CIRCULATION OF AIR IN A LUMBER DRY KILN

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CIRCULATION OF AIR IN A LUMBER DRY KILN

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Purposes

To Distribute Heat Uniformly Throughout the Kiln

During the lumber-drying operation heat is needed within the lumber pile first to heat the lumber and then to replace that used for evaporating moisture. About 1,000 B.t.u. are required for each pound of water evaporated. Additional heat is needed at the air-inlet vents to heat the incoming fresh air to the desired kiln temperature. Heat losses through the kiln walls and doors must also be taken care of to prevent cold spots and condensation troubles. Only a brisk air circulation can supply these needs and thus maintain a uniformity of drying conditions and a satisfactory drying rate.

To Carry Away the Evaporated Moisture from the Board Surfaces

As water evaporates from a board surface, the relative humidity of the air increases due to the drop in temperature and to the gain in moisture. For instance, assume an initial temperature of 130° F. and a relative humidity of 67 percent. The wet-bulb temperature would then be 117° F. Assume, further, that 1 grain (0.000143 pound) of water would be evaporated through the medium of 1 cubic foot of air. This would require 0.146 B.t.u. and would lower the temperature of the 1 cubic foot of air about 9° F. As there would be no change in total heat, the wet-bulb temperature would remain at 117° F., which, together with the new dry-bulb temperature of 121° F., would give a relative humidity of 88 percent. The drop in temperature would be responsible for the increase from 67 to 85 percent relative humidity, and only an additional 3 percent change would be brought about by the addition of one grain of moisture. This new air condition would result in a much slower drying rate and would gradually increase to a saturated condition if diffusion alone were depended upon to supply the heat and to remove the moisture. Consequently, circulation of rather a brisk nature is necessary to maintain satisfactory drying conditions, particularly when the drying rate is rapid. This is illustrated by the data given in Forest Products Laboratory Report No. R1264.

To Provide a Means of Mixing and Conditioning the Air Before It Enters the Load

After air has passed through the lumber pile, its temperature and relative humidity are no longer those of air on the entering-air side of the load and must be brought back to the desired conditions by venting, mixing with fresh air, and then heating. If leakage or venting is excessive, then steam sprays must be used to regain the desired entering-air relative humidity. Usually, the amount of recirculation needed is far greater than the venting requirements.

To Carry Heat Away From the Heating Coils and Thus Increase the Heat-transmission Rate

Circulation across the heating surfaces is necessary to remove the heat that accumulates around them in order to provide an efficient rate of heat transmission from the steam to the air. For instance, at an air velocity of 50 feet per minute transversely across 1-inch pipe, the heat transmission is about 1 B.t.u. per hour per square foot of radiation per degree difference in temperature between steam and air. At 250 feet per minute, the transmission rate is about 4 B.t.u. per hour.

Methods of Producing Circulation

By Gravity

As air is cooled, it becomes heavier and tends to fall towards the bottom of the kiln. When heated, it rises, causing convection currents that also stimulate the air circulation. Vertical air passages must be provided in natural-circulation kilns to take advantage of these forces.

Moist air is lighter than dry air of the same temperature because water vapor is lighter than dry air. This is illustrated by the values given in the following table:

Weight per Cubic Foot

Barometric Pressure - 29.92 Inch of Mercury

Temperature	Dry Air	Saturated Air (Air and Vapor)
°F.	Pounds	Pounds
100	0.0709	0.0692
200	.0601	.0427

Thus, when water is evaporated, the increase in the weight of air due to cooling is counterbalanced somewhat by the decrease in weight due to the addition of moisture. The combined effect, however, is an increase in weight that tends to cause a downward circulation of air within the load.

By Mechanical Means

As natural circulation is slow and is dependent upon differences in temperature, the uniformity and rate of drying in a natural-circulation kiln are not so good as in a forced-circulation kiln where fans are used to provide an air circulation sufficient to eliminate big temperature differences. Forced circulation has one disadvantage in that it seeks the lines of least resistance, irrespective of temperature and humidity, while natural circulation has the disadvantage of being greatest where differences in temperatures are the greatest. In either case, proper designing of the kiln lay-out and the proper piling of lumber are necessary to obtain efficiency.

A rather large percentage of present-day kiln installations are of the fan type, particularly of the internal-fan type where the fans, heating coils, and steam sprays are located within the drying compartment and the circulation through the load is horizontal. In external-blower kilns, all equipment is outside the drying compartment and the air flows through ducts into the kiln and then back to the fan and heating unit. From the ducts, the air passes upwards into vertical flues in the lumber pile and then laterally between the layers back to the return ducts.

