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Hickory is valued so highly for ax and hammer handles that little of it finds its way into the ordinary lumber market. Only the highest-grade hickory, however, is suitable for handle use. As a consequence, when a hardwood stand is cut over for handle stock, much medium and low-grade hickory that would make good lumber may be left in the woods. This practice not only wastes good material, but also interferes with proper forest management.

As a result of the above situation, the Forest Products Laboratory has undertaken research on a number of subjects that have a bearing on wider utilization of hickory. 2 This report describes kiln schedules of the accelerated type 3 that should make possible considerable savings in drying time. Lumber should become uniformly dry when dried by these schedules and machining operations should be less difficult because of the conditioning treatment recommended.

The schedules given in this report were developed in a series of experiments at the Forest Products Laboratory. The research was done on forest-grown pignut, mockernut, and sand hickory from South Carolina, old-growth shagbark hickory from Kentucky, and second-growth pignut hickory from Mississippi. 4 The experimental kiln runs were made in the Laboratory's small cross-circulation kilns with an air velocity through the load of about 300 to 500 feet per minute. The experimental results were supported by pilot-test or check runs of about 300 board feet of each thickness. The schedules are believed to be generally suitable for all kinds of hickory lumber.

Brief information on care of logs, preliminary air drying, and storage of the dried lumber is included in this report in order to present a complete outline of the seasoning of hickory lumber.

1Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
4Acknowledgment is made to the Poinsett Lbr. & Mfg. Co., Pickens, S. C., the W. M. Ritter Lbr. Co., Pineville, Ky., and Mississippi State College, State College, Miss., for their cooperation in supplying materials for the study; and to the Forest Utilization Service units at the Southeastern Forest Experiment Station, Asheville, N. C., the Central States Forest Experiment Station, Columbus, Ohio, and Southern Forest Experiment Station, New Orleans, La., for their assistance in procuring the test material.
Care of Logs

The most obvious way to prevent losses from end checking, insect attack, stain, and decay of the logs is to mill the logs within 1 to 2 weeks after cutting in the summer and within 3 months in the winter. If this is not practical, the next best way is to store the logs submerged in water. If, however, the logs must be decked up for long-time storage, they should be treated with chemicals that control insect and fungus attack, and the ends should be coated with a good end coating. Such chemicals and coatings should be applied within 24 hours after cutting to be fully effective. Methods of treatment are described in a report that can be obtained from the Laboratory, the Southern Forest Experiment Station, New Orleans, La., or the Southeastern Forest Experiment Station, Asheville, N. C.

Air Seasoning

The best control of drying defects is obtained by kiln drying hickory as soon as possible after milling. Where air seasoning is practiced, certain piling methods are important to insure uniform and fairly rapid drying without causing excessive seasoning defects. Air-dried material, however, should be further dried for interior use. The essentials of good piling practice for hickory are shown in figure 1. When fork-lift trucks and unit-package handling are used, the usual practice is to pile the packages horizontally or on the level. The piles should not be crowded together; they should be roofed, and a 12- to 18-inch air space should be left under each pile. Figure 2 shows a unit-package pile in which slope has been obtained by building a slight pitch into each unit and then piling with a tilting-fork truck.

Hickory sapwood, when air dried in the summer, should be dipped to prevent blue stain, and chemicals serving to prevent insect attack should be included in the dip when borers are known to be prevalent. Information on chemicals for the latter treatment can be obtained from the U. S. Bureau of Entomology and Plant Quarantine, P. O. Box 151, Gulfport, Miss.

