

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. 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

$$\frac{e' - e}{t - t'} = \frac{B - e'}{2800 - 1.3t'} \quad (2a)$$

In the form commonly used,

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

where

e = actual partial pressure of water vapor in the air, in inches of mercury.

e' = saturation pressure at wet-bulb temperature, in inches of mercury.

B = barometric pressure, in inches of mercury.

t = dry-bulb temperature, in degrees Fahrenheit.

t' = wet-bulb temperature, in degrees Fahrenheit.

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.

HUMIDITY

Humidity is the water vapor mixed with dry air in the atmosphere. *Absolute humidity* has a multiplicity of meanings, but usually the term refers to the weight of water vapor per unit volume of space occupied, expressed in grains or pounds per cubic foot. With this meaning, absolute humidity is nothing but the actual density of the water vapor in the mixture and might better be so called. A study of Keenan's Steam Tables¹ indicates that water vapor, either saturated or super-heated, at partial pressures lower than 4 in. of mercury may be treated as a gas with

a gas constant R of 1.21 in the characteristic equation of the gas $pV = wR(t + 460)$. Within such limits, the density (δ) of water vapor is

$$\delta = \frac{w}{V} = \frac{e}{1.21(t + 460)} \text{ (pounds per cubic foot)} \quad (3a)$$

$$= \frac{5785 e}{t + 460} \text{ (grains per cubic foot)} \quad (3b)$$

where

e = actual partial pressure of vapor, in inches of mercury.

t = dry-bulb temperature, in degrees Fahrenheit.

Another meaning sometimes given to absolute humidity is the weight of water vapor mixed with a unit weight of dry air. This quantity is the ratio of the density of the vapor to the density of the dry air, and since the gas constant R for dry air is 0.753, the weight of water vapor mixed with 1 lb of dry air is

$$W = \frac{e}{1.21(t + 460)} \div \frac{B - e}{0.753(t + 460)} = 0.622 \left(\frac{e}{B - e} \right) \text{ (pounds)} \quad (4a)$$

$$= 4354 \left(\frac{e}{B - e} \right) \text{ (grains)} \quad (4b)$$

where

e = actual partial pressure of vapor, in inches of mercury.

B = total pressure of mixture (barometric pressure), in inches of mercury.

Relative Humidity

Relative humidity (Φ) is either the ratio of the actual partial pressure (e) of the water vapor in the air to the saturation pressure (e_t) at the dry-bulb temperature, or the ratio of the actual density (δ) of the vapor to the density of saturated vapor (δ_t) at the dry-bulb temperature. That is:

$$\Phi = \frac{e}{e_t} = \frac{\delta}{\delta_t} \quad (5)$$

Relative humidity, so defined, is not exactly equal to the ratio of the weight of vapor per pound of dry air (W) to the weight of saturated vapor per pound of dry air (W_t). This quantity is sometimes called per cent humidity, for from Equations 4 and 5,

$$\frac{W}{W_t} = 0.622 \left(\frac{\Phi e_t}{P - \Phi e_t} \right) \div 0.622 \left(\frac{e_t}{B - e_t} \right) = \frac{\Phi (B - e_t)}{B - \Phi e_t} \quad (6)$$

It is not *exactly* correct, therefore, to find the weight of vapor mixed with each pound of dry air (W) by multiplying the weight of vapor mixed with each pound of dry air for saturation at the dry-bulb temperature (W_t) by the relative humidity (Φ), although the *error usually is small*, particularly if the relative humidity is high.

With a relative humidity of 100 per cent, the dry-bulb, wet-bulb, and dew-point temperatures are equal. With a relative humidity less than

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