Maximum Initial Moisture Contents for Kiln-Drying 4/4 Hardwoods at High Temperatures

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Abstract

Red oak, soft maple, cherry, pecan, sweetgum, basswood, aspen, white oak, elm, hackberry, black ash, and bur oak were kiln-dried by normal-temperature (180°F maximum) and high-temperature (230°F) schedules. Degrade from warp after drying at normal temperature was compared with degrade from drying at high temperatures. Only the oaks and several boards of "wet pocket" sweetgum and aspen that were green from the saw did not dry successfully at high temperatures—they had a greater amount of honeycomb or warp than the conventionally dried material. However, these species did dry satisfactorily at high temperatures if their average MC was reduced to below 25 percent by air-drying or below 20 percent by normal-temperature kiln-drying.

HIGH-TEMPERATURE drying, at temperatures above 212°F, is widely used for many softwood species in the United States. Drying times are short, energy costs low, and quality is good.

Can high-temperature drying be used for U.S. hardwoods? In a review article on high-temperature drying,[1] it was reported that birch, beech, and yellow-poplar had been successfully dried green from the saw at temperatures between 220° and 240°F and that yellow birch, walnut, redgum, and oak could also be high-temperature dried if they were air-dried first. It was also mentioned in the review that Europeans and Canadians had successfully dried several other hardwood species as well.

The objective of this research was to determine at what moisture content level successful high-temperature drying could be initiated for 12 comthickness portant U.S. hardwoods.

Procedure

Material Preparation

Twelve hardwood species were dried; the species and the drying times for conventional drying are given in Table 1. All of the boards were nominal 4/4 taiir,rness and random width (average width of 6 in. and nntless than 100 in. in length). With the exception of few boards, all were No. 1 Common and Better grade.

Table 1. — SPECIES INVESTIGATED FOR HIGH-TEMPERATURE KILN DRYING.

Commercial name for lumber	Scientific name	Typical drying time[1] (days)
Red oak	*Quercus rubra* L.	5-10
White oak (both northern and southern grown)	*Quercus alba* L.	6-12
White oak	*Quercus macrocarpa* Michx.	6-12
Pecan	*Carya* spp.	7-15
Gum	*Liquidambar styracillua* L.	15-25
Soft maple	*Acer rubrum* L.	7-12
Black ash	*Fraxinus nigra* Marsh.	10-14
Basswood	*Tilia americana* L.	6-10
Cherry	*Prunus serotina* Ehrh.	10-14
Soft elm	*Ulmus americana* L.	10-15
Hackberry	*Celtis occidentalis* L.	7-11
Aspen	*Populus grandidentata* Michx.	6-10

[1] Drying time from green to 6 percent MC (except oak, which is from 20 to 6 percent) by normal kiln-temperature schedules is based on data from "Dry Kiln Operator's Manual" (see text, footnote 2).

Prior to kiln-drying, some of the lumber from each species was stacked for air-drying or for forced-air-drying. The purpose was to provide for a wide range of initial moisture contents for the subsequent- high-temperature kiln-drying. In addition some lumber wis used green from the saw.

For kiln-drying, each board was cut in half, cross wise; a moisture content (MC) section, approximately 1 inch along the grain, was cut from the freshly sawed

[1] Wengert, E. M. 1972. Review of high-temperature kiln drying of hardwoods. S. Lbrmn. 2139(423):17-19.

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end; then one of the end-matched boards was piled for high-temperature kiln-drying, whereas the other end-matched board was piled for normal (180 °F maximum) kiln-drying. In both types of drying, stickers were 24 inches apart so that warp would be more accentuated than if 12- or 16-inch spacing were used. The top of the load was weighted with enough iron to obtain a loading of 10 pounds per square foot. This weight was expected to retard warp in the top layers of the load. Air velocity during drying was 600 feet per minute.

Kiln Schedules and Procedures

Seven kiln charges, about 700 board feet per charge, were dried in a 1,500-board-foot-capacity high-temperature kiln; this is approximately 100 boards (50 dried at normal temperatures, and 50 dried at high temperatures) for each of the 12 species, excel approximately 130 boards for each of the oaks; each board averaged slightly more than 4 feet in length and 6 inches in width.

The normal-temperature kiln schedules were based on the recommendations in chapter 8 of the "Dry Kiln Operator's Manual." When mixed species were included in a run, the slowest drying species (oak) was used as the sample for controlling MC. All samples were dried, including an equalization period at 4 percent equilibrium moisture content (EMC), until none was above 7 percent moisture at which time conditioning was begun. This final MC was based on a resistance-type moisture meter with insulated pin electrodes and with temperature correction applied.

