

# USE OF KILN SAMPLES IN OPERATING A LUMBER DRY KILN

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### Introduction

The usual procedure in the operation of lumber dry kilns is to dry the lumber through the use of prescribed drying schedules of temperature and humidity.<sup>2</sup>—The dry- and wet-bulb temperatures used during the drying period are based on the moisture content of the stock being dried. It is impracticable to obtain moisture-content values on all the stock or on a limited number of long boards in the kiln charge. It has been found, however, that kiln samples cut from boards representing the material being dried can be used to determine, with sufficient accuracy, the moisture content of the charge as a whole whenever desired.

Kiln samples can also be used to determine the uniformity of drying conditions throughout the dry kiln.

To be assured of quality drying in a minimum length of time, the kiln operator, when selecting sample boards, must consider certain variables in wood that affect drying.

### Variability of Material

The drying characteristics of wood vary widely between species as well as within a species. To make full use of modern drying techniques, the entire kiln charge should be composed of material having the same drying characteristics. This may necessitate segregation of the material prior to drying. At many plants, however, segregation is impracticable, and the kiln operator is forced to charge the kiln with material that may have widely different drying characteristics.

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<sup>1</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

<sup>2</sup>Forest Products Laboratory Rept. No. 1791, "Schedules for the Kiln Drying of Wood."

If the entire charge is not uniform, the kiln operator should govern drying by the rate required for the most critical, slowest drying material. He thus takes longer than necessary to dry the fastest drying stock in order to protect the slowest drying stock from severe drying defects. This will require the selection of a group of samples that will represent the various classes of stock in the charge.

In either case, drying segregated or mixed charges, the kiln operator, in order to select representative kiln samples, should know how variability in drying characteristics of wood will affect the drying time and the quality of the drying.

### Factors that Affect Drying

The major factors that influence drying time and quality are:

1. Species
2. Thickness
3. Moisture content, or extent of previous drying
4. Heartwood and sapwood
5. Grain

The woods of the many species that grow in this country have a wide range of physical properties. The property most, pertinent to kiln operation is the ease of drying. Some woods, such as basswood, poplar, and pine, dry readily with little or no danger from drying defects. Others, such as oak and black walnut, are subject to serious surface checking, end checking, and honeycombing during kiln drying. Because some woods dry more readily than others, only one species should be dried in the kiln at one time, or only species that have similar drying characteristics. Although the mixing of species of like drying properties is sometimes permissible, the best procedure is to make up the entire kiln charge of only one species.

Lumber dries from all exposed surfaces, but most of the moisture given up during drying moves from the interior of the lumber to the wide flat surfaces. The thickness of the lumber is thus the critical dimension, and only lumber of uniform thickness should go into a kiln charge.

The extent to which lumber has been dried before it is put into the kiln must also be considered because the initial moisture content limits the temperatures that can be used. If all the free water has been removed by prior seasoning, relatively high temperatures can usually be used with little danger from the usual drying defects. Further, a uniform initial moisture content makes drying to a uniform final moisture content much easier. An equalizing period in the final stage of drying may be necessary if the initial moisture content varies materially and the range of final moisture-content values does not fall within the desired limits.

Sapwood usually dries considerably faster than the adjacent heartwood. Extractives, such as resins, tannins, and oils, are present in the heartwood in such a form that they retard the movement of moisture. Other mechanical

obstructions, such as the tyloses in some of the oaks and locusts, may also retard the movement of moisture. These obstructions greatly reduce the drying rate of the heartwood. Under some conditions the segregation of heartwood and sapwood is practical, and, where this is true, the kiln-drying problem is greatly simplified.

Vertical-grain material usually dries more slowly than flat-grain material. Therefore, when drying mixed charges of flat- and vertical-grained material the drying conditions may have to be governed by the moisture content of the vertical-grain stock. Generally, however, vertical-grain material is not as susceptible to drying defects as is flat-grain material. Therefore, it may be advantageous to segregate the material so that more severe drying conditions can be used on vertical-grain stock, thereby reducing drying time.