Kiln Schedules

The kiln schedules developed for 4/4-, 6/4-, and 8/4-inch hickory lumber are shown in table 1. The final equilization and the conditioning treatment for relief of case-hardening are designed to give a final average moisture content

\[ \text{Prevention of Deterioration in Stored Southern Hardwood Logs. Southern Forest Experiment Station Report, May 1949.} \]

\[ \text{Cause and Prevention of Blue Stain in Wood. Forest Products Laboratory Technical Note 225, revised Sept. 1941.} \]

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of 7 percent. The schedules should be followed by the use of kiln samples. Kiln changes should be made on the basis of the average moisture content of the wetter half of the total number of samples. Even though the moisture content of the stock at the time it goes into the kiln may be near or below 50 percent, the kiln should be run 16 to 24 hours on the first step of the appropriate schedule. The final moisture content of 6 percent shown for the last drying step is estimated to be the average moisture content of the wetter half of the samples when the charge is ready for equalization treatment. (See the section, "Equalization and Conditioning Treatments," later on in this report for more exact methods of applying these treatments and for adjustment of the conditions for different final moisture content values.)

The schedule for 4/4-inch flat-grain lumber and the drying curve of the final experimental run with this schedule are shown in figure 3. Drying time, including equalization and conditioning, was 12 days. The stock dried without any surface checking, and the average end-check penetration was 1.5 inches. The maximum end-check penetration was about 3 inches. In the pilot-test run, made with a slightly milder schedule, total time was 15 days. The stock dried in this run had only very mild end checking.

The schedule for 6/4-inch lumber and the drying curve for the experimental run with flat-grain stock 8 inches wide are shown in figure 4. Drying time, including equalization and conditioning, was 15 days. Ski stock, flat-grain but 4-1/2-inches-wide, took 2 days less time. This and the other flat-grain stock was mostly sapwood, but some heartwood was included. Edge-grain stock about 5 to 7 inches wide took considerably longer, 24 days. The edge-grain specimens included considerable heartwood, which contributed to the increase in drying time.

There was no surface checking except for checks started by defects or end checks. Such checking as occurred was of a very minor nature. The average end-check penetration was about 2-1/4 inches in the 8-inch-wide flat-grain stock, but 1-1/2 inches or less in the other 6/4-inch items. Maximum end-check penetration was about 3 inches, except for the edge-grain stock that had less penetration. In a very few of the specimens the end-checks opened up as honeycomb checks, but these checks did not extend more than 3 inches back from the ends. There was no internal honeycombing, and no collapse or bad distortion of the edge-grain stock, because of inclusion of sapwood and heartwood in the same pieces.

In the pilot test run made with a slightly milder schedule, total time was 21 days. This stock was flat-grain. The results were satisfactory. End-checking in this run was about the same as in the experimental runs. No surface checking occurred.

Segregation of edge-grain stock from flat-grain stock appears to be desirable from the standpoint of drying time. If necessary, the edge-grain stock can be partially air seasoned before kiln drying or 6/4-edge-grain stock could be dried in the same kiln as 8/4-flat-grain sapwood.

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7 Use of Kiln Samples in Operating a Lumber Dry Kiln. Forest Products Laboratory Rept. No. R1607, revised Mar. 1948.

Rept. No. R1794

-3-
The schedule and drying curves for two different classes of 8/4-inch lumber are shown in figure 5. At the start of the experiment on this size of stock, the material was divided into two groups according to the moisture content of the specimens. The average moisture content of the five wettest samples of the wetter group was 65.2 percent. The five wettest samples of the other group had an average moisture content of 52.1 percent. The same schedule was used in drying these two groups, but a longer time was required in each step for the wetter and slower-drying material. Drying time, including equalization and conditioning, was 22 days for the faster-drying stock and 41 days for the wetter stock. The faster-drying stock was largely sapwood, but contained some heartwood. The slower-drying stock was mostly heartwood.

Although the specimens in this experiment were about equally divided between the two moisture content groups, most of the material from the logs included in the entire hickory study was of the faster-drying type. If the proportion of slow-drying material that is obtained from the inner heartwood is small, it would appear worthwhile to segregate it and air dry it, or to cut it into thinner stock, for which its slower drying rate does not seem to be of as much consequence.

There was no surface checking in either group of 8/4-inch specimens except for minor checking connected with a natural defect in one specimen. Average end-check penetration was less than 1.5 inches, and maximum penetration was about 3 inches. There was no honeycombing. The pilot test with this size of stock was made before the experiments under a schedule similar to the schedule for 6/4-inch stock. Surface checking and deep end checking occurred in many of the boards, and collapse and honeycombing occurred in the more refractory material. The results of the pilot test were responsible for the setting up of milder conditions for the final schedule.