The high-temperature schedule involved the following three steps: heating, drying, and conditioning. The heating step is necessary to bring the lumber rapidly up to 200°F without allowing any drying to occur. This is accomplished by using steam spray with a little heat. The spray condenses on the cool lumber; thereby it provides heat and moisture. If this heating period is not used and if the heating rate in the kiln is slow (temperatures above boiling are not obtained within an hour or so), the wood will begin to dry. Because drying conditions will be severe (high dry-bulb temperature and large depression), the risk of checking is high.

After reaching 200°F, the kiln is immediately heated to 230°F (Canadian Forest Products Laboratory suggests holding at 200°F for several hours,[3] but this delay did not appear significant in this work). Based on the present understanding of high-temperature drying, it is of utmost importance that air temperatures throughout the kiln be above 212°F during this step. In contrast, the wet-bulb temperature is not important. The maximum EMC at 230°F is only 7 percent, so drying conditions will be severe at any wet-bulb setting. In fact, we found it advantageous to adjust the wet bulb to a rather high setting (above 180°F) so that the vents would not open and exhaust heat very frequently. Usually the spray valve was off until the conditioning step. The drying time for all high-temperature runs was between 40 and 48 hours.

Conditioning began when the wettest boards were below 7 percent MC (based on readings from a resistance-type moisture meter with insulated pin electrodes and with temperature correction applied). Conditioning, or stress relief, was accomplished by several means: for normal-temperature runs, the procedure in chapter 8 of the "Dry Kiln Operator's Manual"[2] was followed. The conditioning period was 5 hours at a 5°F depression with desuperheated (saturated) steam. The purpose of conditioning was to permit the surface of the boards to pick up moisture, which leads to stress relief, but at high temperatures the surface is too hot to pick up much moisture and the maximum EMC's are too low. Therefore, to condition high-temperature-dried material, the surface of the wood must first be cooled below 212°F.

To cool the lumber, the following two methods were used: 1) pulling the load from the kiln and letting it stand for 4 hours at room temperature, then putting it back into the kiln, or 2) turning off all heat and spray, leaving the fans on, and opening the vents for 2 hours. The kiln reached about 100°F after this 2-hour cooling period. At the end of the cooling period, for both methods, the vents and the heat valves were closed and only the spray and fans were turned on for 2 hours. The wet-bulb temperature reached 170° to 180°F maximum. As a check on the thoroughness of conditioning, stress sections were cut, allowed to cool, and the results interpreted according to the "Dry Kiln Operator's Manual."[2] These cooling and conditioning times relieved stresses for a 4-foot-wide load, but for wider loads the times would probably have to be extended.

Evaluation of Material

Degrade from drying is difficult to evaluate, because evaluation is dependent on the end product to be manufactured. In this study, the end product was a furniture blank 4 inches wide, 25/32 inch thick, and 4 feet long.

After conditioning, the boards were removed from the kiln, ripped to 4-inch widths, and end-trimmed to 4-foot lengths. These lengths were then jointed on one face until clean, and planed on a cabinet planer to 25/32-inch thickness to produce the blanks. They were then crosscut in the center. Internal checking and honeycomb, when present, could be seen on the crosscut face or on the ripped edge. Surface checks too deep to be eliminated, if present, were seen on the planed and jointed faces. Warp, if excessive, would be indicated by rough areas after planing. On every blank, all of these types of degrade, if present, were noted. In addition, several blanks from each species were examined to note any permanent color change caused by high-temperature drying.

Results

High-Temperature Drying

The red—or soft—maple, basswood, cherry, ash, and hackberry dried at high temperatures and at normal

[2]Rasmussen, E. F. 1961. Dry Kiln Operator's Manual. Agri. Handb. No. 188. Forest Prod. Lab., USDA Forest Service. U.S. Govt. Print. Off., Washington, D.C.

[3]Cech, M. Y. 1973. The status of high-temperature kiln drying in eastern Canada. Canadian Forest Ind. 93 (8):63-65, 67, 69, 71.