### Number of Kiln.Samples

The kiln samples should be 24 to 30 inches long cut from material to be dried. They should be placed in the kiln charge where they can be conveniently removed for periodic weighing and testing. The number of kiln samples will depend upon the variability of the material to be dried. Theoretically, if drying conditions are uniform throughout the kiln and the material is completely uniform, only one sample will be required. If there is considerable variability, several samples will be required. The final decision rests with the operator.

Kiln samples can help an operator do three things: (1) to dry a kiln charge according to a prescribed schedule without objectionable degrade, (2) to collect data on the performance of a kiln in drying a routine item, such as 4/4 pine lumber or 4/4 cedar lumber green from the saw, or thoroughly air-seasoned oak barrel staves, and (3) to collect data on the rate of drying in various locations throughout the kiln. In the first case, the object is to dry the particular kiln charge at hand; in the second, it is to collect drying data sufficient to enable the operator to develop a time-temperature schedule that will facilitate his work, and in the third, it is to check the drying performance of the kiln.

case One.--The commercial kiln drying of specific items, such as a kiln load of pine from the West Coast, sweetgum or tupelo from the South, or black walnut from the North Central States, presents a new drying problem for each charge. This might well be called "custom drying," as each kiln load may be quite different from any other. The variability of the material is unknown, even within one charge, and the variation from charge to charge provides no hope of ever developing a reliable time-temperature schedule such as would be possible in drying a routine item (case 2).

In drying such specific items of lumber, many samples are required in order to determine accurately the moisture variation between boards and/or truck-load. The more difficult the drying problem, the greater the number of samples needed. Obviously, the number of samples that can be used is limited both by the operator's capacity to do the work and by management's

reluctance to sacrifice the sample material, The number of samples should be limited only by their ability to pay dividends on the additional man-hours and material they require. Six samples from each kiln charge is probably the minimum number an operator should use,

Case Two.--In the second case, the operator is engaged in practical research. He is gathering data that will enable him to develop a time-temperature schedule by which to kiln-dry his routine item with a minimum of effort, whether it be 4/4 lumber, barrel staves, or shingles. To establish a time-temperature schedule, he needs to use many more samples with each kiln charge in order to obtain a range of drying data sufficiently representative of the stock he is drying. This involves extra work, and he may need assistance, Once the data are acquired, however, the work will be lessened.

Case Three.--Performance studies have shown that dry-bulb temperatures and rates of air circulation through the loads of lumber may vary considerably throughout the kiln, Such variations will affect drying time and the quality of drying. These variations can be easily and quickly found with testing equipment. This equipment, however, may not be available to the kiln operator. If so, kiln samples having the same drying characteristics (this is important) can be used to locate the zones causing trouble, These samples should be located throughout the kiln near the top and bottom of the loads at intervals of 10 feet or less along the kiln length. Zones of low temperatures And/or air velocity will result in slow drying while zones of high temperatures may result in drying defects, such as surface and end checking, honeycombing and collapse. If either of these conditions exist, the cause should be found and corrected. Generally, the zone of lowest temperatures will be found near the kiln doors,

### Selection of Kiln Samples

Boards from which kiln samples are to be cut should be selected while the lumber is being piled, preferably by a lumber handler who is trained to select sample boards. The kiln operator should examine these boards and cut kiln samples from those he believes most desirable for the purpose. For most drying, only one sample should be cut from each board to assure a representative group of samples. The upper drawing in figure 1 shows a good method of cutting and numbering one sample from a board. Most samples should be cut from boards that represent the wetter and thicker stock of the charge and that contain a comparatively high percentage of heartwood. Samples from this slower-drying material will be a useful guide during the early stages of the kiln run, when too rapid lowering of humidity may cause surface checking, and too rapid raising of temperature may cause honeycomb or collapse.

