Chapter 6
Kiln Samples

Chapter 6 was revised by William T. Simpson, Supervisory Research Forest Products Technologist.

Lumber is dried by kiln schedules, which are combinations of temperature and relative humidity applied at various times or at various moisture content levels during drying (see ch. 7). When moisture content levels are the determining factor for adjusting temperature and relative humidity in the kiln, some means of estimating moisture content of the lumber in the kiln during drying is necessary. These estimates are made with kiln sample boards, which are weighed or otherwise sensed during drying.

Kiln samples are not used in drying softwood dimension lumber and are rarely used for drying lumber for higher quality softwood products. Kiln samples are usually used in hardwood lumber drying because incorrect kiln conditions have more severe consequences for hardwood lumber than for softwood lumber.

Traditionally, kiln samples have been removed from the kiln periodically and weighed manually for moisture content estimates. This manual procedure is still used in the majority of hardwood operations, but automated methods are beginning to be developed. One such method utilizes probes that are inserted into sample boards to measure electrical resistance as an estimate of moisture content (ch. 1, table 1-11). This electrical resistance signal can then be fed into a computer control system that makes scheduled changes in kiln conditions automatically. Another system uses miniature load cells that can continuously weigh individual sample boards; the weights are fed into a computer control system.

Whether kiln samples are monitored manually or automatically, the same principles of selection and placement apply. The main principle of selection is that the kiln samples be representative of the lumber in the kiln, including the extremes of expected drying behavior. It is impractical to monitor moisture content of every board in a kiln, so the samples chosen must represent the lumber and its variability. The main principles of placement are that the samples are spread throughout the kiln at various heights and distances from the ends of lumber stacks and that the samples are subject to the same airflow as the lumber.

The handling of kiln samples requires additional operator time, and some lumber is lost when kiln samples are taken. These disadvantages are more than offset by several advantages. The selection, preparation, placement, and weighing of kiln samples, if properly done, provide information that enables a kiln operator to (1) reduce drying defects, (2) obtain better control of the final moisture content, (3) reduce drying time and improve lumber quality, (4) develop time schedules, and (5) locate sources of trouble that affect kiln performance. All these advantages add up to lower drying costs and more uniformly dried lumber.

This chapter covers selection and preparation of kiln samples; the number of samples required in a kiln charge; determination of moisture content and ovendry weight of samples; how to use samples during drying; how to make intermediate moisture content estimates; tests for residual drying stresses; and recording and plotting of data.

Variability of Material

To make full use of known drying techniques and equipment and to assure good drying in the shortest time, each kiln charge should consist of lumber with similar drying characteristics. Differences between boards will invariably exist despite measures to minimize them, and kiln sample selection must include these differences. The following variables should be considered in selecting kiln samples: (1) species, (2) thickness, (3) moisture content, (4) heartwood and sapwood, (5) wetwood or sinker stock, and (6) grain (flatsawn or quartersawn).

Species

Wood of both native and imported species has a wide range of physical properties that can influence ease of drying (ch. 1 and USDA 1987). These properties include specific gravity, shrinkage, moisture diffusion and permeability, strength perpendicular to the grain, and size, distribution, and characteristics of anatomical elements. Such woods as basswood, yellow-poplar, and the pines are relatively easy to dry, with few or no serious drying defects. Others, such as the oaks, black walnut, and redwood, are more likely to check, honeycomb, and collapse during kiln drying. Consequently, it is usually advisable to dry only one species at a time in a kiln, or, at most, a few species that have similar drying characteristics. If mixed species are dried together, kiln samples should be taken from all species.

Thickness

When lumber dries, the moisture evaporates from all surfaces but principally from the wide faces of boards. Thickness, therefore, is the most critical dimension. The thicker the lumber, the longer the drying time and the more difficult it is to dry without creating defects (ch. 1). Lumber of different thicknesses cannot be dried in the same kiln charge without either prolonging the drying time of the thin lumber or risking drying defects in the thick lumber.

Kiln operators should recognize miscut lumber and either dress it to uniform thickness or choose kiln samples accordingly. Nominal l-in-thick lumber can vary from 3/4 in to over 1 in thick, even in the same board. The thinner parts will dry faster than the thick parts, resulting in uneven final moisture content or drying defects.

Moisture Content

The extent to which lumber has been air dried or predried before it is put in a kiln must also be considered, because moisture content often governs the drying conditions that can be used. If all the free water has already been removed, more severe drying conditions can be used in the initial stages of kiln drying, with little or no danger of producing drying defects. Furthermore, a uniform initial moisture content greatly accelerates drying to a uniform final moisture content. If boards vary considerably in initial moisture content, the kiln samples should reflect this variation.

Heartwood and Sapwood

Sapwood usually dries considerably faster than heartwood. Resins, tannins, oils, and other extractives retard the movement of moisture in the heartwood. Tyloses and other obstructions may be present in the pores of the heartwood of some species, principally white oak and the locusts. Sometimes, it is practical to segregate the heartwood and sapwood boards. The green moisture content of sapwood is usually higher than that of heartwood, particularly in the softwoods. For these reasons, heartwood lumber may not reach the desired final moisture content as soon as sapwood, or vice versa. Choice of kiln samples should be guided by the relative proportions of heartwood and sapwood in a kiln charge.

Wetwood or Sinker Stock

Wetwood or sinker stock (Ward and Pong 1980) is a condition (bacterial infection) that develops in the living tree and causes entire boards or parts of boards to be higher in initial moisture content, slower drying, or more susceptible to drying defects. Hemlocks, true firs, red oaks, aspen, and cottonwood develop this kind of wood. Ideally, wetwood should be segregated from normal lumber and dried separately by a different drying schedule. However, it is not always possible or practical to do so. From the standpoint of kiln sample selection, only the hardwoods are really relevant. Bacterially infected wood often has a disagreeable odor, especially in red oaks, or may be darkened (aspen and cottonwood).

If wetwood is suspected, the sample boards should be selected accordingly and observed carefully during drying to detect any drying defects.

Grain

Quartersawn boards generally dry more slowly than flatsawn, but they are less susceptible to surface checking. Thus, more severe drying conditions can be used on quartersawn lumber to reduce drying time. It is sometimes advantageous to segregate quartersawn and flatsawn lumber in drying. If not, kiln samples should reflect the relative amounts of the two grains in a charge.

Number of Kiln Samples

The number of kiln samples needed for any kiln charge depends upon the condition and drying characteristics of the wood being dried, the performance of the dry kiln, and the final use of the lumber. There are several reasons for using kiln samples, which may dictate the number as well as placement of the samples. Kiln samples are used when drying lumber by moisture content schedules and for developing time-based drying schedules.

Moisture Content Schedules

By far the most important purpose of kiln samples is to enable a kiln operator to dry a kiln charge of lumber by a specific moisture content schedule (ch. 7). This type of schedule calls for changes in drying conditions that are based on the moisture content of the lumber during various stages of drying.

