CHAPTER 6 – Basic Drying Methods

Lumber drying chambers (kilns) come in a variety of sizes and shapes. The basic concept of forced air lumber drying however does not vary. The kiln chamber must be an enclosure that directs air to flat, wide surfaces of lumber wood surface and has a way for moisture to exit the enclosure. In its simplest form it is a box with a fan and two vents, in which pieces of wood can be stacked so that the wide, flat surface of air is exposed to the air stream produced by the fans (Figure 1).

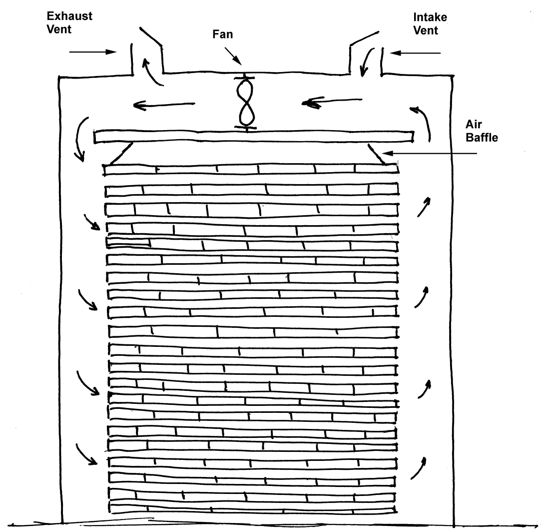


Figure 1. Basic drying chamber without an auxiliary heat source.

In this type of kiln the fan creates a negative pressure in the plenum chamber on the downstream side and a positive pressure on the upstream side. This pressure difference forces the air through the stack of lumber from left to right in the sketch above. The vent on the downstream side draws warmer/dryer air into the chamber and the vent on the upstream side (positive pressure) exhausts cooler/moist air. A forced air chamber like this will dry wood down to a moisture content in equilibrium with the outside ambient air conditions, which dictate how much moisture the air can hold. For example, if the outside air temperature is 70 ^{o} F and the relative humidity (RH) is 80%, then the wood will eventually dry to an equilibrium moisture content (EMC) of about 16%. If it is necessary to dry the wood below this MC than a method must be provided that can either increase the air temperature or lower the RH. Since relative humidity is directly related to temperature a change in one also changes the other. Hot air can hold more moisture than cold air, thus in the absence of any additional moisture added to the air increasing the temperature of the air decreases the relative humidity.

An approximate wood EMC at various air temperature and relative humidity combinations is shown in Figure 2. From this graph it is noted that over the range of conditions to which wood is likely to be exposed the EMC is more sensitive to changes in relative humidity than it is to changes in temperature. For example, keeping RH constant at 40% and varying the temperature from 30°F to 200°F causes a small change in EMC from 7.7 to 4.3 %. Whereas changing the RH from 20 to 80 % while keeping the temperature constant at 120 °F causes a change in EMC from 3.8 to 14.1 %. Where temperature becomes more important is in controlling the rate of drying. The higher the temperature is the more energy will be available to break the bonds between water molecules and wood and to evaporate water. Temperature and drying rate also influence the development of drying defects. Cell walls are weaker at high temperatures than at low temperatures and they are also weaker at high moisture contents than low moisture contents. The strength of wood cells during drying is directly related to the development of defects as the wood dries. For example, wood at a high moisture content exposed to a high temperature may have experienced enough strength loss in the cell walls that the stresses of drying cannot be resisted and the cells will collapse. This complex interaction between temperature, relative humidity, moisture content and drying rate is the basis for controlling the drying of wood.