A few kiln samples should also be cut from boards that represent the drier and faster-drying material. Such boards will probably be scant in thickness and contain a high percentage of sapwood, These samples will be a useful guide during the final stages of drying, when the faster-drying material may become too dry. By proper control of the humidity, these low-moisture-content pieces can be kept from becoming too dry,

## Preparation of Kiln Samples

Kiln samples should be cut from the selected boards after the ends of the boards have been trimmed back to eliminate the effect of previous end-drying. One-inch moisture-content sections should be cut adjacent to each end of each kiln sample. The kiln samples and moisture-content sections should be systematically numbered for future identification (fig. 1). The moisture sections should be weighed and then put, in an oven at a temperature of 214° to 221° F. until they have reached constant weight in order to determine their moisture content.<sup>3</sup> Electric drying ovens with automatic temperature controls are manufactured for this purpose, but any oven in which the temperature can be controlled is suitable. A balance that is accurate to 0.01 gram is needed to weigh the moisture-content sections. Besides the triple-beam balance shown in figure 2, pan balances with auxiliary weights may also be used, but they are somewhat less convenient. The moisture content in percent is calculated by the following formula:

$$\text{Moisture content (Percent)} = \frac{\text{green weight} - \text{ovendry weight}}{\text{ovendry weight}} \times 100 \quad (\text{Formula 1})$$

The use of moisture-content sections measuring 1 inch along the grain is recommended for accurate determinations. Moisture-content sections are sometimes cut only 1/4 to 1/2 inch along the grain. When expediency necessitates the use of sections (less than 1-inch), the operator should take particular care to prevent loss of moisture by using a sharp saw and weighing each section immediately. Use of such short sections usually results in erroneously low moisture-content values. If the kiln were operated on the basis of such erroneous values, temperatures and relative humidities might be used that would be too severe for lumber, which would have a higher moisture content than indicated, and degrade might result.

The average moisture content of the two sections cut from wood adjacent to the kiln sample is assumed to be the moisture content of the kiln sample. Differences in moisture content between the individual sections will reveal any variation in moisture content along the board. A convenient method of obtaining the average moisture content of two sections is to weigh them together, thereby halving the work of weighing and calculating.

The kiln samples should be immediately end-coated to prevent end-drying, and then weighed. Many effective end-coatings are available on the market.<sup>4</sup>

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<sup>3</sup>Forest Products Laboratory Rept. No. 1649, "Methods of Determining the Moisture Content of Wood."

<sup>4</sup>Forest Products Laboratory Tech. Note No. 186, "Coatings that Prevent End Checks."

These should be used as recommended by the manufacturer. A scale or balance that is accurate to 0.01 pound, or approximately 5 grams, is required for weighing the coated samples (fig. 3). All weights should be in the decimal system, either in the metric system or as pounds and hundredths of a pound, but not in pounds and ounces.

The oven-dry weight of the kiln samples should be calculated by the following formula:

$$\text{Calculated oven-dry weight} = \frac{\text{green weight}}{100 + \text{moisture content (in percent)}} \times 100 \text{ (Formula 2)}$$

The moisture content determinations and the weights of the kiln samples should be recorded on suitable forms. Quite often the kiln operator will write the green weight and the calculated oven-dry weight on the kiln sample for ready reference.

### Example

An example of these calculations may be helpful in following this procedure:

Green weight of moisture-content section a<sub>1</sub> = 98.55 grams.

Oven-dry weight of moisture-content section a<sub>1</sub> = 59.20 grams.

Green weight of moisture-content section a<sub>2</sub> = 86.94 grams.

Oven-dry weight of moisture-content section a<sub>2</sub> = 55.02 grams.

Green weight of kiln sample A = 4.46 pounds

Wanted: Oven-dry weight of kiln sample A.

The moisture content section a<sub>1</sub> is found as follows (formula 1):

$$a_1 = \frac{98.55 - 59.20}{59.20} \times 100 = 66.5 \text{ percent.}$$

The moisture content of section a<sub>2</sub> is similarly calculated:

$$a_2 = \frac{86.94 - 55.02}{55.02} \times 100 = 58.0 \text{ percent.}$$

The average moisture content of kiln sample A is the average of these two values, thus:

$$\frac{a_1 + a_2}{2} = \frac{66.5 + 58.0}{2} = 62.2 \text{ percent}$$

The calculated oven-dry weight of kiln sample A. is then determined (formula 2):

$$\frac{4.46}{100 + 62.2} \times 100 = 2.75 \text{ pounds.}$$

### Placing Kiln Samples in Kiln Charge

The kiln samples should be placed in recessed areas in the load (fig. 4) so that they will be subjected to drying conditions similar to those affecting the lumber in the load. It is well to have samples in several loads distributed throughout the kiln, particularly in the coldest and hottest zones. Samples placed where they will be exposed to abnormal heat and air circulation may dry faster than the lumber, and changes of temperature and relative humidity made on the basis of the moisture content of these samples may be too severe and cause degrade in the lumber. Frequently, kiln samples are placed in an upright position near the kiln door, This is very poor practice and should never be done.

