DRY KILN
OPERATIONS MANUAL

THE SPERRY AND HUTCHINSON COMPANY
RESEARCH AND DEVELOPMENT DIVISION
# DRY KILN MANUAL

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drying or machining operations. Listed below are examples of the cost of improper lumber handling procedures and problems that they may cause in later processing steps.

I. Incorrect Moisture Meter Reading

If only a meter is used to operate a kiln and it is reading too low (e.g. says 26% when lumber actually 35%), losses can be as high as 50% of a kiln load of oak due to honeycomb. This would be $5,600 loss in a 50,000 bd.ft. kiln charged with one common oak at $225/M.

If the meter reads high, the lumber will spend excessive time in the kiln. A 50,000 bd.ft. kiln costs approximately $71/per day to operate. One day extra costs $71 while 10 days extra would cost $710.

II. Incorrect Baffling - Incorrect baffling (or not baffling at all) creates a non-uniform air flow pattern in a dry kiln. The air flow goes around, over or under instead of through the hacks of lumber. Two possible problems generally occur together: (1) non-uniform final moisture content in the load and (2) it may take an unnecessarily long time to dry the lumber.

Consider #1 first: Non-uniform M.C. means a percentage of the lumber will be too wet to properly machine and glue. One
percent would be a reasonable estimate. In a 50,000 bd.ft. kiln this is 500 bd.ft. lost. If bad glue joints are the problem, an additional 500 bd.ft. of good lumber can be destroyed by the wet wood. This means that 1,000 bd. ft. of lumber can be lost costing from $180 to $550 per thousand.

A kiln costs approximately $71/day to operate. If two days can be reduced from the schedule, $142 can be saved per charge. If the average charge is dried in 14 days, this is an annual savings of $3,692/year!

III. Incorrect Kiln Instrumentation - If the kiln instruments are incorrect, the conditions in the building may not be what the operator actually wants. If they are too severe, a serious defect such as honeycomb can occur causing loss of half or more of a kiln charge. At $220/M. in a 50,000 bd.ft., this is a $5,500 loss!

IV. Incorrect, or Insufficient Kiln Sampling - Kiln sample boards must be carefully selected so that they represent the moisture conditions of the kiln charge. If they do not, wet spots can be present in the charge, excessive drying time can result, or serious drying defects can occur. Costs of each of these problems were discussed above.
V. Yard Maintenance Causing Kiln Degrade

(1) Standing water causes a part of the bottom 2 or 3 courses of lumber to be wetter than the balance of the stack. Result is excessive degrade in the kiln. The bottom 3 courses equal 3% of a stack of lumber; if ½ is lost, that is 1½% of the affected area. If the area involves 20 stacks of lumber, that is (X3) 60 courses of lumber or at an average of 80 ft. per course, 4,800 bd.ft. The loss is:

<table>
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<th>At:</th>
<th>$180/M</th>
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<td>220/M</td>
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<td>1,060/stack</td>
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<td>550/M</td>
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<td>2,640/stack</td>
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These dollar losses, although not great, when repeated over and over turn into substantial amounts that can easily be saved by correct yard maintenance and drainage.

(2) Weeds restrict air movement through the lower courses of lumber and like standing water create a high moisture condition in the affected boards. The amount of degrade in the kiln will be determined by the height of the weeds; 5 or 6 courses affected is common.
If half of 6 courses are lost, this can amount to 240 bd.ft. per stack or losses that are:

At:  
- $180/M  $ 43.20/stack  
- 220/M  52.80/stack  
- 550/M  132.00/stack
Four elements are involved in drying lumber:

Temperature
Humidity
Circulation
Ventilation

Early dry kilns used only heat which increased the rate of transfer of moisture to the surface of the wood and thus permitted rapid drying.

Humidity plays an important part in determining the quality of seasoned lumber. Control instruments have been developed which automatically maintain both temperature and humidity within the kiln. These devices also make a record of these conditions on a chart.

Air circulation is also important to proper drying. It was not until reversible cross-circulation fan kilns were developed that this important drying element was brought under control.

With the modern kiln, temperature, humidity, circulation and ventilation are under direct control of the operator. He can control them to produce proper conditions to suit the specie, thickness, and moisture content of the lumber he is drying.
How Lumber Dries - As air circulates over lumber it evaporates the water on its surface. Since the wood cells act like the wick in a kerosene lamp, more water is then brought to the surface. If at the same time the wood is heated, this movement of water is increased. This basic action continues until the wood reaches the desired moisture content.

When the cell cavity contains no more water, the drying action slows. This occurs at a Moisture Content (M.C) of approximately 25% and it is termed the wood's "fiber saturation point". Further reduction of moisture produces shrinkage in the wood as water is removed from the cell walls. Drying the wood from 25% M.C. to its final desired moisture content must be done very carefully since drying it too fast creates excess end and surface checking. Drying too slow is also costly since it will tie up a kiln for too long.

It is, therefore, the responsibility of the kiln operator to control temperature, humidity, circulation and ventilation to achieve the best drying rate without creating kiln degrade.
LOADING THE DRY KILN

All kilns are designed to be loaded a specific way for maximum drying efficiency. This section is concerned with the loading of package type and track type internal fan kilns, which are common within the S & H furniture companies.

Both overloading and underloading affect the quality of kiln dried lumber. A proper load consists of packages of lumber stacked in the kiln in a manner that follows the kiln manufacturers' recommendation of spaces between hacks of lumber and between the walls and ceiling of the kiln. (Figure 1 & 2) If these spaces are altered through underloading or overloading, air circulation is changed which has a negative affect on drying time and lumber quality.

This does not mean that a dry kiln can be loaded only with certain lengths of lumber. It does mean that a kiln operator must consider the effects his loading has on air circulation. He must plan his loading patterns to best advantage, deviating as little as possible from the overall charge dimensions best suited for his kiln.

Kiln Baffles - After the kiln has been loaded, all top, side, and bottom baffles must be set in place so that air will be forced through the lumber packages. When it is impossible for the normal kiln baffles to prevent short circuits of air movement, auxiliary load baffles made from plywood or sheet metal should be used.
Figure 1 - Long-shaft, double-track, compartment kiln with alternately opposing internal fans. Vents are over fan shaft between fans. Vent on high-pressure side of fan becomes fresh-air inlet when direction of circulation is reversed.

Figure 2 - Package-loaded compartment dry kiln with internal fans directly connected to motors.
 Listed below are suggested auxiliary baffling techniques:

(1) Butt ends of the truck loads of lumber snugly together. If this is not possible because of uneven package ends, block (baffle) the voids.

(2) In multi-tracked kilns perforated baffles can be used to help stop short circuiting where a track is not fully loaded. Snow fence works well for this. (See Figure 3)

(3) A strip of lumber nailed to the ends of the 4 x 4's between hacks of lumber will stop large volumes of air from passing through these voids. This is only necessary on the face and back of the charge.

(4) Solid or slotted baffles may be required when large voids occur in a kiln charge that is short one or more packages or where the tiers of packages are incomplete.

(5) When loading package kilns, stagger the packages and tiers to prevent voids between rows of packages. (See Figure 4)

Figure 5 illustrates the effect on air movement resulting from improper baffles. The values expressed on this drawing were measured at one of the S & H furniture plant kilns. As it illustrates, the velocity of air through the lumber was only 22 feet per minute, while between the bunks it was 380 feet per minute and beside the bunks it was 220 feet per minute. The need to stop these air short circuits cannot be overemphasized.
Figure 5 - Figure "A" illustrates the actual measured air velocity through hacks of lumber in a dry kiln that has not been properly baffled. Figures "B" and "C" are plan views of similar hacks. Shown in "B" is the uneven air flow. Shown in "C" is how a few simple baffles properly positioned can make air flow uniformly through the lumber. Baffles must be placed between and under the hacks as well as beside and over top of them.
Certain auxiliary equipment is needed to economically operate a dry kiln and obtain good drying results. For example, drying schedules must be based upon the wood's moisture content. Proper schedules cannot be successfully applied unless the moisture content of the lumber is known and this requires instruments.

**Balances and Scales** - Many types of balances and scales can be used for determining the moisture content of wood. The most common are the triple-beam balance, the pan balance, and the self-calculating balance. The self-calculating balance (Figure 6) is the easiest to use. For those not familiar with it, it is essentially a triple-beam balance set up in such a way that the moisture content can be read directly without calculation. It is available from the Irvington-Moore Dry Kiln Company, Jacksonville, Florida, at a cost of approximately $65. This type is highly recommended. A larger version of this scale (illustrated in Figure 7) is available for kiln samples.

**Ovens** - Drying ovens should be large enough to provide adequate open spaces between the sections of wood being dried. The oven temperature must be controlled by a thermostat to maintain a temperature range of 212° to 220°F. The oven should have ventilation (bottom and top) to allow evaporating moisture to escape. The most practical size for kiln operations is one with inside dimensions of 18" x 18" x 18".
FIGURE 6 - Self Calculating Balances
Saws - A small (12" or 14") bandsaw is practically a necessity for kiln operations. It can be used to cut moisture wafers from the kiln samples and is particularly suitable for slotting and slicing small sections to determine moisture distribution and case hardening. A portable hand saw is convenient for cutting awkward boards as well as cutting kiln samples.

