Chapter 4
Inspection and Maintenance of Dry Kilns and Equipment

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

Regular, systematic inspections should cover such items as the kiln structure; doors; floor; tracks; control equipment; heating, spraying, and venting system; trucks; lumber-handling equipment; and general housekeeping. To make sure that inspections are thorough, the operator should note the condition of the kiln structure and the equipment on a checklist. The checklist at the end of this chapter can be made to fit any specific kiln installation.

Kiln Structure

Dry kilns are required to withstand much harsher conditions than those conditions that ordinary buildings are subjected to, regardless of the materials used in construction. Kilns must withstand not only extreme external weather conditions but also even more extreme internal conditions. Relative humidity can vary from 5 to 95 percent, and temperatures can change from -20 °F (ambient) to 250 °F during operation of a high-temperature kiln. In addition, vapors that arise from the woods being dried are often corrosive. Structural components of the kiln and the internal protective coatings must be capable of withstanding this broad range of operating environments.

Walls, Roofs, and Ceilings

The majority of today's commercially built steam-heated or direct-fired dry kilns are made of either (1) prefabricated aluminum panels on a steel or aluminum structural frame or (2) masonry, primarily concrete block or light-weight aggregate block and sometimes precast concrete. Although aluminum prefabricated kilns require a larger capital investment, the amount of maintenance required is considerably less than that required by a concrete block structure.

Prefabricated Aluminum Panels

The prefabricated aluminum panel for walls and roofs of dry kilns was developed in the mid-1950's, and by 1960 it had received rather widespread acceptance. Early designs used the type of insulation board then in common use in residential and commercial buildings. Later designs used fiberglass insulation, and more recent designs use a rigid foam insulation. The design and construction of panels for walls, roofs, and doors are frequently the same, although in some cases panels for roofs are thicker and have more insulation. The aluminum panels generally are not affected by the expansion and contraction that occurs in a kiln cycle, even those cycles in which dry-bulb temperatures go as high as 250 to 300 °F. At operating temperatures above about 215 °F, some manufacturers prefer fiberglass insulation; others prefer rigid foam insulation in the aluminum panels.

Insulation values for aluminum panel kilns range from an R value of about 16 for 2-in-thick panels to about 32 for 4-in-thick panels. In contrast, concrete block kilns have R values ranging from only 1 to 3, depending on thickness, type of aggregate, and whether or not the cores are filled with insulation. A wood-frame wall will have an R value of 4 to 5 when the stud space is not filled with insulation and a value of about 12 when filled with insulation.

Maintenance of aluminum panels usually requires only ensuring that moisture does not get past the skins and wet the insulation, reducing its value. This means repairing (sealing) any holes or tears in the skins as soon as they are noticed. Care should also be taken to repair any separation between the aluminum skin and the metal frame around each panel. Moisture can enter the interior of the panel and wet the insulation through this avenue as well as through holes in the skins. Weep holes are usually put in the bottom of the panels for draining water that may build up in the panel, but the weep holes must be kept open and free from sawdust or dirt.

Steel components of a dry kiln must be protected from water vapor as well as corrosive vapors that are emitted from certain woods during drying, such as oak and hemlock. This is commonly done by painting or spraying a vapor- and corrosion-resistant paint or coating on the steel members. Recoating is usually necessary every 2 to 5 years. Suitable coatings can be obtained from dry kiln manufacturers.

Masonry

Masonry kilns may develop cracks from expansion and contraction caused by temperature changes inside the kiln during the drying run. This problem is sometimes exaggerated by a large temperature difference between the inside and outside environments. Most concrete, including concrete blocks, is rather porous and can adsorb large quantities of water vapor from the kiln atmosphere. If cracks are not sealed when small, they will increase in size, which leads to excessive heat and vapor losses and premature failure of the entire structure. Large cracks may also cause cold zones in the kiln that slow up drying and permit mold and stains to develop on the lumber located in those zones.

Proper maintenance of concrete kilns or concrete parts of a kiln consists of prompt recognition and repair of problem areas. Some good maintenance practices for concrete kiln structures are as follows:

1. For all kilns constructed of masonry or wood (or lined with plywood), coat the inside surfaces with a vapor- and corrosion-resistant material before the kiln is used and whenever required thereafter. Usually recoating is necessary every 2 to 5 years. Suitable coatings can be obtained from dry kiln manufacturers or other knowledgeable suppliers. Never put vapor-resistant coatings on the exterior surfaces of masonry or wooden dry kilns, though a water-repellent coating can be applied if desired.
2. As soon as possible, seal cracks that develop in the structure as a result of repeated expansion and contraction of the building material. If the cracks are small, a coating of kiln paint may be sufficient, but larger cracks should be filled with mastic, mortar, or cement. Coat the mortar or cement fillers with a kiln paint after they have set.
3. Cracks that develop because of settling of the structure can be temporarily repaired in the same manner as expansion and contraction cracks. To reduce future maintenance costs, however, determine the cause of the settling and correct it as soon as possible.
4. Openings in the kiln structure for steam lines, tubing, fan shafts, and the like should be as small as possible. Insert sleeves in the openings and plug the space not occupied by pipe with epoxy or silicone compounds or some similar material.
5. Promptly caulk with a nonhardening filler any open joints and splits that occur in wood or plywood dry kilns. Refasten all loosened boards as soon as possible.
6. Use noncorrosive metal fastenings if possible.
7. Immediately repair or replace failed supporting members of the structure

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Doors

Doors are frequently the weakest and most troublesome part of a kiln structure. They are often damaged when they are opened or closed carelessly, when a forklift operator does not pay attention when loading or unloading the kiln, or when an improperly blocked truckload of lumber in a track-loaded kiln rolls into the doors. The common use of prefabricated aluminum doors, on both aluminum prefabricated kilns and masonry kilns, has solved many of the problems associated with doors on the dry kilns of the 1930's, 1940's, and 1950's. During that time, it was difficult to design and build a large door that was strong, lightweight, easy to handle, well insulated, and resistant to corrosion.