Air Circulation Needs in Fan Kilns

As Affected by Entering-air Temperatures and Relative Humidities

Under the usual range in kiln conditions, from 60,000 to 70,000 cubic feet of air are required to provide the heat (approximately 1,000 B.t.u.) needed for the evaporation of one pound of water when the temperature of this air is lowered one degree. These unit air values (given in figure 1 of Forest Products Laboratory Report No. R1266) vary with both temperature and relative humidity, but for all practical purposes, a single value of 62,000 cubic feet is sufficiently accurate for all of the usual kiln conditions that are used during the initial stages of drying when the need for a brisk air circulation is greatest.

As Affected by the Amount of Water Evaporated and Temperature Drop

This volume of approximately 62,000 cubic feet of air varies directly with the amount of water evaporated and inversely with the drop in temperature. For instance, if the oven-dry weight of 1,000 board feet of lumber is 2,500 pounds and the rate of moisture loss is 0.01 percent per minute, the amount of water evaporated per minute would be 0.25 pounds. Assuming that a temperature drop of 4° F. was desired, the required air delivery would then be $\frac{62,000 \times 0.25}{4}$, or 3,870 cubic feet per minute. From this example, it can be seen that if two of the three variables (air delivery, drying rate, and temperature drop) are given, the third can be readily computed.

It is quite unlikely that actual conditions will conform very closely to the assumptions and computations made, because drying rate is affected by any change in the other two variables and, usually, the chances of estimating drying rates accurately are slight. In other words, some knowledge of actual drying rates is necessary to obtain computed values that are even approximately correct. Any one of the three variables, however, can be rather accurately computed by this method if the other two variables are consistent with any particular set of conditions.

From these computations, it can be seen that the greatest need for fast air circulation is during the initial stages of drying when the rate of drying is greatest and when the temperature drop must be small to prevent condensation on the leaving-air portion of the load.

As Affected by the Velocity over the Board Surfaces

As the air passes between the board layers through the spaces provided by the stickers, it tends towards a stratification of temperatures and relative humidities from the board surface to the center of the air stream. In addition to this variation perpendicular to the board surfaces, there is the normal temperature drop from the entering- to the leaving-air side of the load. Because of this, only the first board on the entering-air side of the load is subjected to the conditions established by the control equipment, and its initial drying rate is usually much faster than that of any other board in the layer.

Such stratification can be broken up by turbulence of air flow brought about (1) by separating the boards so that their edges will interfere with laminar flow and (2) by increasing the air velocity to the point where turbulence is sufficient to reach the board surfaces.

The data presented in figure 1 of Forest Products Laboratory Report No. R1269 indicate that an air velocity as high as 600 feet per minute was necessary to obtain the same drying rate in a solid layer as that obtained in a layer where the edges of boards were 2 inches apart. These data were obtained in drying 4/4 green oak from 80 to 40 percent moisture content. The results would vary a great deal with changes in drying rate.

Because of such transverse temperature and relative-humidity gradients across the air stream, the wood surface will become wet at average temperature drops that are less than the wet-bulb depression. In selecting a suitable temperature drop to use in computing air requirements during the initial stages of drying, a value considerably less than the wet-bulb depression should be used, possibly 50 percent or less, to obtain a good average rate of drying during the early stage of the drying process.

Factors Affecting Efficiency

Short Circuiting

Air from the pressure side of the fans tends to travel in a straight line until deflected by obstructions such as baffles and kiln walls. It also tends to follow the path of least resistance back to the suction side of the fans. For these two reasons, the path may or may not be the shortest route from one side of the fans to the other. Air traveling any route other than through the lumber pile represents wasted energy and should be prevented by proper piling and baffling. In some cases, the total clear areas below, above, and between the truckloads of lumber total more than the sticker spaces, and more than one-half of the air would then bypass the lumber piles.

Resistance

Fan delivery is decreased by increases in the pressure drop across the fan caused by obstructions such as poorly placed baffles, constricted areas, and mold that might develop between layers because of sluggish circulation. The path of air travel leading from and to the lumber pile should be as large as possible, and sudden changes in direction around baffles or obstructions should be avoided.

Venting

Ventilation is often confused with circulation in the kiln drying of lumber. Ventilation refers to the passage of air into and out of the drying compartment to dispose of the evaporated moisture. Circulation refers to the internal movement of air to carry heat from the heating units to where it is needed to establish uniform temperature. A great deal of heat is wasted by excess venting, and for that reason automatic control of venting is helpful in utilizing the evaporated moisture and in preventing excess use of the steam sprays. A method of estimating the venting needs is given in table 1 of Forest Products Laboratory Report No. R1265.