

illustrated on the skeleton psychrometric chart Fig. 15. The case illustrated is typical of tunnel and rotary dryers where heat is applied to the air at one point only. After the first adjustment stage during which both the material and the dryer reach the working temperature, the only heat losses from the dryer are those of radiation and conduction from the housing and these are practically negligible for an insulated dryer. Hence, the drying process can be considered to be adiabatic.

If 100 per cent outside air is used, the air can be considered to enter at point A, Fig. 15, (the prevailing outside air condition) and be heated to point B (the maximum permissible temperature t_m or the temperature determined by previous test). As the air evaporates moisture, it cools along the constant wet-bulb line BD to point C. The difference between the moisture content of air at B and at C represents the moisture *pick up* of the air. The maximum possible *pick up* from B to D is never achieved in practical dryers; the actual *pick up* being anywhere from 10 to 75 per cent of the maximum.

In order to conserve heat and to control the wet-bulb temperature at

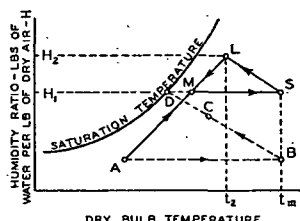


FIG. 15. CHANGES IN AIR DURING DRYING PROCESS

which the drying takes place, recirculation is used. The process is shown on Fig. 15. The outside air at A is mixed with recirculated air until the moisture level is raised to the desired point. The mixture is represented at point M, the heaters heat the mixture to the desired dry-bulb temperature t_m at point S. The moisture is picked up from S to L. Point L is the condition at which air is exhausted.

Actual dryer operation is somewhat more complicated because even if radiation and conduction losses are neglected, the wet-bulb temperature of the air remains constant only as long as surface evaporation of water is taking place. When sub-surface evaporation is occurring, some heat from the air is used to heat the material and hence there is a drop in wet-bulb temperature. Fig. 16 illustrates the drying process in a tunnel dryer in which the air is flowing parallel to the product.¹

In design calculations using Equation 6, the following steps outline the procedure:

1. The unit drying rate, pounds of water per hour, is determined from the experimental drying time curve and the amount of product to be dried per hour. The drying time may also be approximated from previous experience.
2. The experimental data or experience also determine the drying condition, i.e., point L Fig. 15. This fixes H_2 . Where experimental data are lacking L may be approximated from Regain Tables (see chapter Industrial Air Conditioning) since the relationship between the vapor pressure in the product and in the air at equilibrium for the desired final moisture content must prevail in the dryer. The dryer temperature must be not greater than the maximum permissible product temperature.

Drying Systems

3. The rate of air circulation G must be determined and also the supply air condition S. In the design of some dryers such as rotary or tunnel types, it is customary to determine S first and then to calculate the air rate G. In other types of dryers, such as tray dryers or through circulation dryers where a fixed air velocity is maintained, G is calculated first and then point S is found. Because of the many variables involved, it is generally not possible to select S except on the basis of past experience or on the basis of experimental drying tests.

4. The prevailing outside air conditions establish point A and hence the line A L. The per cent of recirculated air can then be calculated.

5. The physical arrangement of the dryer must then be selected to handle the desired quantity of product and at the same time circulate the calculated air quantity at the desired velocity.

6. Equation (6) can then be used to calculate the heat requirements.

TYPICAL SOLUTION OF 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.²

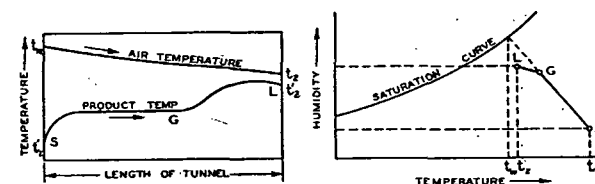


FIG. 16. TEMPERATURE AND MOISTURE CONDITIONS IN A TUNNEL DRYER
Parallel Flow Air and Product

Example 1. Assume 900 lb per hour of ceramic powder is to be produced. The powder has a specific heat of 0.22 and density of 98 lb per cu ft, wet. Initial moisture content is 19 per cent on a wet basis; final moisture content is to be one-half of one per cent on a wet basis.

A continuous belt dryer is a logical choice and previous experience indicates that rubber belts will withstand temperatures up to 200 F which is also about the highest desirable product temperature. Experience also indicates that a drying time of 45 min is possible at about 160 F dry-bulb and 100 F wet-bulb.

Step 1: Let x = pounds moisture at final condition.

$$\text{Then, } \frac{x}{900} = 0.005$$

$$\text{or, } x = 4.5 \text{ lb moisture}$$

and therefore the solid will amount to 895.5 lb.

Likewise the weight of the initial moisture x can be found

$$\text{from } \frac{x}{895.5 + x} = 0.19$$

$$\text{or } x = 210 \text{ lb.}$$

The weight of moisture to be removed is 205.5 lb per hour and wet material entering dryer is 1105.5 lb per hr.

Step 2: Previous tests indicate that a $\frac{1}{4}$ in. layer of powder gives satisfactory results, and that a desirable air velocity is 50 fpm applied at a right angle to the belt. Based on 45 min ($\frac{3}{4}$ hr) drying time, the dryer holding capacity will have to be