Doors, door hangers, stops, rollers, roller tracks, and gaskets that are poorly maintained cause excessive losses of heat and vapor and are difficult to open and close. Lower temperatures occur near damaged or poorly fitted doors because of cold air infiltration, and drying is slower in that zone. In high-temperature kilns, large amounts of condensate form on the framework near the doors when they are opened at the completion of the kiln run. Steel members should be adequately protected to prevent excessive corrosion and rust. Neglect of doors and door equipment may also create a hazard to workers. Some good maintenance practices for door and door equipment are as follows:

1. Immediately repair or replace damaged door hangers, rollers, and roller tracks.
2. Lubricate parts in accordance with the manufacturer's recommendations.
3. Repair or replace torn or missing gasket material or gaskets that no longer provide an adequate seal.
4. Instruct or warn lift truck operators to be alert to minimizing damage to doors (also to walls and baffles) when loading or unloading the kiln.
5. In package-loaded kilns, ensure that piles are stable and will not tip over into doors or walls.
6. In track-loaded kilns, block wheels of standing loaded kiln trucks, so that the trucks cannot roll into the kiln door.

Floors

The floors of most commercial dry kilns are constructed of concrete. In some small kilns, usually operated on a part-time basis and perhaps home designed, the floor may be crushed stone, lumber, or even dirt or sand. All types of floors require maintenance.

Good maintenance practices for kiln floors include the following:

1. Provide a waterproofing treatment on new concrete floors to prevent spalling or scaling. Treat again when necessary.
2. Repair and seal cracks in concrete floors that develop because of settling or expansion and contraction of the concrete.
3. For stone, dirt, or sand floors, maintain an even floor level, filling holes and leveling as needed.
4. Provide proper drainage of site so that rain and surface runoff do not flood kiln floor.

Rails and Rail Supports

Generally, rails and rail supports in kilns with fans or blowers located above or on the sides of the drying compartment are not troublesome, since the rails are usually well supported and anchored. Weak rails or rail supports in old converted natural-circulation kilns and in older design forced-circulation kilns, where the fans or the air-supply ducts are located below track level, may collapse or spread under heavy loads. Failure of the rails or rail fastenings can seriously damage kiln equipment, injure workers, and result in lost drying time.

Good maintenance practices for rails and rail supports include the following:

1. Immediately replace or tighten broken or loose rail fastenings.
2. Promptly realign spread rails and securely fasten them to the rail supports.
3. Leave a break in the rails under the doors to minimize rail corrosion caused by condensate dripping from the doors.
4. As needed, apply corrosion-resistant paints to the rails, metal rail supports, and rail fastenings.

Recording–Controlling Instruments

Accurate control of both the dry- and wet-bulb temperature (or dry-bulb and relative humidity) is essential for efficient kiln operation. The most common and the best method of control is the use of semiautomatic or fully automatic recording-controlling instruments. (See Equipment to Control Drying Conditions section in ch. 2 for a detailed description of control instruments.) Although these instruments are usually efficient, they are at times troublesome. Some problems are associated with improper location of the sensors or bulbs. Once sensors and bulbs are properly located, problems may arise from improper calibration, faulty flow of water to the wet-bulb pan, and dirty wet-bulb wicks. The efficiency of air-operated instruments may be seriously impaired by oil, water, and dirt in the compressed air. Approximately 25 percent of pneumatic instrument failures can be attributed to a contaminated air supply.

Proper Location of Control Sensors or Bulbs

Dry-Bulb Sensors

To accurately sense temperature, the sensor must be mounted in the main airstream flowing in the plenum. It cannot be too close to the wall or to the load of lumber. Care must also be taken not to place the sensors and capillary tubes too close to steam pipes or other sources of heat that may give false readings. The traditional approach has been to have at least two dry-bulb sensors and one wet-bulb sensor in a kiln. Longer kilns usually have four dry-bulb sensors and one wet-bulb sensor. This is known as a dual end control system; one set of dry-bulb sensors is located about one-fourth to one-third the length of the kiln from one end and the other set, one-fourth to one-third the distance from the other end. The dry-bulb sensors are mounted on opposite walls of the kiln and are hooked up such that the bulb on the entering-air (hottest) side of the load provides the signal that is sent to the instrument. When the airflow is reversed by the fans, the bulb on the opposite side of the kiln becomes the controlling bulb. Dry bulbs that are improperly located may result in very high temperatures that increase drying losses or in very low temperatures that prolong drying time and result in mold and stain.

Although it is common to locate one of the dry-bulb sensors near the wet-bulb sensor, never locate the dry-bulb sensor below the wet-bulb sensor. If the wet-bulb water reservoir overflows, or if liquid water falls on the dry-bulb sensor, it will be cooled and will thus sense a temperature that is lower than the actual temperature. This false lower temperature causes the heat valves to open, resulting in kiln overheating and the potential for degrade. Using brackets furnished by the kiln manufacturers and following the instructions for installation should ensure satisfactory readings from the sensors.