Moisture Meters - Moisture meters provide a rapid and convenient means of determining moisture content. They are used to separate wet and dry boards as a preliminary to kiln drying and to determine the wetter boards to be used for kiln samples. Moisture meters are provided with temperature and species correction data which must be used to calibrate a given reading. Lumber at a temperature of 140°F may require a moisture adjustment of 10 or 15% Equilibrium Moisture Content (EMC).

The resistance type of meter is the most common (Figure 8). Meters are an indispensable kiln tool but it must be remembered that they are accurate only within a range of 7% to 25% EMC. Without this range they indicate an approximate moisture content and can vary by as much as 50%.

It is a wise practice to occasionally (once a month) calibrate a moisture meter. This can be done two ways: (1) Measure the moisture content of a board with the meter. Then determine true moisture content of the board by the oven dry method. (2) An easier method is to use a standard moisture block which is very accurate and is available from meter manufacturers or S & H Research. The
Figure 7 - Self-calculating scale or guide for determining moisture content of kiln samples.

Figure 8 - A resistance moisture meter.
prongs of the meter are placed in contact with the block and the indicated meter moisture reading is compared to that of the block.

Thermometers - It frequently becomes necessary to check temperature in a dry kiln to determine the causes for non-uniform drying and the differences in temperature between the areas of the kiln. These temperature measurements are usually made on the "entering" air side of the loads although at times "leaving" air temperatures are also obtained so that the temperature drop across the load can be obtained. Maximum reading etched-stem thermometers are used for this purpose. They are arranged so that one will indicate the wet-bulb and one will indicate the dry-bulb temperatures. (See Figure 9) When set up this way, the unit is called a hygrometer. At least one hygrometer should be at each kiln installation if needed. A unit is available from the S & H Research Division.

Air Movement Indicator - The instrument used to determine the speed of air flow is called an anemometer (Figure 10). It indicates the rate of air flow in feet per minute. It is effective in illustrating air flow through the lumber which graphically emphasizes the importance of good stacking and baffling practice. S & H Research has this instrument and upon request will make an analysis of kiln air flow for any S & H furniture company.
Figure 9 - Humideik a maximum reading thermometer for wet and dry bulb kiln temperature.

Figure 10 - Fan-type anemometer.
KILN SAMPLE

A kiln sample is a clear section (30 inches or more in length) of a rough board placed in the kiln charge so that it can be removed for examination, weighing, and testing in order to determine the progress of drying the lumber. The proper selection, preparation, placing, and weighing of kiln samples provides the information that enables a kiln operator to:

1. Reduce kiln degrade
2. Obtain better control of final moisture content
3. Reduce drying time
4. Improve quality
5. Develop time schedules

All of these add up to lower drying costs and more uniformly dried, stress free lumber.

Sample Selection - In order that full use be made of known drying techniques and equipment and that good drying be assured in the shortest time, each kiln charge should consist of lumber having about the same drying characteristics. If lumber having different moisture content, thickness and species is mixed in a kiln charge, the kiln sample must be taken from the wettest, thickest, slowest drying boards. In other words, the kiln schedule must accommodate the slowest drying characteristics.
Number Required - The number of 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 intended for the lumber. Because of the many variables that affect drying results, the specific number of samples required for a kiln charge must be determined through experience. A rule of thumb is to use at least one sample for each 10,000 board feet of lumber in a charge.

Knots, bark, pitch, and decay should not be included in the parts or boards cut for kiln samples.

Preparation - Moisture sections are cut from a kiln sample board and identified as shown in Figure 11. It is best to mark the sections and sample board before they are cut. The samples must be taken at least 20 inches from the ends of the boards to eliminate the effects of end drying during the air drying process.

The moisture content of a kiln sample is determined from these moisture sections cut from each end of the kiln 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 oven dry weight of the kiln sample by the method described in the next section.

With few exceptions moisture sections are cut not less than one inch along the grain and across the full width of the board. Cut the moisture sections on a sharp, cool running saw, remove loose splinters and weigh them immediately. If it is necessary to cut a number of sections at a time before weighing them, wrap each one separately in aluminum foil to prevent drying.
After the kiln samples are cut, remove all loose splinters and sawdust adhering to them and apply a good end coating. This end coating prevents rapid drying of the sample through the end grain which is 15 to 18 times as fast drying as side grain. End coatings should be applied as directed by the manufacturer. Immediately after end coating, weigh the kiln samples. Mark the weight on the kiln sample and record it on a data form.

After kiln samples are cut, end coated and weighed, they are placed in sample pockets built into the packages of lumber during the stacking operation (Figure 13) or put into pockets made in the load by the tools illustrated in Figure 12.

Calculation of Moisture Content - After weighing the moisture sections, dry them until moisture free in an oven maintained at 212°F to 220°F. This usually takes 24 to 48 hours. To test whether they are thoroughly dry, weigh a few sections, replace them in the oven for three to four hours, and reweigh them. If they have lost no weight, the entire group of sections should be moisture free.

Moisture content of the moisture sections is calculated by dividing the weight of the water removed by the oven dry weight of the section and multiplying the result by 100. Since the weight of the water equals the original weight of the sections minus its oven dry weight, the formula to calculate moisture content is:
Figure 11 - Method of cutting and numbering kiln samples and moisture content sections.

Figure 12 - Tools for removing kiln samples from side of hack.
I. Moisture (in %) Content = \( \frac{\text{Original weight} - \text{Oven dry weight} \times 100}{\text{Oven dry weight}} \)

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. To obtain this average, add the two values and divide by 2. Knowing this value and the weight of the sample at the time the sections were cut, the oven dry weight of the kiln sample can be calculated by using the formula:

II. Oven Dry Weight of Sample = \( \frac{\text{Original weight of kiln sample} \times 100 + \text{moisture content of sample in % as determined by the wafer average}}{100} \)

Placement of Samples in Kiln - Since the kiln samples are representative of the stock being dried, they must at all times be exposed to the same drying conditions or they will give a false indication of the moisture content of the charge. They should not be placed anywhere but in a kiln sample pocket (Figure 13). If leaned against the kiln wall or placed in the space between the lumber hacks (Figure 14), the air flow will not be the same as through the hack. Therefore, the kiln sample will not represent the moisture content of the kiln charge. This would mean that excessive kiln time would be allowed if the sample dries slower than the load or excessive degrade if it dries faster.
Figure 13 - Placement of three kiln samples in sample pockets built in the side of an end-piled load of lumber. The pockets should be deep enough so that the kiln samples do not project beyond the edge of the load.

Figure 14 - Placement of kiln sample between bolsters that separate hacks is improper. More air flows through this space than through the rest of the hack and this sample will not dry the same as the rest of the hack.
If a mixed kiln charge is being dried, place the samples representing each type of lumber in the hacks or bunks containing that material. For example, if 4/4 and 6/4 pine are being dried in the same charge, put the 4/4 samples with the 4/4 lumber and the 6/4 samples with the 6/4 lumber. As before this is to insure that the sample will truly represent the drying conditions of the kiln load.

**Calculation of Intermediate Moisture Content** - To calculate the current moisture content of a sample, two weights are required; the current weight and the calculated oven dry weight (Formula II). This formula is as follows:

III. Current Moisture Content =

\[
\frac{\text{Current weight} - \text{Calculated oven dry weight}}{\text{Calculated oven dry weight}} \times 100
\]

**Data** - Properly recorded and evaluated kiln sample data assists the operator:

1. Modify the drying schedule to obtain faster drying without sacrificing quality.
2. Develop time schedules for certain classes of material.
3. Determine the effect of seasonal weather conditions on drying time.
4. Check the performance of the dry kiln.
5. Determine the causes for non-uniform drying and seasoning degrade.
The data should include items such as species, grade, origin of material, date of cutting, kind of grain (flat or quartered), percentage of sapwood, moisture content, thickness, drying schedule used, drying start date, drying time, drying defects, method and length of storage before and after drying, and date of intended use.
A dry kiln, no matter how well equipped with controls, is only as efficient as the operator who runs it. In the final analysis, it is the operator's judgment that determines how a charge of lumber goes through the kiln in minimum time and emerges uniformly dried to the desired moisture content, free of undesired stresses and defects.

After the kiln has been started, the lumber is dried in accordance with the schedule selected. Kiln schedules resulting from extensive public and private testing are available to all kiln operators. Most are considered conservative. They are intended as a starting point from which an operator can develop schedules for his kiln and his particular drying situation. Since these schedules have been frequently published, they are not repeated here. They are available from S & H Research.

The schedules are intended for lumber dried from the green condition containing a mill-run mixture of grades, sapwood and heartwood. The schedules must be modified when all sapwood, all low grade, or any special consideration is encountered. Also the schedules are intended for use in a kiln having air flow of at least 200 fpm with wet and dry bulbs correctly located in the kiln.

As indicated above, the operator is called upon constantly during the drying process to exercise his judgment. Successful drying depends on his knowledge, experience, awareness of problems and attention to details.
Near the end of the drying process, equalizing and conditioning treatments are applied as required depending upon the final use of the lumber. Final tests should be made on the stock before it is pulled from the kiln.
STORAGE OF KILN DRIED LUMBER

Proper storage of kiln dried wood is very important since a change in the wood's moisture content will result in many problems in the furniture plant. This is due to the wood's hygroscopic nature which is its desire to attain the EMC of the climate surrounding it.

Open Storage - Kiln dried lumber can be stored outdoors for a very short time. The top side of the pile should be protected from rain by a canvas or sheet plastic cover.

