Chapter 9
Operating a Dry Kiln

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A dry kiln, no matter how well equipped with controls, is only as efficient as the operator who runs it. Despite advances in control technology that give the operator more information than was possible in the past, it is still largely the operator's judgment that determines whether a charge of lumber will go through the kiln in a minimum time, emerge uniformly dried to the desired moisture content, and be free of undesired drying defects and stresses. The operator determines what kiln schedule to use, and whether it should be a time or moisture content schedule. If kiln samples are to be used, whether manually or automatically weighed or monitored with probes, the kiln operator is still responsible for selecting representative kiln samples. The kiln operator must monitor the progress of drying, whether manually or with the assistance of computer readouts, and apply judgment in deciding if adjustments are necessary during drying. Also, the operator must apply judgment in determining when the lumber has reached final moisture content with a minimum of moisture content variation and apply any necessary equalizing or conditioning treatments.

Most of these basic techniques are discussed in other chapters of this manual. The purpose of this chapter is to summarize and present various aspects of kiln operation to guide the operator in exercising good judgment in reaching decisions required before and during drying.

Kiln Samples

When kiln samples are used to control a drying schedule, their selection, preparation, and use are important in kiln operation. Poor procedures here can result in erroneous estimates of moisture content that may increase drying defects and drying time. The procedures described in chapter 6 should be followed as closely as possible.

Selecting a Drying Schedule

One of the first decisions in selecting a dry kiln schedule is whether to use a schedule based on moisture content or time. This is usually a routine decision because softwood-drying technology has developed time schedules and hardwood-drying technology has developed moisture content schedules. However, there are exceptions to this general division of schedules. If drying problems or customer complaints occur with high-quality softwood lumber dried by a time schedule, consideration should be given to changing to a moisture content schedule. Conversely, repeated experience with drying a hardwood species of constant thickness in the same kiln, particularly one of the easier drying low-density hardwoods, may well lead to the development of a time schedule.

Chapter 6 provides guidelines for selecting a kiln schedule. They include species, thickness, moisture content, heartwood or sapwood, and grain (quartersawn or flatsawn). Selection of a drying schedule is simplified when the charge consists of one species, one thickness, a uniform moisture content, all heartwood or all sapwood, and all quartersawn or flatsawn. The uniformity of variable factors should be maintained as much as possible for high drying uniformity and quality.

Schedules for Homogeneous Charges

For charges that consist entirely of one class of lumber, a schedule for that class as recommended in chapter 7 should be used as a start. After experience is gained with that particular class, the schedule can be modified as discussed in chapter 7.

Schedules for Mixed Charges

Sometimes it is necessary to dry lumber in mixed charges, even though this practice is not generally recommended. It reduces the production rate through kilns and increases the likelihood of variability in the dried lumber. Most mixing is caused by lack of enough kilns or improper kiln sizing to accommodate different classes of drying sorts (groups of sorted lumber). Some mixing is necessary to avoid undue delay in drying sorts that accumulate slowly and will degrade or stain if left in green storage too long. In selecting a drying schedule for a mixed charge of lumber, the drying characteristics of all the lumber to be included should be considered. Mixed charges can be dried according to moisture content or time schedules. The following examples and suggestions should be helpful guidelines in selecting kiln schedules for mixed charges.

Example 1: If a charge of lumber is composed of the same species and moisture content but of varying thickness, use the schedule recommended for the thickest lumber. For example, if the kiln charge is both 6/4 and 8/4 sugar maple, follow the drying schedule for the 8/4 lumber, T5-C2, rather than for the 6/4, T8-C3. If the charge is of 4/4, 5/4, and 6/4 sugar maple, schedule T8-C3 could be used. In both cases, the changes in drying conditions would be based on the kiln samples with the highest moisture content, which almost surely will be the thicker samples. Kiln samples from the faster-drying thinner lumber must also be used in order to equalize properly.

Example 2: If two or more species of the same thickness and moisture content are dried together, use the schedule recommended for the species that is the most difficult to dry, that is, the slowest or most susceptible to surface or internal checking. Make every effort to mix species that require much the same drying schedule and about the same drying time (ch. 7, table 7-33). For example, both 4/4 white ash and 4/4 black cherry call for the same drying schedule, T8-B4. Several species have approximately the same drying characteristics. These include 4/4 yellow birch, schedule T8-C4; 4/4 black cherry, T8-B4; and 4/4 sugar maple, T8-C3. These species have the sane temperature schedule, T8, but their wet-bulb depression schedules are different. Since the mildest drying condition is recommended, use the C3 wet-bulb depression schedule.