Wet-Bulb Sensors

The wet-bulb sensor must be located so that air circulates around it at all times. Experience suggests that air speeds as low as 150 ft/min are satisfactory, but more reliable readings are obtained at air speeds of 300 to 600 ft/min or higher. Only one wet-bulb sensor is located in each kiln because the wet-bulb temperature is essentially the same throughout the kiln and is not as variable as the dry-bulb temperature. The wet-bulb sensor should be located about the middle of the kiln lengthwise and at a height above the floor that allows convenient inspection of wick and water level. Improper location and care of the wet-bulb sensor result in poor control of the wet-bulb temperature. When the kiln is operating, the wick must be kept wet by a constant supply of clean water to the water pan or reservoir. A dry or partially dry wick will result in an actual wet-bulb temperature *in* the kiln lower than that recorded or indicated on the instrument. The instrument then signals the vents to open in an effort to reduce humidity. Therefore, occasional cleaning of the water reservoir and flushing of the supply line are recommended. The flow of water to the water reservoir is usually controlled by a needle valve, which needs to be regulated from time to time. If the flow of water is too rapid, its temperature may be too low when it reaches the bulb, and the thermometer can give a false reading.

In some steam-heated kilns, condensate from the drain end of the coils is used to supply water to the wet-bulb wick. The condensate is piped from the drain line through a coiled copper tube for cooling and then piped to the water reservoir. In using this system, care must be taken to assure that the water is adequately cooled, for water that is too hot will also give false readings.

The wet-bulb sensor itself should never, under any circumstances, touch the water in the reservoir nor should water drip directly on the sensor.

The water reservoir should be equipped with an overflow line that has its discharge end outside the kiln, and the water supply should be regulated so that the discharge is a very slow drip, not a steady flow. The overflow line must be kept open to prevent water spilling over the top of the pan into the kiln. If the kiln is shut down for a day or more, shut off the water supply; if the temperature in the kiln is likely to drop below freezing during this time, drain the water lines and water reservoir. After a shutdown, the wick should be replaced when the kiln is restarted.

A dirty or badly encrusted wick affects wet-bulb control. The wet-bulb wick should be made of highly absorbent cloth. Replace the wick frequently with a new or laundered one whenever the kiln is loaded with a new charge of lumber or more frequently if necessary.

The wet-bulb sensor in a gas-filled or liquid-vapor system is frequently plated to minimize corrosion. When changing the wick, check the bulb for pitting or other surface deterioration. When necessary, have the bulb replated or replaced by the instrument manufacturer.

Because of the cooling effect of evaporation, the wet-bulb temperature in a dry kiln is usually lower than the dry-bulb temperature; at no time can it be higher. If the reading is higher, the instrument is out of calibration.

Equilibrium Moisture Content and Relative Humidity Sensors

Some recorder-controllers and some drying systems use sensors that tense equilibrium moisture content or relative humidity directly, rather than indirectly through wet-bulb thermometry. While the manufacturer's instructions should be followed to the letter, the same general principles for locating dry-bulb sensors apply to wet-bulb sensors.

Care of Recording–Controlling Instruments

The period of reliable performance of control instruments can be greatly increased by proper care. The parts of a recorder-controller are precision built and can be easily damaged. However, they are well protected against injury and dust, and they will give troublefree service for many years if the case is not left open too long at a time. Replace broken cover glass immediately. Never use compressed air, brushes, or cloth to clean off dust that may settle within the instrument case.

Generally, repairs of gas-filled or liquid-vapor systems should not be attempted in the field. Instrument repair and cleaning require special tools, skills, and equipment. Such work should be done at the manufacturer's plant or by an authorized serviceperson.

The only part of the control instrument that requires lubrication is the clock, and this should not be done too frequently. Never lubricate the pivot points on the linkage arms.

The compressed air flowing into an air-operated instrument must be free of oil and moisture. The quality of the compressed air is very important. For this reason, the air is passed through a filter dripwell or trap before entering the instrument. The trapped oil or moisture is blown from the dripwell or trap at least once daily by opening a blowoff valve. Usually the elements in filters must be replaced once a year or more frequently if they become discolored.

Repairs to electronic or computerized recorder-controllers should be made only by an experienced technician or authorized serviceperson. The skills and tools needed are different from those used in gas-filled systems. For those instruments controlling air-actuated valves, the compressed air supply must be clean and protected from oil and moisture. The clock must be lubricated occasionally. The slide wires on the servo motors may need to be cleaned if pen response becomes sluggish.

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, check calibration at two or three points over total range at the time of installation. Thereafter, check it for accuracy frequently by using thermometers.

Recalibration of a recorder-controller found to be in error is not difficult, but it should be done carefully. The equipment required includes a liquid container and an accurate temperature-measuring device. Because the difference in height between bulbs of gas-filled systems and the recorder-controller case affects the recorded temperature, verify that the bulbs are at the correct height in relation to the instrument by checking the notation on the information plate inside the instrument case. Calibrate the instrument with the bulbs at about the same height above or below the instrument case as they will be in service. Height does not affect resistance temperature detectors (RTD). Two people are required for the calibration-one at the sensor in the liquid container and one at the instrument.

The procedure for calibration is as follows:

1. Fill the liquid container with water or oil at least as deep as the sensors are long, so that the sensors can be completely submerged. Heat the water to 200 °F or the oil to about 280 °F, and place the container near the sensors.
2. Remove the sensors from their fastenings and completely submerge in the heated liquid. If the dry- and wet-bulb sensors are located together in the kiln, calibrate them together. Avoid sharp bends in the tubing of gas-filled systems. The sensors should

not touch the sides or bottoms of the container. In a dual dry-bulb system, only one sensor usually needs calibration. If there has been a difference in the temperatures recorded by the dry-bulb thermometers at fan reversal during kiln operation, check each sensor separately. The person stationed at the liquid container should gently and constantly stir the liquid during calibration.

