

mixture, at a given temperature, contributes to the observed pressure the same amount that it would have exerted by itself at the same temperature had no other gas or vapor been present. If p = the observed pressure of the mixture and p_1, p_2, p_3 , etc. = the pressure of the gases or vapors corresponding to the observed temperature, then

$$p = p_1 + p_2 + p_3, \text{ etc.} \quad (1)$$

Pressures of saturated water vapor and other properties for various temperatures are given in Table 1.

HUMIDITY

Humidity is the moisture or water vapor mixed with the air in the atmosphere. Absolute humidity is the weight of water vapor per unit of space and is usually expressed as grains or pounds per cubic foot at a given temperature and percentage of saturation (1 lb = 7000 grains). *Relative humidity* is the ratio of the weight of water vapor in a given space as compared to the weight which the same space is capable of containing when fully saturated at the same temperature, and is usually expressed as a percentage. It is the ratio of the absolute humidity for the given condition involved to the absolute humidity at saturation for the corresponding dry-bulb temperature. When air is unsaturated, the vapor pressure is lower than the maximum corresponding to the temperature of the mixture. The ratio of such unsaturated vapor pressure to the vapor pressure of the mixture when saturated is also the relative humidity. That is:

$$\begin{aligned} rh &= \frac{e}{e_t} \\ &= \frac{D}{D_t} \text{ (approximately)} \end{aligned} \quad (2)$$

where e and D are the pressure and density of the vapor in the air, and e_t and D_t are the saturation pressure and density respectively of the vapor corresponding to the temperature t of the mixture.

WET, DRY-BULB AND DEW-POINT TEMPERATURES

The quantity of moisture mixed with the air under different conditions of temperature and saturation is usually determined by means of some form of instrument in which a dry-bulb and a wet-bulb thermometer are used. *Dry-bulb* temperature is the temperature of the air as determined by an ordinary dry-bulb mercury thermometer. *Wet-bulb* temperature is the temperature as determined by a similar thermometer, except with its bulb encased in a fine mesh fabric bag moistened with clean water and whirled through the air until the temperature depression due to the cooling effect of evaporation from the moistened bag reaches equilibrium. Wet-bulb temperature corresponds to that which a thoroughly wet body will attain if the air passes over it for a sufficient length of time and with a high enough velocity.

Air is usually deficient in water vapor; that is, it is unsaturated. Therefore, the water vapor exists at a temperature above that of saturation, or is superheated. If the pressure is above atmospheric (14.7 lb per

square inch) the vapor is superheated steam; if the pressure is below atmospheric, it is superheated vapor.

If an unsaturated mixture of air and water vapor be cooled without the removal of any moisture pressure, it will ultimately become saturated. The temperature at which saturation is obtained for a given weight of water vapor is termed the *dew-point* temperature. Any further cooling beyond this temperature will result in a precipitation of moisture from the mixture, that is, condensation.

Table 1 gives the pressure of saturated vapor, the weight of saturated vapor, as well as the volume in cubic feet of one pound of dry air and air saturated, also the sensible heat content above 0 deg F of one pound of dry air, and the latent heat of the vapor required to saturate one pound of dry air, for various dry-bulb temperatures. If the weight of unsaturated water vapor of a mixture is known, the dew-point temperature may be ascertained from Table 1 by noting the temperature corresponding to saturation for this weight. The data in Table 1 may be conveniently used for solving humidifying and cooling problems.

Example 1. Humidifying Air. Air is to be maintained at 70 F with a relative humidity of 40 per cent when the outside air is at 0 deg F, with a relative humidity of 70 per cent. Find the weight of water vapor per pound of dry air to be added by the air washer, the temperature of the saturated air leaving the washer, and the heat required to bring the air to this condition.

Referring to Table 1, one pound of air at 70 F, if saturated contains 0.01578 lb of water vapor; hence with 40 per cent humidity it contains $0.40 \times 0.01578 = 0.006312$ lb. One pound of air at 0 deg F contains 0.000781 lb of vapor when saturated and $0.70 \times 0.000781 = 0.000547$ lb when the humidity is 70 per cent. The water vapor to be added per pound of dry air is therefore $0.006312 - 0.000547 = 0.005765$ lb. By inspection it is found that air at 45 F completely saturated contains the same weight of vapor, namely, 0.00631 lb, as air at 70 F with 40 per cent humidity; hence the air should leave the washer at 45 F. The heat content of air at 0 deg F and 70 per cent humidity is $0 + 0.70 \times 0.964 = 0.675$ Btu per pound and the heat content of 1 lb of air at 45 F with the vapor required to saturate it is 17.59 Btu. The heat required for the process per pound of dry air is therefore approximately $17.59 - 0.675 = 16.92$ Btu.

Example 2. Cooling. Air enters a washer at 84 F with a relative humidity of 50 per cent and is to be cooled to 54 F. Find the dew-point temperature, weight of vapor condensed and heat removed per pound of dry air.

At 84 F, 1 lb of air contains 0.02547 lb of water vapor when saturated and therefore $0.50 \times 0.02547 = 0.01274$ lb with 50 per cent humidity (see Table 1). At 64 F saturated air contains the same weight of water vapor; hence the dew-point is 64 F. At 54 F, 1 lb of air, if saturated, contains 0.00887 lb of vapor. Hence, in cooling from 64 F to 54 F the weight of vapor removed is $0.01274 - 0.00887 = 0.00387$ lb. The heat content of the air in the initial state (84 F, 50 per cent humidity) is $20.29 + 0.50 \times 26.62 = 33.60$ Btu, and the heat content of 1 lb of dry air at 54 F, with vapor required to saturate it, is 22.45 Btu. The difference is $33.60 - 22.45 = 11.15$ Btu. A slight correction may be made for the heat removed in cooling the water, due to condensation between 64 F and 54 F. At 64 F condensation begins, at 54 F 0.00387 lb has been condensed; hence the heat that must be removed from the water is approximately $\frac{1}{2} \times 0.00387 \times 10 = 0.019$ Btu. Adding this to 11.15 Btu, the heat removed per pound of dry air during the process is 11.17 Btu.

RELATION BETWEEN DRY-BULB, WET-BULB AND DEW-POINT TEMPERATURES

As previously stated, the dew-point temperature represents the saturation temperature for a given quantity of moisture. When the temperature has been reduced to the dew-point, the wet- and dry-bulb