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HIGH TEMPERATURE DRYING *of* *Southern Hardwoods*

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HIGH TEMPERATURE DRYING
of Southern Hardwoods[1]

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THE IDEA of drying lumber at temperatures above the boiling point of water has intrigued lumbermen for years. Since World War II there has been a renewed interest in this subject, stimulated largely by successful applications in Europe and encouraging research results with Canadian woods.

It is well known that different species and different thicknesses of lumber differ considerably in drying rate and in tolerance to accelerated drying schedules. In view of these facts, the present exploratory study was designed to learn if useful lumber thicknesses of representative southern hardwoods could be dried at temperatures above the boiling point of water without excessive degrade. The effectiveness of high temperature drying in reducing the hygroscopicity of wood was also to be evaluated.

PROCEDURE

Red oak, white oak, hickory, beech, blackgum, sweetgum, and yellow poplar were the hardwoods selected for this study. Southern pine sapwood, an easily dried softwood, was used for comparison.

A freshly cut bolt of each wood was sawed into boards 1/4, 1/2, 3/4, and 1 inch thick and about 6 inches wide. In addition to flat sawed sapwood boards, both flat sawed and quarter sawed heartwood boards were cut whenever it was practical to do so. From the bolts of blackgum and hickory, several 6/4 boards were also obtained. The boards were cut to a length of 18 inches, end

[1] Based on a cooperative study supported by the Birmingham Research Center, Southern Forest Experiment Station, U.S. Forest Service.

coated with Moore's Endtite, and weighed. They were then stacked with adequate spacing in a forced circulation drying oven and dried to constant weight at a temperature of 110° C. (230° F.). During the drying process, the boards were removed at intervals and weighed. From these data drying curves were plotted.

After the boards were dried, three thin cross sections were cut from the central region of each. All sections were examined for internal checking and collapse. One section from each board was used to test for case hardening; one was impregnated with water under pressure, then oven dried, and the shrinkage calculated; and one was weighed and measured at equilibrium with successively higher relative humidities up to 100 per cent and then at equilibrium with successively lower humidities down to 12 per cent.

DISCUSSION *of* RESULTS

Drying Rate

In general, the rate of drying was rapid until 30 per cent moisture content[2] was reached, then it slowed down conspicuously. The drying curves for quarter sawed beech heartwood are presented as an example, Figure 1, since they are fairly representative of the hardwoods studied.

As expected, the thinnest boards dried most rapidly. With the exception of white oak heartwood, all of the ¼-inch boards dried from green condition to 4 per cent moisture content in less than 6 hours. The ¼-inch white oak heartwood required 8 to 11 hours. In order that all species could be compared on the same basis, the time required to dry from 60 per cent to 4 per cent moisture content was calculated, Table 1. Some of the species had a high initial moisture content (above 90 per cent) and required 1 to 3 hours to dry to 60 per cent. Hence, the time required to dry from green to 4 per cent would be 1 to 3 hours longer than the values of Table 1. In spite of this fact, a 24-hour drying schedule seems possible for many of these woods. Although the relationship was not at all consistent, on the average the ½-inch boards dried in about half the time of the 1-inch boards, Table 1. Since the ¾-inch boards displayed a drying rate intermediate between that of the 1-inch and the ½-inch boards, they are not shown in Table 1 or Figure 1.

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[2] All moisture contents reported are expressed as a per cent of the oven-dry weight.

