FUNCTION AND CALCULATION OF VENTILATION IN DRYING COMPARTMENTS

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FUNCTION AND CALCULATION OF VENTILATION

IN DRYING COMPARTMENTS

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In kiln drying work, ventilation should not be confused with circulation. 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 which is necessary to carry heat to the drying surfaces and to replace the heat lost through the roof, walls, and doors. Ventilation is necessary to maintain scheduled relative humidity conditions, while circulation is needed so that these conditions can be maintained, as uniformly as practical, within all parts of the compartment.

In kiln drying green lumber, a great deal of heat would be wasted if all the air necessary for a satisfactory rate of air circulation were drawn from the outside, heated, humidified, and then discharged after having passed through the load only once. For that reason, most of the circulation should be provided by recirculation and the amount of fresh air taken in should be sufficient to absorb only the evaporated moisture when raised to kiln conditions.

Modern kilns are equipped with fans to recirculate the air, but these may act also as exhaust fans by taking in and discharging air through vents located on both vacuum and pressure sides. The desired humidity is maintained by opening or closing these vents either manually or automatically. A separate exhaust fan and motor, automatically operated by a hygrostat or by a wet bulb thermostat, can be used also. Steam sprays are used ordinarily to humidify the air in case of overventing or if, because of leakage, the amount of evaporated moisture is insufficient to maintain the desired humidity. In an automatic system the sprays should not come on until after the vents are closed or the exhaust fan is shut off.

The problem of estimating the amount of venting needed involves a knowledge of the drying rate, and of the outside air conditions as well as those within the kiln. The basis of the calculation is that the amount of incoming air must be such that, when heated to the kiln temperature and mixed with the evaporated moisture, the relative humidity is raised to that called for by the kiln schedule.

The first step is to estimate the amount of moisture loss per minute. This value when divided by the difference in moisture associated with one unit of inside and outside air, gives the amount of fresh air to be taken in per minute. By using 1 pound of dry air as the unit, the complication due to volume changes is eliminated. Expressed in terms of an equation:

$$A = \frac{R}{V_1 - V_2}$$

Where:

A = Amount of dry air to be taken in per minute (pounds)
R = Drying rate (pounds of water per minute)
V_1 = Amount of vapor per pound of dry air in kiln (pounds)
V_2 = Amount of vapor per pound of dry air outside (pounds).

The last step is to convert "A" to volume of air by multiplying by the volume (cubic feet) of 1 pound of dry air plus its associated vapor at the temperature and humidity of the outside air.

Air properties in tabular form are given usually for either dry air or fully saturated air and those for partly saturated air must be estimated or computed. Figures 1 and 2 present these values graphically and can be used with sufficient accuracy for computations such as these. To illustrate their use in computing the volume of outside air to be taken in, certain assumptions will be made and the corresponding values and results tabulated. To show that the needed amount of outside air varies with outside air conditions, two possible winter and two possible summer conditions will be assumed. The winter and summer conditions will be represented by relative humidities of 90 and 50 percent, respectively, under a winter temperature of 20° F. and a summer temperature of 80° F. As the need for venting at any one set of air conditions varies directly with the drying rate, only one rate will be given in the illustration. A rate of 0.5 pound per minute will be assumed as being that possible from 1,000 board feet of 1-inch sugar maple during the initial stage of drying under a temperature of 130° F. and a relative humidity of 80 percent. It will be assumed also that all the evaporated moisture is mixed with the incoming fresh air.

The results of the computations given in table 1 show that 108 cubic feet is the maximum volume of fresh air needed under these particular assumed conditions. Fresh air at 80° F. and 90 percent relative humidity, when heated and humidified to 130° F. and 80 percent humidity, increases in volume from 14.0 cubic feet per pound of dry air to 16.9 (fig. 2). Using this ratio of expansion, the 108 cubic feet of fresh air is increased to 130, which, if passed through 1,000 board feet of 4/4 lumber piled on 1-inch stickers to a width of 4 feet, results in an air velocity of 6 feet per minute through the load. This is approximately only 2 percent of the air velocity common in present day fan kilns.

