Values in Table 9 are intended to aid in determining the density of saturated air at different pressures. Values for temperatures and pressures other than those listed can be obtained by linear interpolation which is aided by the next to last column of figures. Thus, at 100 F, 29.921 in. Hg, the density of saturated air is, from Table 9, 0.06818 + (4.21 × 0.00024) = 0.06919 lb per cubic foot, in approximate agreement with Table 6.

A column of figures is included in Table 9 giving the approximate average increase in density per degree wet-bulb depression. This makes it easy to calculate a value for the density of moist air taking into account its moisture content as well as its temperature and pressure.

Volume Chart

A volume chart drawn for a total pressure of 29.921 in. Hg will be found in the envelope attached to the inside back cover of this book. On this chart values of volume per pound of dry air v are plotted as abscissa against values of humidity ratio W as ordinate. The chart is self-explanatory.

Enthalpy

Thermodynamically, Equation 10a implies that the specific enthalpies of dry air and water vapor are independent of pressure and that the enthalpy of moist air (per pound of dry air) is the sum of separate contributions from the dry air and water vapor according to the simple equation

$$h = h_a + \mu\,(W_s h_w) \tag{18}$$

Equation 18 is also linear in degree of saturation μ and of the form

$$h = h_a + \mu\, h_{as} \tag{19}$$

where h_a denotes the specific enthalpy of dry air at the given temperature and total pressure; and h_{as} denotes the difference between this and the enthalpy of the saturated mixture per pound of dry air h_s. Provisional values are listed in Table 6.

Example 9. Find the enthalpy (per pound of dry air) of air at 96 F, 60 per cent saturation and 29.921 in. Hg.

Solution. Using Table 6, $h = 23.04 + (0.60 \times 41.58) = 47.99$ Btu per pound dry air.

Thermodynamic Wet-bulb Temperature

If liquid (or solid) water be injected into an air stream it will evaporate and thus increase the humidity ratio of the air. Enough water may be injected to saturate the air. If the process is one of steady flow with *observed pressure constant*; if it is *adiabatic*; and if the temperature at which the air reaches saturation *coincides* with the temperature of the liquid (or solid) as added; then the common temperature is called *thermodynamic wet-bulb temperature*. This lengthy definition is easily visualized by referring to Fig. 1 in which h'_w denotes the specific enthalpy of the liquid (or solid) as injected.

The process being adiabatic, weight and energy accountings give

$$h_1 + (W_s - W_1)\, h'_w = h_s \tag{20}$$

If the temperature of the saturated air at the leaving section *coincides* with that of the injected liquid (or solid), then W_s, h'_w and h_s are functions of a single temperature t' which can therefore be determined by solving

(20). This is the thermodynamic wet-bulb temperature corresponding to conditions at the entering section.

Example 10. Find the thermodynamic wet-bulb temperature of dry air at 80 F and 29.921 in. Hg.

Solution. Using Table 6, the equation to be solved is $19.19 + (W_s - 0)\, h'_w = h_s$.

A trial value is obtained by ignoring the small quantity $(W_s - 0)\, h'_w$; it is 48 F corresponding to $h_s = 19.19$ Btu per pound dry air. A final value of 48.26 F is then obtained from $h_s = 19.19 + (0.007072 \times 16.1) = 19.30$ Btu per pound dry air.

Example 11. Find the degree of saturation of moist air at 90 F dry-bulb, 70 F wet-bulb and 29.921 in. Hg.

Solution. Using Table 6, the equation to be solved is $(21.59 + 34.11\,\mu) + (0.01574 - 0.03102\mu) \times 38.0 = 33.96$ from which

$$\mu = 11.77 \div 32.93 = 0.357 \text{ or } 35.7 \text{ per cent.}$$

It is important to note in connection with Equation 20 that the enthalpy per pound dry air is not constant along a line of constant thermodynamic wet-bulb temperature on account of the term $(W_s - W_1)\, h'_w$. In rough calculations, however, it is usually legitimate to ignore this term.

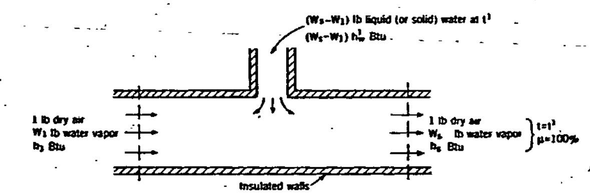

FIG. 1. DIAGRAM ILLUSTRATING THERMODYNAMIC WET-BULB TEMPERATURE

Thermodynamic wet-bulb is an important property of moist air because it is approximately the temperature indicated by the wet-bulb psychrometer. This instrument consists of a thermometer with its bulb covered with gauze moistened with clean liquid water. It is whirled through the air until the thermometer reads a steady temperature. At this point, the temperature of the liquid evaporating from the wetted surface has adjusted itself so that the air immediately in contact with the liquid is brought to saturation at the same temperature. Unfortunately, the mixing taking place beyond the liquid surface is not adiabatic; for one reason because the wet-bulb *sees* objects at dry-bulb temperature and considerable heat is transferred by radiation. Also there are other reasons why the readings of the psychrometer depend upon the design of the instrument, the velocity of the air stream in which it is placed, and other factors. Therefore wet-bulb temperature as indicated by the psychrometer cannot be regarded as a thermodynamic property; in fact, the approximate agreement with thermodynamic wet-bulb temperature in the case of moist air has been shown to be largely fortuitous [4].

Mollier Diagram

A thermodynamic analysis of any air conditioning process consists in writing: (1) a weight balance for the dry air; (2) a weight balance for the water; (3) an energy balance. The first is reduced to its simplest form by basing all quantities on one pound of dry air. The second is the most simply expressed in terms of humidity ratio, or weight of water per