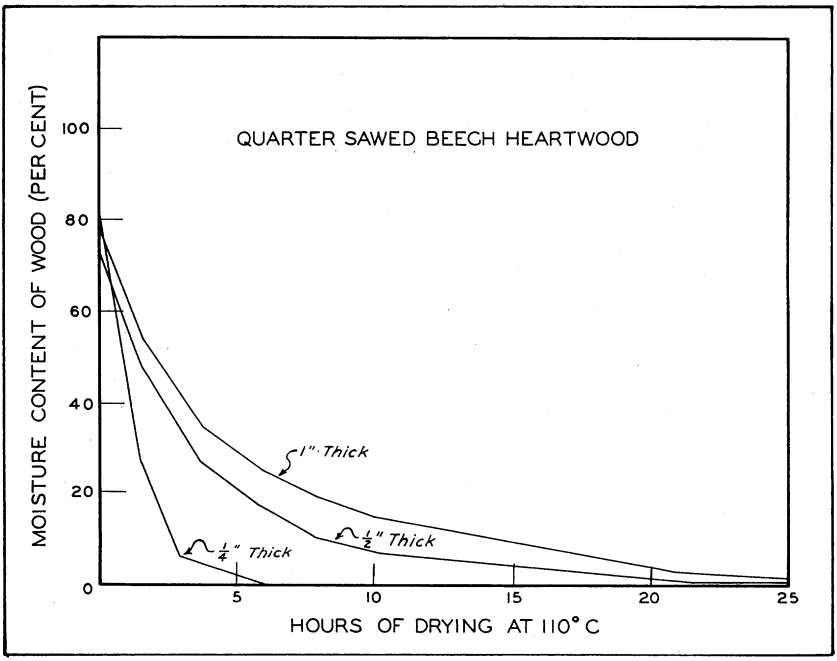

Figure 1. Drying curves for quarter sawed beech heartwood dried at 110° C. These are similar to curves for other hardwoods dried at this temperature.

TABLE 1. TIME REQUIRED TO DRY LUMBER OF VARIOUS SPECIES FROM 60 PER CENT TO 4 PER CENT MOISTURE CONTENT AT 110° C.

Species	Position in log	Sawing method	1-inch lumber	½-inch lumber
			Hours	*Hours*
Beech	Heartwood	Quarter	19.1	15.0
Beech	Sapwood	Flat	16.8	8.3
Blackgum	Sapwood	Flat	14.2	5.0
Sweetgum	Heartwood	Flat	24.4	18.0
Sweetgum	Heartwood	Quarter	19.2	--
Sweetgum	Sapwood	Flat	17.5	8.7
Southern pine	Sapwood	Flat	7.6	3.2
Yellow poplar	Sapwood	Flat	18.0	8.4
Red oak	Heartwood	Quarter	20.0	8.2
Red oak	Sapwood	Flat	17.7	5.8
White oak	Heartwood	Flat	18.9	15.0
White oak	Heartwood	Quarter	28.6	16.4
White oak	Sapwood	Flat	17.3	8.3
Hickory	Sapwood	Flat	21.7	9.3
Hickory	Heartwood	Quarter	24.7	12.7

Drying Defects

Checking and Collapse. While some of the species showed excessive degrade, more than half of the test boards came through the drying in acceptable condition. In thicknesses of 1 inch and less, yellow poplar, blackgum, beech, and southern pine showed no checking due to high temperature drying, Figures 2 and 3. Hickory and sapgum (sapwood of sweetgum) showed an occasional internal check in thicknesses of 3/4 inch and 1 inch, but the checking was not considered serious enough to preclude most normal uses of the wood. Internal checking and collapse were so severe in redgum (heartwood of sweetgum), white oak, and red oak, Figures 2 and 3, that there appears to be little promise for drying these species at high temperatures, except perhaps in thicknesses of 1/4 inch or less. Even at 1/4 inch thickness, flat sawed heartwood of the oaks showed such serious checking that it appears necessary to restrict high temperature drying of oak to sapwood and quarter sawed heartwood. In view of these serious