If both the kiln temperature and humidity are lowered until the amount of vapor per pound of dry air is the same as that of the outside air, then the amount of needed venting as computed above becomes infinitely large. This, of course, is a fallacy because, as the amount of venting increases, more and more of the evaporated moisture passes directly out of the kiln, and less and less remains to be mixed with the incoming air. For that reason the amount of evaporated moisture to be mixed with the fresh air should be reduced by a percentage based somewhat on the ratio of ventilation to circulation rates, and the limit is reached when items B and C in table 1 become zero, meaning that the air passes directly through the kiln with no recirculation occurring. For this reason the accuracy of the results as computed is greatest where the required venting is only a small part of the total air circulation through the load, but becomes increasingly erroneous as the computed value approaches the desired circulation rate which represents the upper limit of venting.

To summarize:

(1) Ventilation refers to the disposal of the evaporated moisture by venting.

(2) Circulation refers to the rate of air movement through the load.

(3) The amount of needed ventilation is governed by the drying rate and by the difference in the amount of vapor per pound of dry air within and without the kiln. Ordinarily the needed ventilation is only a small part of the desired circulation and recirculating fans should be provided which are independent of the venting system.

(4) The fresh air requirements as computed here are greater than needed because some of the evaporated moisture is vented without being recirculated. The greater the amount of venting, the greater becomes the error. The limit is reached when the needed ventilation is equal to the desired circulation rate. In this case, the proper kiln condition is attained simply by heating the outside air to the kiln temperature and no recirculation is necessary or possible. Where the desired kiln condition is such that the unit amount of vapor in the kiln is less than that outside, a condensing system must be employed to remove the evaporated moisture.

(5) Best economy can be secured by automatically controlling the vent dampers or ventilating fan to prevent overventing and, therefore, unnecessary heat losses.

Table 1

	1	2	3	4	
	Kiln condition	Outside conditions			
	130° F. 80 percent relative humidity	20° F. 50 percent relative humidity	20° F. 90 percent relative humidity	80° F. 50 percent relative humidity	80° F. 90 percent relative humidity
(A) Amount of vapor per pound of dry air (Pounds)	(Figure 1) 0.085	(Figure 1) 0.001	(Figure 1) 0.002	(Figure 1) 0.011	(Figure 1) 0.020
(B) Amount of vapor per pound of dry air to be added (Pounds)		(1A - 2A) 0.084	(1A - 3A) 0.083	(1A - 4A) 0.074	(1A - 5A) 0.065
(C) Amount of evaporated moisture added to fresh air per minute (Pounds)	0.5				
(D) Amount of dry air to be taken in per minute (Pounds)		(1C ÷ 2B) 5.95	(1C ÷ 3B) 6.02	(1C ÷ 4B) 6.75	(1C ÷ 5B) 7.69
(E) Volume of 1 pound of dry air plus vapor (Cubic feet)		(Figure 2) 12.10	(Figure 2) 12.11	(Figure 2) 13.83	(Figure 2) 14.03
(F) Amount of fresh air to be taken in per minute per 1,000 board feet (Cubic feet)		(2D x 2E) 72.00	(3D x 3E) 73.00	(4D x 4E) 93.00	(5D x 5E) 108.00