Shed Storage - An open (3 walled) or closed shed affords lumber good protection from the weather. The lumber will, however, absorb moisture during periods of high relative humidity. Figure 15 (page 27) illustrates the effect on kiln dried lumber of long-term storage in sheds. As it indicates, the average moisture content is too high for the lumber to be used in furniture production. This means the lumber will have to go through the kiln again which adds more cost to the final product.

Lumber moisture conditions in winter time can easily reach 12-14%. This indicates that the kiln dried lumber should move as quickly as possible from the kiln to the rough mill. If it has been in storage for a week or more, it is generally a good idea to check the moisture content before further processing. If the lumber MC is too high, it must be put back in the kiln and redried.
DRYING DEFECTS

Drying defects fall into three classes based on their cause:

1. Shrinkage
2. Fungi
3. Chemicals in the wood

Defects concerning shrinkage are increased where excessively high dry bulb temperatures or large wet bulb depressions are used during critical stages of drying. Fungal defects occur when low temperatures and high humidities are used in drying wet wood. Chemical stains that occur in wood during drying are due mainly to the effect of heat on extractives in the wood.

Shrinkage - Many drying defects are associated with the shrinking of wood as it dries. Knowing where, when and why they occur will enable an operator to take action to keep these at a minimum. The most common shrinkage defects are as follows:

1. Surface-checks - Surface checks are fractures that usually occur in the wood rays on the flat sawed faces of lumber. They can also occur in resin ducts and mineral streaks. These failures usually take place early in the drying process but in some softwoods the danger persists beyond the initial stages of drying. They develop as the surface of the lumber dries and shrinks around the core. The stress increases until it is relieved in the form of a failure or check. Thick, wide, flat sawed lumber is more prone to surface-check than thin, narrow stock.
(2) **End-checks** - End checks often occur in great number at the ends of boards, generally in the rays. They occur in the initial stage of drying and can be minimized by using initial higher relative humidity in the kiln. End-checked stock should not be wetted or subjected to very high humidities prior to, during, or after drying. (See Figure 16)

(3) **End Splits** - End splits usually result from the extension of end checks. One or possibly two end splits generally occur. The placing of tiers of stickers at the extreme ends of the boards being dried will reduce end splitting.

(4) **Collapse** - Collapse is a severe distortion or flattening of wood cells. When severe, it often shows up as grooves or corrugations on the wood surface. This defect is associated with excessively high dry-bulb temperatures in the early stages of drying dead green lumber. The use of special drying schedules planned to diminish its occurrence or initially air drying susceptible woods is recommended. (See Figure 17)

(5) **Honeycomb** - Honeycomb is an internal void caused by tensile failure across the grain and usually occurs in the wood rays. It is produced by the use of excessively high temperatures for too long a time while free water is still present in the cell cavities. It is generally an extension of a surface check and occurs midway in the drying process. Honeycombing can be held to a minimum by avoiding excessively high dry-bulb temperatures until all free
Figure 15 - Chart illustrating the effect on kiln dried lumber of long-term storage in sheds.

Figure 16 - End checks in oak plank.

Figure 17 - Severe collapse in wester red cedar.
water has been evaporated from the entire kiln charge. (See Figure 18)

(6) Ring Failure - Ring failure occurs parallel to the annual ring either within the ring or between rings. It can occur as a failure in the end grain in the initial stages of drying and extend in depth and length as drying continues. The failure can also occur internally because case hardening and a weakening of the bond between annual rings when high temperatures are used. Ring failure can be kept to a minimum by end coating thick stock and by using higher initial relative humidities and low dry-bulb temperature schedules. (See Figure 19)

(7) Boxed-Heart Splits - Boxed heart splits start in the initial stages of drying and become increasingly worse as the wood becomes drier. It is most common in thick boards prone to end splitting. The difference between tangential and radial shrinkage of the wood surrounding the pitch causes severe stresses in the faces of the piece that the wood is split. It is very difficult to prevent this defect since the reason for the stress cannot be controlled. (See Figure 20)

(8) Warp - As wood dries, it may become distorted in shape and form because of differences in radial, tangential, and longitudinal shrinkage. Various types of warp are shown in Figure 21. Warp can be reduced to some degree by modifying the drying schedules and avoiding over drying. Good stacking practice is the best control of warp.
Figure 18 - Honeycombing in oak.

Figure 19 - Two ring failures (vertical breaks) and a check (horizontal break) in a 3- by 8-inch Sitka spruce.

Figure 20
Boxed-heart split in red oak.
Figure 21 - Various types of warp.
(9) **Casehardening** - Casehardening is the result of drying stresses associated with normal shrinkage which occur as the wood dries. Casehardening can be relieved by a conditioning treatment described in the operation section of this manual. (See Figure 22)

![Figure 22 - Distortion caused by casehardening. Left to right: resawed stock; heavy machining on one face; and grooved.](image-url)
Drying Defects of Major Concern in Species Used by

S & H Furniture Companies

White Pine - Brown stain, blue stain, end checks in thicker (8/4) stock.

Cherry, black - Surface checks, honeycomb in 8/4 and thicker stock.

Oak, red and white - End and surface checks, honeycomb, particularly in thick stock.

Poplar - Checking, only if severe kiln schedules are used.

Ash - End and surface checks, honeycomb in white ash only.

Walnut - End checks, honeycomb generally associated with end check in thicker stock.

Soft Maple - End checks.

Hard Maple - End checks and honeycomb associated with end checks in 6/4 and thicker stock, chemical stain.
CALIBRATION OF RECORDING - CONTROLLING INSTRUMENTS

When instruments are out of calibration, the actual drying conditions within the kiln differ from those recorded on the chart, and serious kiln-drying defects or increased drying time may result. Because a new instrument may be jarred during shipment, calibrate it at the time of installation. Thereafter, check it for accuracy frequently by using glass-stemmed thermometers or other temperature measuring devices.

Recalibration of an instrument found to be in error is not difficult, but it must be carefully done. The equipment required includes a water container and an accurate temperature-measuring device (a glass-stemmed thermometer is commonly used). Since the difference in height between the bulbs and the instrument case affects the recorded temperatures, calibrate the instrument with bulbs at about the same height above or below the instrument case where they will be in service. Two men are needed - one at the instrument and one at the bulbs.

The procedure is as follows:

(1) Fill a container at least 14 inches deep with water heated to about 200°F. and place it near the bulbs.

(2) Remove the bulbs from their fastenings and completely submerge them in the hot water. If the dry and wet bulbs are located together in the kiln, calibrate them together. Avoid sharp bends in the tubing. The bulbs
should not touch the sides or bottoms of the container. Usually in a dual-bulb system only one dry bulb need be calibrated. If there has been a difference in the recorded temperature upon reversal of air circulation during kiln operation, check each bulb separately. The man stationed at the container gently and constantly agitates the water during calibration.

(3) After about 10 minutes, the man stationed at the container takes a temperature reading of the hot water with the thermometer. He then calls this reading to the man at the instrument, who records it, together with the corresponding temperature indicated by the instrument pen.

(4) Make a check at every 20° or 30°F. drop in the temperature of the water as it gradually cools. If cool water is added to the hot water to reduce calibration time, let 5 to 10 minutes elapse before temperatures are taken so that the temperature change is reflected at the instrument. Make periodic check readings until the water temperature drops to about 100°F.

(5) If the indicated temperatures on the instrument chart are consistently lower or higher than the water temperatures by a constant amount, adjust the recording-pen arms upward or downward by that amount. This is done by adjusting a small screw located on the pen arm or on the pen-arm pivot. If the differences between the indicated temperatures and the water temperatures are not constant,
have a trained serviceman make the adjustment. A correction chart can be made so that the instrument can be used until the adjustment is made.

(6) The next step is the adjustment of the control setting indicator. This must be done with the air or electricity on. Lower the setting indicator to a temperature below that indicated by the pen on the chart and then move it slowly upward until the motor valve it controls begins to open. Record the temperature shown by the setting indicator. Then move the setting indicator slowly downward until the motor valve begins to close, and record the indicated temperature. If the average of the two recorded is different than the temperature indicated by the pen, move the control indicator by means of adjustment screws on the indicator upward or downward by the amount of difference.

Some kiln operators prefer not to adjust the instrument pens or control indicators. Instead, they list the calibration data on a small card which they place inside the face of the instrument. These data are used as a guide for setting the instrument in subsequent control of drying conditions.

When dry kilns are provided with double-end heating systems with the coils at opposite ends controlled by separate dry bulbs, each bulb must be calibrated. Many kiln operators prefer to have a gap of about 50°F. between the two
recorded dry-bulb temperatures so that temperature fluctuations at each end of the kiln are readily seen on the chart. After calibration, therefore, the pen arm of one dry bulb is intentionally adjusted upward or downward the desired amount. The amount of underset or overset should be noted on a card attached to the instrument so that anyone reading the chart will know that the temperature recorded by that pen does not show the actual kiln temperature.

Dry kiln technicians should be familiar with the manufacturer's instructions for the care and maintenance of recorder-controllers. If the instrument should fail, however, call in an authorized serviceman to locate and correct the trouble.
MAINTENANCE

Adequate kiln maintenance is essential to efficient dry kiln operation. It can be accomplished only through frequent inspections of the kiln and auxiliary equipment. If inspections reveal the necessity for repairs or replacements, they should be made as soon as possible to avoid many drying problems.

