

Vacuum drying northern red oak

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Abstract

Vacuum drying of lumber has been considered for many years, but until recently has not been in commercial use. The main attraction of vacuum drying is that by lowering the boiling temperature of water in vacuum, free water can be vaporized and removed at temperatures considerably below 212°F almost as rapidly as it can with high-temperature drying above 212°F. Drying rate is therefore increased without the dangers of drying defects that usually occur above 212°F. In this study, 4/4 northern red oak (*Quercus rubra* L.) was vacuum-dried from green to 6 Percent moisture content in less than 4 days. No surface checking was noted, and after surfacing the lumber for further inspection only 2.2 percent of the volume of lumber contained honeycomb. Ten-quarter red oak was vacuum-dried in 12.5 days with only a small amount of honeycomb.

“Patented vacuum processes for the drying of lumber have been exploited from time to time during the last 30 years, but appear to have had very little commercial success.” This statement could have been written anytime up until a few years ago, but in fact was written in 1931 (2). One early patent was granted in 1904 (1). Vacuum-drying of lumber is an old idea, and it has usually been written off as uneconomical. Because of this lack of favorable economics, little technical data have been published on vacuum-drying—either fundamental or practical details. The objective of this study is of a practical nature—to determine the drying time and quality of northern red oak dried in one particular type of vacuum-dryer.

The principal attraction of vacuum-drying is that, with the lowered boiling point of water in a partial vacuum, free water can be vaporized and removed at temperatures below 212°F almost as rapidly as it can with high-temperature drying above 212°F. Drying rate is therefore increased without the dangers of defects that would surely develop in some species during drying above 212°F. It is essentially high-temperature drying at low temperatures.

Apparently, the economic outlook for vacuum-drying became more favorable in the early 1970s (due to the increased costs of holding large inventories during long drying processes), because a number of new patents were granted (6, 8-12). Also, in the late 1970s and early 1980s several vacuum lumber dryer designs began to appear commercially. However, even with this increased interest and activity, little technical data on vacuum-drying have appeared in published literature. Harris and Taras investigated a combination radio-frequency/vacuum-drying process on 8/4 red oak and found that vacuum-drying from 67 to 7 percent moisture content (MC) required only 88 hours, which is only one-seventeenth the time required by conventional kiln-drying (4). No evaluation of surface checking or honeycomb was presented. Harris et al. also dried 5/4 mixed oak species by this same vacuum process and dried the lumber from green to 8 percent MC in 65 hours, compared to 6 weeks for conventional kiln-drying (5). The quality of the dried lumber was good, and in fact the yield of usable furniture cuttings was greater in the vacuum-dried lumber than in the kiln-dried lumber. Trebula dried 1-inch squares of hornbeam from 55 to 10 percent MC in 20 hours with no checking (14). Wengert and Lamb evaluated several methods for drying 5/4 and 8/4 red oak, including two vacuum processes (15). Predrying followed by kiln-drying required 38 days for 5/4 and 75 days for 8/4; a cyclic vacuum process (cycles of heating at atmospheric pressure and then vacuum-drying) required 13 days for 5/4 and 23 days for 8/4; and a vacuum-drying process where heating was by radio frequency energy took 2 days for 5/4 and 4 days for 8/4. The percent of lumber that contained surface checks was 9,5, and 11 percent, respectively, for

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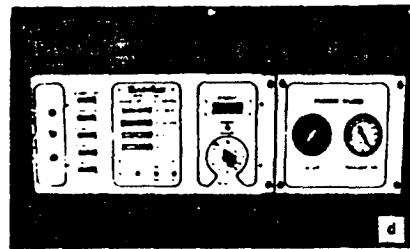
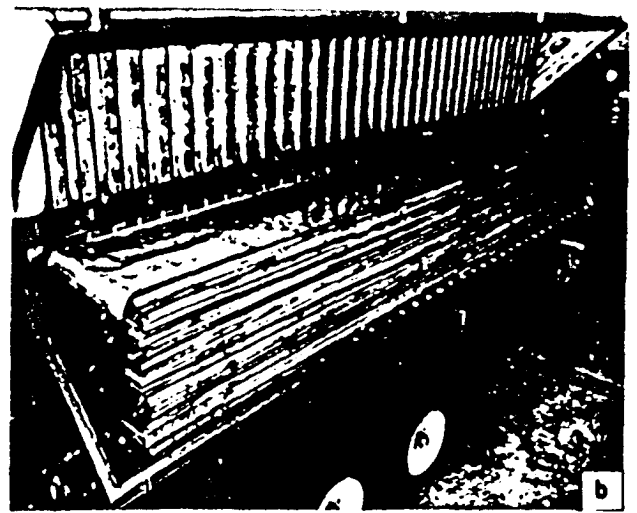
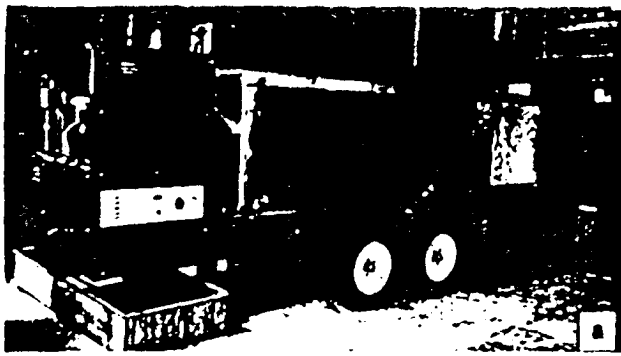


