

effect is usually less than one per cent. This error depends upon the temperature and velocity of air movement, and the relationship of this error to these factors is shown in a paper entitled *The Temperatures of Evaporation of Water into Air*, presented by W. H. Carrier and D. C. Lindsay, before the *American Society of Mechanical Engineers* in 1924.

From the foregoing, the following fundamental principles in air conditioning may be evolved:

1. When dry air is saturated adiabatically the temperature is reduced as the absolute humidity is increased, and the decrease of sensible heat is exactly equal to the simultaneous increase in latent heat due to evaporation.

2. As the moisture content of air is increased adiabatically, the temperature is reduced simultaneously until the air is saturated, when no further heat metamorphosis is possible. This ultimate temperature may be termed the temperature of adiabatic saturation.

3. When an insulated body of water is permitted to evaporate freely in the air, it assumes the temperature of adiabatic saturation of that air and is unaffected by convection, i.e., the true wet-bulb temperature of air is identical with its temperature of adiabatic saturation.

4. The true wet-bulb temperature of the air depends entirely on the total of the sensible and the latent heat in the air and is independent of their relative proportions. In other words, the wet-bulb temperature of the air is constant, providing the total heat of the air is constant.

It will be obvious in considering the foregoing process, that a formula relating the latent heat change to the sensible heat change establishes the relationship of this theoretical wet-bulb temperature to the temperature and moisture of the air. This was first pointed out by W. H. Carrier in the Rational Psychrometric Formula:

$$r^1 (W^1 - W) = C_{pa} (t - t^1) + C_{ps} W (t - t^1) \quad (3)$$

in which

$(t - t^1)$ = the true wet-bulb depression.

$(W^1 - W)$ = the moisture absorbed per pound of pure air when it is adiabatically saturated from an initial dry-bulb temperature t_0 and an initial moisture content W .

C_{pa} = mean specific heat of air at constant pressure between temperature t and t^1 .

C_{ps} = specific heat of steam at constant pressure between t and t^1 .

r^1 = latent heat of evaporation at wet-bulb temperature t^1 .

Knowing any two of the three important values of t , t^1 or W , the third may be solved.

This is an exceedingly useful relationship, not only in air conditioning and the drying of materials but in the psychrometry of air or other gases to which it directly applies. It is evident that if the wet-bulb temperature of air of a known dry-bulb temperature but unknown moisture content be determined experimentally with the wet-bulb thermometer, it will be possible to calculate directly the moisture content of that air from the relationship.

From equation (3) a psychrometric chart in common use has been evolved. (See Figs. 1, 2, 3, 4, 5, Chapter 3, and Fig. 4, Chapter 29). This is most useful in all problems pertaining to air conditioning, drying, and in the determination of the moisture content of air.

A formula has also been derived which will permit the approximate

calculation of the vapor pressure from the wet-bulb temperature observation. This is useful particularly in determining relative humidities for conditions other than the standard barometric conditions for which the chart is made. The formula for expressing this relationship is:

$$e = e^1 - (P - e^1) (t - t^1) 2,800 - 1.3t^1 \quad (4)$$

where

e = partial pressure of the moisture in the air, which also equals vapor pressure corresponding to the dew point.

e^1 = the vapor pressure corresponding to saturation at wet-bulb temperature t^1 .

P = the barometric pressure.

t = dry-bulb temperature in deg. fahr.

t^1 = wet-bulb temperature in deg. fahr.

Total Heat

In cooling and dehumidifying air, it is necessary to take into consideration not only the sensible heat of the air itself but the latent heat of the moisture removed.

Air at any temperature and moisture content may be considered as having a certain definite total heat in thermal units per unit weight as calculated from some arbitrary base, such as zero moisture and zero temperature. By using the psychrometric chart, on which are given wet-bulb temperatures and corresponding total heats, it is possible to determine the total heat to be removed in the process of dehumidification by subtracting the total heat of the cooled air with its reduced moisture content from that of the air in its initial condition as indicated on the chart.

This process is simplified greatly by taking into account the fourth psychrometric principle, by observing the fact that the wet-bulb temperature of the air may be used as the measure of the total heat which the air contains. Thus, by referring to the chart, having given air of known temperature and known moisture content, a corresponding wet-bulb temperature is obtained. Then, under standard barometric conditions, the quantity desired is determined by reference to the curve of total heat. For example, air at $85\frac{1}{2}$ deg. with 80 per cent relative humidity has exactly the same total heat as air at 101 deg. and 40 per cent relative humidity, because in both cases the wet-bulb temperature is 80 deg. This wet-bulb temperature represents about the maximum wet-bulb temperature ever encountered in the Temperature Zones under extreme conditions, and is nearly the maximum found in the Tropics. A normal high wet-bulb temperature for the Temperature Zone may be taken at 75 deg. in calculating requirements for air cooling, as this is seldom exceeded, except for short periods.

Relation of Dew-Point to Relative Humidity

A peculiar relationship exists between the dew-point and the relative humidity and this is found most useful in air conditioning work. This is, that for a fixed relative humidity there is substantially a constant difference between the dew-point and the dry-bulb temperature over a considerable temperature range. The following table giving the room