UPPSC-AE 2020

Uttar Pradesh
Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Mechanical Engineering

Environmental Control

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

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Environmental Control

Contents

CHAPTER 7

Properties of Moist Air

7.1 Introduction

Properties of moist air includes dry bulb temperature (DBT), wet bulb temperature (WBT), humidity, relative humidity (RH) etc. Such a study is important because the atmospheric air is not completely dry but is a mixture of air and water vapour.

7.2 Working Substance in Air Conditioning

- Moist air is a mixture of two gases.
  (i) Dry air, which itself is a mixture of a number of gases.
  (ii) Water vapour which may exist in a saturated or superheated states.
- Dry air is a pure substance, water vapour is also a pure substance. But moist air is not a pure substance.
- Both dry air and water vapour can be considered as perfect gas. Since both exist in the atmosphere at low pressures.

7.2.1 Dalton's Law of Partial Pressure

In Psychrometry, Dalton's law of partial pressure states that in a mixture of non-reacting gases, the total pressure exerted is equal to the sum of the partial pressures of the individual gases. Dalton's law is related to the ideal gas law.

Mathematically, the pressure of a mixture of non-reactive gases can be defined as the summation.

$$p_{\text{total}} = \sum_{i=1}^{n} p_i$$

or

$$p_{\text{total}} = p_1 + p_2 + p_3 + \ldots\ldots + p_n$$

where, $p_1, p_2, p_3, \ldots\ldots, p_n$ represent the partial pressures of each component.

$$p_i = \text{ptotal } x_i$$

where x_i is the mole fraction of the i^{th} component in the total mixture of n components.

7.2.2 Amagat's Law of Partial Vapour

Amagat's law of partial volume describes the behaviour and properties of mixtures of ideal (as well as some cases of non-ideal) gases. This law states that the extensive volume, $V = Nv$ of a gas mixture is equal to the sum of volume V_i is the k components gases, if the temperature T and the pressure p remains the same.

$$V_i = \frac{n_i}{\Sigma n_i} V$$

$$\Rightarrow \quad \frac{P_i}{P} = \frac{V_i}{V} = \frac{n_i}{\Sigma n_i} = \gamma$$

γ = mole fraction of gas i in mixture of gases.

This is the experimental expression of volume as an extensive quantity.

7.2.3 Molecular Mass of Mixture

$$M_{mix} = \sum M_i \gamma_i$$

- Universal gas constant R = 8.314 kJ/kg mole K

  characteristic gas constant $R_a = \dfrac{R}{M_a}$.

7.3 Psychrometric Properties

Phase rule: The phase rule is a general principle governing systems in thermodynamic equilibrium. If F is the number of degrees of freedom, C is the number of components and P is the number of phases, then

$$F + P = C + 2$$

$$F + P = C + 2$$

F = Degree of freedom; P = Phases in mixture; C = Components of mixture

For a mixture of 2 gases we need 3 properties to fix its thermodynamic state whereas for pure substance we need only 2 properties.

7.3.1 Dry Bulb Temperature (DBT)

- DBT is the actual temperature 't' of the moist air.
- The dry bulb temperature (DBT) is the temperature of air measured by a thermometer freely exposed to the air, but shielded from radiation and moisture. The dry bulb temperature that is usually thought of as air temperature and it is the true thermodynamic temperature.
- DBT is measure of sensible enthalpy of moist air.

7.3.2 Humidity ratio (specific humidity)

- It is the ratio of mass of water vapour to the mass of dry air contained in the sample air. It is denoted by 'ω'. It is normally expressed in g/kg of dry air.

$$\omega = \frac{\text{Mass of water vapour in air}}{\text{Mass of dry air in air}}$$

Specific humidity/Humidity ratio, $\omega = \dfrac{m_w}{m_a} = \dfrac{V_a}{V_w} = 0.622\dfrac{P_v}{P - P_v}$

P_v = Partial pressure of vapour

P = Total pressure of moist air

- Dry Air Mass = m_a ; Specific Volume = v_a

  Water Vapour mass = m_w ; Specific Volume = v_w

  where, V = Volume; m = Mass; P = Pressure; T = Temperature
- Specific humidity is a function of partial pressure.

