UCH 1201 Principles of Chemical Engineering

Humidification

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Contents

Objectives

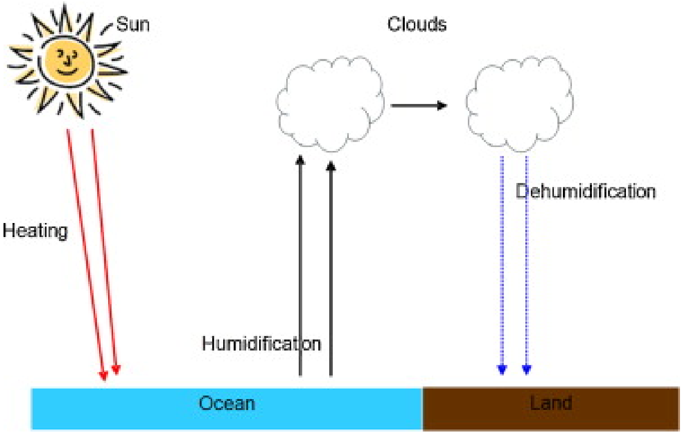
- To give an overview of role of humidification in chemical industries.
- To give an overview of terminologies of humidification.

Humidity & Saturation

When a gas is in contact with a liquid, the gas receives vapor from the liquid until the partial pressure of the vapor in the gas mixture equals the vapor pressure of the liquid at the existing temperature. When the concentration of the vapor in the gas mixture reaches this equilibrium value, the gas is said to be saturated with the vapor.

If the partial pressure of the vapor in the gas mixture exceeds the vapor pressure of the liquid, condensation of the vapor takes place.

Formation of Rain



Vaporization of water from the surface of water-bodies is to saturate the surrounding air with water. As and when, the surrounding air is saturated with water vapor, the water tends condense in the form of rain.

Cooing of Water in Mud-clay Pot

Water in the mud-pot is colder than that in steel-pot. This is because of vaporization of water from the pores on the surface of mud-pot. This vaporization is happening so as to saturate the surrounding air with water-vapor.

Relative Saturation (Relative Humidity)

If the partial pressure of a vapor in the gas mixture is less than the vapor pressure of the liquid at the existing pressure, the gas mixture is partially saturated. The ratio of the partial pressure of the vapor to the vapor pressure of the liquid at the liquid at the existing temperature, expressed in percentage, is termed relative saturation. The term 'humidity' is used if the vapor is water and the gas is air.

$$\text{Relative saturation} = \frac{P_A}{P_A^{\text{sat}}} \times 100$$

where

P_A = partial pressure of the vapor (A) in the gas mixture

P_A^{sat} = vapor pressure of component A.

Humidity and Temperature

The capacity of a gas to hold water depends on its temperature. The higher the temperature, the more water vapor it can contain.

- normal room temperature - air typically holds about 1% of water vapor
- hot-atmosphere has greater capacity to hold water vapor

When the air holds the maximum amount of water vapor at a particular temperature it is said to be saturated.

Humidity and Temperature (contd..)

- Relative humidity is strongly governed by temperature.
- Interaction of water-vapor with materials is often in proportion to relative humidity.
- Lowering the relative humidity of surrounding air increases evaporation and drying of materials.

Humidity and Temperature (contd..)

For the same amount of air and water-vapor, relative humidity decreases with increase in temperature of the gas mixture.

e.g.:

Temperature ($^\circ$C)	15	20	25	30	35	40
Relative humidity	100	71	50	36	27	19

Humidification

- Humidification operations involve simultaneous transfer of heat and mass between a gas and a liquid when the gas is brought into contact with the liquid in which it is insoluble.
- When the partial pressure of the vapor in the vapor-gas mixture is equal to the vapor pressure of the liquid at that temperature, the mixture is said to be saturated.
- When the partial pressure of the vapor in the vapor-gas mixture is less than the equilibrium vapor pressure of the liquid at that temperature, the mixture is said to be unsaturated and there is scope for further vaporisation.

Humidification

- **Molal Absolute Humidity**:
  Moles of vapor per mole of vapor-free gas is called molal absolute humidity (H_m).

$$H_m = \frac{\text{moles of vapor}}{\text{moles of dry air}} = \frac{n_W}{n_A} = \frac{P_W}{P_A} = \frac{P_W}{P - P_W} \quad \frac{\text{mol vapor}}{\text{mol dry air}}$$

- **Absolute Humidity**:
  The mass of vapor per unit mass of vapor free gas is called absolute humidity (H_a)

$$H_a = \frac{n_W}{n_A}\frac{M_W}{M_A} = \frac{P_W}{P - P_W}\frac{M_W}{M_A} \quad \frac{\text{kg vapor}}{\text{kg dry air}}$$

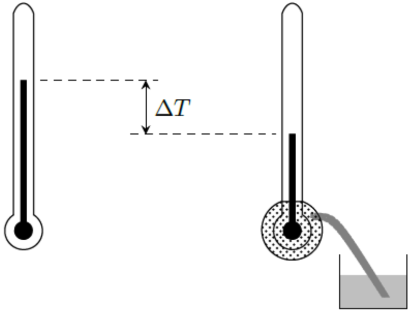
- **Percentage Humidity**:
  Percentage humidity is the ratio of actual absolute humidity to the absolute saturation humidity.