Figure 1. — Photo of 1,000 BF vacuum kiln: a) kiln with lid closed; b) kiln with lid open showing lumber and heating blanket; c) heating blankets between layers of boards; d) control panel.

these processes, and the percent with honeycomb was 3, 0, and 0 percent. Laskowski developed a vacuum-dryer using electrical resistance heating and has dried 4/4 red oak from green to 6 percent MC in 75 hours, and 8/4 red oak in 120 hours (7).

Materials and methods

The vacuum-dryer used in this study is the one described by Laskowski (7) (Fig. 1). It has a 1,000 BF capacity of 4/4 lumber. The dryer operates at a partial vacuum of approximately 27 inches Hg, which brings the boiling temperature of water down to about 95 to 100°F. Lumber is solid-piled in the dryer with a heating blanket between each course of lumber. The heating blankets are aluminum foil laminated in plastic and are heated by electrical resistance. As water is removed from the lumber, it is condensed on cooling coils of a dehumidifier, and removed from the dryer by a vacuum pump. A typical drying schedule calls for various percentages (segments) of a cycle time (one cycle can be set to be any time from 60 to 120 minutes) to be devoted to heating and/or dehumidification. The vacuum pump is also activated several times during a cycle. Thermistor probes are used to monitor and control surface temperatures. During some of the kiln runs, thermocouples were inserted into the center of boards to monitor core temperatures.

Northern red oak (*Quercus rubra* L.) logs from Wisconsin were sawed into approximately 4,000 BF of 4/4 lumber and 1,000 BF of 10/4 lumber. In the first load of 4/4, heat-up was to 105°F, at which time the dehumidifier was activated to begin drying. In the other

three loads of 4/4, heat-up was to 115°F. Heat-up was to 110°F for the 10/4. The water removed from the dryer by the dehumidifier and vacuum pump was collected and weighed periodically to determine drying rate. There are many combinations of heating and dehumidification possible. Each cycle is divided by a microprocessor into 20 segments, and any combination of these 20 heating and 20 dehumidification segments is possible. We did not attempt to optimize the drying schedule in this study—only demonstrate the short drying time and good quality possible in this or any vacuum-drying process. With all of these possible combinations as well as some experience with the consequences of the possible temperature levels during various stages of drying, optimized schedules can be developed.

Shrinkage measurements were taken on selected boards before and after drying. A conditioning process was applied to one kiln load, and stress tests (13) were taken on both conditioned and unconditioned boards for comparison. The conditioning process at the end of drying consisted of turning off all dehumidification segments, and turning on all heat segments for 3 hours. After this time the heat was turned off, and the lumber was left undisturbed in the kiln for 1 hour before opening.

After drying, the 4/4 lumber was examined for surface checks. It was surfaced, both sides, to 0.75 inch and the 10/4 to 2.0 inches. Then each board was crosscut into two equal lengths. The surfacing would expose honeycomb, and the crosscutting would create one internal surface to examine for honeycomb.

Results

Drying rates and wood temperatures

The drying curves are shown in Figure 2. The drying times from green to 6 percent MC for 4/4 lumber ranged from 90 hours to 140 hours.