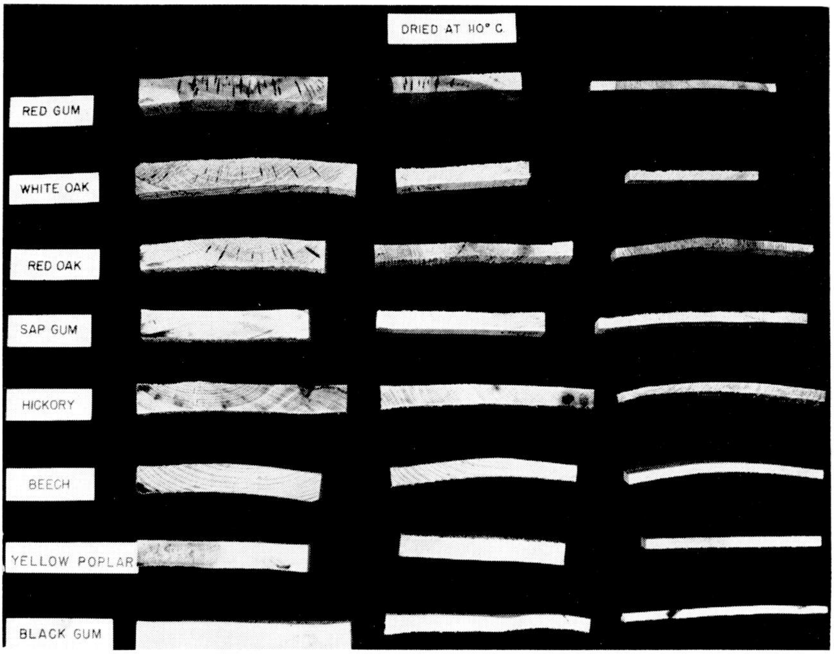

Figure 2. Cross sections of boards of various species that were dried at 110° C. The sections on the left are from 3/4 inch, in the center from 1/2 inch, and on the right from 1/4 inch boards.

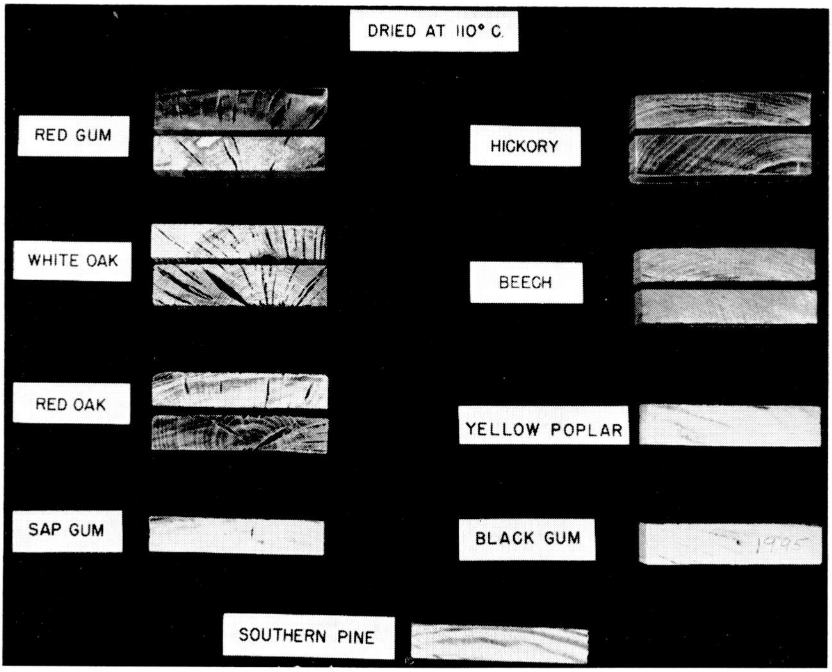

Figure 3. Cross sections of 1 inch boards of various species that were dried at 110° C.

thickness limitations, it was decided to withdraw the oaks and redgum from further consideration in this study.

In additional tests, 5/4 or thicker boards of blackgum, hickory, and redgum were dried at high temperatures. Redgum checked severely, and even blackgum and hickory showed slight to moderate internal checking at 6/4 thicknesses, Figure 4. These specimens also displayed slightly sunken surfaces, suggesting that some collapse may have occurred. Since most lots of nominal 4/4 lumber contain some boards that are nearly 5/4 and an occasional miscut as thick as 6/4, the marginal performance of the 6/4 stock stands as a warning that degrade will probably occur in some pieces even in the drying of 4/4 stock.