Because many variables affect drying results, the specific number of kiln samples required when using moisture content schedules has not been firmly established. The requisite number is different for different species, initial moisture contents, and kilns, and it is best determined through experience. A rule of thumb given in the earlier version of this manual (Rasmussen 1961) is to use at least four samples in charges of 20,000 fbm or less. For charges of 100,000 fbm or more, 10 to 12 kiln samples per charge are usually sufficient. More samples should be used when (1) drying a charge of lumber of different species, thicknesses, moisture contents, grain, or mixture of heartwood and sapwood, (2) drying an unfamiliar species, (3) drying costly lumber, (4) obtaining drying data for modifying a drying schedule or developing a time schedule, and (5) using a dry kiln whose performance is unknown or erratic.

Since publication of the earlier edition of this manual, research has been conducted to better define the necessary number of kiln samples (Fell and Hill 1980). Although this research is not directly applicable to commercial practice, it provides some guidelines. In their scheme, which applies to hardwoods, Fell and Hill recommended using 10 to 12 kiln samples to monitor moisture content from green to 40 percent. Twenty to 23 samples are recommended for 40 to 12 percent moisture content because this range requires a more precise estimate of moisture content. Finally, only 7 to 12 samples are recommended for 12 to 6 percent moisture content. These recommendations call for considerably more kiln samples than the rule of thumb guidelines, but they are based on statistical sampling. Operators should use their experience and individual circumstances to weigh the value of the increased precision, at an increased cost, that comes with increasing the number of kiln samples.

Time Schedules

At plants where certain species and thicknesses of lumber from the same source are dried regularly, kiln operators can utilize kiln samples to develop time schedules for subsequent charges of the same material dried from and to the same moisture content. This may involve extra sampling work to measure the full range of variables, but after sufficient information and experience are obtained, kiln samples can be eliminated for future charges.

Time schedules are generally used in drying softwoods. It is possible, however, to develop satisfactory time schedules for some of the more easily dried hardwoods. Some samples should be used occasionally to check the performance of the kiln and the final moisture content of the lumber.

Checking Kiln Performance

Studies of kiln performance show that dry-bulb temperature and rate of air circulation throughout a kiln may vary considerably and affect the time and quality of drying. Variations in temperature and air circulation can be determined with testing equipment (ch. 3). But if such equipment is not available, kiln samples can be used to check variability of kiln performance. All samples for this purpose should be cut from the same board to minimize variation in drying characteristics between samples. The samples should be placed near the top and bottom of the stacks and on both sides, at intervals of 10 to 16 ft along the length of the kiln.

Kiln samples that dry slowly indicate zones of low temperature or low air circulation, and those that dry rapidly indicate zones of high temperature or high air circulation. If the drying rates vary greatly, action should be taken to locate and eliminate the cause. Differences in drying rates between the samples on the entering-air and leaving-air sides of the stacks will assist the operator in determining how often to reverse air circulation. The greater the difference in drying rate between these two, the more frequently the direction of air circulation should be reversed.

Selecting Kiln Samples

Ideally, segregation of lumber is based on all the factors that affect drying rate and quality. Since this is frequently not possible or practical, a kiln operator must be guided in the selection of kiln samples primarily by the drying rate of the most critical, slowest drying material. The largest number of samples should be selected from the slowest drying material. Some samples should also be selected from the fastest drying material, since these will determine when the equalizing period should be started (ch. 7).

The best time to select boards from which kiln samples will be cut is during stacking. Some boards are selected to represent the heavier, wetter, and thicker boards and to contain a relatively high percentage of heartwood. Usually one kiln sample is cut from each sample board to assure a representative group of kiln samples (fig. 6-1). Some kiln samples are also cut from boards that represent the drier and faster drying boards. Such boards are usually flatsawn, narrow, and scant in thickness, contain a high percentage of sapwood, or are drier than the rest of the lumber at the time of stacking.

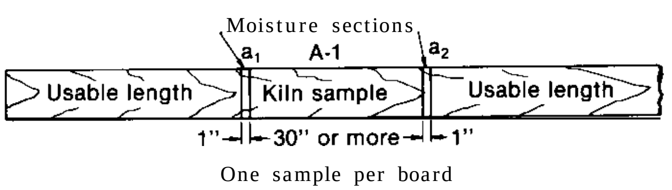


Figure 6-1—Method of cutting and numbering kiln samples and moisture content sections. (ML88 5587)

Preparing Kiln Samples and Moisture Sections

Kiln samples that will be weighed during drying and moisture sections are prepared as shown in figure 6-1. Kiln samples should be 30 in or more long. Moisture sections, cut for the purpose of estimating initial moisture content, should be about 1 in. in length along the grain. Knots, bark, pitch, and decay should not be included in the kiln samples, except when drying lumber of the common grades. The moisture sections that are cut from each end of the kiln sample must be of clear, sound wood. Any bark on the kiln sample or moisture sections should be removed before weighing because it causes error in the moisture content estimate and interferes with drying.

Cutting Kiln Samples and Moisture Sections

Mark the kiln samples and moisture sections for identification, as shown in figure 6-1, before they are cut. Usable lengths of lumber can be salvaged from each end of the board when the kiln samples and moisture sections are cut. If no usable lengths would be left, cut the samples and moisture sections about 20 in or more from the ends of the boards to eliminate the effects of end drying.

With certain exceptions, moisture sections are not cut less than 1 in along the grain and are cut across the full width of the board. It may be necessary to cut moisture sections less than 1 in. in length along the grain if a quick estimate of moisture content is needed. To minimize errors, take extra precautions in cutting, handling, and weighing these thinner sections. In dimension stock 1 in square or less in cross section, moisture sections are cut 2 in or more in length along the grain. A sharp, cool-running saw should be used and the sections weighed immediately. If it is necessary to cut a number of sections at a time before weighing them, the sections should be wrapped in aluminum foil or a sheet of plastic wrap.

Determining Moisture Content and Weight of Kiln Samples and Moisture Sections

The moisture content of a kiln sample is determined from the moisture sections cut from each end of the sample. The average moisture content of these two sections and the weight of the kiln sample at the time of cutting are used to calculate the ovendry weight of the sample. The ovendry weight and the subsequent weights of the sample obtained at intervals during drying-called current weights—are used to calculate the moisture content at those times.

Weighing Moisture Sections

After cutting the moisture sections, rapidly remove all bark, loose splinters, and sawdust, and weigh the sections immediately. Weigh each section on a balance that has precision of 0.5 percent of the weight of the section and that reads in grams. Triple beam or top loading pan balances are suitable for this (ch. 3). Balances with the precision to weigh moisture sections are somewhat delicate, and they require proper care and maintenance. The manufacturer's recommendations and procedures should be consulted to ensure accurate measurement.

To save weighing and calculating time, the two moisture sections cut from each kiln sample are sometimes weighed together. This technique, however, does not distinguish the difference in moisture content usually present between the two moisture sections; therefore, separate weighings are preferred. After weighing the moisture sections separately or together, mark the weight on each section with an indelible pencil or a felt-tip pen with waterproof ink and record the weight or weights on a data form.

