gas is heated or cooled at constant pressure, the volume V varies as the absolute temperature T. Stated mathematically,

$$\frac{P}{T} = \text{constant} \quad \text{(volume constant)} \tag{10}$$

$$\frac{V}{T} = \text{constant} \quad \text{(pressure constant)} \tag{11}$$

Boyle's Law and Charles' Law may be combined to form the equation of state for the ideal or perfect gas,

$$PV = RT \tag{12}$$

where

R is a constant whose value depends on the units selected for P, V, and T.

Dalton's Rule. Dalton stated that each gas in a mixture occupies the total volume of the mixture just as though the other gases were not present. Gibbs later expanded this statement for perfect gases into the following principles:

1. The pressure of a mixture of gases is the sum of the partial pressures of the individual gases when they exist at the total volume and temperature of the mixture.
2. The internal energy, enthalpy, and entropy of a mixture of gases are respectively equal to the sums of the individual internal energies, enthalpies, and entropies of the components when they exist at the total volume and temperature of the mixture.

While these relationships do not hold exactly for all systems of real gases, they may be used with a good degree of precision for many engineering applications at low pressures. Moreover, since water vapor very closely follows the perfect gas relationships in the range usually encountered in air conditioning, the Gibbs-Dalton Rule may frequently be applied to mixtures of dry air and water vapor.

Thus,

$$V_m = V_a = V_w \tag{13}$$

$$T_m = T_a = T_w \tag{14}$$

$$p_m = p_a + p_w \tag{15}$$

$$m_m h = m_a h_a + m_w h_w \tag{16}$$

where

Subscript m denotes mixture; subscript a denotes dry air; subscript w denotes water vapor.

Symbol m = weight of dry air crossing any duct section, pounds per minute.

Using Equations 12, 13, 14, and 15, the relation is obtained as follows:

$$v_T = \frac{n_a RT}{p_a} = \frac{n_w RT}{p_w} = \frac{(n_a + n_w)RT}{p} \tag{17}$$

where

v_T = total volume, cubic feet.

n_a = number of mols of dry air.

n_w = number of mols of water vapor.

R = universal gas constant, 1545 foot-pounds per (Fahrenheit degree) (mol).

p_a = partial pressure of dry air.

p_w = partial pressure of water vapor.

T = absolute temperature, Fahrenheit degrees.

The partial pressure of water vapor in the mixture is then

$$p_w = \frac{n_w}{n_a + n_w} p \tag{18}$$

or, the partial pressure of the water vapor in moist air is equal to the product of the mol fraction of the water vapor and the observed pressure of the mixture. A similar expression is obtained for the dry air.

Assuming that the perfect gas laws can be applied to water vapor at saturation at low pressures, the partial pressure of water vapor in a *saturated* mixture may be written as

$$p_s = \frac{n_s}{n_a + n_s} p \tag{19}$$

where

n_s = number of mols of water vapor at saturation.

The relative humidity may be obtained by combining Equations 18 and 19 and solving for the ratio of mol fractions. Thus, using perfect gas relationships,

$$\phi = \frac{p_w}{p_s} \tag{20}$$

The humidity ratio W may be obtained from Equation 17:

$$W = \frac{18.016}{28.966} \frac{p_w}{p_a} = 0.622 \frac{p_w}{p - p_w} \tag{21}$$

where 18.016 and 28.966 are the molecular weights of water and dry air, respectively.

Equation 16 may be rewritten as

$$h = h_a + Wh_w \tag{22}$$

where

h = enthalpy, Btu per pound of dry air.

In relating the enthalpy to the state of the moist air, the fact that in all applications only differences in enthalpy are involved, allows the arbitrary selection of a datum or zero enthalpy point. Accordingly, from perfect gas relationships, it is possible to write for any temperature of t, Fahrenheit greater than 0 F

$$h_a = 0.24\, t \tag{23}$$

where it is assumed that the same arbitrary datum of 0 F is used as in determining the properties of moist air in Table 2.

Tabs of Thermodynamic Properties of Moist Air

Research work conducted at the *University of Pennsylvania* and at other institutions has shown that the Gibbs-Dalton Rule is inaccurate in varying degrees, depending on temperature, pressure and the amount of water