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

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

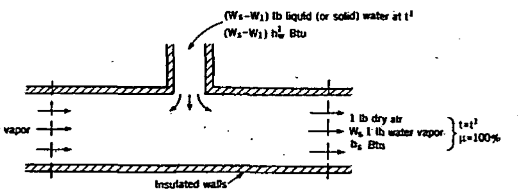

Fig 1. Diagram Illustrating Thermodynamic Wet-Bulb Temperature

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.

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.

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 pound of dry air. Since most air conditioning processes are of the steady flow type in which the thermal energy convected with the fluid is its enthalpy, the third is most simply expressed in terms of enthalpy per pound of dry air. It is clear, therefore, that humidity ratio W and enthalpy per pound of dry air h are fundamental coordinates. Their use for the purpose of graphical representation is due to Mollier. A convenient modification of the Mollier diagram devised by Goff is obtained by taking humidity ratio W as ordinate and *reduced enthalpy* $(h - 1000W)$ as abscissa, as shown in the chart enclosed in the envelope attached to the inside back cover of this book.

The reasons for the use of the difference $(h - 1000W)$ as abscissa instead of h itself in the Mollier Diagram for Moist Air are the following: (1) it amounts to plotting on oblique coordinates and thus reduces to convenient proportions a diagram which would otherwise take the form of a scroll; (2) by the choice of the factor 1000 the necessary multiplication reduces to shifting the decimal point; (3) the ease with which the ordinate W can be multiplied by 1000 and added to the abscissa to obtain the enthalpy h makes it unnecessary to complicate the chart by a family of isenthalpic lines.

In the Mollier diagram, the lines inclined upward and slightly to the right are lines of constant (dry-bulb) temperature. They are straight under Dalton's Law but actually have slight curvature. The lines inclined upward to the left are lines of constant thermodynamic wet-bulb and are straight by definition. The dry-bulb and wet-bulb lines meet at the saturation curve and coincide in the region to the left of this curve. This region is divided into three subregions by the narrow *wedge* with apex at the junction of the 32 F wet-bulb and dry-bulb lines. Above the wedge, the mixture consists of two distinct phases, saturated vapor and saturated liquid. At point *A*, for example, the temperature is 60 F and the vapor phase contains 0.01103 pounds of water vapor per pound of dry air from Table 6. From the Mollier diagram, $W = 0.016$ lb, leaving 0.00497 lb per pound dry air in the liquid phase. The total enthalpy of the mixture is $10.51 + (1000 \times 0.016) = 26.51$ Btu per pound dry air of which $15.34 + (1000 \times 0.01103) = 26.37$ Btu per pound dry air is contributed by the vapor phase.

Within the wedge, the mixture consists of three distinct phases, saturated vapor, saturated solid and saturated liquid. The temperature is 32 F; and the relative proportions of the three phases depend upon the location of the state point within the wedge. Below the wedge, the mixture consists of saturated vapor and saturated solid.

The curved lines in the single vapor-phase region to the right of the saturation curve are lines of constant per cent saturation. Lines of constant dew-point are, of course, horizontal straight lines of constant humidity ratio. At point *B*, for example, the dry-bulb temperature is