Weighing Kiln Samples

After cutting the kiln samples, remove all bark, loose splinters, and sawdust. Then, immediately apply an end coating. Most kiln companies offer an end-coating product, and asphalt roofing compounds are effective and readily available. Immediately after end coating, weigh the kiln samples on a balance that is sensitive to 0.01 lb or approximately 5 g. The balance capacity should be about 35 lb (15 kg). Weight should be expressed in either metric units or in pounds and decimals of pounds (not ounces). Mark the weight with a waterproof pencil or ink on the kiln sample and also record it on a data form. The weight of the end coating can usually be disregarded. If for some reason the kiln sample has to be shorter than recommended and is made from a low-density species, it may sometimes be desirable to consider the weight of the end coating. If so, weigh the kiln sample immediately before and after end coating; the difference, which is the weight of the end coating, should be subtracted from all subsequent sample weights.

Ovendrying Moisture Sections

After weighing the moisture sections, they should be dried until all water has been removed in an oven maintained at 214 to 221 °F (101 to 105 °C). This usually takes 24 to 48 h in a convection oven. To test whether the sections are thoroughly dry, weigh a few sections, place them back in the oven for 3 to 4 h, and then reweigh. If no weight has been lost, the entire group of sections can be considered completely dry. A typical electric oven for drying moisture sections is shown in chapter 3.

The moisture sections should be open piled in the oven to permit air to circulate freely around each section (ch. 3, fig. 3-7). Avoid excessively high temperatures and prolonged drying because they cause destructive distillation of the wood. The result is that ovendry weights are too low, and thus the estimate of moisture content is too high. If newly cut sections are placed in an oven with partly dried sections, the newly cut sections may cause the drier sections to absorb some moisture and unnecessarily prolong drying time.

Microwave ovens can also be used for ovendrying moisture sections. Such ovens are much faster than a convection oven (moisture sections can generally be dried in less than 1 h), but care must be taken not to overdry or underdry the sections. In a convection oven there is a considerable margin of error. If a moisture section is left in longer than necessary, no great harm is done, and the ovendry weight will not be affected significantly. However, if a moisture section is left in a microwave oven even slightly longer than necessary, considerable thermal degradation can occur. The indicated ovendry weight of the moisture section will be less than it should be, and the calculated moisture content will be too great. This danger can be decreased by using a microwave oven with variable power settings. Through experience, the operator can establish combinations of species, size, and initial moisture content of moisture section, ovendrying time, and oven power setting that give accurate ovendry weights.

Weighing Ovendry Moisture Sections

Ovendried moisture sections are weighed by the same procedures as freshly cut moisture sections. However, the sections must be weighed immediately after removing from the oven to prevent moisture adsorption.

Calculating Moisture Content of Moisture Sections

Moisture content of the moisture sections is calculated by dividing the weight of the removed water by the ovendry weight of the sections and multiplying the quotient by 100. Since the weight of the water equals the original weight of the section minus its ovendry weight, the formula for this calculation is

$$\text{Moisture content in percent} = \frac{\text{Original weight} - \text{Ovendry weight}}{\text{Ovendry weight}} \times 100 \qquad (1)$$

Example: Calculate the average moisture content of two moisture sections (fig. 6-1) when

Green weight of moisture section a_1 is 98.55 g

Ovendry weight of moisture section a_1 is 59.20 g

Green weight of moisture section a_2 is 86.92 g

Ovendry weight of moisture section a_2 is 55.02 g

Wanted: The average moisture content of moisture sections a_1 and a_2, Two methods of calculating average moisture content in percent can be used.

Method 1:

Moisture content of section a_1

$$= \frac{98.55 - 59.20}{59.20} \times 100 = 66.6 \text{ percent}$$

Moisture content of section a_2

$$= \frac{86.92 - 55.02}{55.02} \times 100 = 58.0 \text{ percent}$$

The average moisture content of moisture sections a_1 and a_2 is

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

Method 2:

If the sections are weighed together, the combined green weight of sections a_1 and a_2 is 185.47 g, and their combined ovendry weight is 114.22 g. Then

Average moisture content

$$= \frac{185.47 - 114.22}{114.22} \times 100 = 62.4 \text{ percent}$$

Although the average moisture content of moisture sections a_1 and a_2 calculated by method 2 results in a slightly higher value than that obtained by method 1, the calculated ovendry weight of the kiln sample using either method will be the same when corrected to the nearest 0.01 lb.

It is sometimes convenient when making calculations to use a shortcut method of calculating moisture content by the formula

Moisture content

$$= \left(\frac{\text{Original weight}}{\text{Ovendry weight}} - 1\right) \times 100$$

Substituting the weights for moisture section a_1 in this formula

Moisture content in percent of section a_1

$$= \left(\frac{98.55}{59.20} - 1\right) \times 100 = (1.6647 - 1) \times 100$$

$$= 66.5 \text{ percent}$$

Calculating Ovendry Weight of Kiln Samples

The moisture content of a kiln sample at the time of cutting and weighing is assumed to be the same as the average of the moisture content values of the two moisture sections cut from each end of the sample. Knowing this value and the weight of the sample at the time the sections were cut, the ovendry weight of the sample can be calculated by using the following formula:

Ovendry weight of kiln sample

$$= \frac{\text{Original weight of kiln sample}}{100 + \text{MC of sample in percent}} \times 100 \quad (2)$$

where MC is moisture content

Example: Calculate the ovendry weight of kiln sample A-1 (fig. 6-1), which had an original weight of 4.46 lb, using the average moisture content calculated for moisture sections a_1 and a_2, 62.2 percent.

$$\text{Ovendry weight of kiln sample} = \frac{4.46}{100 + 62.2} \times 100$$

$$= 0.02749 \times 100$$

$$= 2.75 \text{ lb}$$

A shortcut version of equation (2) that is useful with calculators is

Ovendry weight of kiln sample

$$= \frac{\text{Original weight of kiln sample}}{1 + \text{Moisture content in decimal form}}$$

Substituting the weights for kiln sample A-l,

Ovendry weight of kiln sample

$$= \frac{4.46}{1 + 0.622} = 2.75 \text{ lb}$$

Placing Samples in Kiln Charges

After kiln samples are cut, end coated, and weighed, they are placed in sample pockets as described in chapter 5 and illustrated in figure 6-2. Sample pockets are usually placed at several locations along the length of the kiln in the sides nearest the walls. Since the kiln samples are representative of the lumber being dried, they should at all times be exposed to the same drying conditions or they will give a false estimate of the moisture content of the kiln charge. For example, if samples are cut and weighed several days before the lumber is loaded into the kiln, the samples should be inserted in the loads or packages during the time the lumber is outside the kiln.

