

tobacco and other farm crops, may be found in current issues of the *Agricultural Index*.¹⁰

SOLUTION OF TYPICAL DRYING PROBLEM

Since there are so many types of dryers which may be used, and so many special conditions surrounding each particular problem, it is usually recommended that those having experience with the dryer to be used be consulted. The following example, however, will serve as a guide for typical dryer calculations.

Example 2: Magnesium Hydroxide is to be dried from 82 percent moisture on bone dry basis to 4 percent moisture content on bone dry basis. The production rate is to be 3000 lb per hr on 4 percent bone dry basis. Previous experience indicates that a continuous single conveyor through-circulation dryer with a fin drum feed as illustrated in Fig. 9 should be used. The dryer is to be heated with steam at 50 psig. The optimum circulating air temperature is 160 F which is not limited by the existing steam pressure.

Step 1: Laboratory tests or previous experience indicate that the material enters the dryer at a temperature of 60 F, with an initial moisture content of 82 percent bone dry basis. The test drying time is 25 min and the final moisture content is 4 percent bone dry basis. The temperature of make-up air is 70 F dry-bulb and 60 F wet-bulb. The temperature of circulating air is 160 F dry-bulb and 100 F wet-bulb. The air velocity down through the preformed bed is 250 fpm, and the static pressure drop through the bed is 0.4 in of water. The dryer bed is to be loaded with 6.820 lb per sq ft of bone dry material. Depth of the bed is to be 4 in.

Step 2: Previous experience indicates that the commercial drying time is 70 percent greater than the test time obtained in the particular laboratory setup used.

Therefore, the commercial drying time = $1.7 \times 25 = 42.5$ min.

Step 3: In order to dry the desired 3000 lb per hr of material the holding capacity of the dryer is $3000 \times \frac{42.5}{60} = 2125$ lb at 4 percent bone dry basis.

The required conveyor area is $\frac{2125}{6.820} = 312$ sq ft. Assuming that a perforated plate conveyor with an 8 foot effective width is used, the length of the drying zone is $\frac{312}{8} = 39$ ft.

Step 4: The amount of water entering the dryer is $\frac{3000}{1.04} \times \frac{82}{100} = 2370$ lb per hr, while the amount of water leaving the dryer is $\frac{3000}{1.04} \times \frac{4}{100} = 115$ lb per hr. Thus, the evaporation rate in the dryer is $2370 - 115 = 2255$ lb per hr.

Step 5: Since the air circulation is perpendicular to the perforated plate conveyor, the total quantity of air that must be circulated equals the air velocity (based on the face area) multiplied by the conveyor area. Thus,

$$\text{Supply air} = 250 \times 312 = 78,000 \text{ cfm}$$

From Fig. 5 the humidity ratio of the supply air at 160 F dry-bulb, 100 F wet-bulb is 0.0285 lb per lb dry air. The specific volume of the supply air is 16.33 cu ft of moist air per lb of dry air, from Table 2 and Equation 27 of Chapter 3.

The quantity of dry air circulated is

$$\frac{78,000 \times 60}{16.33} = 286,500 \text{ lb per hr.}$$

Step 6: The amount of moisture pickup is $\frac{2255}{286,500} = 0.0079$ lb per lb of dry air.

The humidity ratio of the exhaust air is $0.0079 + 0.0285 = 0.0364$ lb per lb dry air.

Substitute in Equation 6 and solve for G , the mass velocity of dry air, to determine the required quantity of make-up air. The humidity ratio of the make-up air is 0.0086 lb per lb dry air, from Fig. 5.

$$G(0.0364 - 0.0086) = \left(\frac{3000}{1.04}\right)\left(\frac{82 - 4}{100}\right)$$

$$G = 81,000 \text{ lb dry air per hr.}$$

Therefore,

$$\text{Make-up air} = \frac{81,000}{286,500} = 28.2 \text{ percent.}$$

$$\text{Recirculated air} = 71.8 \text{ percent.}$$

Step 7: Heat Balance

$$\begin{aligned} \text{Sensible heat of material} &= M(t_{m2} - t_{m1})c_m \\ &= \frac{3000}{1.04} (100 - 60) 0.3 = 34,600 \text{ Btu per hr} \end{aligned}$$

$$\begin{aligned} \text{Sensible heat of water} &= Mw_1(t_w - t_{m1})c_w \\ &= 2370 (100 - 60) 1.0 = 94,800 \text{ Btu per hr} \end{aligned}$$

$$\begin{aligned} \text{Latent heat of evaporation} &= M(w_1 - w_2)H \\ &= 2255 \times 1037 = 2,338,400 \text{ Btu per hr} \end{aligned}$$

$$\begin{aligned} \text{Sensible heat of vapor} &= M(w_1 - w_2)(t_2 - t_w)c_v \\ &= 2255 (160 - 100) 0.45 = 60,900 \text{ Btu per hr} \end{aligned}$$

$$\begin{aligned} \text{Required heat for material} &= 2,528,700 \text{ Btu per hr} \end{aligned}$$

The temperature drop ($t_2 - t_1$) through the bed is

$$\frac{\text{Required heat}}{\text{Supply air, lb per hr} \times c_a} = \frac{2,528,700}{286,500 \times 0.24} = 37 \text{ deg}$$

Therefore, the exhaust air temperature is $160 - 37 = 123$ F

$$\begin{aligned} \text{Required heat for make-up air} &= G_T(t_2 - t_1)c_a \\ &= 81,000 (123 - 70) 0.24 = 1,030,300 \text{ Btu per hr.} \end{aligned}$$

The total heat required for material and make-up air is

$$2,528,700 + 1,030,300 = 3,559,000 \text{ Btu per hr.}$$

Additional heat must be provided for the radiation and convection losses, which may be calculated from the known construction of the dryer surfaces.

LETTER SYMBOLS USED IN CHAPTER 47

- A = area of heat transfer and evaporation, square feet per pound of material.
- a = drying area, square feet per cubic foot of bed volume.
- c_a = specific heat of air, Btu per (pound) (Fahrenheit degree).
- c_m = specific heat of material, Btu per (pound) (Fahrenheit degree).
- c_s = humid heat, Btu per (pound of dry air) (Fahrenheit degree).
- c_v = specific heat of water vapor, Btu per (pound) (Fahrenheit degree).
- c_w = specific heat of water, Btu per (pound) (Fahrenheit degree).
- d = diffusivity of the liquid or vapor, square feet per hour.
- D_p = average diameter of particle, feet.
- G = mass velocity of dry air, pounds per (hour) (square foot).
- G_T = dry air supplied as make-up air to the dryer, pounds per hour.
- H = enthalpy of evaporation of water at wet-bulb temperature, Btu per pound.
- h = film heat transfer coefficient, Btu per (hour) (square foot) (Fahrenheit degree).
- h_c = coefficient of heat transfer by convection, Btu per (hour) (square foot) (Fahrenheit degree).
- h_r = coefficient of heat transfer by radiation, Btu per (hour) (square foot) (Fahrenheit degree).
- h_i = total gas film heat transfer coefficient, Btu per (hour) (square foot) (Fahrenheit degree).
- k_t = gas film thermal conductivity, Btu per (hour) (square foot) (Fahrenheit degree per foot).
- k_s = mass transfer coefficient, pounds per (hour) (square foot) (atmosphere).
- L = one-half material thickness, feet.