SEPARATION PROCESS

DRYING
Part 2

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Humidity

- Humidification - transfer of water from the liquid phase into a gaseous mixture of air and water vapor.
- Dehumidification - reverse transfer where the water vapor is transferred from the vapor state to the liquid state.
- Humidity, H – the kg of water vapor contained in 1 kg of dry air.

$$H = \frac{18.02}{28.97}\frac{p_A}{P - p_A}$$

- Saturated air is air in which the water vapor is in equilibrium with liquid water at given T an P. In this mixture the partial pressure of the water vapor is equal to the vapor pressure p_{AS} of pure water at given T
- Saturation humidity, H_s – $$H_S = \frac{18.02}{28.97}\frac{p_{AS}}{P - p_{AS}}$$
- Percentage humidity, H_p – $$H_P = 100\frac{H}{H_S} = \frac{p_A}{p_{AS}}\frac{P - p_{AS}}{P - p_A}(100)$$
- Percentage relative humidity, H_R – $$H_R = 100\frac{p_A}{p_{AS}}$$

Humidity

- Dew point - the temperature at which a given mixture of air and water vapor would be saturated/ or temperature at which vapor begins to condense when the gas phase is cooled at constant pressure.
- Humid heat, c_S - amount of heat required to raise the temperature of 1 kg of dry air plus the watervapor present by 1 K.

$$c_S\ (kJ/kg\ dry\ air.K) = 1.005 + 1.88H \quad (SI)$$

where, $c_{P\ water(v)}$ = 1.88 kJ/kg water vapor. K; $c_{P\ air}$ = 1.005 kJ/kg dry air. K

- Humid volume, v_H - total volume (m^3) of 1 kg of dry air plus the vapor it contains at 1 atm abs pressure and the given gas temp.

$$v_H\ (m^3/kg\ dry\ air) = (2.83 \times 10^{-3} + 4.56 \times 10^{-3}\ H)\ T\ (K).$$

- Total enthalpy of an air-water mixture, H_Y - the total enthalpy of 1 kg of air plus its water vapor/ or sensible heat of the air-water vapor mixture plus the latent heat if T_{ref} for both components = 0 ºC

$$H_Y\ (kJ/kg\ dry\ air) = (1.005 + 1.88\ H)\ (T\ ºC - T_{ref}) + \lambda_{ref} H$$

$$H_Y\ (kJ/kg\ dry\ air) = (1.005 + 1.88\ H)\ (T\ ºC - 0) + 2501.4H$$

Humidity Chart/Psychometrics Chart

Air entering a dryer has a dry bulb temperature of 60C and a dew point of 26.7C. Determine, H, H_p, c_s and v_H