If a mixed kiln charge is being dried, the samples representing each type of material should be placed in the truckloads or packages containing that lumber. For example, if 4/4 and 6/4 pine lumber are being dried in the same charge, the 4/4 samples should be with the 4/4 lumber and the 6/4 samples with the 6/4 lumber.

Some operators of poorly lighted kilns place small colored-glass reflectors or reflective tape on the edges of the samples or the edges of boards above and below the sample pocket. These reflectors can be located with a flashlight. To guard against replacing samples in the wrong pocket after weighing, a number or letter corresponding to the sample can be written on the edge of the board immediately above or below the pocket.

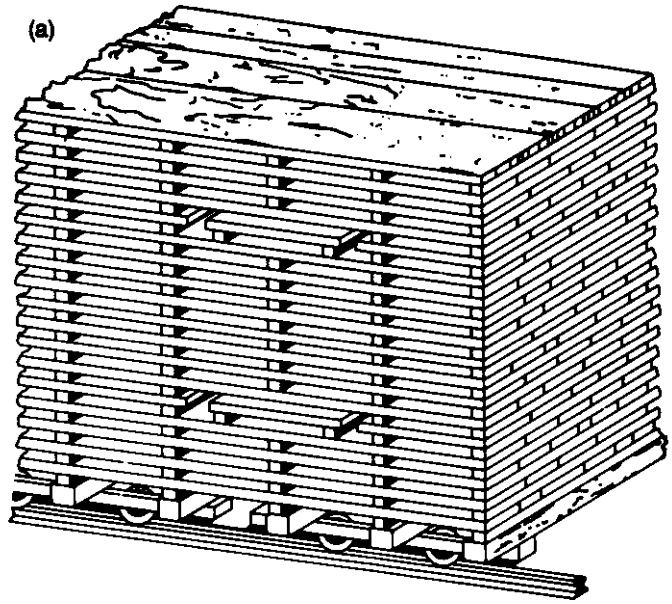
Using Kiln Samples During Drying

As drying progresses, the drying conditions in the kiln are changed on the basis of the moisture content of the samples at various times during the run. How frequently the samples must be weighed will depend on the rate of moisture loss; the more rapid the loss, the more frequently samples must be weighed. The samples must be returned to their pockets immediately after weighing.

Calculating Current Moisture Content of Samples

Two weights are required to calculate the current moisture content of a sample: the current weight and the calculated ovendry (OD) weight. The formula used is as follows:

$$\text{Current moisture content} = \frac{\text{Current weight} - \text{Calculated OD weight}}{\text{Calculated OD weight}} \times 100 \quad (3)$$



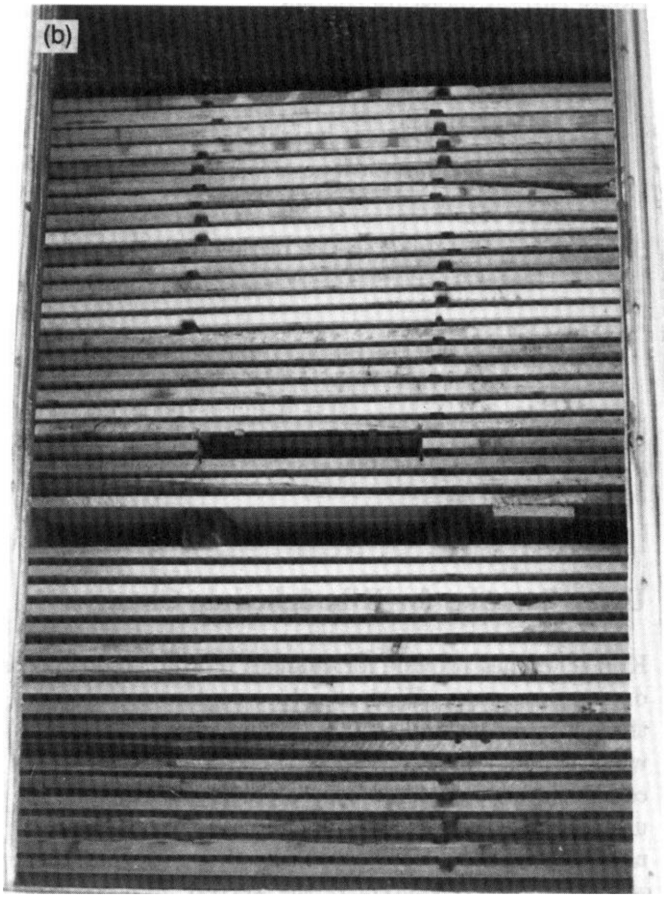


Figure 6-2—(a) Schematic showing placement of kiln samples in sample pockets built in the side of a load of lumber. The pockets should be deep enough so that the kiln samples do not project beyond the edge of the load. (b) Photograph showing kiln sample in place. (ML88 5624, MC88 9028)

Thus, if the calculated ovendry weight of the sample is 2.75 lb and its current weight 4.14 lb, then

$$\text{Current moisture content} = \frac{4.14 - 2.75}{2.75} \times 100$$
$$= 0.5054 \times 100$$
$$= 50.5 \text{ percent}$$

After another day of drying, this sample may weigh 3.85 lb. The current moisture content of the sample will then be

$$\frac{3.85 - 2.75}{2.75} \times 100 = 0.400 \times 100$$
$$= 40.0 \text{ percent}$$

The following shortcut formula can also be used to calculate current moisture content:

$$\text{Current moisture content} = \left(\frac{\text{Current weight}}{\text{Calculated ovendry weight}} - 1\right) \times 100$$

Substituting the above values in this formula,

$$\left(\frac{3.85}{2.75} - 1\right) \times 100 = (1.400 - 1) \times 100$$
$$= 0.400 \times 100$$
$$= 40.0 \text{ percent}$$

Using Samples for Kiln Schedule Changes

Kiln schedules provide for changes in kiln conditions as drying progresses. With moisture content schedules, the temperature and relative humidity are changed when the moisture content of the kiln samples reaches certain levels as defined by the particular schedule in use. If the schedules recommended in chapter 7 are used, drying conditions should be changed when the average moisture content of the wettest 50 percent of the kiln samples equals a given moisture content in the schedule. Sometimes, a kiln operator may change drying conditions according to the wettest one-third of the samples or the average moisture content of a smaller group that may be distinctly wetter or more difficult to dry than the others. These are called the controlling samples. The moisture content of the driest sample determines when equalizing should be started (ch. 7).

Using Automatic Systems

When automatic control systems are used, the use of kiln samples and moisture sections is changed somewhat. When electronic probes are used, there is no need to cut kiln samples or moisture sections. The principles of selecting sample boards still apply, however, because the probes will be inserted in sample boards. Variation in drying time between sample boards also needs to be known. When miniature load cells are used, kiln samples and moisture sections are still necessary. However, since the weights of the sample boards are taken automatically and continuously, there is no need to enter the kiln to get kiln samples. Computer interface and control do not require manual calculation of current moisture content.

