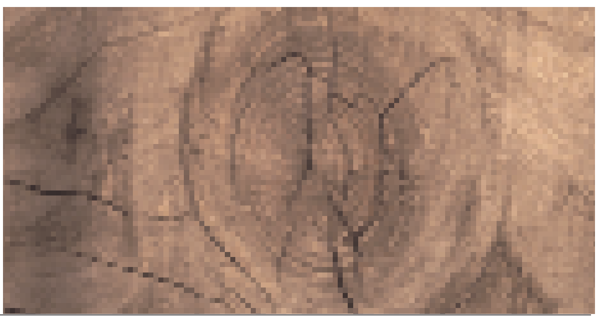
How Wood Dries

A TECHNICAL (Yet Practical) EXPLANATION

BY GENE WENGERT



There are three environmental variables that control the rate and quality of drying. They are

- **temperature**
- **relative humidity** (RH), sometimes expressed as wet-bulb depression or EMC (equilibrium moisture content)
- **velocity of the air flow**ing past the lumber

The drying rate and, therefore, drying quality is controlled by precise manipulation of the three critical variables. The key is the word "precise." Often, for best quality, temperatures in the kiln must be controlled to within 1/2 degree F; humidities within 1% RH, and velocities within 50 fpm.

Temperature

As the temperature in a dryer increases, the drying rate increases. Further, hot air holds more moisture than cooler air, so drying is usually more uniform throughout the dryer. Hotter temperatures, however, do mean that the wood is weaker; therefore, hotter temperatures mean more risk of checks and splits, as well as more risk of warp. On the other hand, when stickering is perfect, the hotter wood will be held flat by the sticker more easily than cooler wood (that is, the stickers bend the wood flat). Conversely, poor stickering means more warp. Hotter temperatures usually mean lower RHs and a greater risk of overdrying, which aggravates warp and machining problems.

Relative Humidity

Lower RHs mean faster drying, more uniform drying throughout the pile, flatter lumber, and brighter lumber. However, lower RHs can mean a higher risk of checks and splits and more risk of overdrying and subsequently excessive warp and machining problems.

The relative humidity is an expression of the amount of moisture in air compared to the maximum amount that it can hold at the same temperature.

Relative humidity is important in drying—at any given moisture content, the drying rate of the wood can be expressed as

Rate = coefficient x (100 - RH).

This expression means that if initially the RH is 80%, but then is lowered to 60%, the lumber will dry twice as fast. That is, at 80%, the rate is [coefficient x 20]; at 60%, the rate is [coefficient x 40]. The coefficient in this equation is a constant at a given MC, temperature, and velocity. As the wood dries, the coefficient gets smaller (that is, drying rate slows); as the temperature increases, the coefficient increases; and as the velocity increases, the coefficient increases. The coefficient also is dependent on species and thickness of the lumber.

Relative humidity can be measured directly or can be determined by measuring the wet-bulb temperature, and then the RH value is looked up in an RH table of wet-bulb and dry-bulb temperatures. (A wet-bulb thermometer is a regular thermometer with a wet muslin wick on the thermometer; the wick is kept wet with distilled water. Brisk air velocity across the wick produces cooling, compared to the dry-bulb temperature.) This RH table was initially formulated over 75 years ago.

Because of the occasional problem with supplying water to the wet-bulb thermometer, in supplying adequate air flow, and in keeping the wick clean, some drying control systems use a cellulose wafer as the humidity sensor. The cellulose gains and loses water in response to changes in RH. The electrical resistance of the wafer is related to RH or, more commonly, to EMC (equilibrium moisture content) of the air. EMC can be related directly to shrinkage, which in turn is closely related to stresses, which in turn is related to several types of degrade, including checks, splits, and some warp. Hence, EMC can be a useful expression for indicating the moisture content of the air in a dryer.

As might be expected, the RH (and the EMC) of air increases as the air moves through the load of lumber. (In contrast, the wet-bulb temperature is uniform throughout the pile. Although this may seem strange, it is indeed true, in an air path that does not go across heating coils or does not have outside air [hot or cold] introduced in the airstream.) Because the RH increases as the air moves through the pile of drying lumber, the drying rate slows through the pile. Likewise, as the EMC increases through the pile, the risk of stress-related degrade falls. Generally, the RH or EMC of the entering air is measured and controlled, as the entering air conditions are the most severe. However, we are beginning to see some operating scenarios using the change in RH or EMC through the load as a control variable, as well.

Air Velocity

When lumber is quite wet, the major resistance to drying is how fast the air can scrub the water molecules off the surface and how fast heat can be supplied to evaporate moisture. (The process is controlled by the boundary layer.) As a result, changes in velocity result in direct changes in drying rate—higher velocities mean faster drying.

However, as the lumber becomes quite dry (under 20% MC), the major resistance to drying is the speed with which the molecules can move from the interior of the wood to the surface. Hence, the velocity of the air through the pile of lumber (or the boundary layer) has very little effect on drying.

At intermediate MCs, the boundary layer and internal diffusion will be of nearly equal magnitude, so both are very influential.

Higher velocities also mean more uniform drying throughout the pile.

An important concept in air flow is that the volume of air going into the load is equal to the amount coming out. There cannot be a buildup of air within the pile. Therefore, air velocity is usually measured on the exit side of the pile, as it is very easy to do so, but it is hard to measure velocity accurately on the entering air side. One problem that must be considered, however, when measuring air flow in this manner, is that there is a tendency for the air to move upward as the air moves horizontally through the piles. Hence the exit air side may show higher velocities near the roof than near the floor, but this pattern may not exist on the entering air side of the load. Nevertheless, this upward trend does exist and does indicate the need for horizontal baffles in the space between adjacent packs, especially in track kilns when drying green lumber. (Recall green lumber is more influenced by velocity than is partly dried.)

Effects of Temperature, RH, and Velocity on Drying

•Role of temperature—when the temperature rises,

a) lumber dries faster, which in turn means brighter, flatter lumber with more risk of checking
b) lumber dries more uniformly throughout the kiln
c) lumber develops darker (usually browner) colors
d) lumber is weaker and therefore lumber is more prone to checking and splitting
e) lumber is weaker and therefore lumber is more prone to warping unless stacking is precise
f) insects and fungi are less active above 100°F and are killed when the temperature is above 130°F

•Role of relative humidity—when the humidity drops,

a) lumber dries faster, which in turn means brighter, flatter lumber with more risk of checking
b) lumber dries more uniformly throughout the kiln
c) lumber develops lighter colors
d) lumber is stronger and therefore less prone to warping
e) lumber is stronger and therefore less prone to checking and splitting

•Role of velocity—when the velocity is increased,

a) above 40% MC, lumber dries faster, which in turn means brighter, flatter lumber with more risk of checking
b) below 20% MC, velocity has very little effect on the drying rate
c) lumber dries more uniformly throughout the kiln ■

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