Example 3: Another example is two species or more of the same thickness but of varying moisture content, such as a mixture of green 4/4 black cherry and air-dried 4/4 sugar maple with an average moisture content of 25 percent. Green black cherry calls for schedule T8-B4 and green sugar maple for schedule T8-C3. The air-dried sugar maple with a moisture content of 25 percent calls for initial drying conditions of 150 °F dry-bulb temperature (step 3 of T8 schedule) and a wet-bulb depression of 35 °F (step 5 of C3 schedule), while the T8-B4 schedule for green black cherry calls for an initial dry-bulb temperature of 130 °F and a wet-bulb depression of 7 °F. To avoid damage to the green cherry, use the milder T8-B4 schedule.

Example 4: Sapwood of ponderosa pine of Common grades can be mixed with white fir dimension lumber, provided the white fir does not contain wetwood. A typical sapwood Common-grade schedule of moderate temperature and wet-bulb depression should be used to protect the pine and to equalize the final moisture content between the pine and white fir.

Example 5: Heartwood of Common-grade ponderosa pine can be mixed with Douglas-fir dimension lumber. The initial temperature should be 160 °F with a maximum wet-bulb depression of 10 to 15 °F.

Example 6: 4/4 sugar pine wetwood can be dried with 6/4 or 8/4 ponderosa pine Shop or Select. Use as large a wet-bulb depression as the ponderosa will tolerate without surface checking, but keep the starting temperature low enough to prevent brown stain in the sugar pine wetwood.

Example 7: Mill run mixtures of white fir, Englemann spruce, and lodgepole pine can be dried together. However, a moderate schedule should be used to reduce the variation in final moisture content. Care should be exercised to prevent overdrying.

Example 8: Green Douglas-fir and larch clear lumber does not always store well while enough wood to fill a kiln charge is being accumulated. Water spray is sometimes used to prevent checking during this storage. Another alternative is to mix the clear lumber with other sorts to avoid long storage while green.

In general, species that have a wide variation in schedule requirements should not be mixed for drying. The main concern here is stain and surface checking. Kiln conditions that are humid enough to avoid surface checking in some species may cause brown stain, blue stain, or mold to occur in others. For example, Douglas-fir may surface check at the low humidity needed to prevent brown stain in sugar pine.

These examples serve to illustrate that mixed charges can be dried successfully, but that caution should be used and that often there is a penalty, such as excessive drying time, nonuniform final moisture content, and the danger of drying defects.

Starting the Kiln

The danger of drying defects and excessive drying time can be reduced if prestart checks and proper starting procedures are followed. These checks and procedures vary somewhat with the type of kiln, but all are aimed at ensuring that the equipment is operated properly.

Prestart Checks

Several checks should be made before starting a kiln.

1. Calibration of the wet- and dry-bulb thermometers is not necessary for every charge, but the state of the calibration check should be kept in mind. If a long time has passed since the last calibration check or if previous performance suggests the possibility that the kiln is out of calibration, plans should be made for a check.
2. A check should be made for adequate steam pressure. Is more than one kiln starting up at once? If so, the demand on the steam system may be too great to attain desired initial conditions.
3. The air pressure to the recorder-controller should be checked and any water drained from the air line.
4. Water delivery to the wet-bulb reservoir must be fast enough to keep pace with evaporation. Experience will dictate the necessary rate of flow.
5. The wet-bulb wick should be changed if it is dirty or encrusted with mineral scale from the water. Ensure that the wick does wet.
6. Check that nothing is obstructing airflow over the wet bulb.
7. Consider sir velocity through the lumber. Have checks in the past indicated a sufficient and uniform flow? Is there anything different in the current charge that could change the flow? Are necessary end, bottom, or top baffles in place?
8. The vents should be inspected and checked for operation. See that all vents open and close completely.
9. Check the fan operation. See that all fans are turning correctly, no motors are malfunctioning, fans are not spinning on their shafts, and belts are not slipping.
10. Check that doors are in good repair and close tightly.

Steam-Heated Kilns

The following are the general startup procedures for steam-heated kilns.

1. Set the dry- and wet-bulb controls at the initial temperatures called for in the schedule.
2. Keep the hand valve on the steam spray line closed during warmup to avoid excessive steam consumption and condensation on the lumber. If there is no hand valve on the steam spray feedline, set the wet-bulb temperature to the lowest temperature possible to prevent opening the spray line valve. This procedure should only be used if it is possible to prevent the vents from opening. Au alternative procedure for adjusting the wet-bulb control is described in item 11.
3. Implosion can occur in cold climates for up to one or more hours after startup. To prevent implosion, open the small inspection door or leave the main door slightly open before starting the fans. After the fans have operated for several minutes, the door can be closed.
4. Open the hand valve on the main steam supply line.
5. Open the hand valves on the feedlines to all heating coils.
6. Open the hand valves between all the heating coils and steam traps and in the return lines from the steam traps to the boiler.