The 140-hour drying time was for the load where drying was started at 105°F, while the shorter times were for starting temperatures of 115°F. The 10/4 lumber required slightly over 300 hours. Figure 3 shows the surface and core temperatures of the run where drying started at 105°F. In this particular run, the heating and dehumidification segments were such that both surface and core temperatures were kept in the high 80 to low 90°F range in the early part of drying. The evaporative cooling during the dehumidification segments of the cycle kept the temperatures lower than the initial 105°F. As drying progresses, drying rate diminishes and evaporative cooling is less. The result is that both surface and core temperatures increase during drying until they reach approximately 150°F at the end of drying, when the MC is only 6 percent.

Figure 3 also shows the cooling effect of the drying during the dehumidification segments. In the early part of drying, surface temperatures were cooled by 8 to 10°F during the dehumidification segments, and core temperatures by 5 to 7°F. These particular temperature patterns are only the result of the particular combination of heating and dehumidification segments used in this run. But, they illustrate a little of the

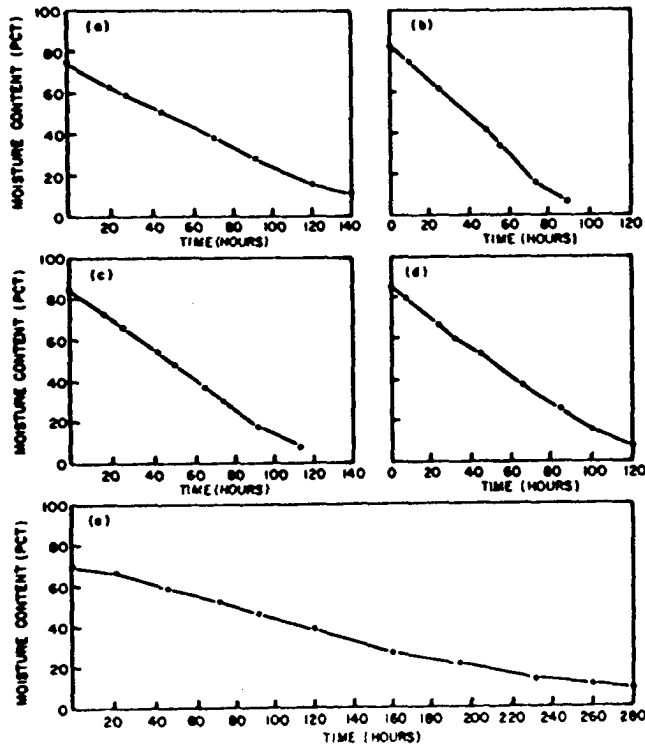


Figure 2. — Drying curves: a) 4/4 red oak, drying started at 105°F; b-d) 4/4 red oak, drying started at 115°F; e) 10/4 red oak, drying started at 110°F.

physics of what is happening and, more importantly, that considerable control over surface and internal temperatures is possible by manipulating heating and dehumidification segments.

Figure 4 shows temperature patterns for one of the runs where drying was started at 115°F. In addition to this higher starting temperature, heating segments occupied a larger proportion of the total cycle than in the 105°F run. This shows up in the temperature patterns of Figure 4, where both initial surface and core temperatures begin to rise early in drying, which is in contrast to the fairly constant temperatures early in drying in Figure 3.

Quality of dried lumber

The lumber in this study was ungraded and included all boards from the logs. There were some very poor quality boards containing pith with attendant pith cracks, large knots and distorted grain, ingrown bark, and occasional decay. The assumption was made that these defects are natural and not caused by any particular drying process. Evaluation of defects was made only on sound wood. Surface checks were not present on the unsurfaced lumber. No honeycomb was present on any of the the board ends created by crosscutting. Out of

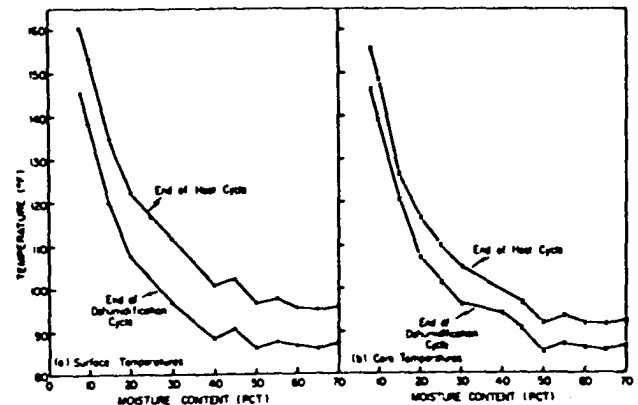


Figure 3. — Temperatures of lumber during drying when starting temperature was 105°F: a) surface temperatures; b) core temperatures.