Regular, systematic inspections should cover such areas as the kiln structure, doors, tracks, control equipment, heating, spraying, vents, trucks, lumber handling equipment and general housekeeping. To make sure that inspections are thorough, the operator should use a checklist on which the condition of the kiln structure and equipment can be noted. See Figure 23 for a sample of a kiln inspection checklist.
(Where maintenance or replacement is recommended, indicate kiln no.)

(Check appropriate boxes)

**I. AIR CIRCULATION SYSTEM**

<table>
<thead>
<tr>
<th>GOOD</th>
<th>POOR</th>
<th>FAIR</th>
<th>NEED MAINT.</th>
<th>NEED REPLAC</th>
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</thead>
</table>

A. Fans and Motors, present condition:

Condition of Electrical Connections and Switches:

What maintenance or replacement is recommended:


B. Shafts and Bearings, present condition:

Are motor and shaft bearings properly lubricated:

What maintenance or replacement is recommended:


C. Fan Baffles, present condition:

What maintenance or replacement is recommended:


D. Load Baffles, present condition:

What maintenance or replacement is recommended:


E. Air Passageways, present condition:

Are air passageways open and unobstructed:

Could air movement be improved:

What maintenance or replacement is recommended:


II. HEATING AND HUMIDIFYING SYSTEM

A. Feed lines and Headers, present condition:

Are they properly insulated: ________________________________

What maintenance or replacement is recommended: ________________________________

B. Heating coils, present condition:

Are all pipes open to full flow of steam: ________________________________

Condition of supports: ________________________________

What maintenance or replacement is recommended: ________________________________

C. Traps, present condition:

Are traps in best possible location: ________________________________

What maintenance or replacement is recommended: ________________________________

D. Hand valves and automatic control valves present condition:

Are hand valves provided for blowing out coils: ________________________________

Are hand valves provided for shutting off individual coils: ________________________________

Are check valves working properly: ________________________________

What maintenance or replacement is recommended: ________________________________
E. Spray lines, present condition:

Are spray holes or nozzles open:

Does condensate from spray line drip on lumber:

What maintenance or replacement is recommended:

F. Vents, present condition:

Do vents open and close properly:

What maintenance or replacement is recommended:

III. CONTROL SYSTEM

A. Recorder-controller, present condition:

Is recorder-controller properly calibrated:

Are capillary tubes protected:

Are bulbs properly located and mounted for accurate readings of kiln conditions:

What maintenance or replacement is recommended:

B. Water Supply

Is water supply line to wet bulb open:

Is wet bulb water pan clean:

Is drain line from water pan open:
Is wet bulb wick replaced regularly: _____________________.

What maintenance or replacement is recommended: _____________________.

C. Air Supply

Is supply adequate, clean, and uninterrupted: _____________________.

Is compressor in good condition: _____________________.

Are water and grease traps in good condition: _____________________.

What maintenance or replacement is recommended: _____________________.

IV. BUILDING

A. Doors, present condition:

What maintenance or replacement is recommended: _____________________.

B. Walls, present condition:

Is protective coating adequate: _____________________.

What other maintenance is recommended: _____________________.

C. Ceilings, present condition:

Is protective coating adequate: _____________________.

What other maintenance is recommended: _____________________.

D. Floors and walkways, present condition:

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What maintenance or replacement is recommended:____________________
____________________

E. Rails and supports, present condition:

What maintenance or replacement is recommended:____________________
____________________

V. GENERAL

A. Yard tracks and transfer condition:

Kiln truck condition:

What maintenance or replacement is recommended:____________________
____________________

Are kilns and surrounding area neat and clean:____________________
TROUBLE SHOOTING

When carrying a pre-set temperature and humidity schedule in a dry kiln with automatic controls, it may appear that the controller is having difficulty maintaining the Dry Bulb and Wet Bulb temperatures in the kiln. Listed are possible causes of the trouble.

Check all possibilities before removing the controller from the kiln.

I. When the recorded dry bulb temperature fails to reach set point:

   A. Insufficient steam entering heating coils:
      1. Low steam pressure being supplied to kilns (check steam pressure gauges at kiln).
      2. Hand valves in heating coil feed or drain lines not fully open (check position of hand valves).
      3. Steam trap air-bound or stuck closed so that heating coils fill the water (open air vent and blow-off valve on trap until steam enters trap).
      4. Steam trap stuck open letting steam blow on through trap, losing steam pressure in coils (listen to trap).
      5. Hand valve in by-pass around trap not closed (check position of by-pass valve).
      6. Automatic head diaphragm valve not opening fully (check position of indicator on valve stem).
         a. Packing around valve stem too tight, hard or dry.
         b. Scale or dirt lodged inside of valve.
         c. Scale formed on valve stem near packing gland.
         d. Leak in rubber diaphragm in automatic diaphragm valve, or leak in copper tubing line from controller to diaphragm valve (check air pressure on HEAT gauge beneath the controller case).
         e. Dirt, oil or water clogging small air lines and air valves inside controller case.
         f. Failure of proper air supply of 15 to 17 lbs. to the controller (check AIR SUPPLY gauge).
B. Excessive heat load on kiln:
   1. Excessive ventilation.
      a. Automatic ventilators not closing properly
         (check their position).
         (1) Counterweight on motor lever shifted so
             that vents cannot close.
         (2) Bearings in ventilator system need oil.
         (3) Dirt, oil or water clogging small air
             lines and air valves inside controller
             (check air pressure on VENT GAUGE).
         (4) By-pass valve in air line to vent motor
             lever not fully closed (check position
             of hand valves for manual control of vents).
   2. Leaky kiln building.
      a. Kiln doors not fitting properly (see if light
         enters kiln around doors).
      b. Holes in side walls or roof, openings into
         old ventilating stacks inside walls of kiln.
   3. Kiln filled with snow covered or frozen lumber.
   4. Water seeping into bottom of kiln.

C. Incorrect recording of dry bulb temperature (check bulbs by
   water immersion).
   1. Excessive water from wet bulb water box splashing or
      being blown up onto dry bulb (check needle valve
      controlling supply of water to water box).
   2. Improper circulation of heated air over controller
      bulbs. (Too close to wall or coated with paint.)
   3. Dead thermal element - the thermal element consists
      of the controller bulb, the long capillary tube to
      which the bulb is attached, and the spiral mechanisms
      inside the controller case. Loss of the fluid from
      any part of this thermal element will cause a dead
      thermal element. NEVER CUT OR KINK THE TUBING WHICH
      CONNECTS THE CONTROLLER BULBS TO THE CONTROLLER CASE.
   4. Wrong chart placed on controller face (check chart
      number with number stamped on controller nameplate).
   5. Instrument out of calibration.

II. When the recorded dry bulb temperature shows a wide zigzag line
    from set point.

   A. Excessive radiation being used in kiln:
      1. Too many heating coil units being used.
      2. Too high steam pressure being used.
      3. Panel board vibrating.
III. When the recorded dry bulb temperature rides continuously above set point:

A. Excess steam entering heating coils.
   1. Automatic heat diaphragm valve not closing properly (check position of indicator on valve stem).
      a. Packing around valve stem too tight, hard or dry.
      b. Scale formed on valve stem near packing gland.
      c. Dirt or scale lodged in valve seat.
      d. Insufficient compression in valve spring.
   2. Air pressure remaining on diaphragm valve (check air pressure on HEAT GAUGE).
      a. Dirt, oil or water clogging small air lines and air valves inside controller case.
   3. Hand valve in by-pass around diaphragm valve not fully closed (check position of valve).
   4. In kilns using uncontrolled exhaust steam in center coils - these coils may be giving off more heat than is needed.

B. Insufficient heat demand on kiln:
   1. Kiln controller may be set for very low dry bulb temperature when outdoor temperature is high.
   2. Heat may be leaking through walls from adjacent kiln.
   3. Heat may be drifting back from hot end of progressive kiln.

C. Incorrect recording of dry bulb temperature:
   1. Steam pipe leaking directly onto controller bulb.
   2. Direct radiation from nearby steam pipes on controller bulb.
   3. Wrong chart on controller face (check chart number with number stamped on controller nameplate).
   4. Instrument out of calibration.

IV. When the recorded wet bulb temperature fails to reach set point.

A. Insufficient steam entering spray pipes:
   1. Low steam pressure being supplied to kilns (check steam pressure gauges at kiln).
   2. Hand valve in spray feed line not fully open (check position of valve).
   3. Automatic spray diaphragm valve not opening fully (check position of indicator on valve stem).
      a. Packing around valve stem too tight, hard or dry.
      b. Scale formed on valve stem near packing gland.
      c. Scale or dirt lodged in valve.
d. Leak in rubber diaphragm in automatic diaphragm valve or leak in copper tubing line from controller to diaphragm valve (check air pressure on SPRAY gauge beneath the controller case).
e. Dirt, oil or water clogging small air lines and air valves inside controller case.
f. Failure of proper air supply of 15 to 17 lbs. to the controller (check AIR SUPPLY gauge).

B. Excessive loss of humidity from kiln.
1. Excessive ventilation.
a. Automatic ventilators not closing properly (check their position).
   (1) Counterweight on motor lever shifted so that vents cannot close.
   (2) Bearings in ventilator system not oiled properly.
   (3) Dirt, oil or water clogging small air lines and air valves inside controller case (check air pressure on VENT GAUGE).
   (4) By-pass valve in air line to vent motor lever not fully closed (check position of hand valves for manual control of vents).
2. Leaky kiln building.
a. Kiln doors not fitting properly (see if light enters kiln around doors).
b. Holes in side walls or roof, openings into old ventilating stacks in side walls.