7. Open the main air supply valves to the control instrument and to the air-operated valves on the heat and spray lines. If the control system is electrically operated, turn on the power switches.
8. Blow all steam traps to the atmosphere for a short time to remove scale and dirt from them.
9. Just before the dry-bulb temperature reaches set point, open the hand valve on the steam spray line or reset the wet-bulb temperature to the recommended wet-bulb temperature.
10. If the kiln is equipped with auxiliary vents, keep them closed during warmup until the wet-bulb temperature reaches set point.
11. Sometimes when warming up a kiln charge of green lumber susceptible to surface checking, the wet-bulb temperature can be brought up gradually rather than according to the procedures in items 2 and 9. For example, if the initial drying conditions call for a wet-bulb depression of 4 °F, this temperature can be approximated during warmup by opening the hand valve on the steam spray line for short periods or by gradually raising the wet-bulb indicator if it was initially set at a low value. This procedure requires frequent monitoring of conditions during warmup.

Direct-Fired Kilns

Direct-fired kilns vary in type of burner and air delivery system, and many do not have a source of steam for humidification. The starting procedures do not differ much from those of a steam-heated kiln and can be summarized as follows:

1. Set the dry-bulb temperature, and wet-bulb temperature if the kiln is equipped with spray lines, at the initial set point or points called for in the schedule.
2. To prevent implosion, open the small inspection door or leave the main door slightly open before turning on the fans. After the fans have operated for a few minutes, the doors should be closed.
3. Start the burner system according to the manufacturer's procedures.
4. If the kiln is equipped with auxiliary vents, keep them closed during warmup.
5. If the kiln is equipped with steam or water spray, keep the spray shut off until the dry-bulb temperature has almost reached set point. In warming up a charge of lumber susceptible to checking, the procedure outlined for steam-heated kilns can be followed.

Dehumidification Kilns

Startup procedures for dehumidification kilns may depend on the particular manufacturer's recommendations. Certainly, the status of the heating and refrigeration systems should be checked for proper operation. Auxiliary heat is often added in a dehumidification kiln to reach set point. After that, it is turned off and the heat from the compressor is sufficient to maintain drying temperature in many cases.

Warmup Period

Spray During Warmup

Both heat and steam spray are sometimes used in the warmup period. This procedure will reduce to some extent the time required for warmup, but the potential problems may more than offset the gain in time.

When both the heating and spray systems are on during warmup, a large quantity of steam is used. The steam consumption may exceed the boiler capacity and thereby affect the drying conditions in other kilns already in operation.

When the steam spray is on, moisture condensing on the cold lumber, cold kiln walls, ceiling, and other metal parts will have several effects. Condensation does not allow much drying during warmup, and in fact the lumber will usually pick up moisture. Condensation can cause water stain on the lumber and contribute to corrosion of kiln parts. Another danger is the effect on partially dried lumber that may contain some surface checking. Rewetting the surface will usually widen and deepen surface checks.

Time Needed for Warmup

The time required for warmup depends on many factors and can vary from 1 to 24 h. Warmup time is lengthened if (1) lumber and kiln structure temperatures are low, (2) lumber is frozen, (3) temperature of the outside air is low, (4) initial moisture content of the lumber is high, (5) lumber is thick, (6) density of the species is high, (7) heat losses through the kiln walls and roof are high, (8) seals around closed vents and doors are poor, (9) some heating coils are inactive, and (10) boiler output is too low.

Operating a Kiln After Warmup

Reducing Heat

About 1 h after the kiln has reached set point, the heating system can be cut back. In direct-fired kilns, the rate of firing can be reduced. In steam-heated kilns, the amount of heat-transfer surface area, steam pressure, or both can be reduced. Surface area is decreased by closing valves in the feed and drain lines of some heating coils, and steam pressure is reduced by adjusting the steam pressure regulator. The usual procedure in reducing radiation surface area is to cut off the larger heating coils first and gradually work down to the smallest coil that will maintain the desired dry-bulb temperature. This procedure should be followed unless past experience has shown how much radiation is required to maintain the desired temperature. Experience will establish the best combinations of coils and steam pressure for given situations, and these can be noted for future reference.

Controlling Dry-Bulb Temperature

Variations in dry-bulb temperature on the entering-air side of the loads are a major source of poor control of drying conditions. These variations are sometimes associated with faulty kiln design or poor trap maintenance (chs. 2 and 4). The most common cause of temperature variation is excessive heat-transfer area, that is, too many active coils. Excessive coil heat-transfer area can result in large temperature cycles and waterlogging or air binding of the active heating coils, and these in turn can cause excessive temperature variations along the length of coils. To reduce these effects, the smallest amount of radiation and the lowest steam pressure necessary to maintain the desired dry-bulb temperature at any stage of drying should be used.