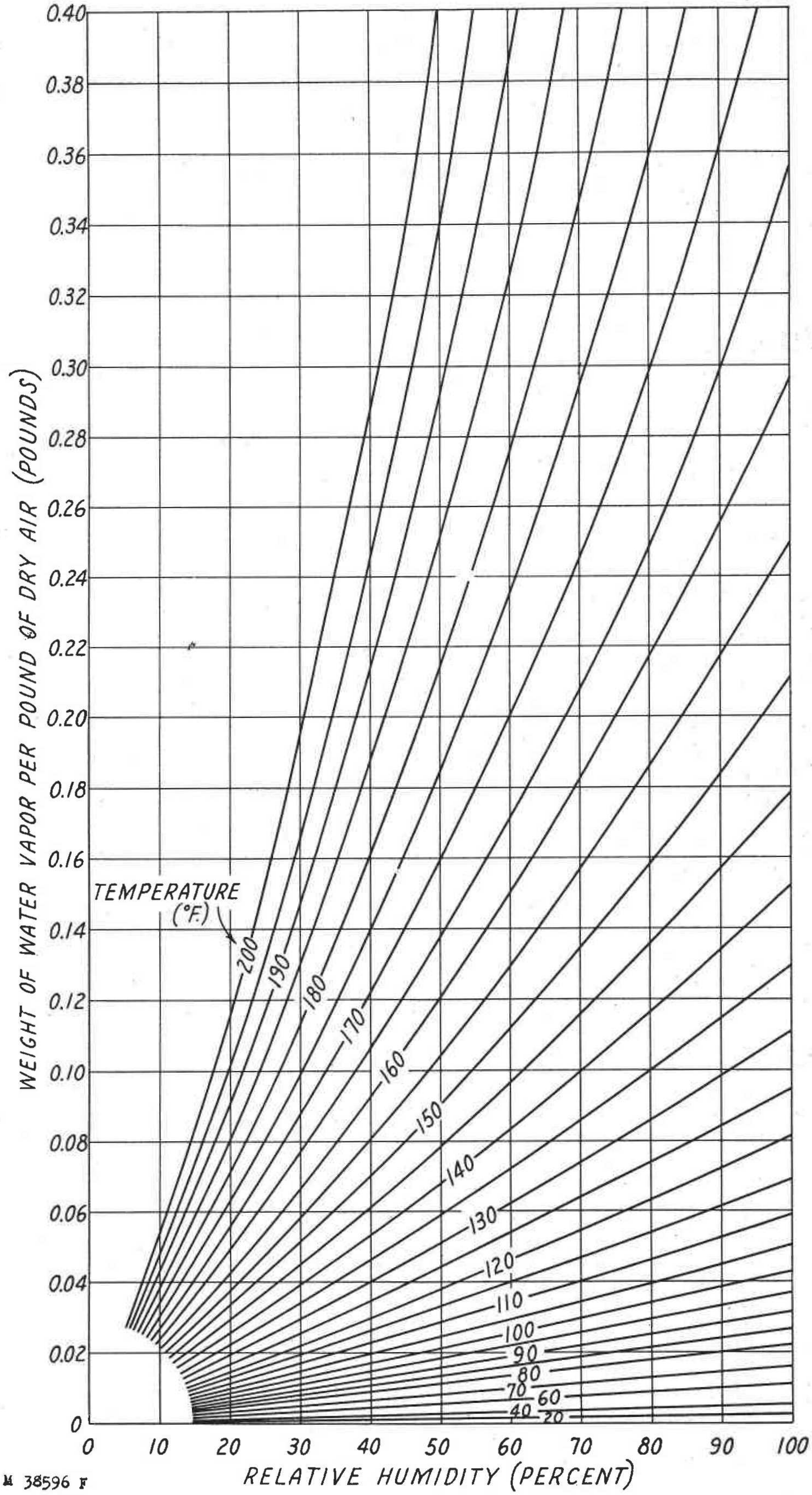

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Figure 1.--Weight of vapor (pounds) per pound of dry air at various combinations of temperature and relative humidity and a barometric pressure of 29-92 inches of mercury.