C. Incorrect recording of wet bulb temperature (check bulb by hot water immersion).
1. Excessive water from wet bulb water box striking the controller wet bulb (check needle valve controlling supply of water to water box).
2. Improper circulation of air over controller bulbs.
3. Dead thermal element - the thermal element consists of the controller bulb, the long capillary tube to which the bulb is attached, and the spiral mechanisms inside the controller case. Loss of the fluid from any part of the thermal element will cause a dead thermal element. NEVER CUT OR KINK THE TUBING WHICH CONNECTS THE CONTROLLER BULBS TO THE CONTROLLER CASE.
4. Wrong chart placed on controller face (check chart number with number stamped on controller nameplate).
5. Instrument out of calibration.
V. When the recorded wet bulb temperature rides continuously above set point.

A. Excess steam entering spray pipes.
   1. Automatic spray diaphragm valve not closing properly (check position of indicator on valve stem).
      a. Packing around valve stem too tight, hard or dry.
      b. Scale formed on valve stem near packing gland.
      c. Insufficient compression in valve spring.
   2. Air pressure remaining on diaphragm valve (check air pressure on SPRAY GAUGE).
      a. Dirt, oil or water clogging small air lines and air valves inside controller case.
      b. By-pass valve in air line to spray diaphragm valve not fully closed (check position of all hand valves for manual control of sprays).
   3. Hand valve in by-pass around spray diaphragm valve not fully closed (check position of valve).

B. Excess water in kiln.
   1. Water seeping into bottom of kiln.
   2. Leaking steam or water pipes in kiln.

C. Insufficient ventilation.
   1. Automatic ventilators not opening properly (check their positions).
      a. Counterweight on motor lever shifted so that vents cannot open.
      b. Bearings in ventilator system not oiled properly.
      c. Leak in rubber diaphragm in motor lever or in copper tubing line connecting motor lever to controller (check air pressure or VENT gauge beneath controller case).
      d. Dirt, oil or water clogging small air lines and air valves inside controller case.
      e. Failure of proper air supply of 15 to 17 lbs. to controller (check pressure on AIR SUPPLY gauge).
      f. Improper use of hand valves for manual control of vents (check position of valves in air line to motor lever).
   2. Attempting to carry low wet bulb temperature in kiln when outdoor humidity is high.

D. Incorrect recording of wet bulb temperature (check controller with Humideik).
   1. Water box gone dry (check drip from overflow pipe).
   2. Wick not on wet bulb, or wick too dirty to absorb water from water box (inspect wick).
   3. Improper circulation of air over controller bulbs.
   4. Wrong chart on controller face (check chart number with number stamped on controller nameplate).
   5. Instrument out of calibration.
NOTE: INSTRUCTIONS FOR RETURNING KILN CONTROLLER TO FACTORY

1. Remove all controller bulbs from kiln, being careful not to kink or bend the small tubing too sharp. NEVER CUT THE TUBING WHICH CONNECTS THE BULBS TO THE CONTROLLER CASE.

2. Disconnect all copper tube lines from the unions at the bottom of the controller case, and insert pipe plugs into these controller connections. Mark each with tag for reconnection.

3. Remove controller from panel board, wrap and seal it in brown kraft paper.

4. Pack controller carefully in light wooden box, coiling bulb and tubing loosely under controller case. Fill box and voids with soft packing.

HINTS FOR LOCATING TROUBLE IN CONNECTION WITH KILNS

If variations in temperature through the length of the kiln are encountered, these may be traced to the following:

1. Faulty trap operation.
2. Heat losses through doors.
3. Water standing in bottom of kiln.
4. Spray system not properly fed or drained.
5. Incorrect setting of deflector baffles.
6. Leaky or poorly insulated kiln doors.
7. Fresh air ducts and ventilators improperly regulated.

In case temperature runs too high in kiln, examine for the following condition:

1. Leaky diaphragm valves.
2. By-pass open or leaking.
3. Heat transmitted from adjoining kilns.
4. Too high steam pressure on heating coils or on spray line.
5. Loads so spaced that a blank space occurs near control bulbs.
In case temperatures range too low, examine for the following:

1. Low boiler steam pressure.
2. Insufficient radiation.
3. Faulty trap operation.
4. Water dropping on dry bulb of instrument.
5. Cracked or leaking diaphragm on steam feed valve.

If wet bulb temperatures range too high, examine for the following:

1. Leaky diaphragm valves.
2. Insufficient ventilation.
3. Insufficient fresh air supply.
4. Lack of water for wet bulb or dirty wick.
5. High moisture content lumber load adjacent to bulbs.
THE DON'TS OF DRY KILN PRACTICE

Don't let anyone manipulate the kilns except the man who is in charge and hold him responsible.

Don't take for granted that the kilns are working satisfactorily. Look and see if they are.

Don't run your kilns in a slip-shod way. Have a system and work it.

Don't take lumber out of the kiln just because someone seems to want it badly when it is not ready to come out.

Don't let anything get out of order about the kiln. The time to repair is when you first discover it. At that time it will cost but little.

Don't forget that there is a reason for every cause. If something goes wrong, find the cause and correct it.

Don't try to operate kilns half or three-quarters full. Keep it filled at all times for then you will dry not only better but more lumber.

Don't open the doors of kiln when not necessary for every time the doors are opened, changes will take place in the kiln conditions. It also wastes steam.

Don't fail to make proper records on all kiln charges. This is the only method of checking your results.
Don't forget to make the daily morning and evening check (1) Indicator lights or fans, (2) Instrument setting, (3) Water for wet bulb, (4) Air supply and compressor if controller is air operated.
OPERATING RULES FOR SAFETY

Working in or around dry kilns is not hazardous if ordinary precautions are taken. Carelessness may lead to serious or fatal injuries, however. Care must be exercised at all times and observance of the safety rules given here will help prevent accidents:

1. Shut off the heat, spray, and fans before entering a kiln in which a charge of lumber is being dried. If the kiln has been operating at high temperatures, it should be cooled to some extent by opening the doors and ventilators before it is entered.

2. If it is necessary to enter a kiln that has the heat, spray, and fans on, station someone outside the door to give assistance if it is needed. If a guard cannot be stationed at the door when a person enters the kiln, leave the door open and hang a sign on it reading "Man Inside Kiln, Do not Close Door".

Never enter a kiln when the wet-bulb temperature is 120°F or more without wearing protective clothing that covers the head and body. This temperature limit applies to a person in good health. Anyone afflicted with heart or respiratory ailments should never enter dry kilns when the wet-bulb temperature is 110°F or more. The critical dry-bulb temperature depends on the individual. If the kiln atmosphere feels too hot, do not enter the kiln.
(3) Equip all small access doors in the kiln with a latch that can be operated from both sides. Repair faulty latches immediately. Never use props to hold a door closed. The wrong person may use these at the wrong time. Set up an emergency signal that can be used if a man is accidentally locked in. A signal rapped on kiln pipes will carry a considerable distance.

(4) Exercise care in opening and closing large kiln doors. If they are too heavy for one man to handle, use two or more men to open them.

(5) Door carriers that are worn or poorly maintained may slip from the door or jump the track. Keep them in good repair.

(6) Be on guard against falling or protruding objects when in a kiln.

(7) Shut off the fans when they are to be inspected or lubricated and lock the fan switch in an "off" position. If the fan switch is not provided with a lock, place a sign on the switchbox reading "Do Not Start Fans".

(8) The fan floor of an overhead fan system may be oily. Be on guard against slipping.

(9) Install good open-type walkways over track level openings in natural-circulation or underload fan kilns. Keep these in good repair.

(10) Install guards around shafts and pulleys.
(11) If truckloads of lumber are pushed into and out of the kiln by men, make sure the men have good footing and that they will not be crushed between loads of lumber.

(12) If loaded kiln trucks are moved into and out of a dry kiln by cable, stay clear of the cables when they are under tension.

(13) Always carry a flashlight when entering a kiln, whether or not it is equipped with lights.

(14) Keep the dry kilns and the area around them free of debris to reduce the tripping hazard.
PREVENTION OF FIRE IN DRY KILNS

Fires in dry kilns are usually caused by carelessness, improper maintenance, and poor housekeeping. Suggestions that will minimize the possibility of fires follow:

1. Never smoke in a dry kiln.

2. Use care with welding and cutting torches. When they are used for repair work in a kiln, have a fire extinguisher available for immediate use.

3. Keep all electrical circuits in good condition.

4. Keep all moving parts well lubricated. A hot bearing may cause a fire.

5. Never run uninsulated steam pipes through, or allow them to contact, flammable material.

6. Install an automatic water sprinkler system in the kilns.

7. Keep the kiln and the surrounding area free of all debris. A fire in a dry kiln should be put out promptly. Instruct the watchmen to check on the kilns at regular intervals to detect fires that may occur when the regular crew is off duty. Be sure they know what action to take in the event of fire.
The following will at least reduce the spread of a fire in a kiln, if not extinguish it completely:

1. Keep the kiln doors closed.

2. Close the ventilators.

3. If the kiln is of the natural-circulation type, close the fresh-air supply doors.

4. If the kiln is of the forced-circulation type, shut off the fans or blower.

5. Saturate the air in the kiln with steam by opening the hand valve in the bypass line around the steam-spray control valve, or set up the wet-bulb indicator on the control instrument.
This glossary includes the generally accepted definitions of a limited number of terms currently used in wood seasoning literature. It also includes closely related terms that are not fully defined in their special application to present-day seasoning in most dictionaries or glossaries. Common abbreviations:

**B.t.u.** - British thermal unit  
**C.O.D. Wt.** - Calculated oven dry weight  
**C.Wt.** - Current weight  
**D.B.** - Dry Bulb  
**EMC** - Equilibrium moisture content  
**F.S.P.** - Fiber saturation point  
**G.Wt.** - Green weight  
**M.C.** - Moisture content  
**O.D.Wt.** - Oven dry weight  
**R.H.** - Relative Humidity  
**Sp.gr.** - Specific gravity  
**W.B.** - Wet Bulb  
**W.B.D.** - Wet bulb depression  
**Wt.** - Weight

**Air binding** - The presence of air, generally in pockets, in steam coils and traps, which interferes with the normal flow of steam and condensate.