The use of electronic probes that estimate moisture content from electrical resistance is growing. Such probes offer automatic control, but they currently have some limitations. The change in electrical resistance with moisture contents above 30 percent is small, so that the probes are limited in accuracy above this level of moisture content. Currently, charges in kilns that use these control systems are dried to 30 percent moisture content using home other control principle, and probes are able to control from 30 percent to final moisture content.

Intermediate Moisture Content Tests

If the moisture content of the moisture sections does not truly represent that of the kiln sample, the calculated ovendry weight of the kiln sample will be wrong. This may mislead the operator into changing kiln conditions at the wrong time, with such serious consequences as prolonged drying time, excessive drying defects, and nonuniformly dried lumber. For example, if water pockets are present in the moisture sections but not in the sample, the calculated ovendry weight of the sample will be too low and its current moisture content too high. This will lead the kiln operator to believe that the moisture content is higher than it really is, and scheduled kiln condition changes will be delayed. The end result is an unnecessary extension of drying time. Conversely, if water pockets are present in the sample but not in the moisture sections, the calculated ovendry weight of the sample will be too high and its current moisture content too low. This will lead the kiln operator to believe that the moisture content is lower than it really is, and scheduled kiln condition changes will be made too soon. The result is an acceleration of the kiln schedule that could cause drying defects. These potential problems can be avoided by making intermediate moisture content estimates.

When to Make Intermediate Tests

When the calculated moisture content of one or a few kiln samples is much higher than that of the other samples, or if their rate of drying appears to be much slower than the average rate, a moisture check should be made on those samples for a better estimate of their calculated ovendry weight. The best time for making an intermediate estimate is when the average moisture content of the samples is about 20 to 25 percent. Intermediate estimates can be made on all the samples in the charge if the operator wants an even better estimate of moisture content.

How to Make Intermediate Tests

Trim a section about 5 in long from one end of the kiln sample. Then, cut a l-in-wide moisture section from the newly exposed end of the sample, weigh it immediately, and ovendry. Coat the freshly cut end of the shortened sample and weigh it immediately. The new weight of the sample is the new “original” weight used in equation (2). After weighing the sample, place it in its pocket in the kiln charge. As soon as the moisture section has been dried, weigh it and calculate its moisture content with equation (1). Substitute the new moisture content value, together with the new original weight of the sample in equation (2), to obtain a new calculated ovendry weight. Use the new calculated ovendry weight in equation (3) to obtain the current moisture content of the sample in all subsequent weighings.

A moisture content check may be desirable near the end of the kiln run to obtain a better estimate of when to start equalizing.

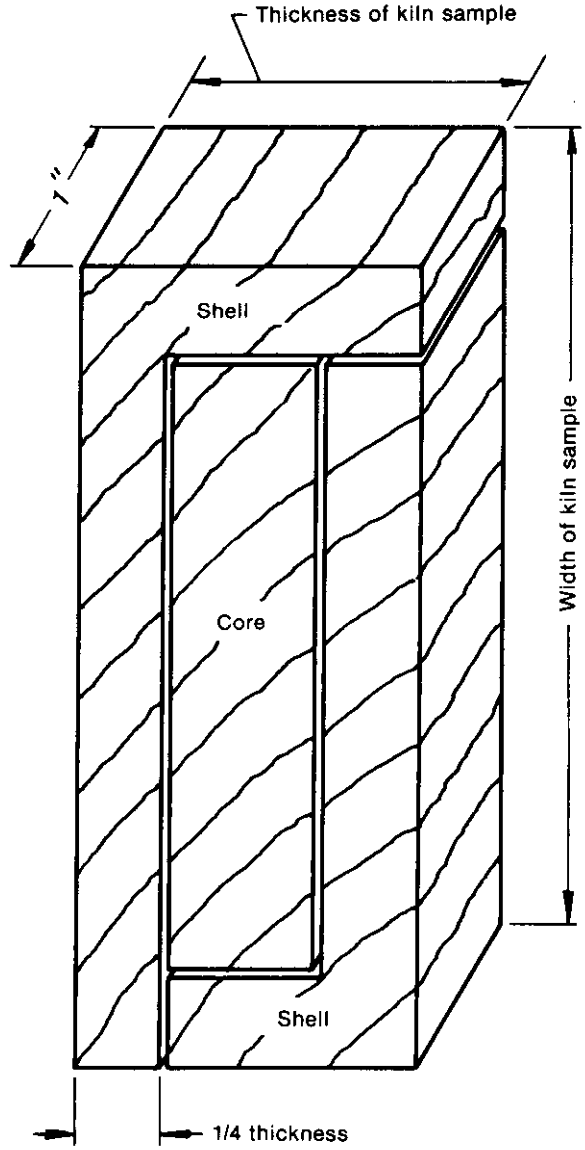


Figure 6.-3—Method of cutting section for measuring shell and core moisture content. (ML88 5586)

Intermediate Shell and Core Moisture Tests

Moisture content gradients are discussed in chapter 1. Sometimes, it is useful for the kiln operator to know the moisture contents of the shell (the outer part of the board) and the core (the inner part of the board). For example, in a species that is susceptible to drying defects, such as oak, it is quite important to delay raising the temperature in the kiln to the high temperatures of the last few steps in the kiln schedule until the core moisture content is 25 percent or below. Otherwise, honeycomb is likely to develop (ch. 8). However, when the core is at 25 percent moisture content, the average moisture content for the whole piece will be something less than 25 percent and thus will not always be a reliable indicator of the core moisture content. Therefore, shell and core moisture content estimates are sometimes useful. A typical moisture section, 1 in along the grain, is cut and then further cuts are made into the shell and core portions, as shown in figure 6-3. The shell and core are weighed separately and then ovendried so that the moisture content can be calculated according to equation (1).

Final Moisture Content And Stress Tests

After the lumber has been dried to the desired final moisture content, the drying stresses relieved by a conditioning treatment (ch. 7), and the charge removed from the kiln, a final moisture content check on the sample boards is often desirable. The average moisture content as well as shell and core estimates can be made in the same way as already described.