If a mixed kiln charge is being dried, the sample or samples of any given class of material should be placed with that material during drying. For example, if three truckloads of lumber compose a kiln charge, one each of 4/4, 5/4, and 6/4 oak, the samples cut from the 4/4 stock should be placed in the truckload of 4/4 lumber and not in the truckload of 5/4 or 6/4 lumber.

Distribution of the kiln samples throughout the load will show, in a very general way, differences in drying rate throughout the kiln. Consistent results in repeated runs will indicate the areas in the kiln where an operator can expect fast drying, and the areas where he can expect slow drying. When an operator is particularly interested in obtaining such information the samples should be matched as closely as possible. This is generally done by cutting more than one sample from a board. The lower drawing in figure 1 shows a good method of cutting and numbering two kiln samples from a board.

### Regular Weighing of Kiln Samples

During the operation of the kiln, the samples should be removed periodically (usually daily) from the kiln for weighing. The fans and steam spray should be turned off before an operator enters the kiln. When high temperatures and humidities are being maintained, protective clothing and a suitable mask should be worn, and the door should be left open to create a cool draft of air near the floor. As a safety measure, a second person should be stationed

nearby, while the operator is inside the kiln, The samples should be returned to their respective places in the loads of lumber as soon as possible.

The current moisture content of each sample in percent is determined by the following formula:

$$\text{Current moisture content (percent)} = \frac{\text{current weight} - \text{calculated oven-dry weight}}{\text{calculated oven-dry weight}} \times 100 \quad (\text{Formula 3})$$

### Example

By continuing the first example, the current moisture content of the kiln sample whose calculated oven-dry weight is 2.75 pounds, will be found after drying in the kiln to a weight of 4.14 pounds, as follows (formula 3):

$$\text{Current moisture content (Percent)} = \frac{4.14 - 2.75}{2.75} \times 100 = 50.5 \text{ percent.}$$

### Evaluation of Kiln-Sample Data

The calculated moisture-content values of the kiln samples will usually indicate a spread in moisture content. This spread presents the problem of interpreting those values for the purpose of following a kiln schedule. The schedules recommended by the Forest Products Laboratory are set up so that the drying conditions are changed in accordance with the moisture content of the kiln charge. Sometimes, the kiln operator will change drying conditions by using the average moisture content of all the kiln samples. At other times, however, he may change conditions according to the average of the wettest half or third of the kiln samples, and occasionally according to the wettest one or two kiln samples in the charge.

The operator should be guided in the evaluation of kiln-sample data by the drying characteristics and the value of the material. While the drying of mixed charges is not considered good practice, this procedure may have to be followed in some cases. If so, the kiln operator must use good judgment in determining what samples will be used to control drying conditions. For example, if a charge of lumber contains some stock that is of a low grade and does not require precise drying yet dries much slower than the balance of the charge, the kiln operator should not use samples from this stock to control drying conditions. If this were done, drying time on the higher-grade material would be extended unnecessarily.

## Intermediate Moisture-Content Tests

Lumber from most species of wood contains water pockets; zones of very high moisture content. These water pockets cannot be seen, may be very irregular in shape and size, and there is no practicable method of locating them.

If, when making the initial moisture-content determinations, the 1-inch sections cut from the sample contain water pockets, the calculated oven-dry weight of the sample will be affected. If water pockets are present in the sections, the calculated oven-dry weight of the sample may be too low. If there are water pockets in the sample but none in the sections, the calculated oven-dry weight of the sample will be too high. To guard against this possible error in calculations, it is suggested that an intermediate moisture-content determination be made on all kiln samples from all classes of stock that have entered the kiln at an average moisture content of 25 percent or more. These intermediate determinations should be made when the kiln samples have reached an average moisture content of about 15 to 20 percent.