**Air, short circuiting of** - The movement of air through other than desired channels. Usually results when a kiln charge is improperly loaded and/or baffled.

**Air travel, length of** - The distance between the entering and leaving air sides of the kiln charge.

**Air velocity** - The speed at which air moves, generally measured in feet per minute.

**Air volume** - The total amount of air occupying or moving through a given space, generally measured in cubic feet.

**Baffle** - A piece of canvas, metal, or wood used for deflecting, checking, or otherwise regulating for flow of air.
Bastard sawn - Lumber in which the annual growth rings make angles of $30^\circ$ to $60^\circ$ with the surface of the piece.

Bow - The distortion in a board that deviated from flatness lengthwise but not across its faces.

Boxed heart - The term used when the pith falls entirely within the outer faces of a piece of wood anywhere in its length. Also called boxed pith.

British thermal unit - B.t.u., The amount of heat necessary to raise 1 pound of water 1°F. in temperature.

Double-end control - Control bulbs, usually located in each longitudinal half of the kiln, which control kiln temperatures for their respective zone, independent of each other.

Dual control - Two bulbs of a Y-shaped control system. They are usually located on each kiln wall directly opposite each other and control the temperature of the entering air regardless of the direction of air movement.

Recorder - The temperature-sensitive part of a system that records but does not control kiln conditions.

Recorder - Controller - A bulb attached by means of a capillary tube to a recording-controlling instrument.

Capillary action - The combination of solid-liquid adhesion and surface tension by which a liquid is elevated in a vertical tube or moved through a cellular structure.

Casehardening - A condition of stress and set in wood in which the outer fibers are under compressive stress and the inner fibers under tensile stress, the stresses persisting when the wood is uniformly dry.

Casehardening, reserve - A final stress and set condition (in lumber and other wood items) in which the outer fibers are under a tensile stress and the inner fibers are under a compressive stress as a result of overconditioning.

Chamber, plenum - A chamber on the pressure side of a fan or blower in which the air is maintained under pressure.

Chart recorder - A sheet, usually circular, on which a graphic record of kiln temperatures is transcribed.

Check - A lengthwise separation of the wood that usually extends across the rings of annual growth and parallel to the wood rays, resulting from drying stresses.

Surface check - A check starting on a side grain surface and extending into the interior of a board.
End Check - A check starting on an end grain surface and extending along the length of a board.

Internal check - Checks originating in the interior of a piece of wood or extensions of surface and end checks.

Circulation, air - The movement of air within a kiln by either natural or mechanical means.

Direction of - The direction of movement of air through the kiln charge, expressed as longitudinal, transverse, or vertical.

Forced - The movement of air within a kiln by mechanical means.

Longitudinal - Air movement through the kiln charge to be expressed as front to rear or rear to front.

Natural - The movement of air within a kiln by natural means.

Reversible - Capable of change in the direction of air movement.

Transverse - Air movement through the kiln charge from wall to wall to be expressed as right to left or left to right.

Vertical - Air movement through the kiln charge from top to bottom or bottom to top.

Coil header (or manifold) - A pipe fitting to which a number of pipes are connected on one side.

Coil, intermittent operation of - The alternate opening and closing of the valve controlling steam flow into the coil.

Coil, pipe - One or more runs of pipes, the function of which is to heat the air in the kiln.

Booster - A supplementary coil, usually located between tracks of a multiple-track kiln, used to add heat to air that has already moved across a trackload of lumber.

Ceiling - A coil placed near the kiln ceiling to warm the ceiling and roof, thus preventing moisture condensation.

Plain header, (horizontal or vertical) - A coil consisting of a supply and discharge header at opposite ends with the pipes running from one to the other.

Single - return - bend header (horizontal or vertical) - A coil with the discharge header usually located under or on the side of the supply header, the pipes running from the supply header to a 180° bend and back to the discharge header.

Multiple - return - bend header - A coil usually with the discharge header located below the supply header, the pipes running back and forth with a 180° elbow at the bends.
Double-end - Coils usually extending half the length of the kiln from both ends and usually operating as separate units.

Coil radiating surface - The entire uninsulated surface area of a heating coil.

Collapse - The severe distortion or flattening of single cells or rows of cells in wood during drying, often evidenced by a caved-in or corrugated appearance of the surface of the piece.

Compression failure - Rupture of the wood structure resulting from excessive compression along the grain. It may develop as a result of bending in the living tree or during felling. In surfaced lumber, compression failures appear as fine wrinkles across the face of the piece.

Compression wood - Abnormal wood formed on the lower side of branches and inclined trunks of softwood trees. It has relatively wide, eccentric growth rings with little or no demarcation between springwood and summerwood and more than normal amounts of summerwood. Compression wood shrinks more than normal wood longitudinally, causing bow, crook, and twist.

Condensate - Water formed by the cooling of steam.

Conditioning treatment - A controlled high temperature - high relative humidity condition used in a dry kiln after the final stage of drying to bring about a uniform moisture distribution in the boards and to relieve drying stresses.

Conduction, heat - Transmission of heat through or by means of a conductor.

Controller - An instrument that automatically controls kiln temperatures.

Convection, heat - Transfer of heat from heating coils to lumber by means of air.

Course, lumber - A single layer of lumber.

Crook - A distortion of a board in which the edges deviate from a straight line from end to end of the board.

Cup - A distortion of a board in which there is deviation from flatness across the width of the board.

Cycle, heating - The time intervening between successive openings of a control valve.

Cycle, temperature - The time between the maximum and minimum temperatures during a heating cycle.

Decay - The decomposition of wood substance by fungi.
Advanced (or typical) decay - The older stage of decay in which the destruction is readily recognized because the wood has become punky, soft and spongy, stringy, ring-shaked, pitted, or crumbly. Decided discoloration or bleaching of the rotted wood is often apparent.

Incipient decay - The early stage of decay that has not proceeded far enough to soften or otherwise perceptibly impair the hardness of the wood. It is usually accompanied by a slight discoloration or bleaching of the wood.

Defects, drying - Any irregularity occurring in or on wood, as a result of drying, that may lower its strength, durability or utility value.

Degradation, kiln - A drop in lumber grade that results from kiln drying.

Density - The weight of a body per unit volume.

Depression, wet-bult - The difference between the dry and wet bult temperatures.

Dew Point - The temperature at which steam or water vapor begins to condense.

Diamonding - A form of warp in which the cross section assumes a diamond shape.

Diffuse-porous wood - A hardwood in which the pores tend to be uniform in size and distribution throughout each annual ring or to decrease in size slightly and gradually toward the outer corner of the ring.

Diffusion - Spontaneous movement of heat, moisture, or a gas throughout a body or space. Movement is from high points to low points of temperature or concentration.

Dry-bulb temperature - The temperature of the air indicated by any type of thermometer not affected by the water vapor content or relative humidity of the air.

Drying, air - Process of drying lumber by natural conditions in a yard or in an open unheated shed.

Drying in transit - The partial or complete kiln drying of lumber by a drying facility located between the shipping and fabrication points.

Drying, precision kiln - Process of drying wood in which controlled procedures are followed in order to obtain a stress-free product that has a desired moisture content and has suffered a minimum loss in strength.

Drying rate - The amount of moisture lost from the lumber per unit time.
Duct, air - A rectangular, square or circular passageway to conduct air.

End coating - A coating of moisture-resistant material applied to the end-grain surface to retard end drying of green wood or to reduce moisture changes in dried wood to a minimum.

Equalization - Bringing the pieces of lumber in a kiln charge to a nearly uniform moisture content.

Equilibrium moisture content (EMC) - The moisture content at which wood neither gains nor loses moisture when surrounded by air at a given relative humidity and temperature.

Evaporation - The changing from the liquid to the vapor form.

Extractives - Substances in wood, not an integral part of the cellular structure, that can be removed by solution in hot or cold water, ether, benzene, or other solvents that do not react chemically with wood substance.

Fiber saturation point - The stage in the drying or wetting of wood at which the cell walls are saturated with water and the cell cavities are free from water. It is usually taken as approximately 30 percent moisture content, based on weight when oven-dry.

Fiber, wood - A comparatively long (1/25 or less to 1/3 inch), narrow, tapering hardwood cell closed at both ends.

Flat-sawed - Lumber sawed in a plane approximately perpendicular to a radius of the log. (See grain)

Fluctuation, steam pressure - Variation of steam pressure.

Flue, "A" - A vertical wedge-shaped space provided in the transverse center and extending the length of a kiln load of lumber, usually 15 inches wide at the bottom and tapering to a point 1 or 2 courses down from the top of the load.