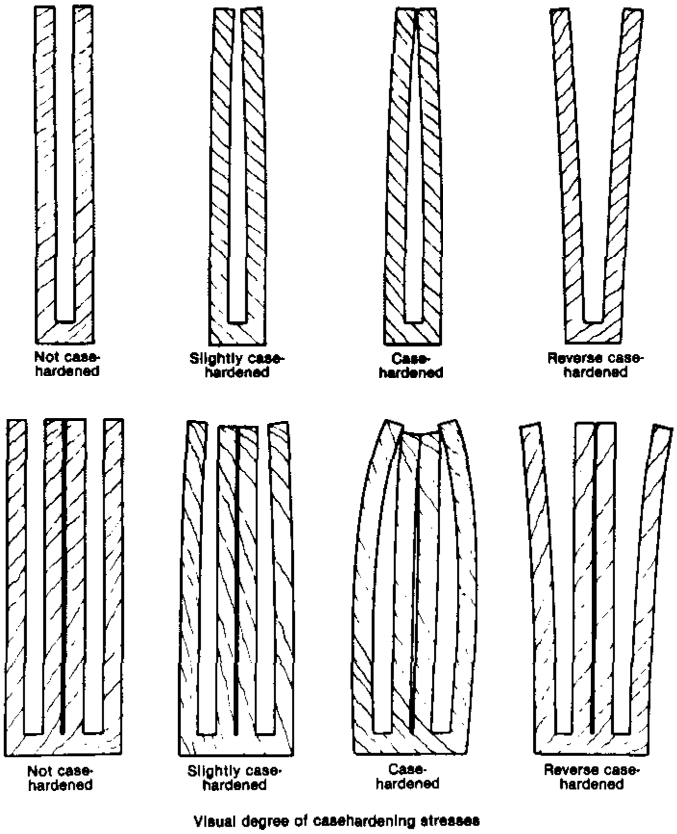


Figure 6-4—Method of cutting stress sections for casehardening tests. Lumber that is less than 1-1/2 in thick is cut into three prongs, and the middle prong is removed; lumber that is 1-1/2 in thick or thicker is cut into six prongs, and the second and fifth prongs are removed. (ML88 5585)

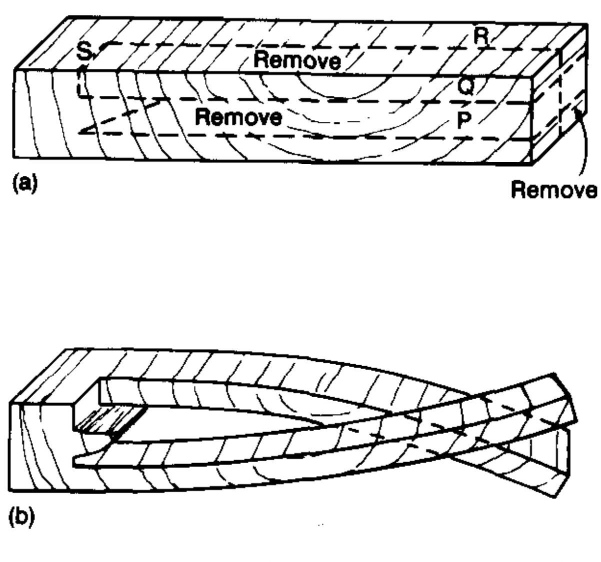


Figure 6-5—(a) Method of cutting stress sections for severe casehardening tests. (b) Prongs are offset so that they can cross and indicate severity of casehardening. (ML88 5584)

Drying stresses are discussed in chapter 1, the relief of drying stresses (conditioning) is discussed in chapter 7, and the consequences of unrelieved stresses are discussed in chapter 8. Here, we describe how to prepare and interpret stress sections. There are two basic ways to prepare stress sections. Both methods work on the principle that the stresses, that is, tension in the core and compression in the shell, will become unbalanced when a saw cut is made. Figure 6-4 shows one way to cut stress sections and illustrates the reaction of sections that are casehardened (sections with residual drying strews). When the sections have stress, the two outer prongs pinch in because the tension stress in the core is released by the saw cut. Thus, the inner faces of the prongs shorten because of the release of stresses.

In situations where drying stresses are severe, the prongs as cut in figure 6-4 will touch and in fact snap together tightly. Because they touch, it is difficult to judge the severity of the stresses. The second method of making the casehardening test visually distinguishes between severe and moderate drying stresses. The stress section is sawed to allow diagonally opposite prongs to bypass each other by an amount related to the severity of drying stresses (fig. 6-5b). The sawing diagram for preparing these sections is shown in figure 6-5a. After cutting the section from the sample board, saw on lines P and Q but do not remove the section loosened by these cuts. Saw along line R, which is approximately midway in the section's width. Saw diagonally along S and its diagonally opposite counterpart. Remove the diagonally opposite prongs and the loose center section to allow free movement for the remaining diagonally opposite prongs. If the drying stresses are severe, the prongs will cross, as shown in figure 6-6.

Unfortunately, residual drying stresses and moisture gradients sometimes interact and can cause confusion. If the core of a cut stress section is not at the same equilibrium moisture content as the air where it is cut, the moisture content of the core will change, and the inner face will either shrink and react as if casehardened, or swell and react as if reverse casehardened (fig. 6-4). Most commonly, the moisture content of the core is high enough so that the core shrinks when exposed to the surrounding air. Then, the inner face created by the saw cut loses moisture and shrinks. The result is that the prongs pinch in as if casehardened. The time required for prong movement is a good indication of whether residual drying stresses or moisture gradients cause prong movement, or if the cause is a combination of these. Residual drying stresses cause prong movement immediately, whereas a change caused by moisture content requires at least several hours to complete. If immediate prong movement is observed,