The kiln schedules given in table 1, as stated above, are the final results of a number of experiments with a wide variety of hickory material. The schedules prescribed for hickory in the new Forest Products Laboratory Report No. D1791 follow these schedules closely. Since the new Laboratory schedules had to be set up in a general way, so as to be useful for all hardwoods and softwoods, they could not be expected to match individual schedules worked out for each species and item. The schedules given in table 1 are the best schedules resulting from the specific experimental work on hickory. Different experimental material and further extension of research might, however, give somewhat different results.

One difference between the two sets of schedules needs some comment. The most applicable new Laboratory schedules call for initial temperatures that are 5 degrees higher than the initial temperatures in table 1. These particular temperatures and relative humidities were not actually tried in the research. Enough research was done, however, with temperatures in the range given in the 1951 Laboratory schedules to indicate that the slightly higher temperatures are safe in kilns that have good uniformity of drying conditions in all parts of the kiln.

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Rept. No. R17914
The graduated pattern of the 1951 Forest Products Laboratory kiln-drying schedules provides a good basis for modifying the schedules given in table 1 when modification is required for color control or variation of material.

Modification of Kiln Schedules for Color Control

All of the above schedules will cause pinking. Pinking is a pinkish to reddish-brown coloration of the sapwood brought about by chemical changes in the sap normally present in the wood. The control of pinking in hickory handle stock is described in another report. In brief, pinking can be prevented except for a very small discoloration in the cores of a small percentage of the boards, by keeping the dry-bulb temperature down to 105°F or below until the stock has dried to an average moisture content of 20 percent. From 20 to 12 percent moisture content, the temperature should not exceed 115°F. Below 12 percent, any kiln temperature can be used.

Modification of Kiln Schedules for Variation of Material

The schedules given in this report, and the corresponding drying curves, were obtained with the forest-grown pignut, mockernut, sand, and shagbark hickory from South Carolina and Kentucky. This material was considerably slower drying and required milder schedules than the second-growth pignut hickory from Mississippi. It is believed that these schedules can be used generally for any hickory.

If the end checking actually encountered is less than that reported here, or if more can be tolerated, the schedules can be made more severe by slightly increasing the initial wet-bulb depression. The depression in the second step of the schedules could be increased correspondingly.

As an example of how some hickory may be very easy to dry, the 4/4-inch stock from Mississippi dried satisfactorily with an initial dry-bulb temperature of 130°F and a wet-bulb depression of 20°F. Initial conditions were maintained down to 30 percent moisture content; then the kiln was changed to 150°F and 38°F wet-bulb depression. At 20 percent moisture content, conditions were changed to 180°F and 45°F wet-bulb depression. Drying time, including 1 day of conditioning, was only 6 days. Most of the material in this run was sapwood, but one specimen contained some heartwood.

On the other hand, a small percentage of the specimen material from South Carolina and Kentucky used in the handle-blank study appeared to be especially prone to surface and deep end checking. This type of material was not included in the experiments on the drying of hickory lumber, but it is not believed to make up a very large percentage of normal hickory lumber. If, however, any commercial lot of hickory lumber should give evidence of having


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a large percentage of boards prone to checking, the schedules given in this report should be modified by reducing the initial or early wet-bulb depressions, reducing the dry-bulb temperatures, or both.

The older heartwood material from the old-growth shagbark hickory appeared to be slower drying than the other hickory tested and more prone to honeycombing and collapse. If any of this type of material is included in a charge, the humidity schedules given are satisfactory, but the kiln temperature should be kept at 130° F. or below until the stock is dried down to 20 percent moisture content, or to 15 percent for 8/4 or thicker material.