After the samples are weighed, a section about 5 inches long is cut from the end of each sample and discarded. A 1-inch moisture section is then taken from this freshly cut end, immediately weighed, and placed in a drying oven. End coating is applied to the freshly cut end of the kiln sample, and the shortened sample is weighed to the nearest 0.01 pound. This weight will be considered the new "green" weight in formula 2. As soon as the 1-inch section has reached constant weight in the drying oven, its moisture content is calculated by formula 1. This moisture-content value together with the new "green" weight of the kiln sample are substituted in formula 2 to obtain a new calculated oven-dry weight of the sample. This new calculated oven-dry weight is then used in formula 3 to obtain the current moisture content of the samples in all subsequent weighings.

In cases where the stock went into the kiln at a moisture content at about 25 percent, intermediate moisture-content tests usually are unnecessary. Where doubt exists, or when extreme precision is needed, another moisture-content test can be made after some drying.

## Moisture Tests Near the End of the Drying Period

Additional moisture-content tests are not needed near the end of drying, if intermediate moisture-content tests have been made. Equalizing and conditioning treatments can be accurately regulated using the moisture-content values obtained by weighing the shortened kiln samples.

After the lumber has been properly dried and conditioned, it is desirable to make final tests for moisture content and stress condition. This will help the kiln operator develop his experience and know if he is getting the quality of drying required. A statistical method of checking quality is

available.<sup>5</sup> Such final tests will also enable the operator to discover improperly dried stock in case some phase of operation has gone wrong.

Final tests should be made by cutting 2 or 3 sections near the longitudinal center of all kiln samples. If the wood has been dried to a fairly low level, 10 percent or less, these sections need be no longer than 1/2 inch.

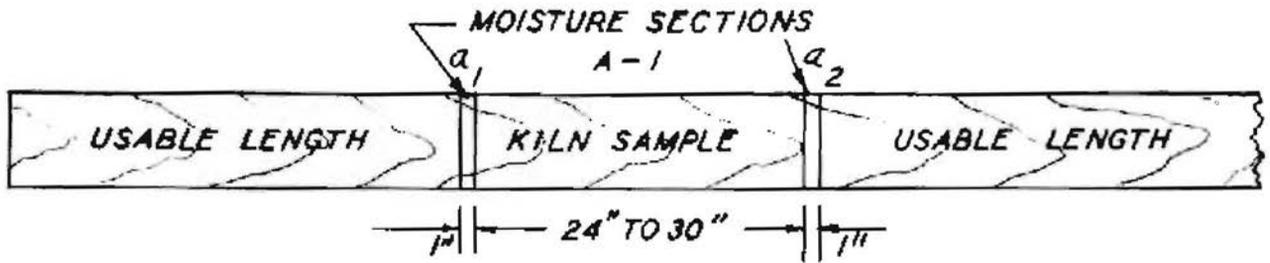
One of these sections should be used to determine average moisture content by means of formula 1.

Another section should be used for stress tests, This section should be slotted as shown in figure 5.

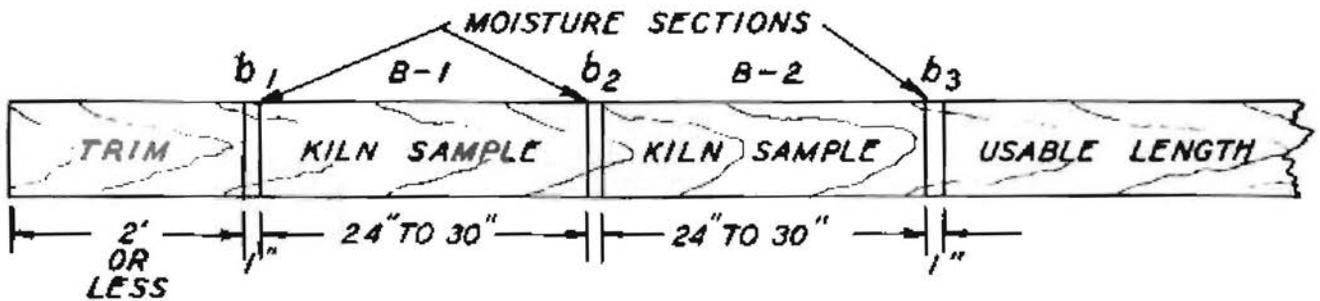
The third section can be used for a moisture-distribution test. This section is further cut so that the core and shell can be weighed separately (fig. 6). Formula 1 is used to calculate the moisture content.

