

used in the laboratory tests should be identical to that which will be encountered in commercial operation. Otherwise the test results may not be an accurate indication of the drying characteristics of the commercial material.

In many cases where it is impracticable to run laboratory tests, commercial drying data are derived from the experience of the equipment manufacturer. This should not be overlooked since it can be an important source of data which would otherwise have to be obtained by less reliable methods.

Method 3, estimating drying time from the theoretical equations, should be used only as a last resort, on account of the approximate nature of the results.

### Commercial Drying Time

The first step in selecting a commercial dryer is to apply the estimated drying time to determine the size of the commercial machine necessary for a given capacity. If the drying time has been derived from laboratory tests it is necessary to consider the following factors:

1. In a laboratory dryer considerable drying may have been effected by radiation and conduction of heat to the material, whereas in a commercial dryer these factors are usually negligible.
2. Humidity conditions in a commercial dryer may be higher than in a laboratory dryer. For drying operations with controlled humidity, this factor can be eliminated by duplicating the commercial humidity condition in the laboratory dryer.
3. Operating conditions usually cannot be maintained as uniform in a commercial dryer as in a laboratory dryer.
4. Because of the relatively small sample used, the test material may not be representative of the material handled commercially.

In consideration of the preceding factors 1 to 4, it should be stressed that the test drying time must be corrected to suit commercial conditions. This is a matter of experience and judgment on the part of the designer.

### DRYER CALCULATIONS

To determine preliminary cost estimates for a commercial dryer it is usually necessary to make the following calculations:

**Circulating air.** The amount of circulating or supply air required is established by the optimum air velocity with reference to the material. This may be obtained from laboratory tests or previous experience, keeping in mind that there is also an optimum moisture pickup for the air, as explained in the section Application of Hygrometry to Drying.

**Make-up and Exhaust.** The amount of make-up and exhaust air required to maintain steady state conditions within the dryer is discussed under the section Application of Hygrometry to Drying. In any continuously operating dryer, the relation between moisture content of the material and quantity of make-up air is given by Equation 6

$$G_T(W_2 - W_1) = M(w_1 - w_2) \text{ where } W_2 \text{ is constant.} \quad (6)$$

where

- $G_T$  = dry air supplied as make-up air to the dryer, pounds per hour.
- $M$  = stock dried in a continuous dryer, pounds per hour.
- $W_1$  = humidity ratio of entering air, pounds of water vapor per pound of dry air.
- $W_2$  = humidity ratio of leaving air, pounds of water vapor per pound of dry air.
- $w_1$  = moisture content of entering material dry basis, pounds of water per pound.
- $w_2$  = moisture content of leaving material dry basis, pounds of water per pound.

In batch type dryers, the drying operation is given by Equation 7

$$G(W_2 - W_1) = M_1 \frac{dw}{dt} \quad (7)$$

where

$M_1$  = weight of material charged in a discontinuous dryer, pounds per batch.

$\frac{dw}{dt}$  = the instantaneous rate of evaporation corresponding to  $w$ .  $W_2$  is a variable during a portion of the cycle.

In actual practice the quantity of make-up air supplied is maintained constant and is based on the average evaporation rate. Equation 7 then become identical with Equation 6 where  $M = \frac{M_1}{\theta}$ . Under this condition the humidity in the batch dryer will vary from a maximum to a minimum during the drying cycle; whereas, in the continuous dryer the humidity at any given point is constant with constant load.

**Heat Balance.** In order to estimate the fuel requirements of a dryer it is usually necessary to make a heat balance, consisting of the following:

1. Radiation and convection losses from dryer.
2. Heating of the commercial dry material to the leaving temperature (usually estimated).
3. Vaporization of the water being removed from the material (usually considered to take place at the wet-bulb temperature).
4. Heating of the vapor from the wet-bulb temperature in the dryer to the exhaust temperature.
5. Heating of the total water in the material from the entering temperature to the wet-bulb temperature in the dryer.
6. Heating of the make-up air from its initial temperature to the exhaust temperature.

The energy absorbed by items 1 to 6 must be supplied by the fuel. The proper selection and design of the heating equipment is an important part of the over-all design of the dryer.

### DRYING METHODS AND EQUIPMENT

Drying systems are sometimes classified according to the method of heat transfer that is employed, since the entire problem of drying resolves itself into individual problems of heat transfer and the thermodynamics of air and water vapor. The methods of heat transfer are radiation, conduction and convection. Many types of dryers have been built on these principles for different purposes.

Drying systems can also be classified, according to the method of product handling, as batch operation, semi-continuous and continuous.

The method of supporting or transporting the material to be dried, efficiency of operation, cost of investment, and the method of applying heat to the material are to be considered in selecting the equipment. Usually the final selection is a compromise between mechanical design, heat efficiency, quality, and product loss.

A systematic procedure is often justified when selecting a dryer for a given process. A general procedure will consist of:

1. Survey of suitable dryers
2. Preliminary cost estimates of various types
  - a. Initial investment
  - b. Operating cost