University of Diyala
College of Engineering
Mechanical Department

# Air Conditioning
# 3- PSYCHROMETRICS

*Dr. Wameedh. T.M. Al-Tameemi*

## Moist Air

The most familiar example is a mixture of air and water vapor in contact with liquid water or ice, such as the problems encountered in air conditioning.

**Psychrometrics** is the science involving thermodynamic properties of moist air and the effect of atmospheric moisture on materials and human comfort. The definition is broadened to include the method of controlling the thermal properties of moist air.

When moist air is considered to be a mixture of independent, perfect gases, dry air, and water vapor, each is assumed to obey the perfect gas equation of state:

$$\text{Dry air: } P_a V = n_a RT$$

$$\text{Water vapor: } PV = n_w RT$$

Dry air: $P_aV = n_aRT$

Water vapor: $PV = n_wRT$

Where:

$P_a$ = partial pressure of dry air

$P$ = partial pressure of water vapor

$V$ = total mixture volume

$n_a$ = number of moles of dry air

$n_w$ = number of moles of water vapor

$R$ = universal gas constant (8.31441 J/g-mol·K)

$T$ = absolute temperature

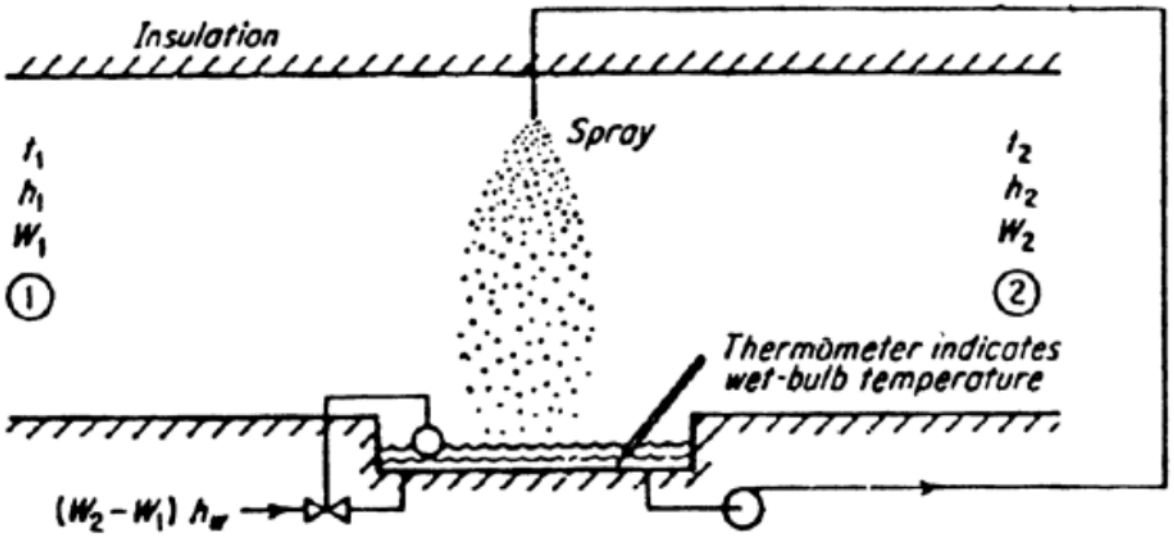
The mixture also obeys the perfect gas equation:

$P_BV = nRT$ or $(P_a + P)V = (n_a + n_w)RT$

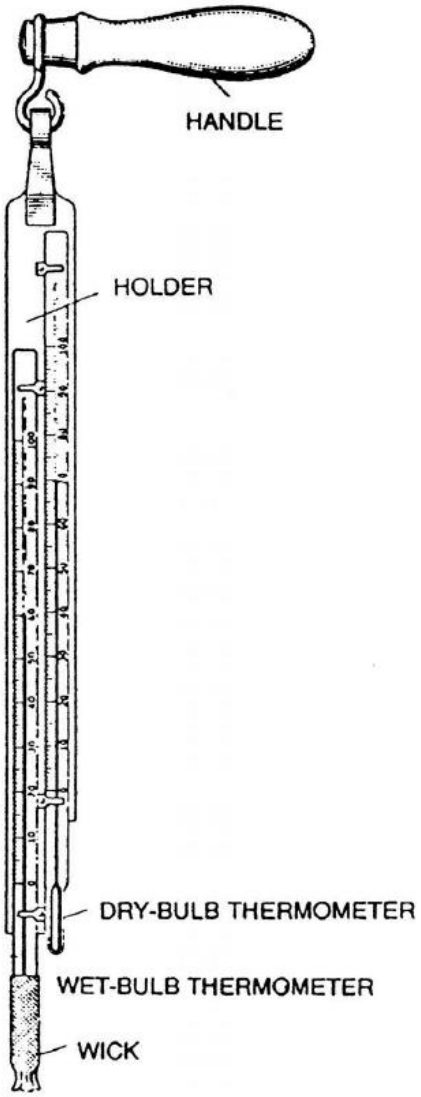
**Dry-bulb temperature:** $t_d$ is the temperature of air as registered by an ordinary thermometer.