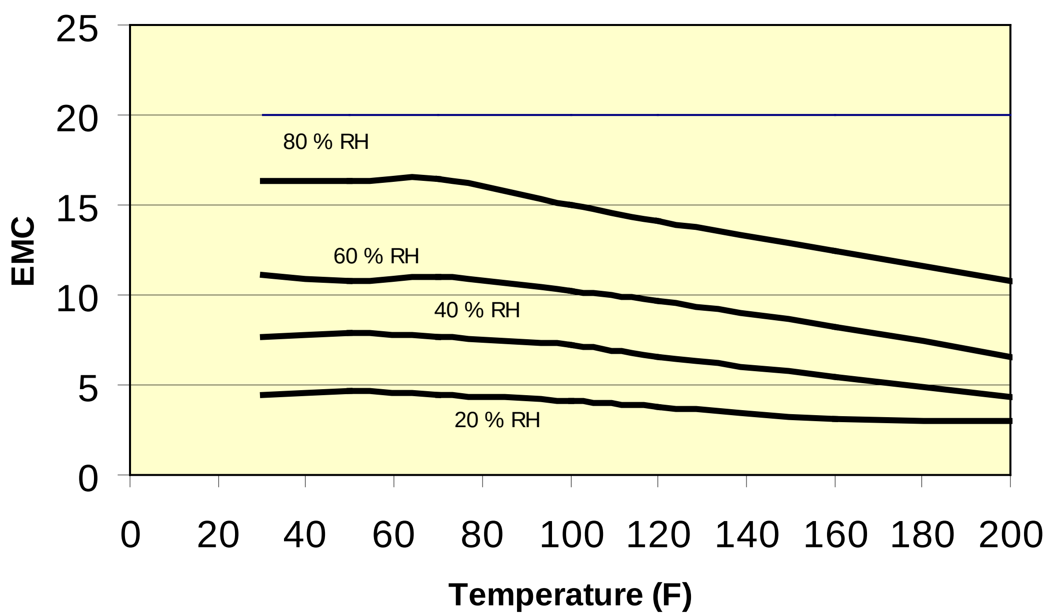


Figure 2. The Effect of Temperature and Relative Humidity on EMC

In most natural climates the RH is unlikely to be much below 50% which means that if wood at a MC lower than about 10% is desired then something will have to be done to the drying environment to reduce the RH. Various methods are used to accomplish this task. A solar panel, electrical heater, or steam heated heat exchanger are conventional ways often used to raise the air temperature in kilns, which in effect also lowers the RH. Another option is to use a dehumidifier to pull moisture out of the air.

A solar heated kiln is shown below in Figure 3 and a steam-heated kiln is shown in Figure 4. Controlling the air temperature and RH in these kilns controls the rate of drying.

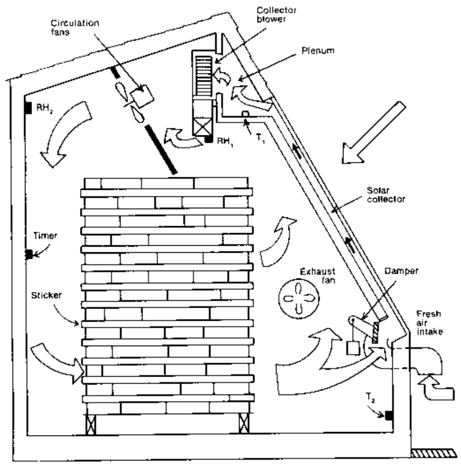


Figure 3. Solar kiln

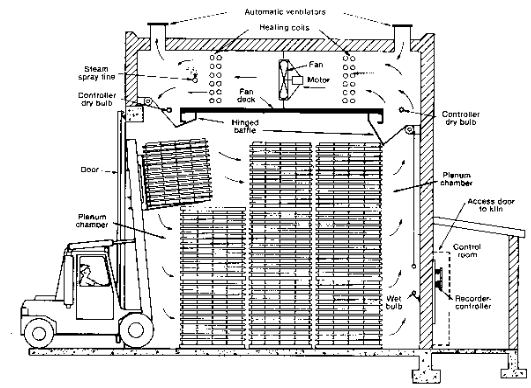


Figure 4. Typical steam-heated dry kiln

Source: Dry Kiln Operators Manual, USDA Forest Service

Both of the above kilns are similar in that the air is forced through the lumber, the air picks up heat by passing through a heat exchanger (solar collector, or steam heated coils), and takes in cooler, drier ambient air through an intake vent while expelling hot humid air through the exhaust vent. Close monitoring of the temperature and relative humidity of the air and careful controlling of the vents, temperature of the heat exchanger provide precise control of the drying environment.

An alternative to the heat exchanger methods described above is the dehumidification method in which a dehumidifier (operating on the thermodynamic heat pump principle) removes the moisture from the air in the drying chamber. This unit can be placed inside or outside the drying chamber. If it is outside then the air from the drying chamber must be ducted through the dehumidifier as shown in Figure 5. A dehumidification kiln does not need vents to control humidity, but they may still be needed to vent excess heat during critical periods of drying.

