APPLICATION OF HYGROMETRY TO DRYING

In analyzing any particular drying problem it is sometimes advisable to consider the thermodynamic changes involving the drying medium, since in most cases the drying medium is an air-water vapor mixture. The thermodynamic process can be traced on a psychrometric chart.

The psychrometric chart, Fig. 5, suggested by Grosvenor,[6] is suitable for most drying calculations. The adiabatic cooling lines on the chart indicate the paths along which the changes in the thermodynamic properties of the air occur in an adiabatic dryer.

The theoretical ability of air to pick up moisture corresponds to the difference between the final saturation content at the wet-bulb temperature (approximately the adiabatic cooling temperature or thermodynamic wet-bulb temperature) and the initial moisture content at the supply air dew point. The maximum possible pickup is never achieved in practical dryers because on the basis of good design, this would be undesirable. Experience has shown that there is an optimum pickup which is a function of the

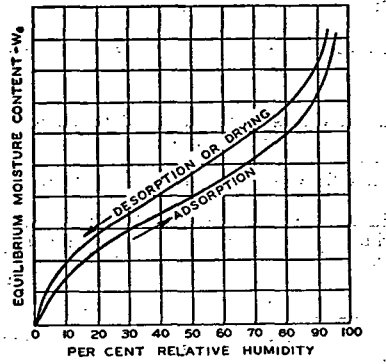

FIG. 4. TYPICAL EQUILIBRIUM MOISTURE CONTENT CURVES[1]

independent drying variables and is less than the maximum theoretical value as obtained from the psychrometric chart.

It should be noted that in practice the process will not necessarily follow exactly the adiabatic cooling line since there may be a transfer of heat to the tray or conveyor itself.

Use of the psychrometric chart for analyzing drying problems is illustrated by Example 1.

Example 1: Assume a dryer having a capacity of 100 lb of gelatin per hour at 11.1 percent bone dry basis. The initial moisture content is 228 percent bone dry basis and the final moisture content is to be 32 percent bone dry basis. The rate of production of bone dry gelatin is 90.5 lb per hr. Supply air is available at 120 F dry-bulb, 85 F wet-bulb, with make-up air at 80 F dry-bulb and 65 F wet-bulb. Air is exhausted from the dryer at 100 F dry-bulb and 84.5 F wet-bulb.

Find (1) the required amount of make-up and exhaust air, and (2) the percentage of recirculated air.

Solution: Refer to psychrometric chart, Fig. 5, and obtain the humidity ratio of the make-up air and of the exhaust air. In order to maintain a steady state condition in the dryer the water which is evaporated from the material must be carried away by the exhaust air. Therefore, the difference between the humidity ratio of the exhaust air and that of the make-up air (known as pickup) is equal to the water

evaporated from the material divided by the pounds per hour of dry air in the exhaust.

Step 1: The moisture in exhaust air at 100 F dry-bulb and 84.5 F wet-bulb is found to be 0.022 lb per pound of dry air. The moisture in make-up air at 80 F dry-bulb and 65 F wet-bulb is found to be 0.010 lb per pound of dry air. Therefore the moisture pickup is 0.022–0.010, or 0.012 lb per pound of dry air.

The amount of water evaporated in the dryer = 90.5 (2.28 − 0.32) = 177 lb per hr.

The weight of dry air, make-up and exhaust, required to remove the water of evaporation = $\frac{177}{0.012}$ = 14,750 lb of dry air per hour.

Step 2: Let x = percentage of recirculated air and $100 - x$ = percentage of make-up air.

Then $\frac{x}{100}$ (humidity ratio of exhaust and recirculated air) + $\frac{100 - x}{100}$ (humidity ratio of make-up air) = humidity ratio of supply air. Hence, $\frac{x}{100}$ (0.022) +

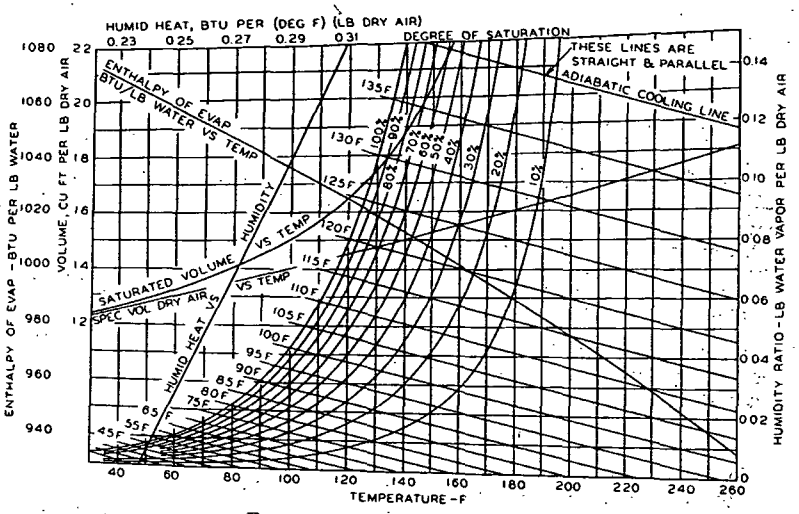

FIG. 5. PSYCHROMETRIC CHART[6]

$\frac{(100 - x)}{100}$ (0.010) = 0.018 at 120 F dry-bulb, 85 F wet-bulb, or x = 66.7 percent recirculated air and therefore the required make-up air = 33.3 percent.

DETERMINATION OF DRYING TIME

In most drying problems it is necessary to obtain the drying time of a particular material. Three methods are listed below in order of preference.

1. Conduct tests in a laboratory dryer simulating conditions in the commercial machine, or obtain performance data directly from the commercial machine.
2. If the specific material is not available, obtain drying data on similar material by either of the above methods. This is subject to the experience and judgment of the investigator.
3. Estimate drying time from the theoretical equations which have been considered under Mechanism of Drying.

In designing commercial equipment the usual procedure is to conduct tests in a laboratory dryer in which commercial operating conditions are simulated. A representative sample of the physical form of the material