If the division of coils is not fine enough to have the correct amount of heat transfer area and the steam pressure cannot be regulated, the kiln may have to be operated at a dry-bulb temperature slightly lower than desired to obtain a nearly constant flow of steam. In that event, the wet-bulb temperature will also have to be adjusted downward to obtain the desired wet-bulb depression.

Controlling Wet-Bulb Temperature

Poor control of wet-bulb temperature is usually associated with inadequate kiln maintenance (ch. 4). Quite often, however, the use of a high-pressure steam spray causes wide variations in both the dry- and wet-bulb temperatures. The use of wet, low-pressure steam should overcome this difficulty. If the reduction in pressure does not have the desired effect, desuperheaters may have to be installed on the steam spray line. The flow of water should not be excessive and may be controlled by a needle valve. To make this possible, the water pressure must be greater than the steam pressure. Ordinarily, water is used to saturate the steam spray only during equalizing and conditioning, or during the early stages of drying a species that requires a low initial dry-bulb temperature with a small wet-bulb depression.

Proper venting is also required to obtain good control of wet-bulb temperature. Such control is attained by good maintenance and operation of the vent system (ch. 4). Excessive venting will add steam consumption and favor the development of drying defects. On the other hand, operating the kiln for extended periods with insufficient venting and at wet-bulb temperatures above those called for in the schedule will prolong drying time and favor the development of stain.

Direct-fired kilns, particularly as employed in softwood drying, often have no steam spray lines, and the only means of controlling the wet-bulb temperature is through venting. Wet-bulb temperature control often is not as critical here as in hardwood drying, and for many species the drying rate is fast enough that vents can adequately control wet-bulb temperature. Also, at temperatures very much above the boiling point, venting often is not necessary because equilibrium moisture content is low at these high temperatures. The main problem occurs if equalizing or conditioning is desired because direct-fired kilns are not capable of raising the wet-bulb temperature to high levels at the end of drying when very little water is evaporating from the lumber.

Some hardwood schedules call for low wet-bulb temperatures at certain stages in the schedule. Au example of this is the schedule for 4/4 red oak (T4-D2). When the lumber reaches 30 percent moisture content, the recommended wet-bulb temperature is 90 °F. In the southeastern part of the United States, the wet-bulb temperature of the outside air may be near that temperature, and either excessive or continuous venting will occur as the control system attempts to reach the wet-bulb temperature. When this occurs, the wet-bulb set point must be raised to a level that the control system can achieve. The dry-bulb temperature should not be raised above that called for in the schedule.

Part-Time Kiln Operation

Kilns are usually operated full time in industrial practice; drying is uninterrupted from the start to the finish of the process. However, some plants, particularly secondary producers, operate kilns part time. In part-time operation, the kiln may be shut down during certain hours in order to take advantage of savings in labor, power, or fuel costs.

Most species, particularly when air dried, can be dried in a part-time kiln successfully. However, equalizing and conditioning treatments usually require full-time operation to be effective. For green hardwoods, redwood, and cedars that are susceptible to surface checking, part-time operation during the initial stages may result in checking because of the more rapid drop in the wet-bulb compared to dry-bulb temperature during the off period. Therefore, for these species, operate the kiln on a full-time basis until the danger of surface checking is past. The vents should be kept closed during the off period to reduce heat losses.

Drying Process

After the kiln has been started, the lumber is dried according to the schedule selected from chapter 7. Chapter 7 deals mainly with the mechanics of selecting schedules, and the purpose of this section is to discuss the operational aspects of kiln schedules.

Operation on a Moisture Content Schedule

A moisture content schedule requires changes in drying conditions based on the average moisture content of the controlling kiln samples (ch. 6). Operation on a moisture content schedule is best illustrated by examples.

Example 1: A charge of 4/4 sugar maple is to be kiln dried from green moisture content. In the example we will use six kiln samples, and the average moisture content of the three wettest samples will be used to control kiln conditions. The drying schedule is given in table 9-1, and the schedule is applied in the following way.

Because the lumber is green, the initial moisture content will be above 40 percent. Therefore, the initial drying conditions will be those of step 1 for moisture content above 40 percent.

Subsequent changes in drying conditions are made when the average moisture content of the controlling samples reaches the value given in the schedule. For example, when the average moisture content of the three wettest samples is less than 30 percent but more than 25 percent, the dry-bulb temperature is 140 °F and the wet-bulb temperature is 121 °F. Because the drying rate of the kiln samples may vary from day to day, the same three samples may not be the wettest during all stages of drying. Therefore, the moisture content of all the samples in the charge should be determined each time they are weighed or sensed with a probe. The last step in the schedule is maintained until the desired final moisture content is reached.

