mixed with the dry air is superheated, *i.e.*, if its temperature is above the temperature of saturation for the actual water vapor partial pressure, the air is not saturated.

The starting point of most applications of thermodynamic principles to air conditioning problems is the experimental determination of the dry-bulb and wet-bulb temperatures, and sometimes the barometric pressure.

The *dry-bulb temperature* of the air is the temperature indicated by any type of thermometer not affected by the water vapor content or relative humidity of the air. The *wet-bulb temperature* is determined by a thermometer with its bulb encased in a fine mesh fabric bag moistened with clean water and whirled through the air until the thermometer assumes a steady temperature. According to the theory of W. H. Carrier[2], this steady temperature is the result of a dynamic equilibrium between the rate at which heat is transferred from the air to the water on the bulb and the rate at which this heat is utilized in evaporating moisture from the bulb. The rate at which heat is transferred from the air to the water is substantially proportional to the wet-bulb depression $(t - t')$, while the rate of heat utilization in evaporation is proportional to the difference between the saturation pressure of the water at the wet-bulb temperature and the actual partial pressure of the water vapor in the air $(e' - e)$. Carrier's equation for this dynamic equilibrium is:

$$\frac{e' - e}{t - t'} = \frac{B - e'}{2800 - 1.3t'} \tag{2a}$$

In the form commonly used,

$$e = e' - \frac{(B - e')\,(t - t')}{2800 - 1.3t'} \tag{2b}$$

where

e = actual partial pressure of water vapor in the air, inches of mercury.
e' = saturation pressure at wet-bulb temperature, inches of mercury.
B = barometric pressure, inches of mercury.
t = dry-bulb temperature, degrees Fahrenheit.
t' = wet-bulb temperature, degrees Fahrenheit.

The derivation of Equation 2a was based upon the theory, supported by extensive experiments with atmospheric air, that the wet-bulb temperature and the temperature of adiabatic saturation (see page 11) are identical. Subsequent study and experiment[3,4,5] have shown that these temperatures are very nearly the same for air and water-vapor mixtures in the proportions and temperature range of normal atmospheric air, but that they differ widely for mixtures of dry air and vapors other than water, and for air-water mixtures at high temperature or vapor content.

It is now recognized that the wet-bulb temperature is influenced, not

[2]Rational Psychrometric Formulae, by W. H. Carrier (*A.S.M.E. Transactions*, Vol. 33, 1911, p. 1005).
[3]The Evaporation of a Liquid into a Gas—a Correction, by W. K. Lewis (*Mechanical Engineering*, September, 1933).
[4]The Theory of the Psychrometer, by J. H. Arnold (*Physics*, July, September, 1933).
[5]The Deviation of the Actual Wet-Bulb Temperature from the Temperature of Adiabatic Saturation, by David Dropkin (Cornell University *Engineering Experiment Station Bulletin*, No. 23, July, 1936).

only by the rate of heat transfer by convection from air to wet-bulb, but also by the rate of heat conduction through the thin film of stagnant air that clings to the wet-bulb, and by the rates of outward diffusion of vapor through the air film and of convection of vapor away from the film. Thus, there is no theoretical foundation for the equality of wet-bulb and adiabatic-saturation temperatures; rather, it is by mere chance that in atmospheric air the ratio of the heat transfer and vapor transfer coefficients is such as to make these temperatures substantially equal. In accordance with current air conditioning practice, they are assumed to be equal in the psychrometric equations and chart presented in the 1939 Guide.

Formula 2b may be used to determine the actual partial pressure of the water vapor in a dry air-water vapor mixture. Then, from Dalton's Law of Partial Pressures, Equation 1, it follows that the partial pressure of the dry air is $(B - e)$.

If a mixture of dry air and water vapor, initially unsaturated, be cooled at constant pressure, the temperature at which condensation of the water vapor begins is called the *dew-point temperature*. Clearly the dew-point is the saturation temperature corresponding to the actual partial pressure, e, of the water vapor in the mixture.

AIR PROPERTIES

Density is variously defined as the mass per unit of volume, the weight per unit of volume, or the ratio of the mass, or weight, of a given volume of a substance to the mass, or weight, of an equal volume of some other substance such as water or air under standard conditions of temperature and pressure. The term *specific gravity* is more commonly used to express the latter relation but, when the gram is taken as the unit of mass and the cubic centimeter as the unit of volume, density and specific gravity have the same meaning. The term *specific density* is sometimes used to distinguish the weight in pounds per cubic foot; and as here used, *density* is the weight in pounds of one cubic foot of a substance.

The density of air decreases with increase in temperature when under constant pressure. The density of dry air at 70 F and under standard atmospheric pressure (29.921 in. of Hg.) is approximately 0.075 lb (see Table 1), while that of a mixture of air and saturated water vapor at the same temperature and barometric pressure is only about 0.0742 lb. In the mixture the density of the dry air is 0.07307 and that of the vapor is 0.00115 lb (see Table 2).

In order to make comparisons of air volumes or velocities it is necessary to reduce the observations to a common pressure and temperature basis. The basic pressure is usually taken as 29.921 in. of Hg., but no basic temperature is universally recognized. Common temperatures for this purpose are 32 F, 60 F, 68 F, and 70 F. Since 70 F is the most commonly specified temperature to which rooms for human occupancy must be heated, it is usually understood, when no other temperature is specified, that 70 F is the basic temperature for measuring the volume or the velocity of air in heating and ventilating work.

The *specific volume* of air is the volume in cubic feet occupied by one pound of the air. Under constant pressure the specific volume varies inversely as the density and directly as the absolute temperature.