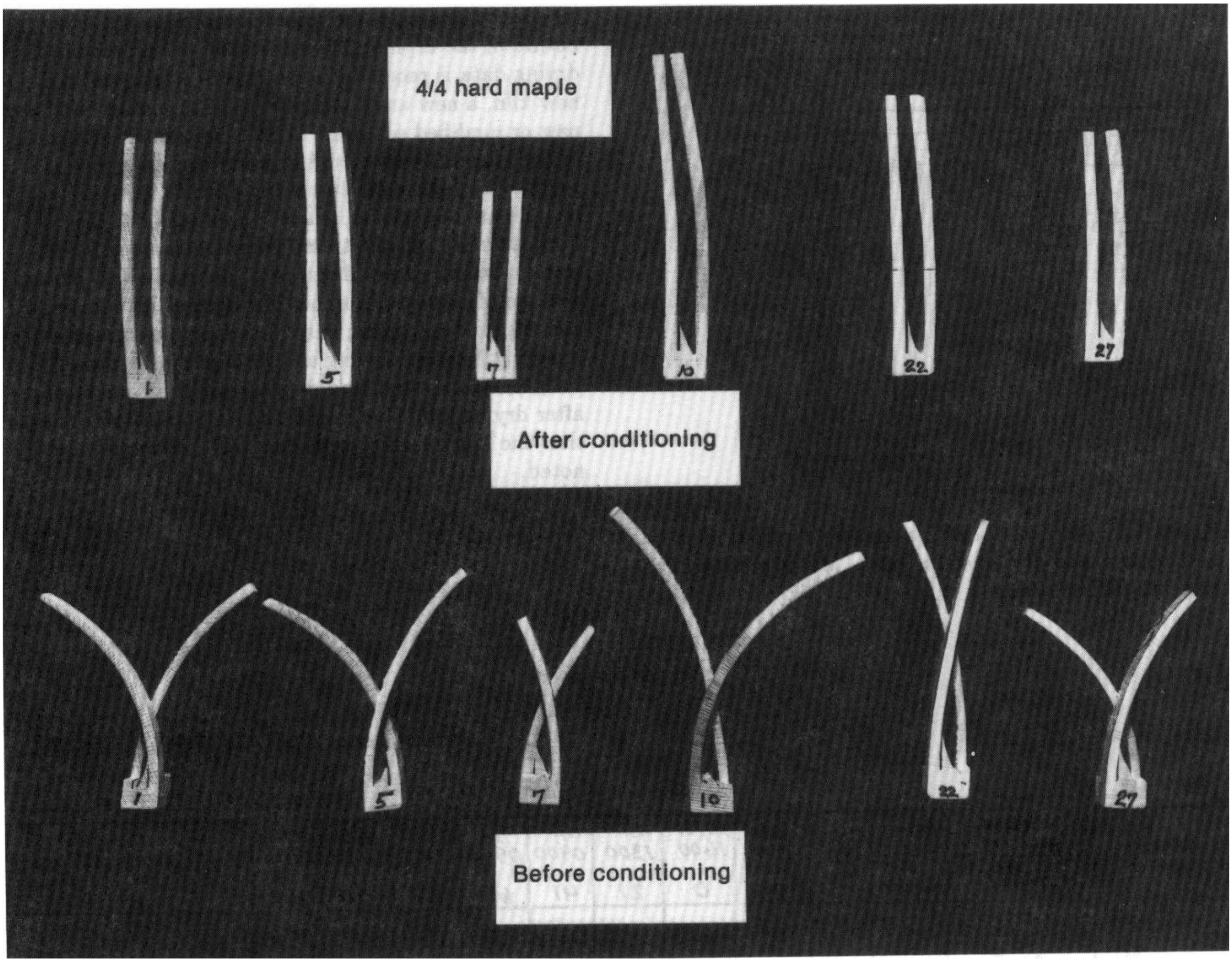


Figure 6-6—Stress sections showing crossing of prongs when sections are cut by the procedure shown in figure 6-5. (MC88 9034)

followed by additional prong movement, both factors are the cause. In either case, prong movement points to a condition that should be corrected to avoid warp upon resawing or machining (ch. 8). Either additional stress relief or equalization or both procedures are required.

Occasionally, the transverse casehardening test will show no stress, but the lumber will bow when resawed. Bowing is caused by longitudinal stress resulting from either longitudinal tension set in the surface zones or longitudinal shrinkage differentials caused by reaction wood (tension wood in hardwoods). These stresses are most likely to be unrelieved when conditioning temperature or equilibrium moisture content is too low or when conditioning time is too short. The longitudinal stress sticks in figure 6-7 show whether such stresses are present. If longitudinal stresses are a problem, conditioning should be at 180°F or higher. The lumber must have been equalized, and the recording instrument must be in calibration. If longitudinal stresses are still a problem, the wet-bulb setting can be raised 1 °F over the recommended value. Also, the conditioning period can be extended about 4 h per inch of thickness. If tension wood stresses are very severe, they may not yield to any conditioning treatment.

Recording Drying Data

Good recordkeeping of the details of kiln runs can be useful to the kiln operator in several ways: (1) for modifying drying schedules on subsequent charges to obtain faster drying without sacrificing quality, (2) for developing time schedules for certain types of lumber that are dried frequently, (3) for determining the effect of seasonal weather conditions on kiln performance and drying time, and (4) for checking kiln performance for causes of nonuniform drying or drying defects.

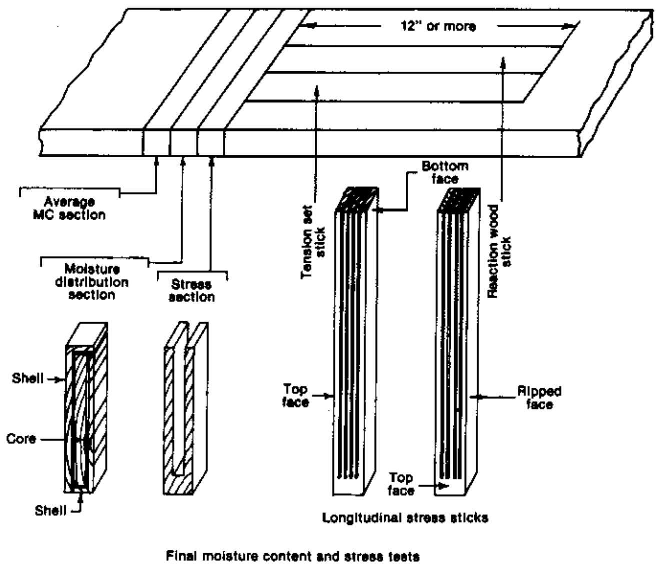


Figure 6-7—Method of cutting sections for final moisture content and drying stress tests. MC is moisture content. (ML88 5583)

The kinds of data to be recorded will vary with the nature of the drying. More than the usual amount of drying data is required in the case of a test run in a new kiln, a new and unfamiliar type of lumber, and a new or modified schedule. Also, good documentation of the kiln run may be useful when precise drying is required or high-value lumber is dried. The data can include lumber species, grade, origin (of both the lumber (sawmill) and the trees (geographical location) it was cut from), grain (flatsawn or quartersawn), percentage of sapwood, number of rings per inch, moisture content, and thickness; date of sawing; intermediate handling between sawing and drying; drying data (initial), schedule, time, and defects; handling and storage after drying; and shipping date. Any other information that the kiln operator considers relevant should also be noted.

Kiln sample record

Kiln number 4 Date run started 10/31/87 Ended 11/9/87

Thickness 4/4 Board feet 30,000 Species SOFT MAPLE

Sample number		Moisture sections Wt. (g)	O.D. wt. (g)	Green wt. of sample	Calc. O.D. wt.	Date Hour Total hours	10/31 1600 0	11/1 1300 21	11/2 0900 41	11/3 0900 65	11/4 0900 89	11/5 1600 120	11/6 1400 142	Remarks
1	Wt.	225.2	165.0	3614	2648		3614	3428	3378	3314	3214	3046	2910	
	M.C.	36.5					36.5	29.5	27.6	25.2	21.4	15.0	9.9	
2	Wt.	195.3	147.4	3155	2381		3155	3133	3101	3051	2956	2783	2633	
	M.C.	32.5					32.5	31.6	30.2	28.1	24.1	16.9	10.6	
3	Wt.	199.0	135.9	4735	3234		4735	4422	4268	4109	3954	3732	3550	
	M.C.	46.4					46.4	36.7	32.0	27.1	22.3	15.4	9.8	
	Wt.													
	M.C.													
	Wt.	AFTER INTERMEDIATE				DATE	11/6	11/7	11/8		11/9			
	M.C.	MOISTURE TESTS				HOUR	1400	1400	1400		1500			
	Wt.					TOTAL HOURS	142	166	190		215			
	M.C.													
1	Wt.	84.7	77.3	2170	1980		2170	2129	2107	STARTED CONDITIONING 11/8–1400	2175	KILN SHUT OFF–11/9–1500		
	M.C.	9.6					9.6	7.5	6.4		9.8			
2	Wt.	79.5	72.3	1952	1775		1952	1911	1893		1952			
	M.C.	10.0					10.0	7.7	6.6		10.0			
3	Wt.	101.9	92.8	2624	2390		2624	2561	2556		2633			
	M.C.	9.8					9.8	7.2	6.9		10.2			