**Thermodynamic wet-bulb temperature:** t* is the temperature at which water (liquid or solid), by evaporating into moist air at a given dry-bulb temperature t and humidity ratio W, can bring the air to saturation adiabatically at the same temperature t*, while the pressure P is maintained constant. Figure may be used as a schematic representation of the adiabatic saturation process, where the leaving air is saturated and at a temperature equal to that of the injected water.

A device used in place of the adiabatic saturator is the psychrometer.



The psychrometer consists of two thermometers or other temperature-sensing elements, one of which has a wetted cotton wick covering the bulb .When the wet bulb is placed in an airstream, water may evaporate from the wick. The equilibrium temperature the water eventually reaches is called the wet-bulb temperature.



**Humidity ratio (Moisture content) W** of a given moist air sample is defined as the ratio of the mass of water vapor to the mass of dry air contained in the sample:

$$W = \left(\frac{m_v}{m_a}\right) = \left(\frac{d_v}{d_a}\right) = 0.622\frac{P}{P_B - P}$$

When the moist air not behave as ideal gas:

$$W = 0.622\frac{fs * P}{P_B - fs * P}$$

| P(mbar) | 0°C | 10 °C | 20 °C | 30 °C | 40 °C | 50 °C | 60 °C |
|---|---|---|---|---|---|---|---|
| **1013.25** | 1.0044 | 1.0044 | 1.0044 | 1.0047 | 1.0051 | 1.0055 | 1.0059 |
| **1000** | 1.0044 | 1.0043 | 1.0044 | 1.0047 | 1.0051 | 1.0055 | 1.0059 |
| **975** | 1.0043 | 1.0043 | 1.0043 | 1.0046 | 1.0050 | 1.0054 | 1.0058 |
| **950** | 1.0042 | 1.0042 | 1.0043 | 1.0045 | 1.0049 | 1.0053 | 1.0057 |
| **925** | 1.0041 | 1.0041 | 1.0042 | 1.0045 | 1.0049 | 1.0053 | 1.0056 |
| **900** | 1.0040 | 1.0040 | 1.0041 | 1.0044 | 1.0048 | 1.0052 | 1.0056 |
| **875** | 1.0039 | 1.0039 | 1.0040 | 1.0043 | 1.0047 | 1.0051 | 1.0055 |
| **850** | 1.0038 | 1.0038 | 1.0040 | 1.0042 | 1.0046 | 1.0050 | 1.0054 |
| **825** | 1.0037 | 1.0037 | 1.0039 | 1.0042 | 1.0045 | 1.0049 | 1.0053 |
| **800** | 1.0036 | 1.0036 | 1.0038 | 1.0041 | 1.0045 | 1.0049 | 1.0052 |

**Relative humidity** Φ is the ratio of the mole fraction of water vapor $x_w$ in a given moist air sample to the mole fraction $x_{ws}$ in an air sample which is saturated at the same temperature and pressure:

$$\phi = \left(\frac{P}{Ps}\right)_{t_d} = \left(\frac{d}{ds}\right)_{t_d} = \left(\frac{x}{x_s}\right)_{P_t}$$

The term $p_s$ is the saturation pressure of water vapor at the given temperature t.

**Degree of saturation** μ is the ratio of the actual humidity ratio W to the humidity ratio Ws of saturated air at the same temperature and pressure.

$$\mu = \left(\frac{W}{Ws}\right)_{t_d} = \phi\left(\frac{1-(P_s/P_B)}{1-\phi(P_s/P_B)}\right) \quad , \quad \phi = \frac{\mu}{1-(1-\mu)(P_s/P_B)}$$

**Dew-point temperature** $t_{Dp}$ is the temperature of moist air which is saturated at the same pressure P and has the same humidity ratio W as that of the given sample of moist air.

