SOME OBSERVATIONS OF THE KINETICS OF LUMBER DRYING IN CONVENTIONAL KILNS

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Three years ago at the New York annual meeting of the Forest Products Research Society this writer presented a paper dealing with the kinetics of conventional kiln drying conducted under carefully controlled laboratory conditions. That paper pointed out that the familiar falling-rate drying curve could be described with considerable confidence by a first order reaction rate equation: $\ln(M_o/M) = k\,t$, in which M_o is the initial moisture content, M is the moisture content at time t and k is the specific drying rate constant having the dimensions of reciprocal time. Thus when $\ln(M_o/M)$ is plotted against t , a straight line with a positive slope and passing through the origin results.

Obviously, as k becomes larger the drying rate increases; that is, M becomes smaller for a given value of t.

It was further reported that the specific drying rate constant is closely defined by the product of wet bulb temperature depression and the velocity of the circulating air. Thus, for a given item it may be expected that the same drying rate or kiln residence time may be expected for all kiln conditions for which the products of the entering air wet bulb depressions and air velocities through the charge are the same. Thus, for a given item stacked in a given way (sticker thickness, load height, load width) very comparable drying rates are obtained if the wet bulb depression is reduced to one-half when the air velocity is doubled, or vice versa.

This conclusion is valid because the wet bulb depression is the intensity factor of the enthalpy available for drying (BTU per pound of air) and the air velocity is a measure of the number of pounds of air which passes through a given load in unit time.

The falling rate which is experienced during conventional drying is due to the fact that the boards in the kiln do not remain at the wet bulb temperature during drying but, rather, exponentially approach the dry bulb temperature with the result that the temperature gradient between the air and the wood becomes progressively smaller. Since this gradient is the "driving force" which determines the rate of heat transfer from air to wood, less heat enters the wood per unit time and, consequently, less water is evaporated per unit time as kiln residence progresses.

It is fortuitous that the rise in wood temperature is roughly exponential which allows the semi-logarithm first order reaction relation to predict drying rates as well as it does.

It is possible, by knowing the characteristics of a kiln and of the item being dried, to use the specific drying rate relation to predict closely the kiln residence time for a certain set of conditions or to estimate the entering air conditions necessary to achieve a desired kiln residence time.

The above discussion is valid only if entering air conditions are carefully controlled and are kept substantially constant. When kiln conditions are not kept constant great variations in drying rates result or will be anticipated when it is seen how sensitive the specific drying rate constant is to wet bulb depression and air velocity. For example, if the kiln conditions are set for $180^\circ F$ dry bulb, 150° wet bulb and 400 fpm air velocity but the dry bulb temperature is $175^\circ F$ and the air velocity is 300 fpm in one portion of the kiln, the specific drying rate becomes 0.625 of its intended value. Thus the moisture loss that would normally require 50 hours will require 80 hours, or, if the kiln is discharged at the end of 50 hours, the portion of the change described will be much wetter than desired.

During the past months the Weyerhaeuser Research Division drying team has had occasion to measure temperature and air velocity uniformities in a number of commercial kilns. Time and position variations have been found to be much larger than expected. It is not unusual to find variations in dry bulb temperatures of 5 degrees or more

at different points on the entering air side of a kiln and variations of as much as 10° have been noted at a single point as a function of time due to the over-ride of controls by non-proportionating equipment. There are great variations in air velocities throughout a kiln due to differences in the configuration, spaces between kiln cars, inadequate baffling, stacking more than one length to a car, differences in static pressure in different parts of the kiln, and others.

Many kilns are not operated with the objective of maximum uniformity in mind. Since drying rates are extremely sensitive to like conditions, it is imperative that temperatures and air velocities be maintained as uniform as possible at all times throughout the kiln. There are enough variations in green moisture content, board thickness, density and grain type to affect kiln dry moisture content uniformity without adding another major variable to the list.

Readers who may wish additional details concerning the development of the drying kinetics relationship referred to above are invited to contact the author and request reprints of the original paper.