3. After about 10 min, the person at the liquid container should take a temperature reading of the hot liquid with the thermometer or other device. The person at the instrument then records this reading together with the corresponding temperature indicated by the instrument.
4. Record these two temperatures every 20 °F as the liquid gradually cools. If cool liquid is added to reduce calibration time in gas-filled systems, let 5 to 10 min elapse before temperatures are taken, so that the temperature change is reflected at the instrument, Resistance systems stabilize almost immediately. Make periodic check readings until the liquid temperature drops to below the lowest kiln temperatures used at the plant.
5. If the indicated temperatures on the instrument chart are consistently lower or higher than the water temperatures by a constant amount, adjust the recorder pen arms upward or downward by that amount by turning the small screw located on the pen arm or the pen arm pivot. If the differences between the indicated temperatures and the water temperatures are not constant, a trained technician should make the adjustment. A correction chart can be made so that the instrument can be used in the interim until it is adjusted.
6. The next step, the adjustment of the control-setting indicator, should be made only by a knowledgeable, experienced person. The indicator is adjusted while the compressed air or electricity is on. Lower the temperature-setting indicator to a temperature below that indicated by the pen on the chart and then move the indicator 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 temperatures is different than the temperature indicated by the pen, move the control-setting indicator-by means of adjustment screws on the indicator-upward or downward by the amount of the difference.

Some kiln operators prefer not to adjust the instrument pens or control-setting indicators. Instead, they list the calibration data and place this list near the face of the instrument. These data are used as a guide for setting the instrument in kiln runs.

Resistance sensors can be calibrated as outlined above, or they can be calibrated quickly with precision electrical resistors. (For a more complete discussion, see the section on semiautomatic control systems in ch. 2.)

Dry kiln operators should be familiar with the manufacturer's instructions for the care and maintenance of recorder-controllers. If the instrument should fail, trained service people should be contacted for advice and service.

Heating Systems

A correctly designed and properly maintained heating system produces uniform drying conditions in a kiln. Unfortunately, the maintenance of heating systems is often neglected, and the consequent nonuniform drying conditions cause kiln degrade, extended drying time, nonuniform moisture in the lumber, and increased drying cost. On the other hand, frequent inspection and prompt corrective action can minimize, if not eliminate, many adverse effects.

Steam-Heated Kilns

Problems that occur with steam-heated kilns include improperly insulated feedlines, leaking pipes and unions, sagging and distorted pipes, defective valves and regulators, faulty pressure gauges, faulty automatic and manual control valves, and faulty steam traps.

Improperly Insulated Feedlines

Insulate all main feedlines from the boiler to the kiln to reduce losses in steam temperature, pressure, and consumption. In control rooms or other areas frequented by workers, steam lines, headers, and valves should be insulated for safety. The insulation on many steam feedlines is either improperly installed or damaged. Replace deteriorated or damaged insulation as soon as possible.

Leaking Pipes and Unions

Leaking pipes, caused by corrosion or mechanical damage, increase steam consumption. If the leak occurs within the kiln, this will affect the wet-bulb temperature. Repair or replace leaking pipes. When necessary, clean all pipes and fittings.

Sagging and Distorted Pipes

Feedline and coil supports frequently fail, causing the pipes to become distorted and to sag. Condensate and scale accumulate in the sagged pipes and eventually plug them. Sagging coils will become water logged, thereby drastically reducing their ability to transfer heat to the kiln. Straighten or replace sagging and distorted pipes. Protect pipe supports against corrosion, and reinforce or replace them when examination shows they are failing.

Defective Valves and Regulators

Fluctuations in steam pressure caused by faulty pressure-reducing valves and regulators result in nonuniform drying conditions. If adjustment does not correct the condition, repair or replace the defective parts.

Faulty Pressure Gauges

The pressure gauges used in conjunction with the reducing valves and regulators occasionally go out of calibration. Recalibrate the gauges at intervals against a gauge known to be accurate or replace them.

Faulty Automatic and Manual Valves

Automatic valves that control steam flow may leak or fail to open or close properly. Failure of an air-operated motor valve to open is usually associated with a leak in the air supply line, a damaged diaphragm, or an overtight packing nut that causes mechanical binding. Some valves have a compression spring that facilitates opening; others have springs that facilitate closing. The springs should be checked periodically for proper adjustment and functioning. Failure of electrically operated valves may be associated with power failure, damaged wiring, or faulty motor. A valve that leaks because of worn parts or the presence of scale on the seat can usually be detected by a slow, continuous rise in temperature above the set point. A valve that is slow to open or fails to open can be detected by a slow drop in temperature below the set point when the instrument is calling for heat.

Repair or replace faulty valves. Keep a spare motor valve on hand as well as extra motor valve parts, including diaphragms, springs, packing compound, valve stems, and valve seats. If leaks occur around the valve-stem packing nut, tighten the nut or replace the packing.

Manual valves are used extensively on steam heating systems. These valves, which are usually of the gate type, should be operated wide open or completely closed. Open or close the valves occasionally to keep them from rusting or corroding in the open or closed position. If leaks occur around the valve-stem packing nut, follow the procedure outlined for faulty automatic valves. Keep replacement valves and spare parts on hand.

Faulty Steam Traps

Consult kiln manufacturers, engineers, and steam-trap manufacturers on trap installations to minimize failures in the trapping system. The following summary will assist the operator in locating and correcting trap problems.

The failure of a steam trap to discharge may be due to (1) excessive operating pressures, (2) failure of condensate to reach the trap, (3) a plugged bucket vent (in the case of bucket traps), (4) dirt in the trap, (5) worn or defective parts, or (6) excessive back pressures in the condensate return line. Excessive operating pressures in the steam feedline may be caused by the failure of the reducing valve or pressure regulator, by inaccurate readings on the pressure gauge, or by the raising of steam pressures beyond the operating range of the trap. Failure of the condensate to reach the trap may be due to a closed motor valve on the feedline, a closed manual valve in the line between the coils and the trap, open or leaking bypass valves that allow the condensate to flow around the trap, or water-logged steam lines. Dirt, rust, or scale in the condensate may plug the bucket vent. This problem can be minimized by installing a strainer ahead of the trap and cleaning it at frequent intervals. A strainer will also prevent the trap body from becoming filled with dirt. Install blowoff valves on all traps, and blow out the traps for a short period each day the kiln is in operation.

