

Despite the fact that the sensible heat loss increases with the rise in temperature of the air, the percentage of heat lost from this source decreases, provided the increase in moisture carrying capacity of the air, due to high temperature, is actually utilized. To secure maximum thermal efficiency in drying, a high drying temperature and high saturation of the outlet air is imperative.

The Ventilation Phase

The technique of attack of the *ventilation phase* of a drying problem is best made clear by an illustration. Assume that a material containing 40 per cent moisture is to be dried until this quantity of moisture is reduced to 5 per cent by weight. The material will stand an air temperature of 150 F and it is possible to provide sufficiently good contact between the material and the drying air so that the effluent air can be brought up to 50 per cent humidity at 150 F. The dryer is to use room air, the temperature and humidity of which may be assumed to average 70 F and 50 per cent. A counter-current dryer will be employed and the air in this dryer will be kept at a substantially constant temperature of 150 F by heaters thermostatically controlled. The stock enters at 70 F, rises quickly to the wet-bulb temperature of the air, with which it is in contact, and is found experimentally to maintain wet-bulb temperature until the moisture content has fallen to 20 per cent. From this point its temperature rises progressively as it dries. In this range the difference in temperature between stock and air, divided by the wet-bulb depression, may be assumed proportional to the moisture content.

The moisture content of the entering stock, in the units here employed, is:

$$w_1 = \frac{40 \text{ per cent water}}{60 \text{ per cent dry stock}} = 0.6667; w_2 = \frac{5 \text{ per cent water}}{95 \text{ per cent dry stock}} = 0.0527$$

$w_1 - w_2 = \Delta w = 0.614$ lb water evaporated per pound of dry stock. Since the air leaving the dryer is 50 per cent saturated at 150 F from Fig. 3, $H_2 = 0.105$. Similarly, $H_1 = 0.008$, corresponding to 50 per cent humidity at 70 F. Consequently $H_2 - H_1 = \Delta H = 0.097$ lb water evaporated per pound dry air.

Inspection of equation (1) shows that (H) is linear in w . Hence, one can construct on Fig. 4, the line marked (H) being drawn connecting the initial and final points just computed.

Since the air leaving the dryer has a temperature of 150 F and a humidity of 0.105, Fig. 3 shows that its wet-bulb temperature is 129 F. This is plotted at the right hand side of Fig. 4. Since the stock maintains a wet-bulb temperature down to 20 per cent moisture, where $w = 0.25$, the corresponding humidity can be computed by the use of equation (1) or by reading directly from the diagram, the value being 0.0392. Fig. 3 shows that the corresponding wet-bulb temperature is 105 F. Any intermediate point on the wet-bulb temperature curve can be calculated similarly. The points for $w = 0.5$ are shown in Fig. 4.

Below the point, $w = 0.25$, the temperature of the stock begins to rise appreciably above the wet-bulb temperature. Its temperature at any given point in this range, for example at $w = 0.15$, may be computed as follows: At this point, $H = 0.0234$ (from equation (1)) and from Fig. 3, $t_w = 95$ F. Hence the wet-bulb depression, $t - t_w = 150 - 95 = 55$ F.

The assumption made regarding the relation between stock temperature and moisture content in this range may be formulated:

$$\frac{\Delta t'}{t - t_w} = \frac{w}{0.25}$$

At the point $w = 0.15$, $\Delta t' = 33$ F, $t' = 117$ F. The temperature of the stock leaving the dryer, similarly computed, is 136 F.

Fig. 4 thus computed gives in graphical form the information as to the temperature humidity relationships in the dryer. The air requirements can be computed by equation (1). Thus, per 100 lb of dry stock, it is necessary to supply 633 lb of dry air. Furthermore, since from Fig. 3 it is seen that the volume of 50 per cent saturated air at 70 F, is 13.55 cu ft per lb, 8580 cu ft of room air must be supplied per 100 lb dry stock.

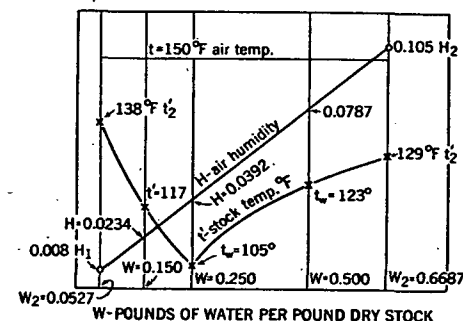


FIG. 4. CHART SHOWING TEMPERATURE-HUMIDITY RELATIONSHIP IN A DRYER

Similarly, since the volume of 50 per cent saturated air at 150 F is 18.0 cu ft per pound, the volume of hot wet air discharged from the dryer is 11,400 cu ft per 100 lb of dry stock. Finally, the heat necessary to supply to the dryer; as a whole, or to any section of it, may be computed from equation (2).

Estimating Method

Estimating methods are often used, especially where approximate figures are desired and time does not permit of more elaborate figures. Such methods are really the result of practical experience and are of value only in proportion to the experience of the user. There are, however, certain of these short cuts which are of value.

The temperature will drop approximately $8\frac{1}{2}$ F per grain of water evaporated per cubic foot of air (measured at 70 F) or approximately 0.62 F per lb of air at any temperature. Air will drop 55 F per cubic foot for each Btu extracted. Generally air will absorb from 2 grains to 5 grains per cubic foot of air in one passage through an air dryer, depending on the temperature and the degree of contact with the material. The amount of steam required to evaporate a pound of water will vary from $1\frac{1}{2}$ lb to a more usual figure of from $2\frac{1}{2}$ to 3 lb of steam per pound of water evaporated.