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<sup>5</sup>Forest Products Laboratory Rept. No. 1685, "Methods for Controlling the Moisture Content of Wood Going Into Furniture Production,"



ONE SAMPLE PER BOARD



TWO SAMPLES PER BOARD

Figure 1.--Method of cutting and numbering kiln samples and moisture content sections. Trim should be of sufficient length to eliminate wood of low moisture content due to end drying. Often a trim of 2 feet is required.

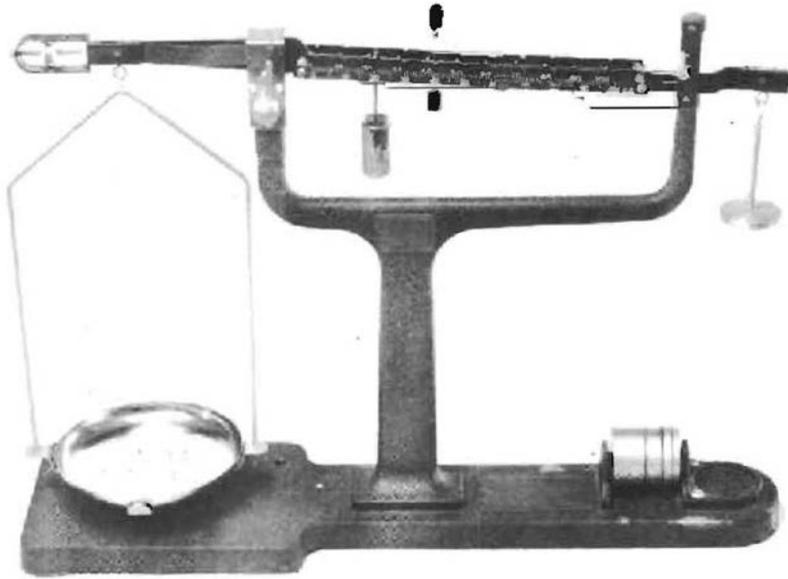


Figure 2.--Triple-beam balance with accuracy of 0.01 gram and auxiliary weights to increase capacity to 1,011 grams, for weighing moisture content sections before and after oven drying.

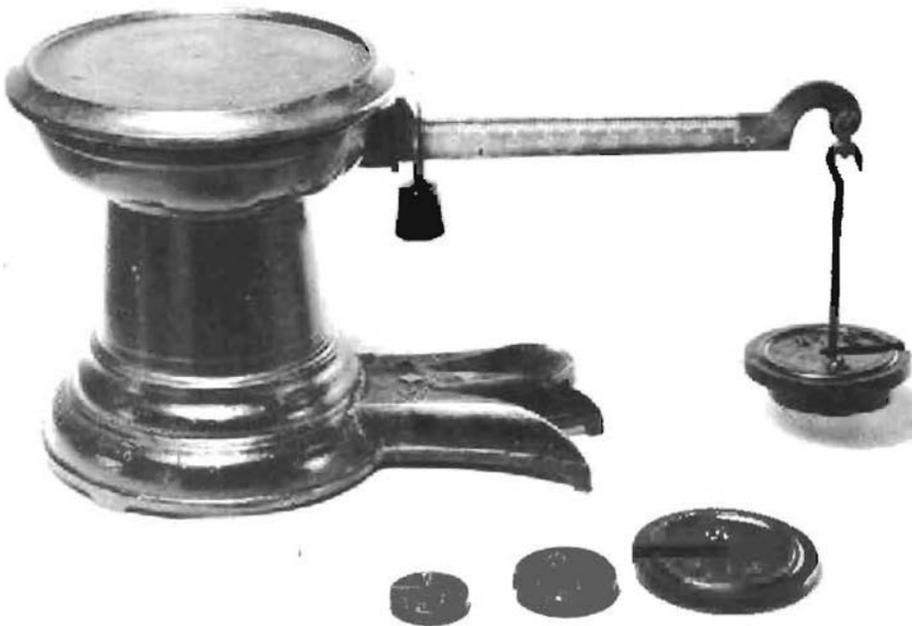


Figure 3.--Scale with capacity of 36 pounds and accuracy of 0.01 pound, for weighing kiln samples.