Continuous discharge of water from a trap can be caused by the inadequate size of the trap or trap orifice (that is, an opening too small for the steam pressure used), rust or scale under the seat in a disc trap, a worn seat that prevents proper closing, or a rusted bellows. These difficulties can be prevented by installing a trap that has been sized correctly and is large enough to handle the peak condensate load, which will usually occur during the warmup period.

If the trap blows live steam, the discharge valve may not be seating. A bucket-type trap that blows live steam may have lost its prime. A badly worn valve seat or dirt lodged between the valve and valve seat will cause improper seating of the valve. A trap that loses its prime is usually subjected to sudden or frequent drops in steam pressure. If this occurs frequently, install a good check valve ahead of the trap. Maintaining a fairly constant supply of steam pressure will also minimize this problem.

Worn or defective trap parts may cause complete failure. Some parts can be easily replaced on the job with very little, if any, loss in operating time. Replacement is even simpler if a bypass line has been installed around the trap. When a defective trap cannot be repaired on the job, replace it with a new or reconditioned trap. Repair the defective trap at the first opportunity. Annual cleaning and overhaul of all traps is recommended.

Trap failure can be detected by observing discharge from the trap, obtaining temperatures on the supply and discharge sides, or listening to the action of the trap. The discharge action of most traps can be observed from test outlets. These should be opened frequently. If steam discharges continuously from a correctly sized trap, the trap is not functioning properly; determine the cause and correct it. Do not confuse flash steam with live steam. Flash steam, which is due to pressure changes, is white as it leaves the test valve. Live steam generally appears in a continuous flow, and it is transparent as it leaves the test valve.

By listening carefully to traps during operation, traps can be checked without visual observation of the condensate discharged. This method is, therefore, much more convenient when working with a closed condensate return system. The necessary equipment consists of an industrial stethoscope or a homemade listening device such as a 2-ft length of 3/16-in steel rod in a file handle, a piece of wood dowel, or a screwdriver (table 4-1). With a little practice, the operation of the internal components of the trap can be heard with any of these homemade devices merely by placing one end of the tool against the trap bonnet and the other end to your ear.

A steam trap is essentially an automatic condensate valve, the only function of which is to pass condensate and hold back steam. This definition implies that a significant temperature differential exists between the upstream and downstream sides of a properly functioning trap. Trap performance, therefore, can be checked by measuring temperatures on the pipeline immediately upstream and downstream of the trap. Two requirements for this method are a simple contact pyrometer for making the measurements on the surface of the pipe and a knowledge of line pressure upstream and downstream of the trap. For each steam pressure, there is a corresponding steam temperature. Table 4-2 shows typical pipe surface temperature readings corresponding to several operating pressures.

Let us assume the upstream pressure in the piping system is 150 lb/in^2-gauge, and the pressure downstream of the trap is 15 lb/in^2-gauge. The pyrometer measures an upstream temperature of 335 °F and a downstream temperature of 225 °F. (File or wire-brush the pipe at points of measurement to provide good contacts for the tip of the pyrometer.) Table 4-2 shows that for an upstream pressure of 150 lb/in^2-gauge, a pyrometer reading between 348 °F and 329 °F should be obtained. For a downstream pressure of 15 lb/in^2-gauge, a pyrometer reading of between 238 °F and 225 °F is desirable. We can conclude, therefore, that the trap is functioning properly.

Now let us assume the same pressures, but a pyrometer reading of 335 °F upstream and 300 °F downstream of the trap. The insufficient spread between the two temperatures indicates that live steam is passing into the condensate return line. The trap has failed while open, and it needs to be repaired or replaced.

In still another example, suppose the pyrometer readings are 210 °F on both sides of the trap. Such a reading is all right downstream, where we know the pressure is 15 lb/in^2-gauge. However, this reading is too low upstream where we know the pressure is 150 lb/in^2-gauge. The low upstream temperature probably indicates a restriction in the line that is reducing the pressure to the trap. A clogged strainer may be the culprit; blow out the trap before looking any further for a cause for the problem.

Although these examples deal with a closed return system, the temperature measurement method can also be used to check traps that discharge to the atmosphere. In this situation, of course, the downstream pressure is always atmospheric.

Direct-Fired Kilns

In direct-fired kilns, the hot gases produced by burning gas, oil, or wood waste are discharged directly into the kiln. Burners commonly have electrically or pneumatically modulated fuel valves. Temperature-limit switches are located on the inlet and discharge ends of the combustion chamber and are set to shut down the burners if they overheat beyond the predetermined set point. Careful attention should be paid to proper monitoring and maintenance of all sensors, temperature-limit switches, and safety equipment associated with the burner. Manufacturer's recommendations and instructions and State safety codes should be closely followed.

Humidification Systems

Steam Spray

Steam sprays supply moisture to the kiln atmosphere when required to maintain the desired relative humidity. Saturated or "wet" steam is preferable to superheated or "dry" steam for this purpose. Using low pressure steam or installing a desuperheater in the steam line are common ways of obtaining saturated steam (see discussion of humidification in ch. 2). Manual or automatic valves controlling the flow of steam spray into a kiln require the same maintenance as those used in steam-heating systems. Follow the inspection and maintenance procedures as discussed for heating systems. A flow of steam or condensate from the steam spray line when the valves are closed indicates leakage through the control valve. A falling wet-bulb temperature when the control instrument is calling for steam spray indicates there is an inadequate supply of spray into the kiln or the steam spray motor valve has failed to open. Repair or replace defective valves immediately.