Flue, vertical - A vertical space, usually 6 inches or less in width and extending the length and height of a kiln truckload or package of lumber.

Grain - The general direction of the fibers in wood or lumber. When used with qualifying adjectives it has special meanings concerning the direction of the fibers or the direction or size of growth rings.

Under fiber direction the specific terms are:

Cross grain - Grain deviating from a line parallel to the sides of the piece.

Diagonal grain - A form of cross grain resulting from sawing...
at an angle with the bark of the log.

Interlocked grain - A form of spiral grain in which the fiber direction gradually alternates from right-hand to left-hand spiral and back again in adjacent groups of annual rings.

Spiral grain - A form of cross grain resulting from the fibers, during growth, taking a spiral course about the trunk of the tree instead of the normal vertical course.

Straight grain - Grain parallel to the sides of the piece.

Under growth ring direction or ring pattern, the specific terms are:

Coarse grain - Wood in which the growth rings are wide or have major differences in density and color between springwood and summerwood.

Edge grain (or vertical grain) - The grain in lumber produced by quartersawing so that the edges of the growth rings are exposed on the widest faces of the piece, and the rings form angles of 45° to 90° with the widest faces.

Fine grain - Wood in which the growth rings are narrow and inconspicuous.

Flat grain - The grain in lumber produced by flat sawing so that the tangential faces of the growth rings are exposed on the widest faces of the piece and the rings form angles of less than 45° with the widest faces.

Green lumber (or grass green) - Lumber cut from freshly felled trees.

Hardwoods - The wood extending from the pith to the sapwood, the cells of which no longer participate in the life processes of the tree. Heartwood may be infiltrated with gums, resins, and other materials that usually make it darker and more decay resistant than sapwood.

Honeycombing - Checks, often not visible at the surface, that occur in the interior of a piece of wood, usually along the wood rays. (See Ring failure.)

Humidity, absolute - The weight of water vapor per unit volume of space.

Humidity, relative - Ratio of the amount of water vapor present in the air to that which the air would hold at saturation at the same temperature. It is usually considered on the basis of the weight of the vapor, but for accuracy it should be considered on the basis of vapor pressures.
Hygroscopicity - The property of a substance which permits it to absorb and retain moisture.

Hysteresis - The tendency of wood exposed to any specified temperature and relative humidity conditions to reach equilibrium at a lower moisture content when absorbing moisture from a drier condition than when losing moisture from a wetter condition.

Kiln - A heater chamber for drying lumber, veneer, and other wood products in which temperature and relative humidities are controlled.

Compartment - A dry kiln in which the total charge of lumber is not dried as a single unit. At any given time, the temperature and relative humidity are uniform throughout the kiln.

Progressive - A dry kiln in which the total charge of lumber is not dried as a single unit but as several units, such as kiln truckloads, that move progressively through the kiln. The temperature is lower and the relative humidity higher at the entering end (green end) than at the discharge end (dry end).

Automatically controlled - A dry kiln in which drying conditions are controlled by the action of thermostats.

Forced-circulation - A dry kiln in which the air is circulated by mechanical means.

Manually controlled - A dry kiln in which drying conditions are controlled by the manual operation of valves and ventilators.

Multiple-track - A dry kiln equipped with two or more tracks.

Natural-circulation - A dry kiln which air circulation depends on the power of gravity and the varying density of air with changes in its temperature and moisture content.

Reversible circulation - A dry kiln in which the direction of air circulation can be reversed at desired intervals.

Single-track - A dry kiln equipped with one track.

Kiln charge - The total amount of lumber or wood items in a dry kiln.

Kiln charge, mixed - Same as kiln charge but composed of more than one species or thickness of lumber or wood items.

Kiln - drying - Process of drying lumber in a dry kiln.

Kiln leakage - The undesirable loss of heat and vapor from a kiln through badly fitted doors and ventilators or through...
Kiln Run - The term applied to the drying of a single charge of lumber.

Kiln Sample - A section 30 inches or more in length cut from a sample board and placed in the kiln charge so that it can be removed for examination, weighing, and testing.

Controlling - Some of the wettest samples used to control the drying. The number depends on the total number of samples used and the composition of the kiln charge.

Driest - The kiln sample containing the least amount of moisture.

Fastest drying - The kiln sample that loses the largest amount of moisture in a given period of time.

Pocket - A space provided for the kiln sample in the kiln truckloads of lumber.

Slowest drying - The kiln sample that loses the smallest amount of moisture in a given period of time.

Weight, current - The weight of a kiln sample at a given time during the drying process.

Weight, final - The weight of a kiln sample after the completion of the drying.

Weight, green (or initial, or original) - The weight of a kiln sample prior to kiln drying regardless of its moisture content.

Wettest - The kiln sample containing the largest amount of moisture.

Knot - That part of a branch which has become overgrown by the body of a tree. The shape of the knot depends on the angle at which the branch is cut.

Loading, cross-piled - Lumber piled on kiln trucks and placed in a dry kiln with the long axis of the load perpendicular to the length of the kiln.

Loading, end-piled - Lumber piled on kiln trucks and placed in a dry kiln with the long axis of the load parallel to the length of the kiln.

Longitudinal - Generally, the direction along the length of the grain of wood. A longitudinal section may be a plane either tangential or radial to the growth rings.

Lumber, kiln-dry - Lumber that has been dried in a dry kiln to a specified moisture condition.
Lumber, shipping-dry - Lumber that has been partially air or kiln dried to an average moisture content of approximately 30 percent.

Lumber storage room - A room maintained within specified equilibrium moisture content limits so that lumber stored in it will not gain or lose moisture beyond fixed limits.

Meter, moisture - An instrument used for rapid determination of the moisture content in wood by electrical means.

Mineral streak - An olive to greenish-black or brown discoloration of undetermined cause in hardwoods, particularly hard maples; commonly associated with bird pecks and other injuries; occurs in streaks usually containing accumulations of mineral matter.

Moisture Content of Wood - Weight of the water contained in the wood, expressed as a percentage of the weight of the ovendry wood.

Average - The percentage of moisture content of a single piece or the sum of the moisture contents of a number of pieces divided by their number.

Core - The moisture content of the inside part of a moisture section remaining after a shell \( \frac{1}{4} \) the thickness of the section has been removed.

Determination of - The testing of lumber to determine the amount of moisture present. This is usually expressed in terms of percent of the ovendry weight.

Final - The moisture content of the wood at the end of kiln-drying.

Green - The moisture content of wood in the living tree.

Initial - The moisture content of the wood at the start of kiln drying.

Shell - The moisture content of the outer one-fourth of the thickness of a moisture section.

Moisture distribution - The variation of moisture content throughout a piece of wood, usually from face to face but sometimes from end to end, or from edge to edge.

Moisture gradient - A condition existing during drying in which the moisture content uniformly decreases from the inside toward the surface of a piece of wood.

Moisture gradient, reserve - A condition following moisture regain in which the moisture content is higher at the surface than inside the wood.

Moisture range - The difference in moisture content between the driest and wettest boards or samples.
Moisture section - A cross section, 1 inch in length along the grain, cut from a kiln or random sample and used to determine moisture content.

Moisture section, initial weight of - The weight of a moisture section immediately after being cut from a kiln sample or board.

Moisture section, ovendry weight of - The weight of a moisture section after being ovendried to a constant weight.

Mold - A fungus growth on lumber taking place mainly at or near the surface and, therefore, not typically resulting in deep discolorations. They are usually ash green to deep green in color, although black is common.

Old growth - Timber in or from a mature, naturally established forest. When the trees have grown during most if not all of their individual lives in active competition with their companions for sunlight and moisture, the timber is usually straight and relatively free of knots.

Ovendry - A term applied to wood dried to constant weight in an oven maintained at temperatures of from 214° to 221° F.

Previous wood - A wood through which moisture moves readily.

Piling box - The flat piling of random length boards on kiln trucks so that the ends of the completed load are in vertical alignment. The longest boards are placed on the outside of the load and the shorter boards are alternately placed with one end even with one end of the load or the other.

Piling, edge - Piling lumber so that the broad face of the board is vertical.

Piling, flat - Piling lumber so that the broad face of the board is horizontal.

Pit - A relatively unthickened part of a wood cell wall where a thin membrane may permit liquids to readily pass from one cell to another. A "bordered" pit has an overhanging rim that is not present in a "simple" pit.

Pitch - The mixture of rosin and turpentine or other volatiles produced in the resin canals of pines and other conifers. Term also applied to mixtures of nonvolatile liquids or non-crystalline solids and volatile oils in other species.

Pitch pockets - An opening, extending parallel to the growth rings, that contains or has contained pitch.

Pitch streak - A well-defined streaky accumulation of pitch in the wood of certain softwoods.

Pith - The small, soft core occurring in the structural center of a tree trunk, branch, twig, or log.
Plainsawed - Another term for flat-sawed or flat-grained lumber.

Pore - The cross section of a specialized hardwood cell known as a vessel. (See Vessels.)

Quartersawed - Lumber sawed so the wide faces are approximately at right angles to the annual growth rings. (See Grain.)

Radial - Coincident with or generally parallel to a radius of the tree from the pith to the bark. A radial section is a lengthwise section in a plane that passes through the pith.

Radiation - Heating coils or elements with a dry kiln.

Balanced - Construction and arrangement so as to insure equal radiating surface and uniform temperatures throughout the kiln.