Example - 7.1 For a typical sample of ambient air (at 30°C, RH = 75% and standard atmospheric pressure), the amount of moisture in kg per kg of dry air will be approximately

(a) 0.002 (b) 0.027

(c) 0.25 (d) 0.75

Solution: (b)

Given, DBT = 30°C, RH, ϕ = 75%

$$\phi = \frac{P_v}{P_{v,s}} \quad \text{(given } P_{v,s} = 0.05628 \text{ bar)}$$

$\Rightarrow$ $$P_v = \phi(P_{v,s}) = 0.75 \times 0.5628 = 0.04221 \text{ bar}$$

$\therefore$ Specific humidity, $$U = 0.622\frac{P_v}{P - P_v} = 0.622\frac{0.04221}{1.0132 - 0.04221} = 0.270 \text{ kg/kg dia}$$

7.3.3 Dew Point Temperature

- It is the temperature of air recorded by a thermometer when the moisture present in it starts condensing.
- At a given partial pressure of water vapour, the saturation temperature is dew point temperature and it can be found from the steam table.

Example - 7.2 Dew point temperature is the temperature at which condensation begins when the air is cooled at constant

(a) volume (b) entropy
(c) pressure (d) enthalpy

Solution: (c)

Example - 7.3 If air is heated without changing its moisture content, the dew point will be ________.

(a) increase (b) decrease
(c) remains same (d) unpredictable

Solution: (c)

7.3.4 Absolute humidity

It is the mass of water vapour present in one cubic metre of dry air. It is expressed in terms of gram per cubic metre of dry air (g/m^3 of dry air). Many a time it is expressed in terms of grains per m^3 of dry air. One kg of water vapour is equal to 15,430 grains.

$$p_v V = m_v R_v T$$

where, p_v = vapour pressure in air or saturation pressure at dew point
V = volume of air, which is also of water vapour
T = dry bulb temperature
R_v = gas constant of water vapour (462 kJ/kg-K)
m_v = mass of water vapour in kg

$\therefore$ $$\text{Vapour density} = \frac{m_v}{V} = \frac{p_v}{R_v T}$$

Example - 7.4 The weight of water vapour in kg contained in 1 m^3 of air vapour mixture at its total pressure is known as ___________.

(a) degree of saturation (b) percent humidity
(c) humidity ratio (d) vapour density

Solution: (d)

7.3.5 Degree of Saturation

It is the mass of water vapour in a sample of air to the mass of water vapour in the same air when it is saturated at the same temperature. Mathematically,

- The capacity of air to absorb moisture is called degree of saturation

$$\mu = \left.\frac{\omega}{\omega_s}\right|_T = \frac{P_v\left[1-P_s/P\right]}{P_s\left[1-P_v/P\right]}$$

ω = specific humidity at partial pressure P_v, ω_s = specific humidity at saturation pressure P_s.

7.3.6 Relative humidity (RH)

It is the ratio of mass of water vapour in a given volume of air at any temperature and pressure to the maximum amount of mass of water vapour which the same volume of air can hold at the same temperature conditions. The air contains maximum amount of water vapour at the saturation conditions.

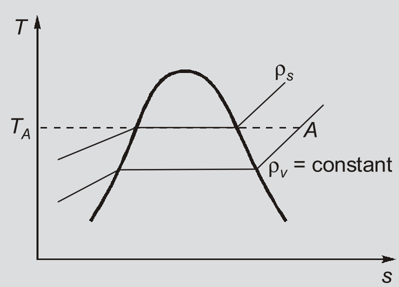
$$RH/\phi = \frac{\text{Mass of water vapour in a fixed volume of moist air at temp. } T}{\text{Mass of water vapour in a saturated sample of moist air at same temp. and volume}}$$

$$= \left.\frac{m_v}{m_{v_s}}\right|_T = \frac{P_vV/RT}{P_sV/RT} = \frac{P_v}{P_s} = \frac{v_s}{v_v}$$

$$\mu = \phi\left[\frac{1-P_s/P}{1-P_v/P}\right]$$

NOTE

- RH is therefore defined as ratio of vapour pressure in a sample of air to vapour pressure of saturated air at the same temperature.
- $\phi = \dfrac{\rho_v}{\rho_s}$



- RH is measured in percentage.
- It has great influence on evaporation of water in the air and therefore on the comfort of human beings.