The steam spray lines usually slant downward from the feed end. Usually a small drain line discharging outside the kiln is provided to drain off the condensate that collects at the low end. Keep this drain line open. Inspect the steam spray line itself periodically to see that the discharge holes or nozzles are open and that the pipe has not been bent or turned so that the spray discharges onto the lumber or the instrument control bulbs.

Water Spray

Occasionally water spray lines are installed in kilns to supply moisture when required for humidification. Generally, water spray cannot supply sufficient water vapor required for effective conditioning treatments. Inspect the valves frequently that control the flow of water into the spray line and repair or replace defective valves immediately. Open plugged spray holes or nozzles and repair or replace damaged lines.

Venting systems

Most kilns are provided with ventilators for exhausting hot, moist air from the kiln and taking in fresh air. Excessive venting increases heating and humidification requirements, and it should be avoided by proper adjustment and maintenance of the venting system. An effective and low-cost method for preventing excessive venting is the installation of an air exhaust valve on the air line at the vent control valve.

The controller and the vent systems should be adjusted so that venting and spraying cannot occur at the same time. This obviously wastes energy, and in cold climates the spray can condense on contact with cold air and cause accelerated corrosion of any steel surface with which the condensate or "rain" comes into contact.

Although vents can be manually or automatically operated, automatic ones are recommended. To prevent excessive venting, frequently inspect the system and keep it in good repair. This generally means going on the kiln roof rather than observing the vents from groundlevel. The inspection and maintenance of vents require the following:

1. Keep the linkage system connecting two or more vent lids or dampers lubricated and inspect it periodically for damage and excessive wear at pivot points. Straighten, repair, or replace bent, broken, or excessively worn pins, hinges, rods, chains, and levers.
2. Inspect the vent lids or dampers when they are in a closed position. If the lids or dampers are partially open, adjust the linkage so that the lids or dampers fit tightly. This adjustment can be made quickly and easily on most kilns.
3. Install gaskets around vent openings if there is excessive leakage when the vent lids are closed.
4. Avoid overventing. Adjust the linkage so that the lids or dampers are open just wide enough to obtain the desired venting. High winds will often keep vent lids open even if no air is supplied to the control valve. This can be corrected with a counterweight.
5. Examine air lines or electric circuits connecting the vent mechanism to the control instrument for air leaks and short circuits.
6. Keep the compressed air used to operate the vent mechanism dry and free of oil. Water in the air supply line may freeze the motor valve during cold weather. If dry compressed air cannot be obtained, protect the air supply line against freezing.

Air-Circulation Systems

The uniform circulation of air in a kiln is extremely important for proper drying, and it is dependent on well-maintained air-circulation equipment. Any failure or damage to the component parts of the air-circulation system extends drying time and may also result in nonuniform drying. Therefore, the maintenance and care of the component parts of the air-circulation system are essential.

The items to be checked in the periodical inspection of the air-circulation system and some of the maintenance procedures include the following:

1. Fan motors
   a. Lubricate fan motors in accordance with the manufacturer's instructions. Replace leaky bearing seals.
   b. Keep windings and armatures free of dust. Dry compressed air may be used for blowing out dust.
   c. Keep motor mounts and anchor bolts tight.
   d. Protect fan motors located outside the kiln from the weather.
   e. Properly ventilate the control room to avoid overheating fan motors.
   f. In the kiln, use fan motors designed for high temperatures and high relative humidities.
   g. Protect fan motors against overloading. Relays should be set to kick out under small overload.
   h. Repair or replace damaged or badly worn motors.
   i. Have a qualified electrician inspect all elements of the electrical circuits periodically and keep them in good condition.
2. Fan shafts
   a. Lubricate shaft bearings according to the manufacturer's instructions and replace leaking oil seals.
   b. Keep bearing supports tight and aligned with the shaft. Misalignment may overload the fan motor and damage the fan shaft and bearings.
   c. Keep fans shafts aligned, both horizontally and vertically.
   d. Keep friction and babbitt bearings tight.
   e. Replace damaged or badly worn bearings.
   f. Replace or repair badly worn keys or keyways.
   g. Keep shaft couplings tight.
   h. Replace damaged fan shafts.
3. Pulleys and belts
   a,. Keep pulleys tight on the shafts.
   b. Replace badly worn or damaged pulleys to prevent excessive belt wear or belt slippage.
   c. Tighten belts according to manufacturer's recommendations. Do not overtighten.
   d. Replace badly stretched or damaged belts.
   e. Keep all belts uniformly tensioned or tight on multibelt systems.
4. Fans
   a. Repair minor damage to fans; replace badly damaged fans.
   b. Keep fans tight on fan shafts.
   c. See that the clearance between the tips of fan blades and the fan shroud conforms to the manufacturer's recommendations.
   d. Ensure that all fans are rotating in the same direction and that all reverse at the proper time. This is especially important to check in cross-shaft fan arrangement.

      Caution: Exercise extreme care when fans must be inspected while they are running. Do not stand on fan deck when fans are running; rather, stand on ladder and look over edge of fan deck. Serious injuries have resulted from carelessness during the inspection of moving fans.
5. Fan baffles and floor
   a. Repair or replace damaged fan baffles and floors.
   b. Keep anchor bolts in fan baffles tight to minimize vibration and possible damage to fans.
6. Load baffle system (includes top, floor, and end baffles)
   a. Repair or replace damaged baffles.
   b. Lubricate baffle hinges.
   c. Maintain pulleys and cables on hinged baffle systems in good condition.
7. Oil lines, connections, and bearings
   a. Leaking oil lines, connections, and bearings increase safety and fire hazards, create an adverse working environment, and may stain the lumber.
   b. Make a systematic inspection for oil leaks and tighten loose connections.
   c. Repair or replace damaged lines.