Degree of superheating= $t_d - t_{Dp}$

The **volume** v of a moist air mixture is expressed in terms of a unit mass of dry air, with the relation :

$$PV = mRT\big|_{air}, \quad PV = mRT\big|_{vapor}$$

$$R(air) = 287\,J/kg.K$$

$$R(vapor) = 461\,J/kg.K$$

The **enthalpy** of a mixture of perfect gases is equal to the sum of the individual partial enthalpies of the components. The enthalpy of moist air is then:

$$h = h_a + Wh_g$$

$$h = h_a + Wh_v = (1.007t - 0.026) + W(2501 + 1.84t) \qquad (0 \le T \le 60)^{\circ}\mathrm{C}$$

$$h = h_a + Wh_v = 1.005t + W(2501 + 1.84t) \qquad (-10 \le T \le 0)^{\circ}\mathrm{C}$$

For adiabatic saturation:

$$h_2 = h_1 + (W_2 - W_1)h_{fw}$$

## Psychrometric Chart

The ASHRAE psychrometric chart may be used to solve numerous process problems with moist air. Processes performed with air can be plotted on the chart for quick visualization, as well as for determining changes in significant properties such as temperature, humidity ratio, and enthalpy for the process.

## HVAC Processes

**Sensible heating** only (C) or **sensible cooling** (G) shows a change in dry-bulb temperature with no change in humidity ratio. For either sensible heat change process, the temperature changes but not the moisture content of the air.

**Humidifying** only (A) or **dehumidifying** only (E) shows a change in humidity ratio with no change in dry-bulb temperature. For these latent heat processes, the moisture content of the air is changed but not the temperature.

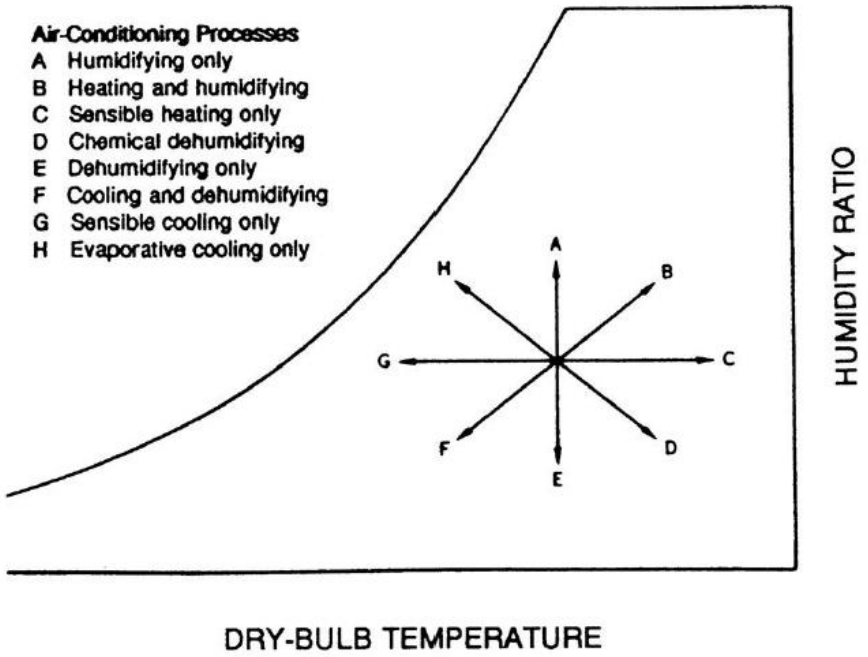
**Cooling and dehumidifying** (F) result in a reduction of both the dry-bulb temperature and the humidity ratio. Cooling coils generally perform this type of process.

**Heating and humidifying** (B) result in an increase of both the dry-bulb temperature and the humidity ratio.

## HVAC Processes

**Chemical dehumidifying** (D) is a process in which moisture from the air is absorbed or adsorbed by a hygroscopic material. Generally, the process essentially occurs at constant enthalpy.

**Evaporative cooling** only (H) is an adiabatic heat transfer process in which the wet-bulb temperature of the air remains constant but the dry-bulb temperature drops as the humidity rises.



## Reference:

- Principles of heating ventilating and air conditioning a textbook with design data based on the 2017 ASHRAE handbook fundamentals by Sauer, Harry J. Howell, Ronald Hunter Coad, William
- W F, Stoecker, and J. W. Jones. Refrigeration and Air conditioning. Second Edi. New York: MCGRAW-HILL Higher Education, 1981.
- مبادى هندسة تكييف الهواء والتثليج د. خالد الجودي

*Thank you very much*