Example - 7.5 Air at 30°C and 1 bar has a specific humidity of 0.016 kg/kg of dry air. By considering the saturation pressure of water vapour at 30°C as 4.246 kPa, the relative humidity of the air will be

(a) 66.1% (b) 60.2%
(c) 58.8% (d) 56.8%

Solution: (c)

$$\omega = 0.622\frac{P_v}{P - P_v}$$

$$\Rightarrow \quad 0.016 = 0.622\frac{P_v}{101.325 - P_v}$$

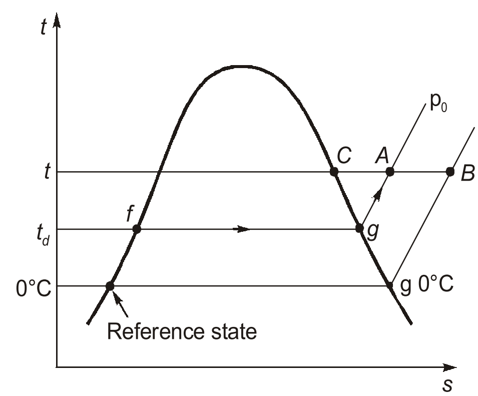
$$\Rightarrow \quad P_v = 2.5 \text{ KPa}$$

Now, $$RH = \frac{P_v}{P_{v \cdot s}} = \frac{2.5}{4.246} = 58.8\%$$

7.3.7 Enthalpy of Moist Air

Enthalpy, h in kJ/kg of moist air is defined as the total enthalpy of the dry air and the water vapour misture per kg of moist air, includes:

- The enthalpy of the dry air - the sensible heat and
- The enthalpy of the evaporated water - latent heat.



$$h = h_a + \omega h_v$$

For 1 kg of dry air and w kg of water vapour.

$$h_a = \text{enthalpy of dry air}$$

$$h_v = \text{enthalpy of water vapour}$$

$$h_v = C_{pw}t_d + (h_{fg})_{td} + C_{pv}(t - t_d)$$

or $$= (h_{fg})_{0°C} + C_{pv}(t - 0) = (h_{fg})_{0°C} + C_{pv}t$$

$$h = h_a + \omega(h_{fg})_{0°C} + \omega C_{pv}t$$

$$h_{fg} = \text{Latent heat of vapourization}$$

$$= (C_{pa} + \omega C_{pv})\,t + \omega(h_{fg})_{0°C} = C_p t + \omega h_{fg}$$

$$h = 1.005t + \omega(2501 + 1.88t) \text{ kJ/kg of dry air}$$

Where, $t \rightarrow$ Dry bulb temperature (°C)

$w \rightarrow$ Specific humidity (kg/kg of dry air

7.3.8 Wet Bulb Temperature (WBT)

- WBT is used to measure humidity by a psychrometer.
- The temperature measured by thermometer whose bulb is covered with wet wick is wet bulb temperature while the bare bulb measures dry bulb temperature.

NOTE

- Wet Bulb Temperature (WBT) is always less than Dry Bulb Temperature (DBT) except when the air saturated. That time wbt is equal to DBT.
- Wet bulb depression = DBT – WBT.
- WBT is an indirect measure of the dryness of the moist air.