Case Hardening. Case hardening was very noticeable in the stock dried at high temperatures, Figures 5 and 6. This is not surprising since neither humidity control nor stress relief technique was employed. While case hardening of stock dried at high temperature was more severe than that of the air dried controls, it was no more severe than that of much of the lumber put in use

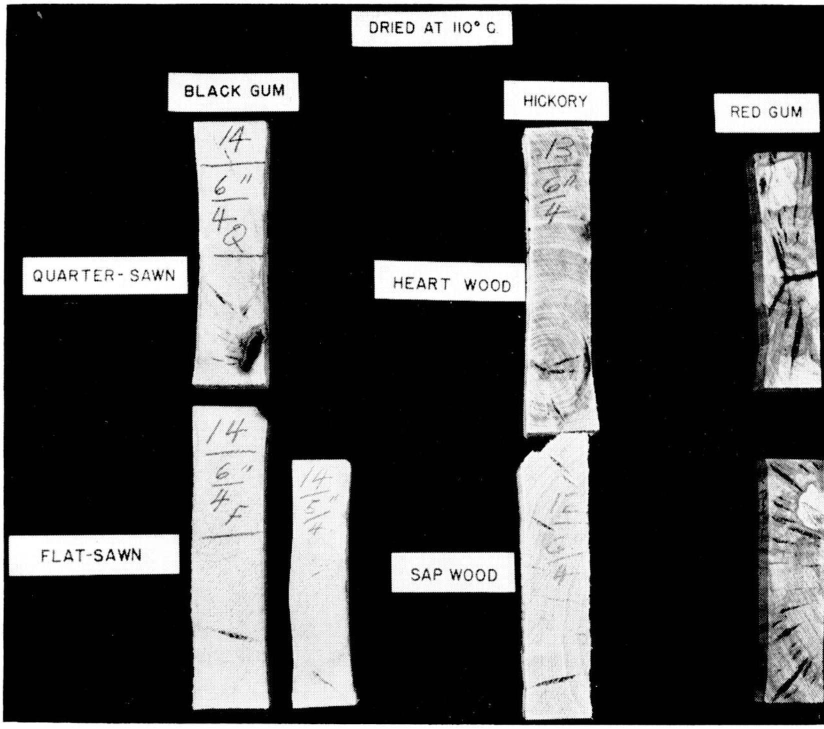

Figure 4. Cross sections of thick boards after high temperature drying. Both of the redgum sections and the smallest blackgum section are from 5/4 boards. The other two blackgum and the two hickory sections are from 6/4 boards.

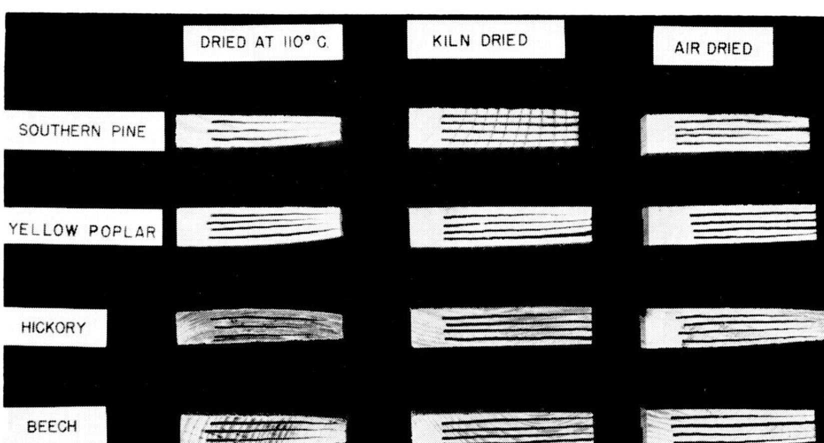

Figure 5. Cross sections band sawed to reveal case hardening. The kiln-dried specimens were seasoned on a mild schedule, with special attention, to assure stress-free stock. The air-dried material was seasoned inside a building.

