Summary:

Air can be treated as a mixture of dry air and water vapor, referred to as moist air. Dry air can be treated as an ideal gas with a c_p = 1.005 kJ/kg °C. Since the partial pressure (vapor pressure) of the water vapor in the air mixture is low, it can also be treated as an ideal gas. Note: the following equations will use the subscript notation a = dry air and v = water vapor.

Total Pressure, *P*

The total pressure P is the pressure of the atmospheric air and corresponds to the sum of the partial pressures of dry air, P_a, and water vapor, P_v

$$P = P_a + P_v$$

Humidity Ratio (Absolute or Specific Humidity), *w*

The humidity ration w is the amount of water vapor in the air.

$$w = \frac{m_v}{m_a} = \frac{P_v V / R_v T}{P_a V / R_a T} = \frac{R_a P_v}{R_v P_a} = \left(\frac{0.2870}{0.4615}\right)\frac{P_v}{P_a} = \frac{0.622 P_v}{P_a} = \frac{0.622 P_v}{P - P_v}$$

Relative Humidity, ϕ

The relative humidity ϕ is the ratio of water vapor, m_v, in the air to the maximum amount of water vapor, m_g, the air could hold at that temperature (saturated air).

$$\phi = \frac{m_v}{m_g} = \frac{P_v V / R_v T}{P_g V / R_v T} \rightarrow \phi = \frac{P_v}{P_g}$$

Rearranging $w = \dfrac{0.622 P_v}{P - P_v}$ and $\phi = \dfrac{P_v}{P_g}$ to obtain $P_v = \dfrac{wP}{0.622 + w}$ and $P_v = \phi P_g$

$$\rightarrow \quad \boxed{\phi = \frac{wP}{(0.622 + w)P_g}} \quad \text{OR} \quad \boxed{w = \frac{0.622 \phi P_g}{P - \phi P_g}}$$

Note: P_g is equal to the saturated water vapor pressure at the air temperature, which can be found in the saturated water – temperature table ($P_g = P_{sat@T}$).

Enthalpy, H

$$h_a = c_p T$$

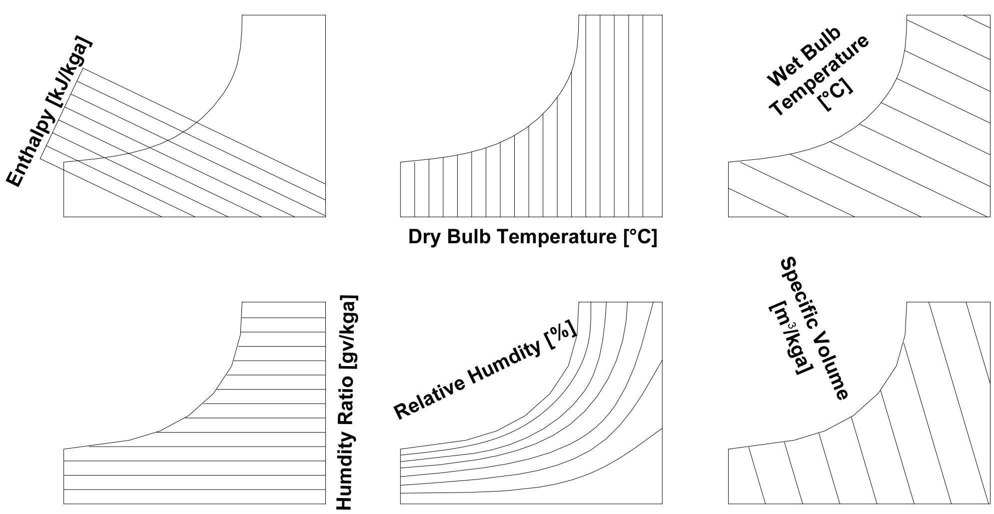
$$h_v \cong h_g(T)$$

$$H = H_a + H_v = m_a h_a + m_v h_v$$

***Since in most practical applications the amount of DRY AIR in the air-water vapor mixture remains constant but the amount of water vapor changes (evaporation, condensation), it is convenient to express enthalpy, h, on a "PER UNIT MASS OF DRY AIR" basis. This term includes the energy content of both the dry air and the water vapor but it is per unit mass of dry air. Understanding this concept is the key to psychrometric analysis.**

$$\boxed{h = \frac{H}{m_a} = h_a + \frac{m_v}{m_a} h_v \rightarrow h = h_a + w h_v}$$

Psychrometric Chart



Question:
Water exiting the condenser of a power plant at 45°C enters a cooling tower with a mass flow rate of 15000 kg/s. A stream of cooled water is returned to the condenser from the cooling tower with the same flow rate. Make-up water is added in a separate stream at 20°C. Atmospheric air enters the cooling tower at 30°C and a wet bulb temperature of 20°C. The volumetric flow rate of air into the cooling tower is 8000 m^3/s. Moist air exits the tower at 40°C and 90% relative humidity. Assume an atmospheric pressure of 101.3 kPa. Determine:

a) the mass flow rate of dry air,
b) the mass flow rate of make-up water, and
c) the temperature of the cooled liquid water exiting the cooling tower.