# SIMPLIFYING THE CALCULATION OF THE QUANTITY OF AIR REQUIRED IN KILN DRYING LUMBER

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# SIMPLIFYING THE CALCULATION OF THE QUANTITY OF AIR REQUIRED IN KILN DRYING LUMBER

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The trend in modern lumber drying is toward the use of fan kilns and high rates of air velocity. By such means green lumber can be dried more uniformly and in less time than if dried in a natural circulation or ventilated type of kiln. Fan kilns, however, could be more efficiently designed if more were known as to (1) the effect that rate of air circulation has on the average rate of drying and (2) how these rates affect the unit cost of kiln drying. The phase concerning the effect of air circulation on drying rate is now being studied at the Forest Products Laboratory. It has been found that air velocity has a very definite effect on the drying lag across the load and, therefore, on the average drying time. The purpose of this article is to explain the three principal factors involved in determining the effect of air circulation on drying rate and to present a chart which simplifies the theoretical calculations of any one factor when the other two are given.

As the air passes through the lumber in a dry kiln, heat is used to evaporate the water in the wood and as a result a temperature drop occurs between the entering and leaving air sides of the load. After the wood and water are heated to the temperature of the surrounding air, this temperature drop becomes a direct measure of the amount of water being evaporated. Of course, the amount of air circulation must be considered also because it governs the amount of heat supplied.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

It can be seen, therefore, that air circulation, drying rate, and temperature drop are the three factors making up the problem and, given any two, the third can be computed.

Because of so many variables such as species, size, air velocity, moisture content, temperature, relative humidity, and length of air travel, innumerable combinations and calculations are possible. To eliminate the repetition of such laborious computations, a set of curves was made for various entering air temperatures and relative humidities and for a 1 degree temperature drop. The curves, shown in figure 1, give the quantity of air needed to evaporate 1 pound of water when the temperature drop across the load is 1 degree Fahrenheit. These unit values can be divided by temperature drops other than one and multiplied by the actual amount of water evaporated to obtain the corresponding air requirements.

The computations were made on the basis that evaporation takes place at the wet bulb temperature. As drying progresses, however, the evaporation temperature becomes greater than this and a slight error is introduced, especially at low relative humidities. In dealing with stock at a moisture content below the fiber-saturation point, the use of the curves would introduce another error by not giving consideration to the heat of adsorption. The need for computing air requirements, however, is greatest at the beginning of the drying process and for that reason the heat of adsorption was omitted from these particular computations. All air quantities were computed for a barometric pressure of 29.92 inches of mercury, but for practical purposes no correction need be made for other pressures.

In computing any one factor from the other two, the following equation (1) can be used:

$$(1) \quad A = \frac{UM_l}{t}$$

Where:

$A$ = Volume of air needed per minute (cu. ft.)
$U$ = Unit air requirement from curves (cu. ft.)
$M_l$ = Moisture loss per minute (lb.)
$t$ = Temperature drop (°F.)

Moisture loss in usually calculated and expressed as a percentage of the oven-dry weight of the wood. To convert this percentage to pounds, equation (2) can be used.

$$(2) \quad M_1 = \frac{M_2}{100} VWG$$

Where:

$M_1$ = Moisture loss per minute (lb.)
$M_2$ = Moisture loss per minute (percent)
$V$ = Volume of green wood (cu. ft.)
$W$ = 62.3 = weight of 1 cubic foot of water at 70° F. (lb.)
$G$ = Specific gravity (based on green volume and oven-dry weight)

It is often more convenient to use the evaporation from one layer 1 foot long in the direction of the length of the boards as given by equation (3). Such a moisture loss when used in equation (1) gives the volume of air to be provided for one sticker space 1 foot wide. This air volume can be converted to air velocity by dividing by the sticker thickness expressed in feet.

$$(3) \quad M_1 = \frac{M_2}{100} DLWG$$

In this equation V in equation (2) is replaced by (DL) where

$D$ = thickness of lumber (ft.)
$L$ = length of air travel (ft.)

As an illustration of how to use the curves, the following assumptions are made as representing the conditions during the first stage of drying when the need for air is greatest: (1) a 4-foot wide pile of 4/4 sugar maple measuring 1-1/16 inches in thickness and having a specific gravity of 0.56; (2) stickers measuring 7/8 inch in thickness; (3) an entering air condition of 130° F. and 80 percent relative humidity; (4) a moisture content loss from 70 to 40 percent during the first 2 days; and (5) an average temperature drop across the load of 2° F.

Perhaps it might be well to explain that with a wet bulb depression of 7° F., an average temperature drop much above 2° for this moisture content range would result in a relatively large increase in drying lag across the load and less conformity to the drying schedule.