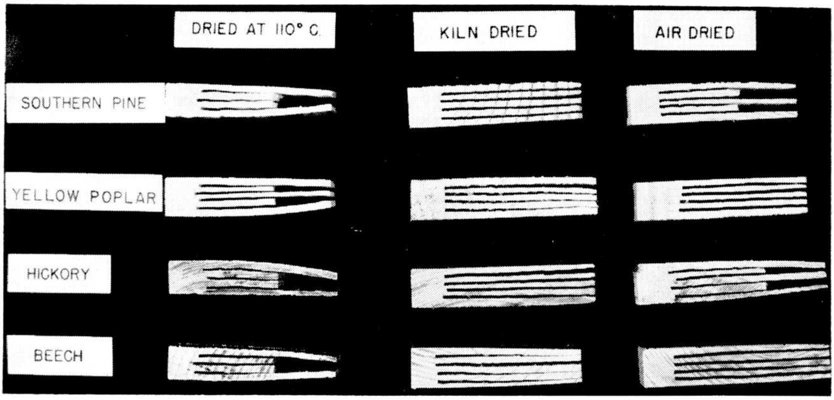

Figure 6. Case hardening specimens similar to those of Figure 5, except that intervening prongs were cut out to reveal the full tendency of the outer prongs to bow inward.

by industry today. The stress-free condition of the kiln dried specimens in Figures 5 and 6 is the result of careful kiln operation and is probably superior to that of much commercially dried lumber. If the end use of lumber calls for resawing or for heavy, unbalanced surfacing, stress-free material is required. Appropriate intermittent and/or final steaming would have to be used in connection with a high temperature drying schedule to produce such material. Since such techniques of stress release are fairly well known, it is felt that case hardening will not prove a major obstacle to high temperature drying.

Hygroscopicity and Swelling

There was a noticeable reduction in hygroscopicity following high temperature drying, Figure 7. Reduction in equilibrium moisture content was most noticeable at relative humidities of 90 per cent and lower. However, there was still some reduction at 100 per cent relative humidity, Table 2 and Figure 7.

Dimensional stability of pine and poplar dried at high temperature was improved more than would be expected on the basis of reduced hygroscopicity alone. Hickory showed some dimensional stabilization due to high temperature drying, but it was little more than half the amount expected on the basis of reduced hygroscopicity, Table 2. The beech samples that had been dried at high temperature swelled even more than the air dried controls when allowed to reach equilibrium at 100 per cent humidity. High-temperature-dried blackgum displayed greater

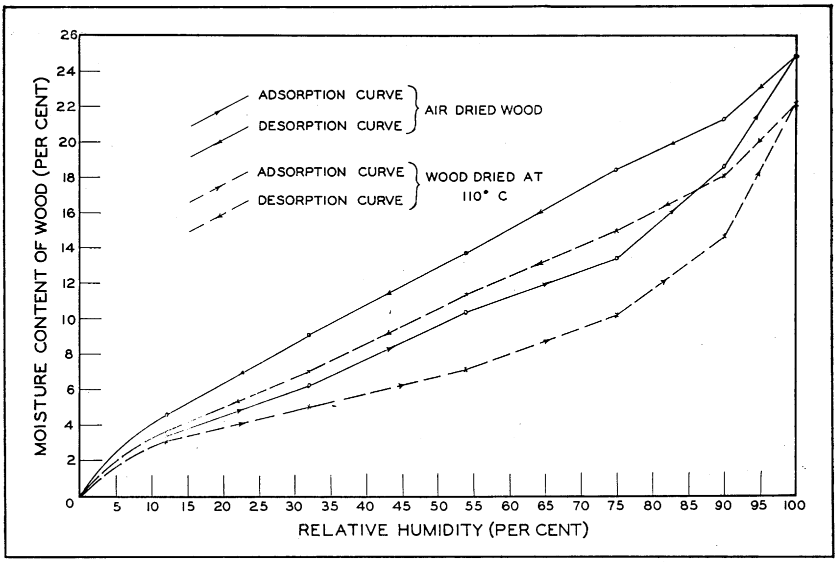

Figure 7. Moisture content of high-temperature-dried and air-dried wood at equilibrium with various relative humidities at room temperature. Each point is the average of all species and thicknesses used in this study.

swelling than the controls at both 90 and 100 per cent humidity. This abnormal swelling of beech and blackgum accounts for the three negative values in Table 2.