Example - 7.6 Wet bulb depression, under saturated ambient air conditions

(a) is always +ve (b) is always –ve
(c) is always zero (d) may have a value depending upon the dew point temperature

Solution: (c)

7.3.9 Thermodynamic wet bulb temperature or temperature of adiabatic saturation

- For any state of unsaturated moist air, there exist a temperature at which the air becomes adiabatically saturated by the evaporation of water into air. That temperature is temperature of adiabatic saturation.
- Only in case of saturated moist air, wet bulb temperature and thermodynamic wet bulb temperature (temperature of adiabatic saturation are equal.
- For moist air having three degree of freedom, three of the four properties can be measured
- total pressure or barometer pressure.
- dry bulb temperature.
- dew point temperature.
- wet bulb temperature.

Thermodynamic WBT is given as $t^* = t - \frac{h_{fg}^*}{C_p}\left(\omega^* - \omega\right)$

7.4 Psychrometry

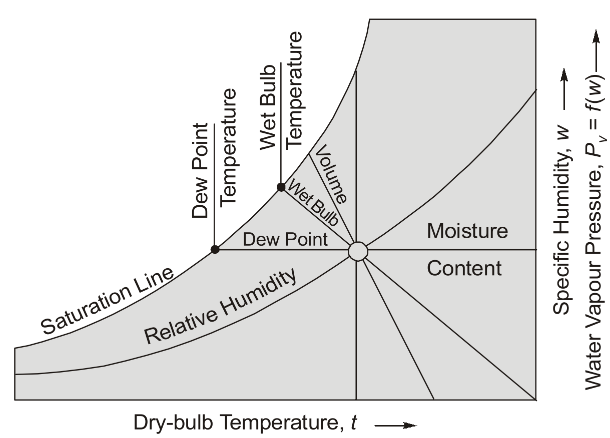
It is the branch of science deals with the study of properties of moist air and its behaviour under different under different conditions.

Moist air is a composition of dry air and water vapour. Dry air is a pure substance but moist air is impure substance, because the percentage of water vapour content varies from place to place as we have seen that at some places there is a high humidity and at some places there is a low humidity.

NOTE: Moist air is generally in superheated state.

7.4.1 Psychrometric Charts

- **DBT lines:** These dry-bulb temperature lines extend vertically upwards and there is one line for each degree of temperature.
- **WBT lines:** The wet-bulb temperature scale is found along the 'in-step' of the chart extending from the toe to the top. These lines extend diagonally downwards to the right. There is one line for each degree of temperature.
- **RH lines:** On the psychrometric chart, the relative humidity lines are the only curved lines on it. The various relative humidities are indicated on the lines themselves. The 100% RH line or saturation curve becomes the boundary of the chart on the left side. The region beyond this line is the supersaturated zone or fog zone.
- **Specific humidity lines:** The scale for specific humidity is a vertical scale on the right side of psychrometric chart. The scale is in grams of moisture per kilogram dry air.



- **DPT lines:** The scale for dew point temperature is identical to the scale of WBT lines. The DPT lines run horizontal to the right.
- **Specific volume lines:** The specific volume lines are drawn along the sole chart and they are equally-spaced diagonal lines.

- **Specific enthalpy lines:** The specific enthalpy scale is located along the 'in-step' of the chart. These lines are similar to WBT lines. Specific enthalpy lines indicate the total heat content.
  Constant enthalpy lines are along the constant wet bulb temperature lines.

Example - 7.7 On psychrometry chart, WBT lines are ____________

(a) horizontal (b) straight inclined sloping downward to the right
(c) vertical (d) curved

Solution: (b)

7.4.2 Psychrometry of Air-Conditioning Process

- Mixing process

  – Specific humidity of the mixture (w), $$w = \frac{m_{a_1} w_1 + m_{a_2} w_2}{m_{a_1} + m_{a_2}}$$

  – Enthalpy of the mixture (h), $$h = \frac{m_{a_1} h_1 + m_{a_2} h_2}{m_{a_1} + m_{a_2}}$$

  – Temperature of the mixture (t), $$t = \frac{m_{a_1} t_1 + m_{a_2} t_2}{m_{a_1} + m_{a_2}}$$

  where for the two moist air stream

  m_{a_1}, m_{a_2} – Mass of the dry air; w_1, w_2 – Specific humidity;
  h_1, h_2 – Specific enthalpy; t_1, t_2 – Temperature (in °C)