In manual control, the controlling kiln samples occasionally lose more moisture between weighings than the interval given in the schedule. When this occurs, a step in the schedule can be skipped. For example, if the kiln is operating at 130 and 119 °F dry- and wet-bulb temperatures, respectively, and the next weighing indicates that the average moisture content of the controlling kiln samples is 24 percent, the drying conditions should be set at 150 and 115 °F dry- and wet-bulb temperatures, respectively, rather than at 140 and 121 °F. In some instances, even two steps can be skipped.

As soon as the final moisture content is reached, the kiln is shut off unless equalizing and conditioning treatments are required.

Example 2: A charge of partially air-dried 4/4 sugar maple is to be kiln dried. Eight kiln samples are used. Therefore, drying conditions will be governed by the average moisture content of the four wettest samples. The drying schedule will be the same as that used in example 1, and the procedure is as follows:

If the initial moisture content of the four wettest samples averages more than 40 percent, the initial drying conditions will be those listed for this moisture content. Subsequent drying procedures will be the same as for example 1.

If the average moisture content of the four wettest samples is 34 percent, the initial drying conditions will be 130 and 119 °F dry- and wet-bulb temperatures, respectively. Subsequent drying conditions will be as given in the schedule.

If, however, the lumber has regained moisture just before entering the kiln, modify the drying procedure to conform to the recommendations given for air-dried hardwoods in chapter 7.

Operation on a Time Schedule

In a time schedule, drying conditions are changed at predetermined times. No kiln samples are used, and the timed changes are based on experience.

Example 1: A time schedule for 8/4 white fir dimension lumber is shown in table 9-2. The kiln is started at 180 and 170 °F dry- and wet-bulb temperatures, respectively; after 12 h the change to step 2 of 180 and 165 °F dry- and wet-bulb temperatures, respectively, is made. After step 2, the change to step 3 is made after 36 h, and to step 4 after 60 h. Step 4 is held until a total time of 96 h has elapsed since the start of drying. At this time, the lumber is expected to be approaching the target moisture content of approximately 15 percent for softwood dimension lumber. The decision to terminate drying should be based on whatever criteria are being used and whether or not the lumber is ready to be removed from the kiln.

Example 2: A time schedule for lower grade 4/4 white fir is shown in table 9-3. It differs from the schedule in table 9-2 only in the expected time required to reach a final moisture content of approximately 15 percent. Thus, the check for final moisture content should be made at 84 h rather than 96 h.

Example 3: A time schedule for upper grade 4/4 white fir is shown in table 9-4. This schedule is milder than the schedule for lower grade lumber given in table 9-3; that is, the initial dry-bulb temperature and the wet-bulb depression are lower. The time intervals are also different, and more total time is allowed before the final moisture content is determined. This not only reflects the milder drying schedule but also the likelihood that the upper grade lumber may have a lower target moisture content than the lower grade lumber.

Final moisture contents are often estimated by moisture meter readings taken inside the kiln. Any required temperature correction factors should be applied. Alternatively, kiln samples may be used, especially with upper grade softwood lumber, to help establish the duration of the final step in the schedule.

Intermediate Moisture Content Checks

Near the final stage of drying high-quality lumber, particularly hardwoods, the moisture content should be known within fairly close limits. Otherwise, the actual final moisture content will not be the same as the desired final moisture content. Furthermore, equalizing and conditioning treatments will not be effective if the moisture content of the kiln samples is not an accurate estimate of the moisture content of the lumber. Intermediate moisture content checks are discussed in chapter 6, and they are often used in the final stages of drying to correct the moisture content estimates. Intermediate checks are sometimes made on a routine basis, but if they are not, certain danger signals indicate that such tests should be made. If the moisture content of one or more kiln samples is suspiciously different from most or if the rate of change of moisture content during drying seems quite different, intermediate checks should be made.

Equalizing and Conditioning Treatments

Good moisture uniformity and stress-free lumber can be obtained by equalizing and conditioning treatments described in chapter 7. The following discussion expands on that of chapter 7 and will be helpful in applying the treatments.

Equilibrium Moisture Content Table

To apply the equalizing and conditioning procedures, an operator must know how to determine the wet-bulb depression needed to give the required equilibrium moisture content (EMC) condition. Equilibrium moisture content values are given in chapter 1, table 1-6. In the example presented here, however, the use of this table is the reverse of the explanation given in chapter 1. Assume, for example, that a dry kiln is operating at a dry-bulb temperature of 170 °F, and the operator wants to know the wet-bulb temperature required to obtain an EMC of 6 percent. The dry-bulb temperature of 170 °F is found in the left column of table 1-6. In the row to the right of this temperature, the EMC of 6 percent is found in the column indicating a wet-bulb depression of 29 °F. Therefore, to obtain an EMC of 6 percent at a dry-bulb temperature of 170 °F, a wet-bulb temperature of 170 °F minus 29 °F, or 141 °F, would be used.