The high-temperature-dried hardwood cross sections that were saturated with water by pressure impregnation and then oven dried yielded some additional information of interest. Allowed to reach equilibrium with room conditions after initial high temperature drying, they had a moisture content of about 6 per cent. After water saturation and redrying at 105° C. for 24 hours, their

TABLE 2. THE REDUCTION OF HYGROSCOPICITY AND DIMENSIONAL CHANGE OF WOOD DUE TO DRYING AT 110° C., AS A PERCENTAGE OF THE SAME PROPERTY OF AIR-DRIED CONTROLS

Species of wood	Per cent reduction in moisture content of wood at equilibrium with the following relative humidities		Per cent reduction in dimensional change of wood between oven dry and equilibrium with the following relative humidities	
	90 per cent	100 per cent	90 per cent	100 per cent
Poplar	26.7	15.3	32.1	28.8
Hickory	26.6	13.0	14.5	7.3
Beech	21.9	6.3	9.4	–24.2
Blackgum	21.1	16.8	–9.6	–7.1
Southern pine	21.5	9.1	27.4	16.5

oven dry dimensions were about 2 per cent greater than their previous dimensions at 6 per cent moisture. This seems to indicate that some type of abnormal shrinkage, probably involving collapse, had been released during the period of water saturation. Since at that time the specimens were in the form of relatively thin cross sections, this abnormal shrinkage did not occur again (at least not to the same extent) during the subsequent oven drying. This indication of collapse may help to explain the seemingly conflicting data concerning dimensional stabilization. When the specimens were brought to equilibrium at 90 per cent relative humidity or higher, some collapse may have been released, causing abnormal swelling that partially or wholly counteracted any stabilizing influence of high temperature drying.

In addition to releasing abnormal shrinkage, the period of water saturation seemed also to reduce the acquired dimensional stability since these specimens shrank nearly normally upon subsequent oven drying. It is possible that this normal amount of shrinkage could be the result of a balancing out of any residual stabilization by a mild amount of collapse during the second drying. Either of these explanations still serves as a warning that any severe cyclic exposure that includes water impregnation or prolonged soaking may remove part or all of the dimensional stability imparted by high temperature drying.

The presence of collapse not only confuses the question of dimensional stabilization but looms as the principal problem to be encountered in the high temperature drying of green hardwoods. In this connection it is noted that the internal checking in redgum and the oaks was probably due in large measure to a severe condition of collapse. The recently reported work of Ladell[3] emphasizes the importance of the collapse problem in high temperature drying of Canadian yellow birch.

At present collapse can best be controlled by careful air seasoning to about 30 per cent moisture content prior to high temperature drying.

SUMMARY *and* CONCLUSIONS

A temperature of 110° C. was used to dry various southern hardwoods from the green condition. It was found that 1 inch lumber of yellow poplar, beech, blackgum, hickory, and sapgum could be dried in a short time without excessive visible defect.

[3] Ladell, J. L. High-temperature drying of yellow birch. Forest Products Jour. VI (11): 469-475. 1956.

Hygroscopicity of the wood was noticeably decreased by this high temperature treatment. Some improvement in dimensional stability was observed. However, display of this property was erratic, probably due to abnormal swelling associated with release of mild collapse that had occurred during drying. Case hardening was in evidence, but it is felt that conventional techniques can control this condition when necessary. Until better techniques are found for solving the problem of mild collapse, it is recommended that controlled air seasoning be used prior to high temperature drying of hardwoods.

Redgum, red oak, and white oak displayed such severe internal checking that it seems impractical to dry normal lumber thicknesses of these species at high temperatures.