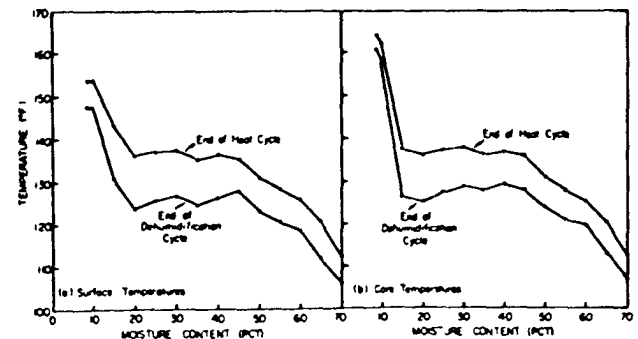


Figure 4. — Temperatures of lumber during drying when starting temperature was 115°F: a) surface temperatures; b) core temperatures.

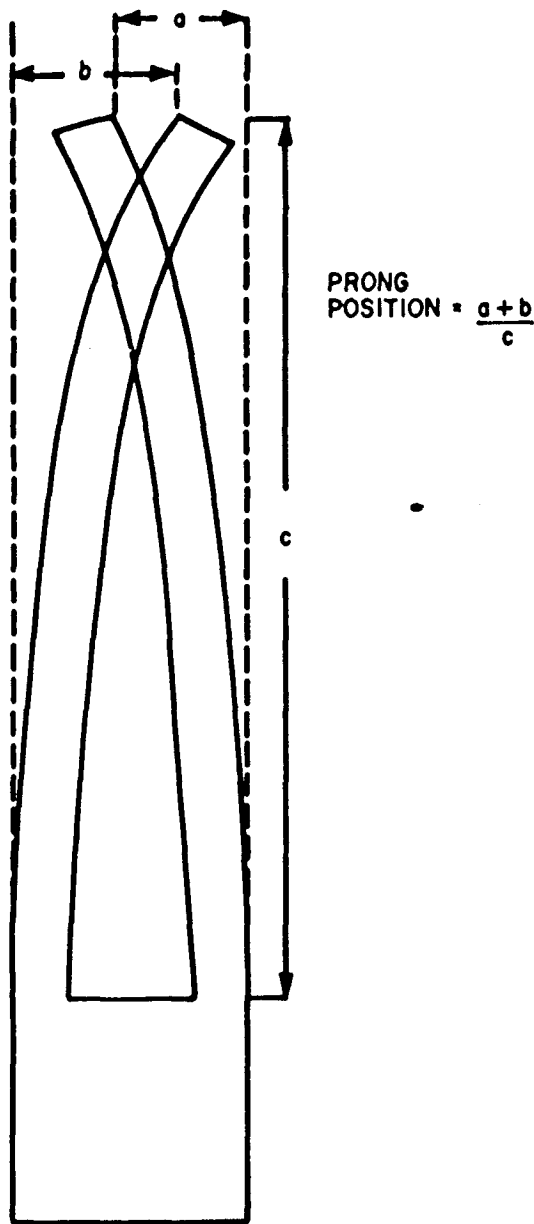


Figure 5. — Schematic showing method of quantifying displacement of prongs in drying stress test.

80 4-foot-long surfaced 10/4 boards, only 2 contained honeycomb checks. The 4/4 lumber was tallied, both with and without honeycomb checks visible on the surface after planing to 0.75 inch, and only 2.2 percent had honeycomb. Average thickness shrinkage was 5.2 percent.

The conditioning process was not totally successful, but it did suggest that the basic procedure might be

successful if prolonged. The deformation of the stress section prongs was quantified as shown in Figure 5. The average prong position of unconditioned boards was 0.175, and for conditioned boards 0.119. This is only a 32 percent improvement, and further testing of the procedure will be necessary to establish its effectiveness.

Research conducted with other vacuum-drying systems has shown a large variation in final MC (3). We did not measure final MC variability with the system used in this study and do not know if it is large enough to be of concern. However, variability is a potential concern, and we plan to investigate it in future studies.

Conclusions

Red oak, both 4/4 and 10/4, was dried in a vacuum dry kiln from green to approximately 6 percent MC. The time required to dry the 4/4 ranged from 90 to 140 hours, depending on initial drying temperature. The 10/4 oak required 300 hours to dry. No surface checking was noted. The occurrence of honeycomb was low — only 2.2 percent of the 4/4 lumber contained honeycomb. Only 2 of 80 10/4 boards contained honeycomb.

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