Kiln Drying of Air-dried Stock

Stock that has been air dried only a short time should be started on the first or second step of the appropriate schedule. Kiln conditions should be maintained for at least a day in each step until the average moisture content of the wetter samples coincides with the moisture content of the schedule. After that, the moisture content of these samples should govern kiln changes. Partially air-dried 4/4 and 6/4 stock between 30 and 20 percent moisture content and 8/4 stock between 30 and 15 percent should be started at 130° to 140° F., with a 10° F. wet-bulb depression. Air-dried 4/4 and 6/4 stock below 20 percent and 8/4 stock below 15 percent can be started at 140° to 150° F., with a 20° F. wet-bulb depression. After 1 day at these conditions, the kiln can be changed to the conditions called for by the kiln schedule given in table 1.

Equalization and Conditioning Treatments

The temperatures and relative humidities shown for the equalization and conditioning steps in the schedules are for a desired final average moisture content of 7 percent. If another final moisture content is desired, the following general suggestions are offered,

In any charge that contains a variety of sizes or classes of material, some kiln samples should be taken from the fastest-drying material, even though the major samples come from the slowest-drying material. Near the end of the run, check the moisture content of the fastest-drying samples. When the moisture content of these samples is 2 percent below the desired final average moisture content, change the kiln to the equalizing condition. This condition consists of the final temperature and a relative humidity adjusted to give an equilibrium moisture content 2 percent below the desired average. This treatment will arrest the drying of those boards that are already sufficiently dry. The kiln should be kept at this condition until the wettest sample is at the desired final average moisture content. Then the kiln should be changed to the stress-relieving conditioning treatment. This treatment consists of the final dry-bulb temperature and a relative humidity to give an equilibrium moisture content 3-1/2 percent above the average. The stock should be held at these conditions for the number of hours shown in the schedules, depending on the size of the stock.
For example, when the desired final average moisture content is 9 instead of 7 percent, dry the driest sample to 7 percent. Then adjust humidity to 7 percent equilibrium moisture content. When the wettest sample is down to 9 percent, adjust humidity to 12 to 13 percent equilibrium moisture content. The 12 percent figure can be used with all-sapwood material. For heartwood material, use 13 percent equilibrium moisture content.

Hickory lumber that is going to be used at 10 to 12 percent moisture content or higher and that is not going to be resawed or shaped may not require equalization and conditioning.

**Dry Storage**

Hickory lumber that has been kiln dried to a low moisture content will absorb moisture readily if exposed to high humidities in unprotected storage. Enclosed storage should be provided, with some provision for increasing the dry-bulb temperature during periods of high humidity, if the low moisture content of the stock is to be retained. Where wood-boring insects are prevalent, the lumber should also be protected from attack by using methods recommended by the Bureau of Entomology and Plant Quarantine.

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Rept. No. RI794
Figure 1.—Good piling practice for hickory lumber.

(ZM7251F)

Rept. No. R1791
ROOF TIES MAY BE NEEDED IN WINDY LOCATIONS

4" TO 6"

PITCH FRONT OF PILE FORWARD
ONE INCH PER FOOT OF HEIGHT

3\(\frac{3}{4}\) x 1\(\frac{1}{2}\) STICKERS

SPACE BOARDS TO PROVIDE 2" FLUES FOR VERTICAL CIRCULATION APPROXIMATELY 15" BETWEEN FLUES

10' TO 12' HIGH

2' MINIMUM TO ADJACENT PILE

6' TO 10' WIDE

TREATED, OR HEARTWOOD OF DURABLE SPECIES

SLOPE = 1 INCH PER FOOT

6" x 6" POSTS

2 FEET OR LESS BETWEEN STICKERS FOR 1/4" OR THINNER LUMBER

GROUND TO BOTTOM LAYER 18" MINIMUM

FRONT VIEW

SIDE VIEW
Figure 3.—Kiln schedule and drying curve for

\[ \frac{1}{4}/4\text{-inch hickory lumber.} \]

\[ (ZM86184F) \]

Rept. No. RL794
Figure 4.—Kiln schedule and drying curve for 6/4-inch hickory lumber.

(ZM86185F)..........................
Figure 5.--Kiln schedule and drying curve for 8/4-inch hickory lumber.

(ZM86186F).................................