Direct - The transmission of heat energy to a body or substance by direct heat rays from the heating system.

Excessive - A greater amount of radiation than required.

Flexible - The arrangement of the heating system into small coils equipped with hand valves that, when opened or closed, permit rapid adjustment of the radiating surface to meet the required needs.

Raised grain - A roughened condition of the surface of dressed lumber in which the hard summerwood is raised above the softer springwood but not torn loose from it.

Rate of growth - The rate at which a tree has laid on wood, measured radially in the tree trunk or in the radial direction in lumber. The unit of measure in use is the number of annual growth rings per inch.

Rays, wood - Strips of cells extending radially within a tree and varying in height from a few cells in some species to 4 inches or more in oak. The rays serve primarily to store food and transport it horizontally in the tree.

Resin canal (or duct) - Intercellular passages that contain and transmit resinous materials. They extend vertically or radially in a tree.

Ring failure (or separation) - A separation of the wood during seasoning. Occurs along the grain and parallel to the annual rings, either within or between rings; called honeycomb and ring check in some localities. (See Shake.)

Sample board - A board from which one or more kiln samples will be cut, or a board taken from a kiln truckload during drying for the purpose of cutting a moisture section.
Sample - (See Kiln sample.)

Seasoning - Removing moisture from green wood, and in some cases relief of stresses, in order to improve its serviceability.

Set - A localized semipermanent deformation in wood caused by internal tensile or compressive stresses.

Compression set - Set, occurring during compression, that tends to give the wood a smaller than normal dimension after drying, usually found in the interior of wood items during the last state of drying but sometimes in the outer layers after over-conditioning or rewetting. Also caused by external restraint during rewetting or dried wood.

Tension set - Set, occurring during tension, that tends to give the wood a larger than normal dimension after drying, usually occurring in the outer layers during the first stages. Also caused by external restraint during drying of wet wood.

Shake - A separation along the grain, the greater part of which occurs between the rings of annual growth. Found in stumps and ends of freshly cut logs and green lumber. (See Ring failure.)

Shrinkage - The contraction of wood caused by drying the material below the fiber saturation point.

Longitudinal - Shrinkage along the grain.

Radial - Shrinkage across the grain, in a radial direction.

Tangential - Shrinkage across the grain, in a tangential direction.

Softwood - Wood produced by one of the botanical group of trees that, in most species, have needle or scalelike leaves.

Specific gravity - The ratio of the oven-dry weight of a piece of wood to the weight of an equal volume of water (39°F). In the field of seasoning, specific gravity values are usually based on the volume the wood has when green.

Split - A lengthwise separation of the wood, due to the tearing apart of the wood parallel to the wood rays.

Spray line - A plain pipe of varying sizes and lengths and drilled with holes of various sizes and spacing through which steam is injected into the kiln.

Springwood (early wood) - The part of the annual growth ring that is formed during the early part of the season's growth. It is usually less dense and weaker mechanically than summerwood.

Stain - A discoloration in wood that may be caused by such diverse agencies as microorganisms, metal, or chemicals. The term also applies to materials used to impart color to wood.
Blue stain (sap stain) - A bluish or grayish discoloration of the sapwood caused by the growth of certain dark colored fungi on the surface and in the interior of the wood, made possible by the same conditions that favor the growth of other fungi.

Chemical stain - A general term including all stains that are due to color changes of the chemicals normally present in the wood, such as pinking of hickory and browning of some softwoods, particularly the pines.

Chemical stain, brown - A chemical discoloration of wood, which can occur during the air-drying or kiln-drying of several soft-wood species, caused by the concentration and modification of extractives.

Iron-tannate stain - A surface stain, bluish-black in color, on oak and other tannin-bearing woods following contact of the wet wood with iron, or with water in which iron is dissolved.

Mineral stain - An olive to greenish-black or brown discoloration in hardwoods, particularly maple, caused by bird peck or other injury and found either in mass discoloration or mineral streaks. The mineral associated with such streaks is frequently calcium oxalate, which has a tendency to dull machining knives.

Sticker Stain - A gray to blue or brown chemical stain occurring on and beneath the surface of boards where they are in contact with stickers, (also fungus sap stain when found only in the sticker area).

Water stain - A yellowish to blackish surface discoloration caused by water that dripped onto the wood during seasoning.

Weather stain - A very thin grayish-brown surface discoloration on lumber exposed a long time to the weather.

Steam - The vapor into which water is converted when heated.

Exhaust - Steam which has already passed through a steam engine or machine.

Flash - The reevaporation of hot water produced by the excess heat, when the water is discharged to a lower pressure.

Live - Steam obtained directly from the boiler.

Superheated - Steam at a temperature higher than the saturation temperature corresponding to the pressure.

Steam binding - The presence of steam in the drain line between the heating coil and trap which temporarily prevents the drainage of condensate and air from the coil.
Sticker - A wooden strip placed between the courses of lumber in a kiln load and at right angles to the long axis of the boards, to permit air circulation.

Alinemernt - The placing of stickers in a pile, package, or truckload of lumber so that they form vertical tiers.

Spacing - The distance between stickers measured from center to center.

Stress, drying - An internal force, exerted by either of two adjacent parts of a piece of wood upon the other during drying, caused by uneven drying and shrinking, and influenced by set.

Tensile stress - The stress found in the outer layers of wood during the early stages of drying when they are trying to shrink but are restrained by the still wet interior region; also the stress in the interior layers later in drying as they try to shrink and are restrained by the set outer shell.

Compressive stress - The stress found in the interior region of wood during the early stages of drying, caused by the shrinking of the outer shell; also the stress in the outer layer later in drying caused by the shrinking of the interior.

Stress-free - Containing no drying stresses.

Stress section - A cross section of a sample that is cut into prongs of equal thicknesses, from face to face.

Stresses, relief of - The result of a conditioning treatment, following the final stage of drying, which causes a redistribution of moisture and a relief of the sets.

Temperature - Degree of hotness or coldness.

Cold zone - The lowest entering air dry-bulb temperature in the kiln.

Drop across the load - The reduction in the dry-bulb temperature of the air as it flows through the load and is cooled by evaporating moisture from the load of lumber.

Dry bulb - The temperature of the kiln air.

Hot zone - The highest entering-air dry-bulb temperatures in a kiln.

Wet bulb - The temperatures indicated by any temperature measuring device, the sensitive element of which is covered by a smooth clean, soft, water-saturated cloth (wet-bulb wick or porous sleeve).
Temperature gradient, longitudinal - A term used to denote longitudinal temperature differences within a dry kiln.

Tension wood - A type of wood found in leaning trees of some hardwood species, characterized by the presence of fibers technically known as "gelatinous" and by excessive longitudinal shrinkage. Tension wood fibers tend to "pull out" on sawed and planed surfaces, giving so called "fuzzy grain". Tension wood causes crook and bow and may collapse. Because of slower than normal drying, tension wood zones may remain wet when the surrounding wood is dry.

Transverse - The directions in wood at right angles to the wood fibers or across the grain, including radial and tangential directions. A transverse or cross section is a section through a tree or timber at right angles to the pith. It has an end-grain surface.

Treatment, equalization - A controlled temperature and relative humidity condition used in a dry kiln at the end of drying to stop the drying of the driest boards while allowing the wettest boards to continue drying, thus reducing the moisture range between boards.

Treatment, steaming - Spraying steam directly into the kiln to attain a condition at or near saturation in the initial stages of kiln drying to retard the growth of mold. Also used to increase the rate of heating cold lumber. Sometimes used needlessly during other stages of drying to restore surface moisture, and often used without proper control to partially relieve stresses at the end of drying.

Twist - A form of warp caused by the turning or winding of the edges of a board so that the four corners of any face are no longer in the same plane.

Tyloses - Extensions of parenchyma cells into the pores or vessels of some hardwoods, notably white oak and black locust, prior to or during heartwood formation. They tend to prevent or greatly retard moisture movement through the vessels.

Vapor barrier - A material with a high resistance to vapor movement, such as asphalt-impregnated paper, that is used in combination with insulation to control condensation.

Vapor pressure - The pressure of a confined body of vapor. The pressure of a given saturated vapor is a function of temperature only.

Ventilator (or vent) - An opening in the kiln roof or wall, or in the blower duct work, that can be opened or closed in order to maintain the desired relative humidity condition within the kiln.

Automatic Control - A ventilator that is opened or closed by a thermostat.
Linkage - The adjustable, pivoted rods connecting the vent cover to an air valve or to a hand operated lever which facilitates the opening and closing of the vents.

Manual control - A ventilator that is opened or closed by hand.

Vessels - Wood cells in hardwoods of comparatively large diameter that have open ends and are set one above the other so as to form continuous tubes. The openings of the vessels on the surface of a piece of wood are usually referred to as pores.

Virgin growth - The original growth of mature trees.

Wane - Presence of bark or the lack of wood from any cause on edge or corner of a piece.

Warp - Any variation from a true or plane surface. Warp includes cup, bow, crook, twist, and diamonding, or any combination thereof.

Water, bound (absorbed, hygroscopic) - Moisture that is bound by adsorption forces within the cell wall; that is, the water in wood below the fiber saturation point.

Water free - Moisture that is held in the cell cavities of the wood, not bound in the cell wall.

Water pocket - An area of unusually high moisture content of various sizes and shapes found in lumber.

Waterlogging - The presence of water in steam coils, which interferes with the normal flow of steam and seriously affects the heating efficiency of the coil.