Substituting in equation (3), the moisture loss per minute = 0.0001042 x 0.0885 x 4 x 62.3 x 0.56 = 0.001287 pound. From figure 1, the unit air requirement is 61,600 cubic feet. When these values are substituted in equation (1), the volume of air needed per minute =

$$\frac{61,600 \times 0.001287}{2} = 39.6$$ cubic feet. This value divided by the sticker thickness (0.0729), expressed in feet, gives 543 feet per minute as the air velocity necessary to satisfy the assumed conditions.

Computations of this kind have been checked by test runs at the Laboratory even to the extent of plotting drying curves from air velocity and temperature drop measurements and finding that they coincide closely with those obtained from actual moisture determinations. To obtain a close check, however, the temperature drop must be measured to a fraction of a degree.

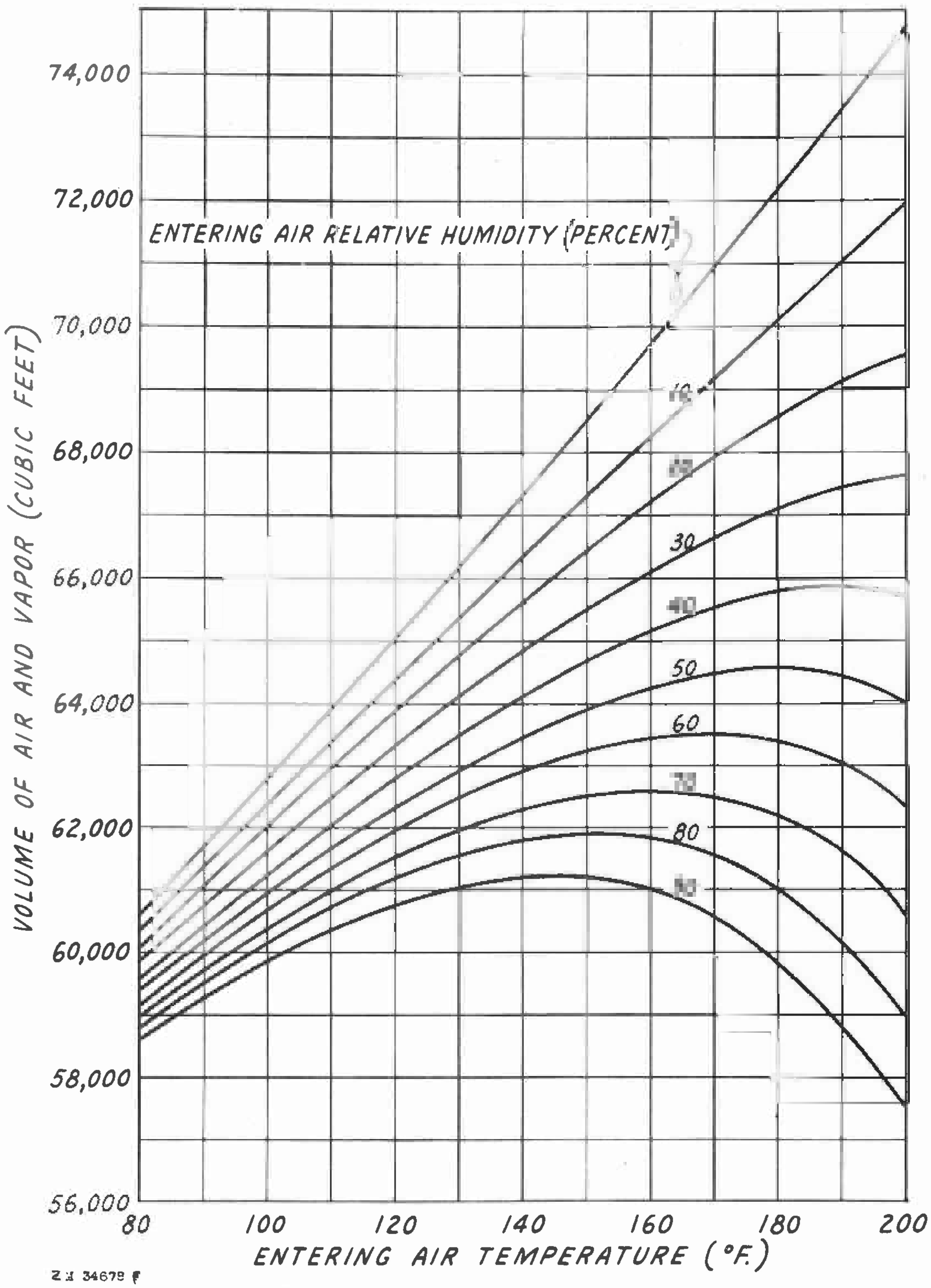


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Figure 1.--Amount of air and vapor needed to evaporate 1 pound of water when the temperature drop across the load is 1° F.
Computed for a barometric pressure of 29.92 inches of mercury.
(To obtain the amount of air and vapor needed for values other than unity, multiply by the amount of water evaporated and divide by the temperature drop.)