The following nomenclature and explanation of terms will be used in the discussion of drying calculations:

H = humidity of air, pounds of water-vapor per pound of dry air.
G = pounds of dry air supplied to the dryer per unit of time.
S = pounds of stock dried per unit of time in a continuous dryer.
S' = pounds of stock changed per batch to a discontinuous dryer.
Θ = time.
Q = total heat supplied to the dryer.
t = air temperature.
t' = stock temperature.
t'' = average stock temperature over short-time interval, in a batch dryer.
t_w = wet-bulb temperature.
s' = specific heat of the stock.
B = total radiation and conduction losses per unit time.
w = pounds of water per pound of dry stock.
r = heat of evaporation of water.
s = humid heat of air, *i.e.*, heat necessary to raise 1 lb. of dry air + H lb. of steam 1 deg.

Subscript 1 designates conditions at the point where the material in question (air or stock) enters and 2 where it leaves the dryer.

Air dryers may be divided into two classes, those in which *all moisture* evaporated from the stock *leaves the dryer as vapor* in the effluent air, and those in which *part or all* of the moisture *is condensed* from the air *in the drying equipment itself*. In any continuously operating dryer of the first type the relation between moisture content of the stock and quantity of air required for the drying operation is given by the equation:

$$G\,(H_2 - H_1) = S\,(w_1 - w_2) \qquad (1)$$

In discontinuous dryers, *e.g.*, compartment dryers, the drying operation is given by the equation:

$$G\,(H_2 - H_1) = S'\,\frac{dw}{d\Theta} \qquad (1_a)$$

In the continuous dryer, the heat consumption per unit time is:

$$\frac{Q}{\Theta} = Gs_1\,(t_2 - t_1) + G\,(r_2 + t_2 - t'_2)\,(H_2 - H_1) + S\,(t'_2 - t'_1)\,(s' + w_1) + B \qquad (2)$$

Equation (2) assumes continuity of operation. For charge or batch operations, the total time of the drying cycle may be broken up into a number of periods, sufficiently short so that over each period average values of t, t' and H may be employed provided the third term of the right-hand member of the equation is modified to read:

$$S'\,(t''_2 - t''_2)\,(s' + w_1),$$

and in the second term t'_2 be replaced by

$$\frac{t'_1 + t''_2}{2}$$

Theoretically these periods should be very short and the equation integrated. Practically the error introduced by using a small number of long periods and employing average values of the variables over each

rarely introduces serious error. The evaluation of equation (1_a) may be approximated in a similar manner.

The first term of the right-hand member of equation (2) represents heat lost as sensible heat in the effluent air. In many drying operations this becomes excessive. Each pound of air supplied should remove the maximum amount of moisture. This is best accomplished by bringing the air into contact with the stock with sufficient intimacy so that the air leaving the dryer is saturated or nearly so. Counter-current as against parallel flow of air and stock gives rise to optimum operating conditions, resulting in a minimum quantity of air required, (G), and a corresponding minimum loss, as sensible heat, in the exit air. Similarly, continuous operation is superior to intermittent operation.

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

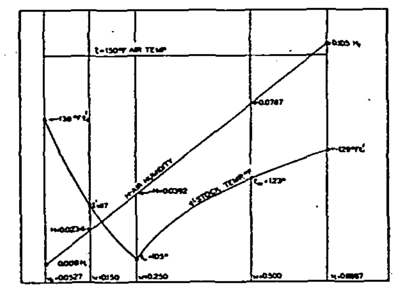

FIG. 5. CHART SHOWING TEMPERATURE-HUMIDITY RELATIONSHIPS IN A DRYER

efficiency in drying a high outlet air temperature and saturation 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 deg. fahr. and it is possible to provide sufficiently good contact between the material and the drying air that the effluent air can be brought up to 50 per cent humidity at 150 deg. The dryer is to use room air, the humidity and temperature of which may be assumed to average 70 deg. fahr. 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 deg. fahr. by heaters thermostatically controlled. The stock enters at 70 deg. fahr., rises quickly to the wet-bulb temperature of the air with which it is in contact and is found experimentally to maintain wet-bulb conditions until the moisture content has fallen to