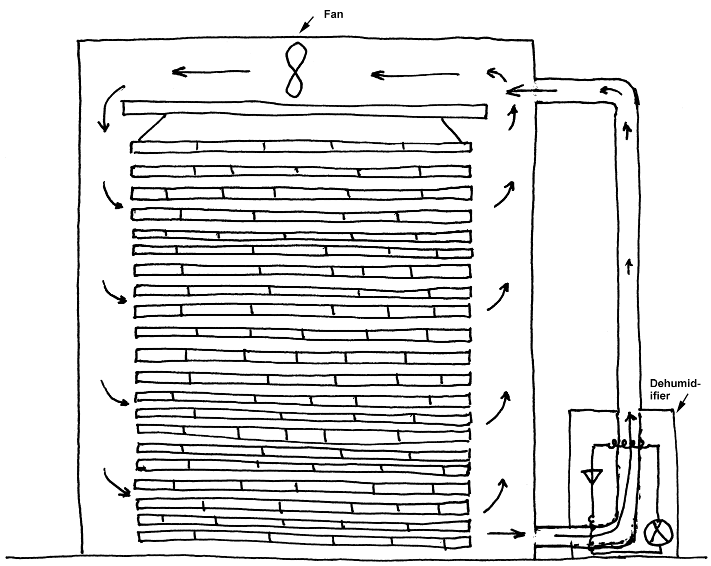
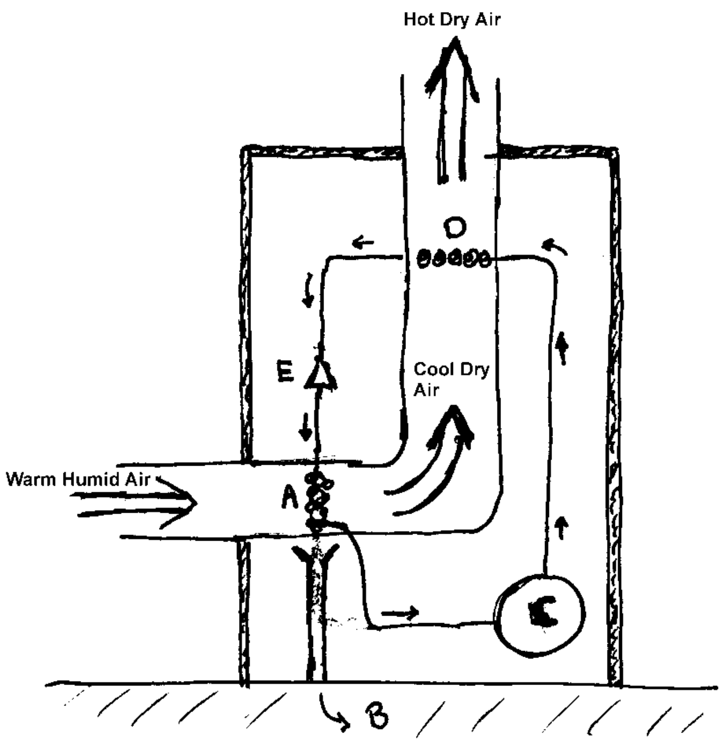


Figure 5. Dehumidification kiln with unit placed outside of kiln chamber

This dehumidifier operates very similarly to your household refrigerator. It is based on the fact that the energy required to cause a phase shift from a liquid to a vapor (the latent heat of vaporization) can be recovered when the vapor condenses back into a liquid and this latent heat is transferred to the surface on which the vapor is condensing. The dehumidifier captures this latent heat when warm moist air condenses onto a cold surface and then pumps the heat to another heat exchanger where the heat is transferred back into the air stream. This transfer of heat works best with the use of a special class of heat transfer fluids know as refrigerants. A typical dehumidifier, consisting of an internal, closed loop refrigerant cycle with two heat exchanger surfaces, is shown in the schematic drawing in Figure 6. In this figure the air flow is depicted by large arrows and the refrigerant is depicted by small arrows. The unit operates as follows.



Warm humid air from the drying chamber enters the dehumidifier and passes through (A), a heat exchanger with very cold surfaces. The moisture in the air condenses onto the cold surfaces, is collected and drains away from the system (B). The condensation at (A) gives up the latent heat to the refrigerant which is then pumped into the compressor (C). The compressor compresses the refrigerant, increasing the temperature even more. This hot refrigerant continues on to heat exchanger D where the air stream (from A) now passes through a heat exchanger with hot surfaces and the captured latent heat in the refrigerant is transferred to the air stream. From D a hot dry air stream emerges that is sent back into the drying chamber. From D the refrigerant, now at a lower temperature, passes through an expansion value (E) which lowers the temperature even more. From (E) the very cold refrigerant passes again to heat exchanger (A) and the cycle continues.

Other Drying Methods – The energy needed to dry wood can also be delivered to the wood in other ways that do not involve forced convection heat and mass transfer of the methods described above. A few examples are microwave, radio-frequency, and vacuum drying. Microwave and radio-frequency methods are very effective at transferring the needed energy to the water molecules and can dramatically reduce the time needed to dry small pieces of wood. Vacuum methods dramatically lower the vapor pressure in the drying chamber so that water can evaporate at much lower temperatures, meaning less energy is needed.

These methods run into difficulty when larger, lumber sizes of wood are dried as the energized water molecules cannot easily escape from inside of the wood due to the tortuous pathways for moisture flow in wood. Without air flow the methods are also challenged in removing from the drying chamber, the moisture released from the wood. The combination of high cost and non-uniform drying keeps these methods from being widely accepted by the industry.