General Considerations

1. The recommended procedures for equalizing and conditioning a charge of lumber will produce good results in a kiln that is performing satisfactorily, but it is important that the control instruments are in calibration. If poor calibration causes the wet-bulb depression in the kiln to be different than the recommended setting, the EMC condition in the kiln will not be correct, and the treatments may not be entirely effective.
2. An equalizing treatment is not necessary if the driest and wettest kiln samples at the end of the drying process have moisture contents within an acceptable range.
3. Some operators prefer drying the driest samples in the kiln to a moisture content 1 percent below the value recommended in table 7-30 (ch. 7) before starting equalization. This may reduce equalizing time and might even eliminate the need for equalizing.
4. If the recommended EMC value for conditioning at a specific temperature cannot be found in table 1-6, use the next highest value given in the table for that temperature. For example, conditioning a charge of lumber at 170 °F with an EMC condition of 11 percent is required. Referring to table 1-6, no wet-bulb

depression is given for an EMC condition of 11 percent at a temperature of 170 °F. Use the next highest value—11.3 percent. The wet-bulb depression for the 11.3 percent EMC condition is 10 °F.

Conditioning Temperature

The higher the dry-bulb temperature used in conditioning, the faster the relief of casehardening. Generally, the required conditioning EMC can be obtained at a dry-bulb temperature of about 180 °F in most well-maintained kilns operated on low steam pressure or equipped with a desuperheater on the spray line or auxiliary water sprays. Sometimes it is impossible, however, to obtain the required high EMC conditions at a temperature as high as desired.

If the required EMC cannot be obtained at a dry-bulb temperature of about 180 °F, the temperature will have to be reduced. In such instances, lower the setting on the control instrument 12 to 24 h before conditioning is started. For example, assume the kiln is operating at a dry-bulb temperature of 180 °F, and the temperature must be reduced to 170 °F to obtain the desired EMC for conditioning. Twelve to twenty-four hours before conditioning is started, the dry-bulb temperature should be reset to 170 °F.

Conditioning Time

High dry-bulb temperatures coupled with high EMC conditions hasten deterioration of dry kiln buildings and metal in the kiln. Also, large amounts of steam are required for conditioning. Therefore, conditioning should not be extended any longer than is necessary to relieve drying stresses (chs. 6 and 7). Conditioning time depends on the degree of stress in the lumber; lumber species, thickness, and moisture content; and kiln performance. It may vary from 4 h for 1-in-thick softwoods to 48 h or more for thick, high-density hardwoods, The minimum time required is determined by making casehardening (prong) tests at times when it is believed that stresses are nearly relieved. Recorded results of these tests will establish good estimates for required times in future charges. The casehardening test is described in chapter 6.

When air-dried lumber is kiln dried, the conditioning time varies from charge to charge because the degree of drying stress in the air-dried lumber varies. Case hardening tests made on air-dried lumber at the time kiln samples are prepared will give an estimate of the amount of stress present and thus a rough indication of the amount of conditioning required.

Stress Relief at High Equilibrium Moisture Content

To reduce the time required for conditioning, some kiln operators use an EMC higher than that recommended. This approach may be satisfactory if conditioning is not continued for too long. If it is, reverse casehardening, which is as serious as casehardening, will result. No satisfactory method of relieving reverse casehardening has been established. In many instances the use of very high EMC values during conditioning gives only superficial relief of drying stresses. Therefore, to obtain good conditioning without incurring risk of reverse casehardening, conditioning should be done at the recommended conditions (ch. 7).

Moisture Content and Stress Tests

Kiln samples are generally used for final moisture content and casehardening tests to make sure that the lumber is at the desired final moisture content and is free of drying stresses. Other boards from the kiln charge can also be used, provided they are representative of the charge.

Method of Testing

To properly interpret the reaction of stress test sections, certain information about the final moisture content and moisture gradient is required. The method of cutting sections for such tests is given in chapter 6. One section should be weighed immediately after cutting, ovendried, reweighed, and the moisture content calculated. This calculation will give the average moisture content of the kiln sample or board from which it was cut. If this test is made immediately after the conditioning treatment, the moisture content obtained will be about 1 to 1-1/2 percent higher than before conditioning because the surface will have regained moisture during conditioning. If, however, the test is made after the lumber has cooled for about 24 h, in most cases the regained moisture will have evaporated.