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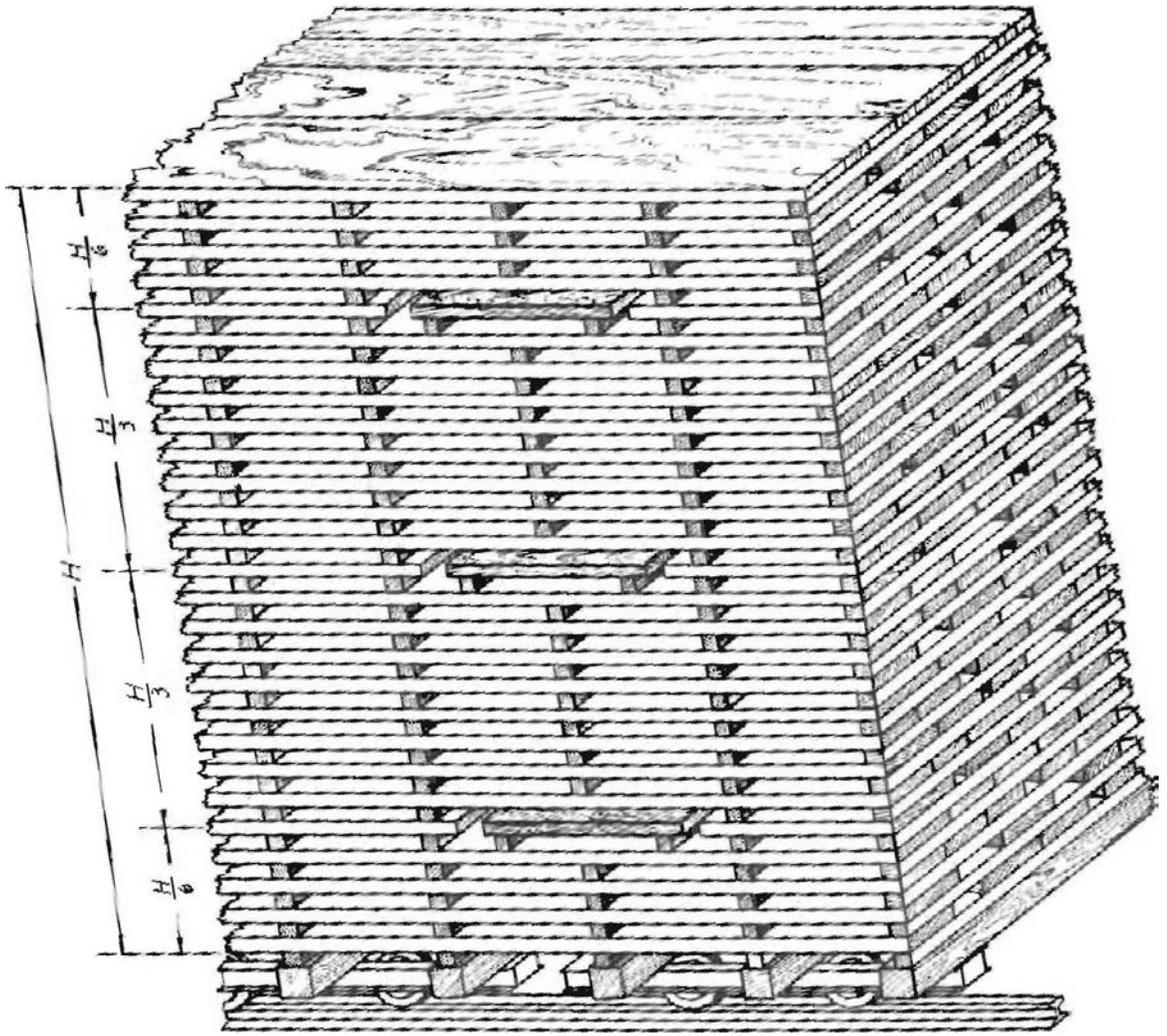
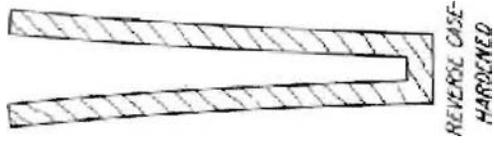


Figure 4.--Placement of three kiln samples in recessed areas built the side of an end-piled load of lumber.