Kiln Trucks

Frequent inspection and proper maintenance of kiln trucks can minimize downtime and accidents. Proper lubrication will help extend truck life. Recommended maintenance procedures are as follows:

1. Repair or replace damaged truck frames, axles, and bearings promptly.
2. Keep bolts and rivets in truck frames tight.
3. Repair or replace damaged metal or wood cross supports.
4. Provide enough trucks so that no truck is loaded over its capacity.

Use of Protective Coatings

Since ferrous (iron) metal in a dry kiln will rust or corrode, frequent inspection of metal parts is essential. Remove rust and coat the affected surface with a suitable protective paint. Such paints can be obtained from dry kiln manufacturers. (If manufacturers do not have these paints, they may furnish names of suppliers.) Typical areas of rapid corrosion are around doors, the lower 16 to 24 in of structural support columns (H or I beams) in aluminum prefabricated kilns, any location where a steel column or beam attaches to or extends through the kiln floor or wall, and any other location where condensation can occur for a prolonged period. Heat- and vapor-resistant kiln paint or coating is necessary for the inside of block and concrete kilns to protect masonry against humidity and condensation and to reduce heat and vapor transmissions. Do not apply to the outside of masonry kilns as the moisture will be trapped in the wall and speed deterioration of the structure.

Housekeeping and Maintenance Around Dry Kilns

Good housekeeping around dry kilns is essential. The possibility of injuries, damage to equipment, derailment of kiln trucks, and fires can be minimized by keeping the dry kiln, operating room, and surrounding area clean and free of safety and fire hazards. Good housekeeping practices include the following:

1. Immediately pick up stickers that have fallen from loads of lumber and place them in conveniently located sticker racks.
2. Pick up lumber that has fallen from loads and repile it on the loads or return it to the storage area.
3. Remove sawdust and other debris that collects on kiln roofs or sifts into the kiln.
4. Keep kiln walkways free of debris.
5. If possible, push any stickers or lumber that project into walkways back into the load to prevent injuries to workers. Boards projecting into plenum spaces or between vertical stacks of lumber can also cause nonuniform air velocities through the loads of lumber.
6. Stop oil or grease leaks around bearings, fans, blowers, and motors, and wipe up spilled oil or grease as soon as possible. Use drip pans to catch oil or grease that drips from bearings. Place oily or greasy rags in closed containers.
7. Keep control rooms clean, free of accumulated debris. and well ventilated at all times.
8. Keep transfers, tracks, and tramways on the loading and unloading ends of dry kilns in good alignment and repair.
9. Inspect stairways and ladders frequently and replace weak members at once.
10. Keep walkways along roof in good repair to provide access for inspection of vents, vent motor valves, vent linkages, oil cups for bearings, and other parts of the kiln.

Locating Problems in Kiln Maintenance and Operation

To assist the dry kiln operator in rapidly finding the causes of poor drying, the common sources of trouble are outlined in this section.

If the dry-bulb temperature does not reach the set point in a reasonable length of time, the causes may be as follows:

1. Steam pressure is too low.
2. Heat transfer is insufficient.
3. Heating coil is damaged, waterlogged, air-bound, or plugged.
4. Manual valves on steam supply or drain lines are closed or only partially open.
5. Automatic motor valve fails to open.
6. Steam trap is defective.
7. Valves are open on bypass line around steam trap.
8. Back pressures in return line to boiler are excessive.
9. Venting is excessive.
10. Leakage from kiln structure and around doors is excessive.
11. Recorder-controller system is malfunctioning because
    a. air or electrical signal fails to travel from controller to motor valve or
    b. sensor bulb (gas-filled or RTD) is not working properly.

If dry-bulb temperature continues to climb above the set point, the causes may be as follows:

1. Automatic motor valve is leaking.
2. Motor valve remains open.
3. Heat is being transferred through a common wall from an adjacent kiln.
4. Heat from steam spray is excessive (more common at low wet-bulb depressions or during conditioning phase of schedule).

If the wet-bulb temperature fails to reach the set point in a reasonable length of time, the causes may be as follows:

1. Insufficient steam is entering the spray line because
   a. steam supply to spray system is insufficient,
   b. automatic motor valve fails to open,
   c. manual valve on feedline is closed or only partially open, or
   d. holes or nozzles in spray line are plugged.
2. Leakage of heat and vapor from kiln structure or around doors is excessive.
3. Venting is excessive.

If the wet-bulb temperature continues to rise above the set point, the causes may be as follows:

1. Motor valve on steam spray line is leaking.
2. Motor valve on steam spray line remains open.
3. Water is standing on kiln floor.
4. Steam or water lines in kiln are leaking.
5. Valve in bypass line around motor valve is open.
6. Venting is insufficient.
7. Wet-bulb wick is dry, dirty, or crusty.

If the lumber is not uniformly dried or has excessive degrade associated with hot or cold zones within the kiln, the causes may be as follows:

1. Hot zones may be caused by
   a. higher than average air velocities across heating coils because of faulty stacking and inadequate baffling,
   b. leakage of heat through a damaged wall common to two kilns, or
   c. leakage in heating coils.
2. Cold zones may be caused by
   a. infiltration of colder air through cracks in the kiln wall or around doors,
   b. damaged fans or fan motors,
   c. short circuiting of the air because of faulty stacking or inadequate baffling,
   d. improper drainage of condensate from coils, or
   e. downdrafts through the vents.