A second section should be cut as shown in chapter 6, figure 6-3, to obtain two outer shells, each with a thickness of about one-fourth the total thickness of the lumber and a core of about one-half the total thickness. The core and shell are weighed separately as quickly as possible after cutting, ovendried, reweighed, and their moisture contents calculated. A third section should be cut into prongs, as described in chapter 6, for the stress test.

Evaluation of Casehardening Tests for Stress

If the prongs of the stress section turn out to only a slight degree immediately after sawing, the lumber can be considered stress free, and conditioning can be terminated. If, however, the prongs remain straight or pinch in, continue conditioning. The amount of additional time required depends on the amount of movement of the prongs, and some experience is necessary before judgments can be made. If the prongs move in only slightly, only a few more hours of conditioning may be required. If they move so far as to cross, the remainder of the day or overnight may be required for conditioning.

Whether or not to continue conditioning must be decided fairly soon after the casehardening test is made; however, all the information required to make that decision is not always immediately available. The prongs may continue to react over a period of time after cutting, and unless a microwave oven is available and the exact drying procedure worked out, the average moisture content and moisture content of the shell and core are not known for 24 h. Observation of the prong movement after 24 h as well as the moisture content values at this time will provide useful information for future charges. The following conditions may be observed after 24 h:

1. If the prongs do not move in significantly immediately after cutting, if they do not move any further after 24 h, and if the moisture content values of the shell and core are within about 1 percent of each other, then the lumber is well equalized and conditioned.
2. If the prongs do not move in immediately after cutting but do after a period of time, the core moisture content is probably greater than the shell moisture content. Longer equalization is then required.
3. If the prongs do not move in immediately after cutting and do so after standing but the shell and core test does not indicate that the core is at a higher moisture content than the shell, then the conditioning period should be lengthened.

Modifying Kiln Schedules

A major cause of excessive drying defects or drying time is to blindly follow a recommended kiln schedule that has not been proven for specific circumstances. No schedule will produce the best drying results on a specific item or species in all types of kilns under all types of conditions. The schedules recommended in chapter 7 are generally conservative, and they are meant to be a starting point for modification to an optimum level. Before modifications can be made, the recommended schedule should be tried. Information for justifying schedules can be obtained by observing (1) the type and severity of drying defects, their time of occurrence, and their effect on degrade or volume loss, (2) the drying time required, and (3) the final moisture content. Systematic procedures for modifying schedules are given in chapter 7.

Cooling a Charge After Drying

After lumber has been kiln dried, it is usually cooled before machining. Sometimes, if kiln demand is low, the charge is cooled in the kiln. More often, the charge is removed from the kiln and held in a protected cooling area at the dry end of the kiln. Lumber dried to a low moisture content should not be stored outdoors or exposed to high humidity for extended periods because it will regain moisture (ch. 10). Sometimes cracking noises are heard as lumber cools. This is usually caused by movement between the stickers and the lumber as thermal contraction occurs and is not the result of the lumber actually cracking or splitting.

Operating Precautions for Safety

Working in or around dry kilns is not hazardous if ordinary precautions are taken. As is the case with most machinery and equipment, carelessness is the major cause of accidents, which can be serious or fatal in and around kilns. Care should always be exercised around high-temperature burners, steam plants and steam lines, and operating fans, belts, and shafts. The following rules and precautions will help prevent accidents.

1. Do not touch the outside surfaces of kilns operating at high temperature because they can be dangerously hot-particularly any part that allows continuous metal conduction from inside to outside.
2. Shut off the heat, spray, and fans before entering an operating kiln. If the kiln has been operating at high temperatures, it should be cooled to a safe level by opening doors and vents before entering.
3. Never enter a kiln in use without the knowledge of a coworker-preferably someone who remains close to the kiln in case assistance is needed.
4. When an access or main door is opened, stand away from the door. Hot and often humid air rushes out and can be an uncomfortable or dangerous shock, particularly if breathed.
5. Occasionally it may be necessary to enter a kiln when the heat, spray, or fans are operating in order to check their operation. In this case, another person should be stationed immediately outside the kiln to ensure the safety of the person inside.