- Mixing with Condensation: When a cool current mixes with hot current with high relative humidity, the moisture may get condensed and relative humidity of mixed stream might be less that that without condensation mass condensed per unit dry air

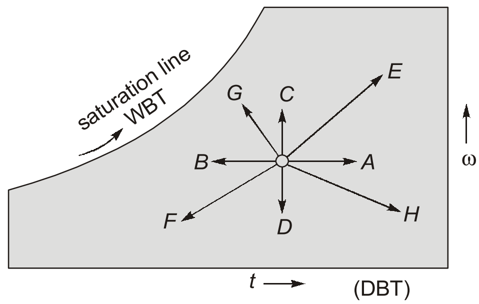
$$\omega_c = \omega_3 - \omega_4$$

$$\omega_4 = \frac{m_{a_1}\omega_1 + m_{a_2}\omega_2}{m_{a_1} + m_{a_2}} - \omega_c$$

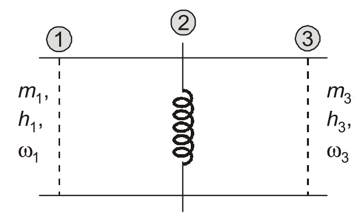
$$h_4 = \frac{m_{a_1}h_1 + m_{a_2}h_2}{m_a + m_2} - h_{f_4}\omega_c$$

7.5 Basic Air Conditioning Process

Process in diagram	Type of Air-conditioning
OA	Sensible Heating
OB	Sensible Cooling
OC	Humidification
OD	Dehumidification
OE	Heating and Humidification
OF	Cooling and Dehumidification
OG	Cooling and Humidification
OH	Heating and Dehumidification



7.5.1 Sensible heating of air



Sensible heat will be added to the moist air while passing it over the hot dry surface. Whose surface temperature is above DBT of the air.

$$Q_{1-3} = m_1(h_3 - h_1)$$

No moisture is added or removed from the air and the specific humidity remains constant.

7.5.2 Sensible Cooling Process

- Sensible cooling of moist air can be done by passing it over a cooling coil whose surface temperature is kept below the DBT of entering air and above DPT.
- No moisture is added or removed and DPT and latent heat content of air remain the same throughout the cooling process.

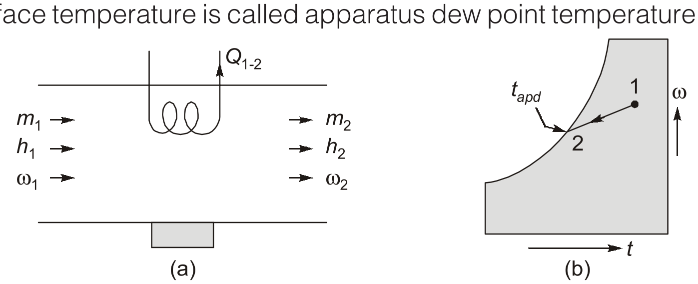
Example - 7.8 During sensible cooling process __________.

(a) specific humidity remains constant
(b) specific humidity increase
(c) specific humidity decreases
(d) specific humidity is unpredictable

Solution: (b)

7.5.3 Cooling and Dehumification of Moist Air

- Air is to be cooled and during cooling water vapour is to be separated from the air.
- Since moisture separation will occur only when moist air is cooled to a temperature below its DPT. Therefore, the effective surface temperature of the cooling coil kept below the initial DPT of the air and this surface temperature is called apparatus dew point temperature (t_{adp}).