$$\%H = \frac{H_a}{H_a^{\text{sat}}} \times 100$$

- **Dry Bulb Temperature (DBT)**:
  The temperature of a vapor-gas mixture as recorded by immersing the bulb of a thermometer in the mixture is called dry-bulb temperature.
- **Wet Bulb Temperature (WBT)**:
  Wet bulb temperature is the steady-state temperature of the vapor-gas mixture measured by a thermometer whose bulb is covered with a wet wick or saturated completely by the same fluid.
  The bulb of the thermometer is covered by a liquid. This when contacted with the vapor-gas mixture the liquid is evaporated by losing its latent heat of vaporization. This latent heat of vaporization is transferred from the vapor-gas mixture and loses its sensible heat. Hence, the temperature is less when the wet bulb temperature is measured.

  $$\text{WBT} < \text{DBT}(\text{except at } 100\% \text{ saturation})$$

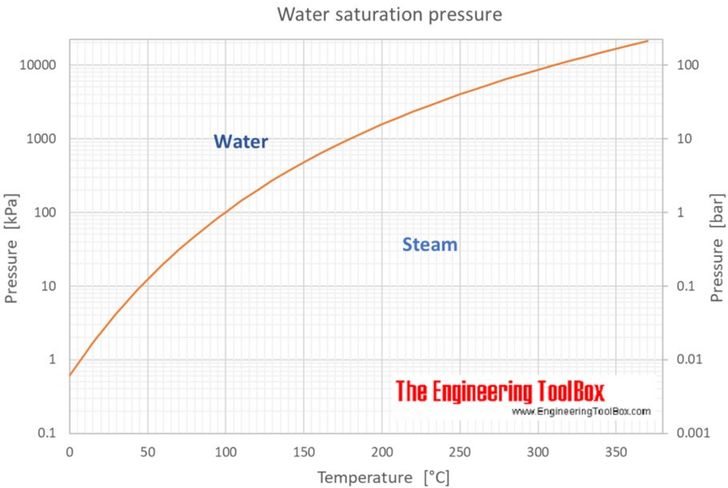
  The difference between DBT and WBT is called wet bulb depression.



(a) Dry bulb (normal) (b) Wet bulb

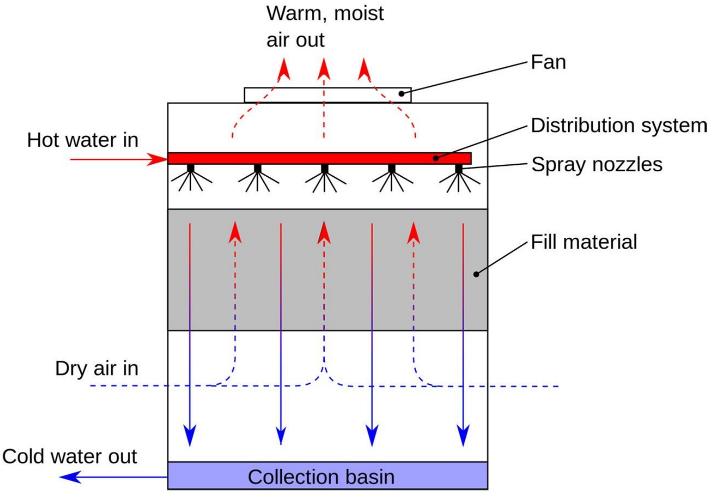
- **Dew Point (DP)**:
  It is the temperature at which a vapor-gas mixture becomes saturated when cooled at constant pressure in the absence of the liquid.
  When the temperature is reduced further less than the DP, the condensation of the saturated vapor occurs.
  At dew point, partial pressure of the vapor in the mixture = the vapor pressure of the liquid.

$$\text{At dew point,} \quad \text{DBT} = \text{WBT}$$



Water saturation pressure
10000
1000
100
10
1
0.1
Pressure [kPa]
100
10
1
0.1
0.01
0.001
Pressure [bar]
Water
Steam
The Engineering ToolBox
www.EngineeringToolBox.com
0
50
100
150
200
250
300
350
Temperature [°C]

Cooling Tower



Cooling Tower

Cooling-water is a common utility in chemical process and energy industries. It picks up heat from various heat exchange processes. For circulating it back to the processes, it's temperature has to be brought back to it's original temperature. This is done by a 'cooling-tower'. Here, the cooling-water is brought in intimate contact with ambient air.

Cooling towers are a special type of heat exchanger that allows water and air to come in contact with each other to lower the temperature of the water. During this process, small volumes of water evaporate, lowering the temperature of the water that is being circulated throughout the cooling tower.

Cooling tower nozzles are used to spray the water onto to the "fill media", which slows the water flow down and exposes the maximum amount of water surface area possible for the best air-water contact. The air is being pulled / forced by a "cooling tower fan".

Quiz

1. What is the reason for the temperature of water in a mud-pot being lower than that in steel-pot? Both the pots are kept in the same environment.
2. Give examples for cooling towers usage in Industries.