6. 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 people in good health. Anyone with heart or respiratory problems should not enter kilns where the wet-bulb temperature is 110°F or more. The critical dry-bulb temperature depends on the individual. In any case, no one should enter or remain in a kiln if either the temperature or the humidity makes the person feel ill or more than mildly uncomfortable.
7. Equip all small access doors with a latch that can be operated from both sides. Repair faulty latches immediately. Never use props to hold a door closed-there is always the possibility that such propping could inadvertently trap someone in the kiln. Set up an emergency signal that can be used if someone is accidentally trapped inside. A signal rapped on steam pipes will carry a considerable distance.
8. Provide sufficient lighting in kilns to provide safe movement for anyone who enters the kiln. As an added precaution, a portable light should be carried.
9. A person should not attempt to open or close kiln doors that are too heavy for a single person.
10. Door carriers should be kept in good repair to guard against a door jumping the track.
11. Fans should obviously be shut off when inspected closely or lubricated, but precautions should then be taken to ensure that the fans are not inadvertently started at these times. If the fan switch is not equipped with a lock in the off position, a sign "Do Not Start Fans" should be placed at the switch.
12. Fan floors are often oily, and precautions should be taken to prevent slipping.
13. Shafts and pulleys should be adequately guarded.
14. When truckloads of lumber are loaded and unloaded, devise a system for workers to know each other's whereabouts so that no one gets crushed between trucks.
15. When loaded kiln trucks are moved by cables, procedures should be established to ensure that all workers stay clear of the cables when they are under tension.

Fire Prevention in Kilns

Fires in dry kilns we usually caused by carelessness, poor maintenance, or poor housekeeping. Precautions for minimizing the possibility of fire are as follows:

1. In direct-fired kilns fueled by wood residue, ensure that the burner is operated according to manufacturer's instructions so that live embers do not enter the kiln.
2. Do not allow smoking in a kiln.
3. Use care with welding or cutting torches.
4. Keep electrical circuits in good repair.
5. Keep all moving parts well lubricated. A hot bearing can cause a fire.
6. Do not allow uninsulated steam pipes to contact flammable material.
7. Keep the kiln and surrounding area free of excess debris.

Kilns should be checked regularly outside of regular working hours so that if a fire starts, it can be fought promptly. A definite procedure should be established for workers to follow if a kiln fire should occur. The following procedures may extinguish the fire or will reduce the spread of fire in a kiln until a firefighting crew arrives.

1. Install a water sprinkler system and check its operation regularly.
2. Have fire extinguishers available in the area.
3. Keep all kiln doors closed.
4. Close the ventilators.
5. Shut off the fans.
6. In a steam-heated kiln, saturate the air in the kiln with steam. If there is a bypass around the steam spray control, open that valve or, if not, set the wet-bulb control point as high as possible.

Sources of Additional Information

Boone, R. S.; Kozlik, C. J.; Bois, P. J.; Wengert, E. M. 1988. Dry kiln schedules for commercial woods temperate and tropical. Gen. Tech. Rep. FPL-GTR-57. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 158 p.

Knight, E. 1970. Kiln drying western softwoods. Moore, OR: Moore Dry Kiln Company of Oregon. 77 p. (Out of print.)

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Table 9-1—Moisture content schedule for 4/4 sugar maple (T8-C3)

step	Moisture content (percent)	Temperature (°F) Dry-bulb	Temperature (°F) Wet-bulb	Equilibrium moisture content (percent)	Relative humidity (percent)
1	Above 40	130	125	16.2	86
2	40 to 35	130	123	14.3	81
3	35 to 30	130	119	11.5	71
4	30 to 25	140	121	8.3	57
5	25 to 20	150	115	5.0	34
6	20 to 15	160	110	3.4	21
7	15 to final	180	130	3.5	26

(Equalize and condition as necessary)

Table 9-2—Time schedule for 8/4 white fir dimension lumber

step	Time(h)	Temperature (°F) Dry-bulb	Temperature (°F) Wet-bulb	Equilibrium moisture content (percent)	Relative humidity (percent)
1	0 to 12	180	170	11.2	79
2	12 to 36	180	165	9.1	70
3	36 to 60	180	155	6.5	54
4	60 to 96	180	145	5.0	41
5	Or until dry				

(Equalize and condition as necessary)

Table 9-3—Time schedule for 4/4 white fir, lower grade

step	Time(h)	Temperature (°F) Dry-bulb	Temperature (°F) Wet-bulb	Equilibrium moisture content (percent)	Relative humidity (percent)
1	0 to 12	180	170	11.2	79
2	12 to 36	180	165	9.1	70
3	36 to 60	180	155	6.5	54
4	60 to 84	180	145	5.0	41
5	Or until dry				

(Equalize and condition as necessary)

Table 9-4—Time schedule for 4/4 white fir, upper grade

step	Time (h)	Temperature (°F) Dry-bulb	Temperature (°F) Wet-bulb	Equilibrium moisture content (percent)	Relative humidity (percent)
1	0 to 12	170	164	14.1	86
2	12 to 24	170	160	11.4	78
3	24 to 48	175	160	9.1	69
4	48 to 72	180	160	7.7	62
5	72 to 96	180	140	4.5	36
6	Or until dry				

(Equalize and condition as necessary)