Considerations in Drying Hardwood Lumber

Bruce E. Cutter, Forestry, School of Natural Resources, University of Missouri-Columbia

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 percent and 14 percent.

However, 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 resulted in kiln drying speeding up the drying process. This 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 percent 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 USDA Agriculture Handbooks Number 188, Dry Kiln Operator’s Manual; Number 402, Air Drying of Lumber; and Number 582, Drying Eastern Hardwood Lumber; and USDA General Technical Report FPL-GTR-57, Dry Kiln Schedules for Commercial Woods.

How wood dries

Three items 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.

More simply stated, we need dry air, heat and wind. In the summer months, low ambient humidity, prevailing winds and the sun provide the necessary three ingredients in order 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 percent 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 percent and 30 percent MC, depending on 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 2 to 3 months, a 2-inch board may take 6 to 8 months and even thicker lumber may take years to become air dry.

Frequently, eastern hardwood lumber, such as red oak, is air dried to 25 percent 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 commonly are called “pre-dryers.” 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 one million BF.

In many of these air-drying facilities there is no supplemental heat. When heat is included, the air temperature usually will not exceed 120°F. The supplemental heat can be provided a number of 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 pre-dryer.

Proper stacking of the lumber is necessary to achieve optimum drying conditions for any species in any situation. Guidelines for proper lumber stacking are given in most of the publications cited earlier, as well as MU Publication G 5550, Air Seasoning (Drying) of Wood.

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 BF of lumber. Temperatures inside the kiln range from 120°F to 190°F, depending on the stage of drying. Although there are kilns in which temperatures reach up to 240°F. Usually, these are 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 1000 BF capacity. Usually, commercial kilns are restricted to tropical areas, to areas where conventional energy sources are not available or 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 to carry 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.

While specific details on humidity and temperature control systems are beyond the scope of this publication, 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. 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. USDA Agriculture Handbook 188, Dry Kiln Operator’s Manual, or USDA FPL-GTR-57, 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 handheld, battery-powered moisture meter. In either event, several measurements must be taken throughout the kiln to get reliable readings.

Special drying methods

Dehumidification kilns

This 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, it requires more time to dry the lumber by this process when compared to a conventional kiln.

**Predryers**

Essentially, predryers are large, low-temperature (below 120°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 reduced air drying defects and discoloration and reduce inventory costs.

**Solar kilns**

Solar kilns became popular in the mid-1970s, when energy prices started to escalate. The main advantage of the solar kiln is the simplicity to construct and operate. It can provide adequate quantities of well-dried lumber for small operations.

The major drawback is the relatively long time period required to dry lumber to 6 percent to 8 percent MC. For further information on solar kilns, write the Extension Forester, School of Natural Resources, University of Missouri-Columbia, 1-30 Agriculture Building, Columbia, MO 65211.

**Vacuum drying**

This method has been used off and on since the early 1900s. Because of costs involved, it 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°F. This 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**

There are other unconventional drying methods that 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.

**Footnote**

1 Moisture content is defined as:

\[
MC \text{ percent} = \frac{\text{Green weight} - \text{overdry weight}}{\text{Ovendry weight}} \times 100
\]

The green or wet weight is the as-is weight. The ovendry weight is determined by drying at 212°F to 215°F until constant weight is reached.