and a humidity H_1 will cool, following this cooling line toward point A. Air leaving with a humidity H_2 will consequently have cooled to t_2, the wet-bulb temperature of the air throughout the dryer being t_w. When heat is lost to the surroundings, the operation is somewhat lower than t_2, so that the actual humidity-temperature relation is represented by the line Bb, having less slope than the adiabatic saturation line. The ratio $(t_1 - t_2)/(t_1 - t_3)$ then gives a measure of the evaporative efficiency of the dryer. For the case of dryers containing steam coils maintained at a constant temperature, the humidity-temperature relation is obviously represented by the vertical line Bc, assuming the initial and final humidities to be H_1 and H_2 as before. The heat supplied within the dryer itself is usually less, but may be greater, than the total heat requirements of the dryer. If less, the cooling is indicated by some such line as Bd, and if greater, by a line such as Be having a positive slope.

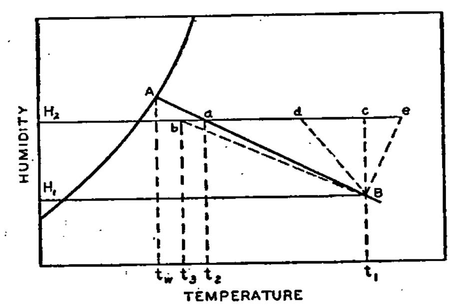

Fig. 7. Humidity-Temperature Relations in Dryers[1]

DRYER CALCULATIONS

As shown in the foregoing part of this chapter calculations for drying during the constant-rate period are different from those applying to the falling-rate period, and in contrast are subject to relatively simple mathematical analysis.

The constant rate of drying by convection is directly proportional to the temperature difference between air and wet solid, and also proportional to the 0.8 power of the air velocity as shown by Equation 3. Usually the wet surface is assumed to attain the wet-bulb temperature of the air passing over it, and evaporation takes place at a constant rate under equilibrium conditions. This is a conservative assumption, however, and when conduction and radiation effects occur, the constant rate may be increased by 30 to 60 percent over that for pure convection.

Fig. 8 permits a ready estimate of the constant drying rate for various air temperatures and humidities. The chart is based on the difference between the dry-bulb and wet-bulb temperatures of the entering stream of air, and on an air velocity of 300 fpm. It may be assumed satisfactory for tray drying of any material in the constant-rate drying period. It does not apply to rotary or through-circulation drying.

A curve for correcting the air velocity in any given problem is incorporated in Fig. 8. This curve is based on the variation of drying rate with the 0.8 power of the velocity, as given by Equation 3.

The use of Fig. 8 in practical drying problems is as follows: Since the drying conditions of temperature and relative humidity are fixed, the corresponding absolute drying rate is read from Fig. 8. This value is then multiplied by the correction factor corresponding to the air velocity employed. The rate so obtained, however, does not include any effects of radiation or of conduction through unwetted surfaces. These effects tend to increase the rate of evaporation so that the chart is conservative.[3]

It has been demonstrated empirically for certain materials that the rate of drying during the falling-rate period is approximately proportional to the free water content of the material. Actual calculations of drying time

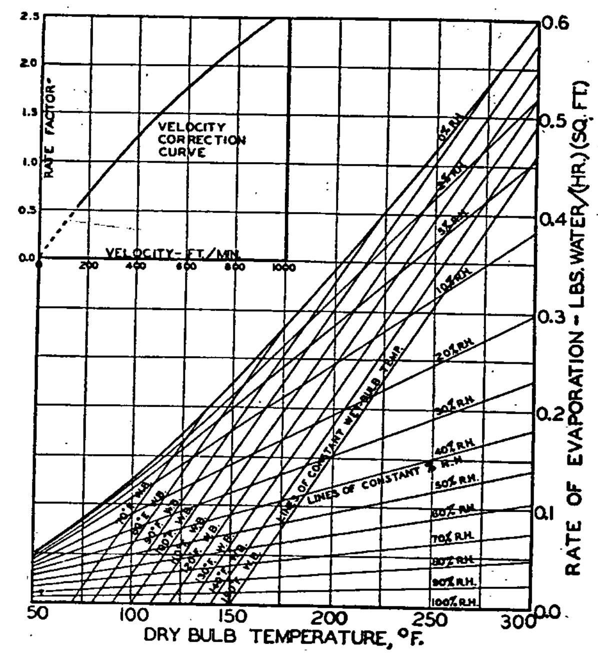

Fig. 8. Rate of Evaporation Chart[3]

during the falling-rate period for this case require only a knowledge of the critical moisture content and the constant rate. For other cases of the falling-rate period, calculations are not feasible. Consequently, it is best to determine drying times for design purposes by means of pilot tests. However, when tests are not feasible, drying times may often be estimated approximately from Equations 22 and 23.

The following nomenclature will be used in the discussion of design calculations:

H = humidity ratio of air, pounds of water vapor per pound of dry air.
N_a = pounds of dry air supplied to the dryer per unit of time.
S = pounds of stock dried per unit of time in a continuous dryer.
S' = pounds of stock charged per batch to a discontinuous dryer.
θ = time, hours.
Q = total heat supplied to the dryer, Btu.