

where the constant rate ends and the drying rate begins to decrease, is termed the *critical moisture content*.

The portion of the curve designated by CB in Figs. 1 and 2 represents a warming-up period, and it may, or may not, be a significant item depending on the total time involved.

Constant-Rate Period. Drying during the constant-rate period is equivalent to evaporation from a free-water surface on the surface of the solid. The rate of drying in this period is determined by the rate of diffusion of water vapor through an air film at the wet surface of the solid. A constant rate of evaporation on the surface of the solid maintains the surface at a constant temperature, which, in the absence of other heat effects, is very nearly the wet-bulb temperature of the air. If heat flows to the surface of evaporation by radiation and conduction, or both, in addition

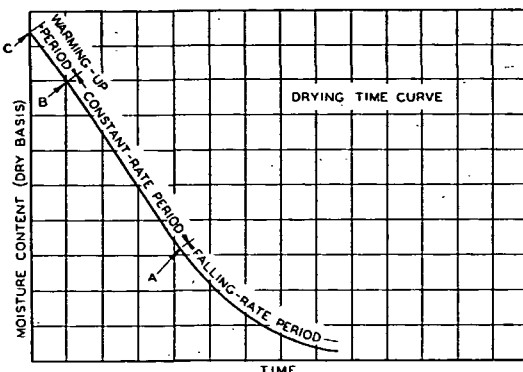


FIG. 1. MOISTURE CONTENT w vs. DRYING TIME θ
(From Reference 2)

to convection, the surface temperature will be constant at some value between the air temperature and the wet-bulb temperature. This higher temperature in turn produces a higher constant rate of evaporation.

In those dryers in which heat is transferred to a wet solid by conduction through hot surfaces, and heat transfer by convection is not a factor, the wet surfaces approach the boiling point temperature rather than a wet-bulb temperature.

When all the heat for evaporation in the constant-rate period is supplied by a hot gas, a dynamic equilibrium is established between the rate of heat transfer to the material and the rate of vapor removal from the surface. This equilibrium between heat and mass transfer rates can be expressed as follows:

$$\frac{dw}{d\theta} = \frac{h_t A \Delta t}{H} = k_s A \Delta p \quad (1)$$

where

$$\frac{dw}{d\theta} = \text{drying rate, pounds of water per (hour) (pound of bone dry material).}$$

- h_t = total heat transfer coefficient, Btu per (hour) (square foot) (Fahrenheit degree).
- A = area of heat transfer and evaporation, square feet per pound of bone dry material.
- H = enthalpy of evaporation at t_s , Btu per pound.
- k_s = mass transfer coefficient, pounds per (hour) (square foot) (atmosphere).
- Δt = $(t_a - t_s)$ = temperature difference between air and surface of evaporation, Fahrenheit degrees.
- t_a = air temperature, Fahrenheit.
- t_s = temperature of surface of evaporation, Fahrenheit.
- Δp = $(p_s - p_a)$ = vapor pressure difference, atmospheres.
- p_s = vapor pressure of water at t_s , atmospheres.
- p_a = partial pressure of water vapor in air, atmospheres.

When $h_t = h_c$, the coefficient of heat transfer by convection only, then t_s under equilibrium conditions becomes t_w , the wet-bulb temperature of the air, and p_a is the vapor pressure at this temperature. If heat is also

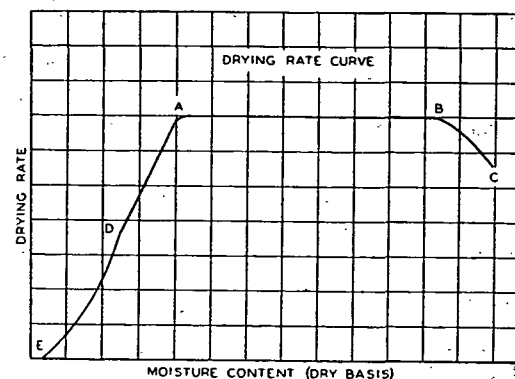


FIG. 2. RATE OF DRYING $\frac{dw}{d\theta}$ vs. MOISTURE CONTENT w
(From Reference 2)

supplied by radiation, then h_t is the sum ($h_c + h_r$) where h_r is the radiation coefficient and h_c is the convection coefficient, and t_s becomes higher than the wet-bulb temperature. A similar result occurs when heat reaches the surface of evaporation by convection and conduction.

Effect of Air Velocity. The principal effect of air velocity is on h_c and k_s , since the rate of transfer of heat and mass in the constant-rate period depends mainly on the rate of diffusion of heat and vapor through the air film at the surface of the solid, and air velocity is the chief factor affecting the thickness of this film. The influence of direction of air flow on the heat transfer coefficient h_c and on the corresponding drying rate $\frac{dw}{d\theta}$ is shown in Table 1.

Effect of Temperature or Humidity. Temperature or humidity enters the drying rate equation as a driving force across the air film. The wet-bulb depression, which is the difference between the dry-bulb temperature and the wet-bulb temperature, is directly proportional to the drying rate in this period. When dealing with heat transfer coefficients the wet-bulb