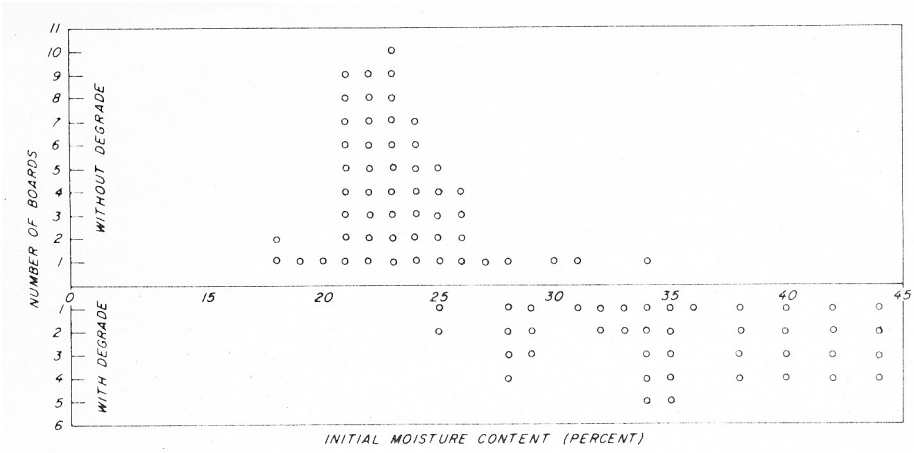

Figure 1. — Degrade in 65 boards of red and white oak that were air-dried, then high-temperature dried (230°F).

temperatures without excessive warp or other measurable degrade, although the maple developed a slight darkening. A few miscut boards of these species were less than 1.00 inch when green; subsequently, the blanks did not dress clean at 25/32 inch, but the boards were end-matched. Because degrade was nonexistent for these species, no detailed data are presented.

Warp was excessive in about one-half of the elm blanks, but this was true for both drying schedules. This warp is attributed to the wide sticker spacing. High-temperature drying was satisfactory for the oaks, if they were first air-dried to less than 25 percent MC (Fig. 1). A few boards of gum and aspen with wet pockets collapsed or honeycombed during high-temperature drying. The high-temperature-dried pecan had slightly less checking and warping than did the matched material dried at normal temperatures. There was some surface checking in this wood. For example, of 45 pecan blanks dried at high temperatures, 15 had one or more small surface checks on one side that did not plane out; of the matched blanks dried at normal temperatures, 25 had checks.

Warp, mostly bow and twist, slightly lower in the high-temperature-dried material than that in the normal-temperature dried. Most warp occurred in the top layers of the pile. For example, of approximately 250 blanks of oak, pecan, and gum dried at high temperatures, 22 did not dress clean at 25/32 inch; of the matched blanks dried at normal temperatures, 32 did not dress clean.

Normal- and High-Temperature Combination Drying

In addition to the schedules mentioned, three loads of mixed red and white oak were dried initially at normal temperatures by the recommended schedule from the "Dry Kiln Operator's Manual"[2] to MC's between 40 and 10 percent, then dried at high temperatures until below 7 percent. No steam spray was used to obtain 230°F; rather, both vents and spray valve were closed and only heat was used. In this procedure, the oak had to be lower than 20 percent moisture to eliminate honeycomb. There was no measurable loss from other types of warp or other degrade.

Conclusions and Recommendations

On the basis of this small-scale work, the following are either concluded or recommended:

1) Soft maple, cherry, pecan, sweetgum, basswood, aspen, elm, hackberry, and black ash 4/4 thick can be dried green from the saw at 230°F in approximately 2 days with no increase in warp or other drying degrade when compared with normal-temperature-dried material. This is a savings of a week or more in drying time compared to that of conventional schedules.

2) Oak can be dried at 230°F in less than 2 days if it is first air-dried lower than 25 percent MC or first kiln-dried at normal temperatures to less than 20 percent MC. This is a savings of several days to a week in drying time compared to that for conventional practice.

3) Honeycomb occurred in the wet pockets of gum and aspen when dried at 230°F, but did not when dried at normal temperatures. Wet pockets are frequent in aspen, but infrequent in gum.

4) The following conditions have proved satisfactory in the small kiln used in this study for high-temperature drying:

A) Uniform air temperature when at high temperatures—with no area below boiling.

B) High air velocity through the load—of approximately 600 feet per minute for 4-foot-wide loads and 900 feet per minute or more for wider loads—is necessary to remove the large amounts of water moving out of the wood and to prevent the dry-bulb temperature from dropping below boiling as air passes through the load.

C) Rapid initial heating, with steam spray to avoid drying of green lumber. (Not suggested if lumber has been well air-dried.)

D) Rapid attainment of target temperature.

5) Stress relief is rapidly attained if lumber is cooled prior to steaming.

6) When drying degrade occurred (checking around a knot), the degrade in high-temperature drying was more severe (checks were larger) than in normal-temperature drying.