Incorrect recording of dry- and wet-bulb temperatures may be caused by

1. control instrument that is out of calibration or damaged,
2. improper air circulation over control bulbs,
3. exposure of control bulbs or capillary lines to direct radiation from heating coils and feedlines or heat from steam spray,
4. water on the dry bulb,
5. dirty or dry wet-bulb wick or wet-bulb wick made of improper cloth,
6. too fast or too slow waterflow to wet-bulb water pan,
7. absence of wick on the wet bulb,
8. misplacement of wick on dry bulb instead of wet bulb,
9. wrong recorder chart, or
10. excess capillary tubing on gas-filled or liquid-vapor systems rolled up in kiln (best to roll up excess capillary tubing in control room rather than kiln).

Table 4-1—Operating sounds of various types of traps

Trap type	Operating sounds of properly functioning trap	Operating sounds of failed trap
Disc (impulse or thermodynamic)	Opening and snap-closing of disc	Normally fails while open—cycles in excess of 60/min
Mechanical (bucket)	Cycling sound of bucket as it opens and closes	Fails while open—sound of steam blowing through Fails while closed—no sound
Thermostatic	Sound of periodic discharge if on medium-to-high load; possibly no sound if light load (throttled discharge)	Fails while closed—no sound

Table 4-2—Pipe surface temperatures at various steam pressures

Steam pressure (lb/in^2-gauge)	Steam temperature (°F)	Pipe surface termperature range (°F)
15	250	238-225
50	298	283-268
100	338	321-304
150	366	348-329
200	388	369-349
450	460	437-414

Appendix-
Kiln Inspection Checklist

(Where maintenance or replacement is recommended, indicate kiln number.)

I. Kiln Structure

1. **Doors and door hangers,** present condition:

   Do door hangers operate properly: ______

   Do doors fit properly: ______

   Do gaskets adequately seal door: ______

   What maintenance a replacement is recommended: ______

2. **Walls,** present condition:

   IS protective coating adequate (masonry kilns): ______

   Are cracks repaired or holes patched: ______

   What maintenance or replacement is recommended: ______

3. **Structural steel** members, present condition:

   Is protective coating adequate: ______

   What maintenance or replacement is recommended: ______

4. **Roof or ceiling,** present condition:

   Is protective coating adequate to minimize corrosion and vapor transmission: ______

   What maintenance or replacement is recommended: ______

5. **Floors and walkways,** present condition:

   What maintenance or replacement is recommended: ______

6. **Rails and supports,** present condition:

   What maintenance or replacement is recommended: ______

II. Control system

1. **Recorder-controller,** present condition:

   Is correct chart paper on instrument: ______

   Is recorder-controller properly calibrated: ______

   Are capillary tubes protected: ______

   Are leads and connections of RTD adequately protected: ______

   Are bulbs or sensors properly located and mounted for accurate reading of kiln conditions: ______

   Does cellulose EMC wafer need replacing: ______

   What maintenance or replacement is recommended: ______

2. **Water supply:**

   Is water supply line to wet bulb open: ______

   Is wet-bulb water pan clean: ______

   Is water supply unusually hot or cold: ______

   Is drain line from water pan open: ______

Is wet-bulb wick replaced regularly: ______

What maintenance or replacement is recommended: ______

3. **Air supply:**

Is compressed air supply at correct pressure, clean, and uninterrupted: ______

Is compressor in good condition: ______

Are water and grease traps in good condition: ______

What maintenance or replacement is recommended: ______

III. Heating and Humidifying System

1. **Steam feedlines and headers,** present condition:

Are feedlines and headers properly insulated: ______

What maintenance or replacement is recommended: ______

2. **Heating coils or ducts,** present condition:

Are all pipes open to full flow of steam: ______

What is the condition of supports: ______

Is ductwork bent or otherwise damaged: ______

What maintenance or replacement is recommended: ______

3. **Traps, present condition:**

Are traps in best possible location: ______

What maintenance or replacement is recommended: ______

4. **Condensate return line,** present condition:

Are condensate pumps working properly: ______

Is line properly sized for volume carried: ______

What maintenance or replacement is recommended: ______

5. **Automatic and manual control valves,** present condition:

Are automatic control valves working properly: ______

Are springs and diaphragms working properly: ______

Are manual blowdown-valves provided for traps: ______

Are manual valves provided for shutting off individual coils: ______

Are check valves working properly: ______

What maintenance or replacement is recommended: ______

6. **Spray lines,** present condition:

Are spray holes or nozzles open: ______

Does condensate from spray line drip on lumber: ______

Is spray line properly trapped: ______

What maintenance or replacement is recommended: ______

7. **Vents,** present condition:

Do all vents open and close properly: ______

Do air motors and linkages work properly: ______

What maintenance or replacement is recommended: ______

IV. Air Circulation System

1. **Fans and motors,** present condition:

   What is the condition of electrical connections and switches: ______

   Are fans slipping on shafts: ______

   Are all fans turning in proper (same) direction: ______

   What maintenance or replacement is recommended: ______

2. **Shafts and bearings,** present condition:

   Are motors and shaft bearings properly lubricated: ______

   What maintenance or replacement is recommended: ______

3. **Fan baffles, cowling, and fan floor,** present condition:

   What maintenance or replacement is recommended: ______

4. **Load baffles,** present condition:

   Can load baffles be improved: ______

   What maintenance or replacement is recommended: ______

5. **Air passageways (including ductwork in direct-fired kilns):**

   Are air passageways open and unobstructed: ______

   Could air movement be improved: ______

   What maintenance or replacement is recommended: ______

V. General Condition of Yard, Kilns, and Control Room

Does grading and surface of yard provide for good drainage directed away from kiln(s): —

Are alleys adequate for maneuvering lift truck: ______

Are kiln trucks in good condition: ______

What maintenance or replacement is recommended: ______

Is control room neat and clean: ______

Are good kiln records kept: ______

Are kilns and surrounding area neat and clean: ______