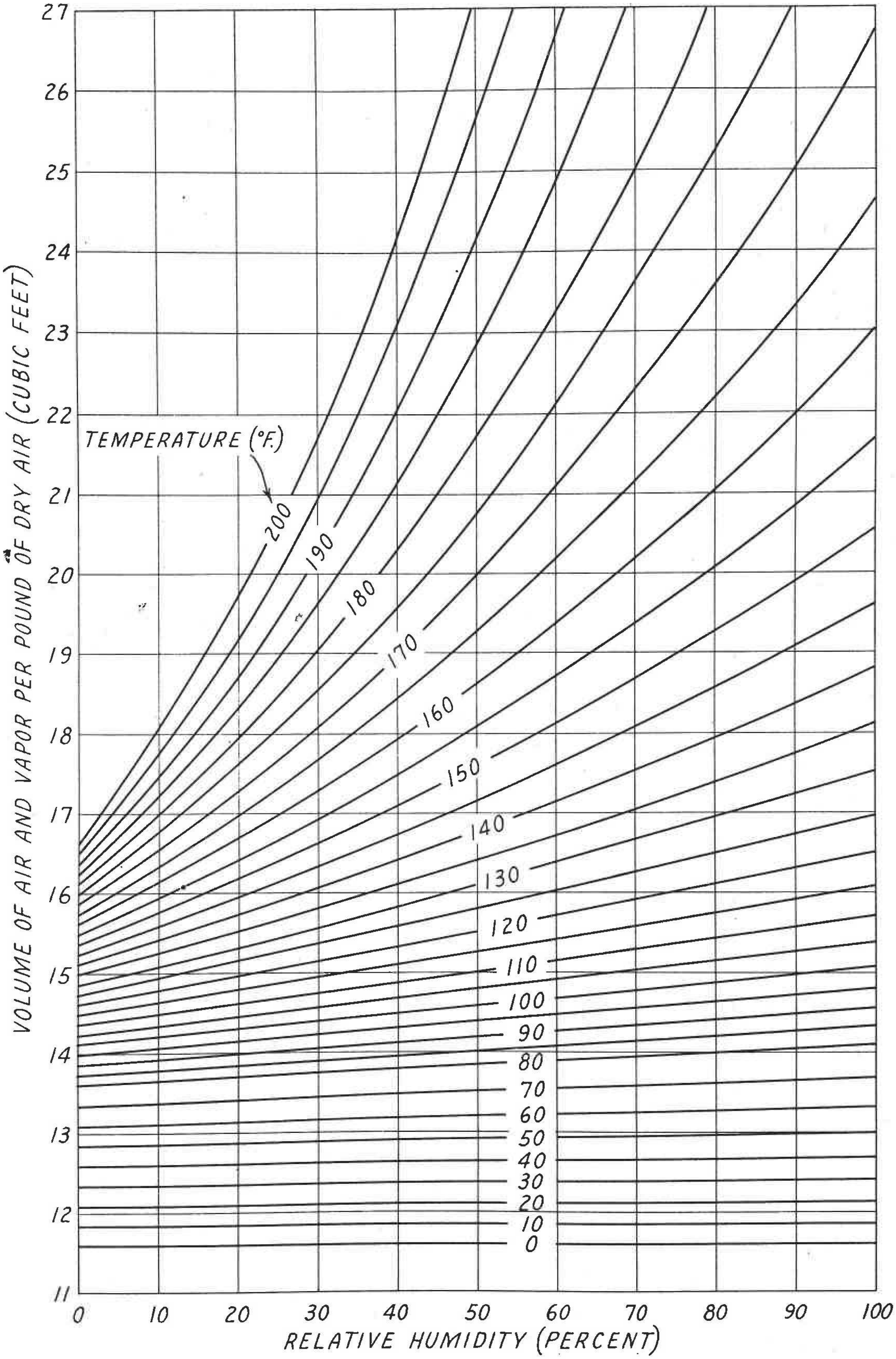

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Figure 2.--Volume of air and vapor (cubic feet) per pound of dry air at various combinations of temperature and relative humidity and a barometric pressure of 29.92 inches of mercury.