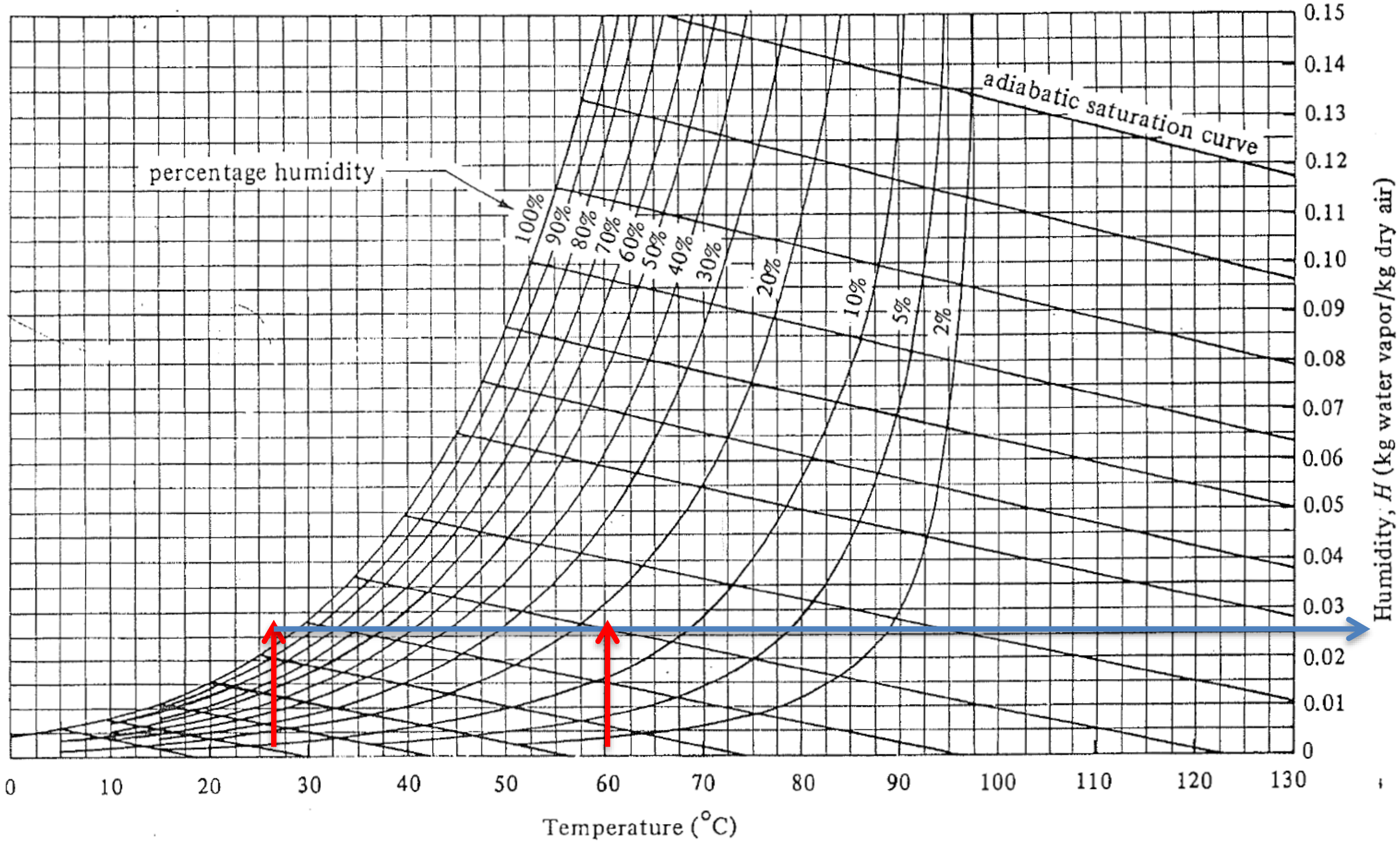

FIGURE 9.3-2. *Humidity chart for mixtures of air and water vapor at a total pressure of 101.325 kPa (760 mm Hg). (From R. E. Treybal, Mass-Transfer Operations, 3rd ed. New York: McGraw-Hill Book Company, 1980. With permission.)*

Adiabatic Saturation Temperature, T_S

- The steady-state temperature attained when a large amounts of water is contacted with the entering gas.
- The leaving air is saturated at at Ts having a humidity Hs.
- Enthalpy balance (Ts is ref T)

enthalpy of the entering gas mixture = enthalpy of the leaving gas mixture.

$$c_S(T - T_S) + H\lambda_S = c_S(T_S - T_S) + H_S\lambda_S$$

$$\frac{H - H_S}{T - T_S} = \frac{c_S}{\lambda_S} = \frac{1.005 + 1.88H}{\lambda_S}$$

- If a gas mixture at T1 and H1 is contact for sufficiently long time in adiabatic contactor, it will leaves saturated at Ts1 and Hs1.
- The values of Hs1 and Ts1 are determined by following the adiabatic saturation line going through point T1, H1 until it intersect the 100% saturation line.
- If contact is not sufficient, the leaving mixture will be at a percentage saturation less than 100% bit on the same line.

Wet Bulb Temperature T_W

- Steady-state nonequilibrium temperature reached when a small amount of water is contacted under adiabatic conditions by a continuous stream of gas.
- The amount of liquis is small so the T and H of the gas is not changed
- Method to measure Tw – thermometer is cover by wet wick or cloth
- A steady state water is evaporating to the gas stream. The water and wick cooled to Tw and stay at this constant temperature.
- Latent heat of evaporation is balance by the convective heat flowing from the gas stream at T to the wick temperature Tw
- The below equation can be assumed quite similar with adiabatic saturation lines with reasonable accuracy
- Hence wet bulb detrmination is often used to measure the humidity of an air-water vapor mixture

$$\frac{H - H_W}{T - T_W} = -\frac{h/M_B k_y}{\lambda_W}$$

Equilibrium Moisture Content Of Materials

- A definite moisture content attain when the wet solid is exposing to the large excess air of air having constant T and H.
- Expressed as kg of water per kg of moisture-free (bone-dry) solid or kg H_20/100 kg dry solid
- Depend on the direction from which the equilibrium is reached
- In drying, wet sample is allowed to dry by desorption
- If the material contains less moisture than it equilibrium value, it will adsorb water until reaches its equilibrium value.
- Depends upon the structure of the solid, the temp. of the gas, & the moisture content of the gas.
- Varies greatly with the type of material for given % relative humidity

Equilibrium Moisture Content Of Materials

- Bound water
  - The WC at 100% relative humidity
- Unbound water
  - Excess WC than indicated WC at 100% relative humidity
  - Held primarily in the voids of the solid
- substances containing bound water is called hygroscopic materials
- Free moisture content
  - moisture above the equilibrium moisture content at given % relative humidity.
  - moisture that can be removed by drying

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