Figure 6-8—Form used for recording kiln sample data in a dry kiln run of 4/4 air-dried soft maple. Data for 3 of 10 kiln samples are shown. (ML88 5582)

Moisture and Stress Record

Kiln number 4

Date 11/9/87 Date run started 10/31/87

Sample number	Shell			Core			Average			Casehardening
	Wt. (g)	O.D. wt. (g)	M.C. (%)	Wt. (g)	O.D. wt. (g)	M.C. (%)	Wt. (g)	O.D. wt. (g)	M.C. (%)	
1	35.80	32.81	9.1	36.55	33.60	8.8	75.19	68.74	9.4	NONE
2	38.59	35.77	7.9	29.57	27.35	8.1	75.37	69.85	7.9	SLIGHT
3	43.70	40.70	7.4	44.81	41.59	7.7	104.16	96.70	7.7	NONE

Figure 6-9—Form for recording final moisture content and drying stress data for three kiln samples. (ML87 5321)

Forms for Recording Data

Kiln sample data should be recorded on suitable forms, such as ones supplied by kiln manufacturers. Many kiln operators develop their own forms to fit their specific needs. Two forms are shown in figures 6-8 and 6-9. Drying data obtained for each sample during the kiln run can be entered on a kiln sample record form (fig. 6-8). Other data such as kiln number, lumber volume, species, thickness, and starting and ending dates for the run can be entered as required in a heading. The form in figure 6-8 is for only three sample boards. This form also shows data recorded for intermediate moisture content estimates and the moisture regained during the conditioning treatment. The weight of the end coating used on the kiln samples can also be recorded, if required.

Data for the final moisture and drying stress tests can be recorded on a form like the one shown in figure 6-9. The degree of casehardening present in the lumber is noted on this form. Supplemental moisture data obtained with a moisture meter should also be recorded.

Graphs of Drying Data

Graphs of drying data show at a glance the time required to reach certain moisture contents. A plot of the moisture contents of several kiln samples is shown in the lower portion of figure 6-10 for 4/4 northern red oak. The curve illustrates the steady loss of moisture over the entire drying period. Curves plotted from data obtained from each sample are useful for checking kiln performance and the reliability of the moisture contents of the kiln samples. For example, if the moisture loss data from some samples in several charges in the same zones in a kiln consistently indicate a slower or faster drying rate than that of the other samples in the charges, this is evidence of a cold or hot zone or different air circulation in that location. The source of trouble can usually be found and corrected. On the other hand, if it is known or if an investigation shows that the cause is not associated with a cold or hot zone or different air circulation, the calculated ovendry weight of the kiln sample may be inaccurate and an intermediate moisture content estimate is needed.

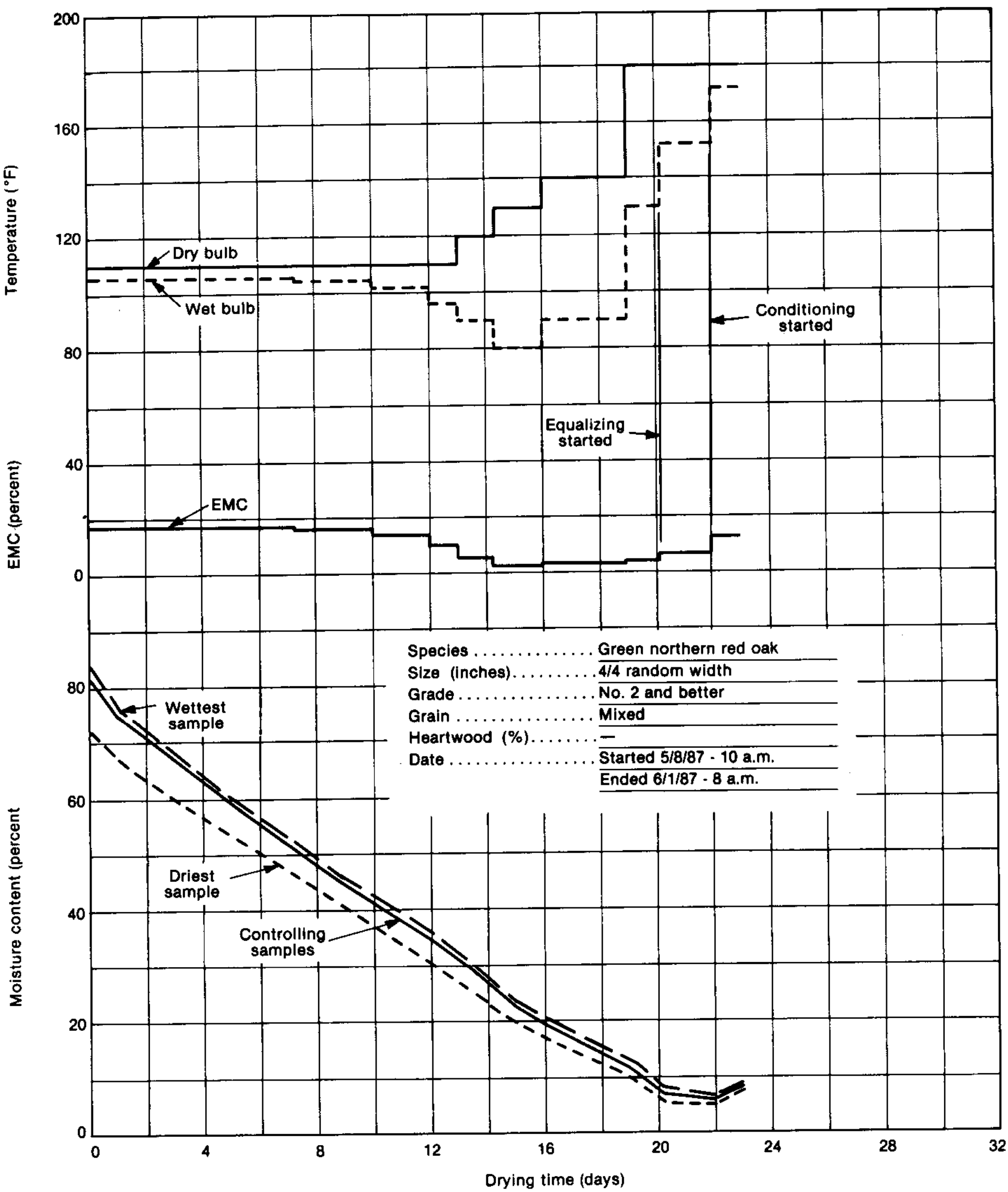


Figure 6-10—Graph showing kiln-drying schedule and moisture content at various times during drying of 4/4 northern red oak. EMC is equilibrium moisture content. (ML88 5581)

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Source of Additional Information

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