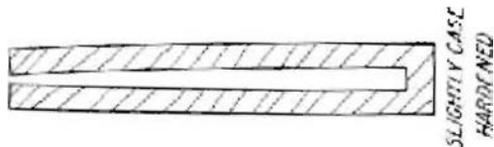
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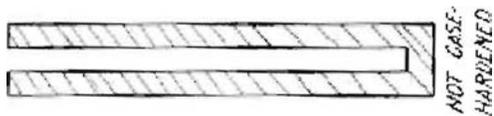
REVERSE CASE-HARDENED



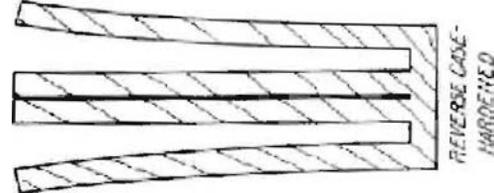
CASE-HARDENED



SLIGHTLY CASE-HARDENED



NOT CASE-HARDENED



REVERSE CASE-HARDENED



CASE-HARDENED



SLIGHTLY CASE-HARDENED



NOT CASE-HARDENED

Figure 5.--Method of cutting specimens for case-hardening tests. Material that is less than 1-1/2 inches thick is cut into three prongs and the center prong is removed; material that is 1-1/2 inches thick or thicker is cut into six prongs and the second and fifth prongs are removed.

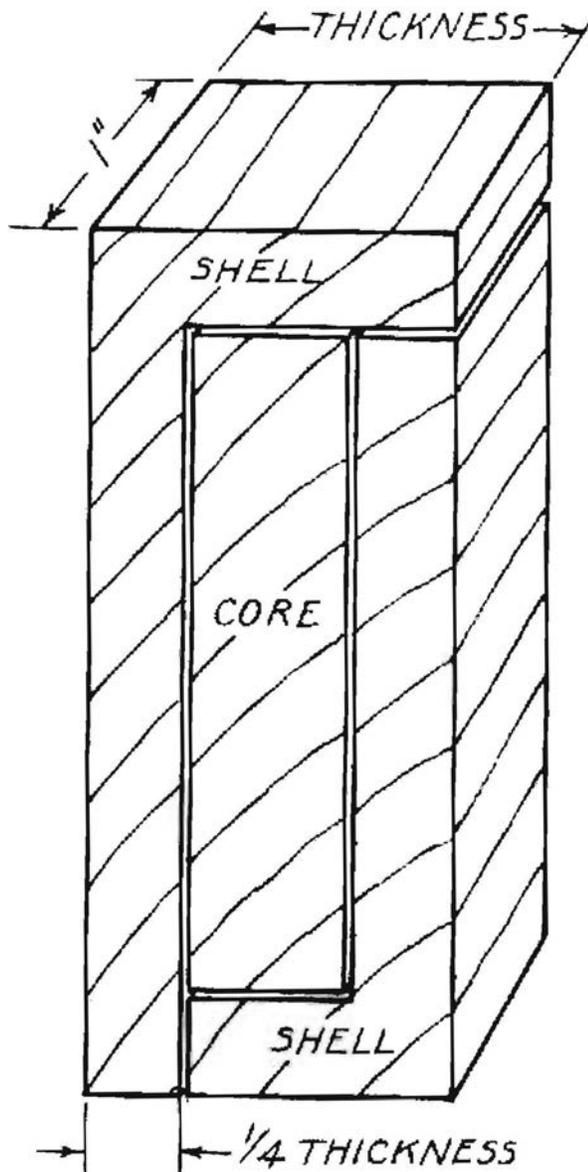


Figure 6.--Method of cutting section for determination of shell and core moisture distribution.

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