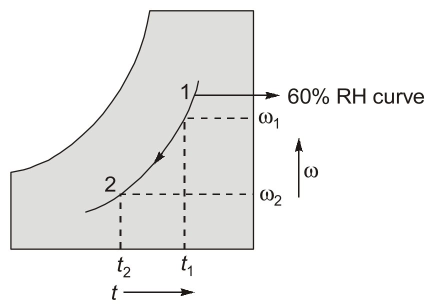


(a) Schematic device of cooling and dehumidification (b) Boiling and dehumidification

Example - 7.9 Atmospheric air from 40°C and 60% RH can be brought to 20°C and 60% RH by

(a) cooling and dehumidification process
(b) cooling and humidification process
(c) adiabatic saturation process
(d) sensible cooling process

Solution: (a)

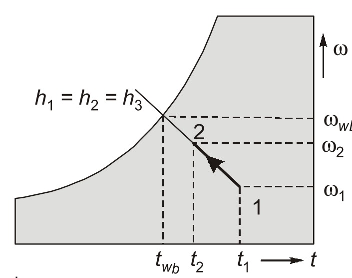


$$\text{Clearly } t_1 = t_2$$

and $$\omega_1 = \omega_2$$

∴ Process will be cooling and dehumidification.

7.5.4 Adiabatic Cooling or Cooling with Humidification



- Adiabatic cooling is because of the water attaining the wet-bulb temperature of air due to constant evaporation.
- This is the process used in air cooler/desert coolers. The extent of cooling, i.e., drop in temperature depends upon the difference between DBT and WBT.
- Air-cooling is higher in dry climate where the difference is large.
- This process also used in cooling tower for cooling of condenser water.
- The lowest possible temperature to which air can be cooled is the wet-bulb temperature.

Example - 7.10 Water by evaporative cooling, can be theoretically be cooled down to __________.

(a) atmospheric temperature (b) air's DBT
(c) air's WBT (d) air's DPT

Solution: (c)

7.5.5 Heating and Humidification

- In this case both heat as well as water vapour are added to the air. To achieve this, the temperature of water to be sprayed in the air stream is kept at a temperature greater than the DBT of incoming air.
- During this process, the humidity ratio, the DBT, the WBT, the DPT and the enthalpy of air increases. The RH may increase or decrease.

Example - 7.11 Water at 42°C is sprayed into a stream of air at atmospheric pressure, dry bulb temperature of 40°C and WBT of 20°C. The air leaving the spray humidifier is not saturated. Which of the following statement is true?

(a) Air gets cooled and humidified (b) Air gets heated and humidified
(c) Air gets heated and dehumidified (d) Air gets cooled and dehumidified

Solution: (b)

As $t_{\omega} > t_{dbt}$ $\therefore$ heated and humidified

7.5.6 Sensible Heating and Cooling

(a) **Sensible heating:** It is the process of increasing the dry bulb temperature at constant specific humidity.

Effect of sensible heating:

(i) Dry bulb temperature increases.
(ii) Specific humidity (ω) constant.
(iii) Dew point temperature (DPT) constant.
(iv) Relative humidity (ϕ) decreases.
(v) Enthalpy, wet bulb temperature and specific volume all increase.

(b **Sensible cooling:** It is the process of decreasing the dry bulb temperature at constant specific humidity.

Effect of sensible cooling:

(i) Dry bulb temperature decreases.
(ii) Specific humidity (ω) constant.
(iii) Dew point temperature (DPT) constant.
(iv) Relative humidity (ϕ) increases.
(v) Wet bulb temperature, enthalpy and specific volume all decrease.

$$Q_s = m_a(1.005 + 1.88\,\omega)\,(t_1 - t_2)$$

m_a – mass flow rate of dry air ; ω – specific humidity of moist air ; t_1, t_2 – initial and final temperature

7.5.7 Latent Heating and Coolings

$$Q_L = m_a[h_1 - h_2]$$

m_a – mass flow rate of dry air

h_1, h_2 – initial and final specific enthalpy

- If CMM be the cubic meter per minute supply of air and $\rho_{air} = 1.2$, $(C_p)_{air} = 1.02$

Then $$Q_s = 0.0204\,(\text{CMM})\,\Delta t \text{ kw}$$

$$Q_L = 50(\text{CMM})\,\Delta\omega \text{ kw}$$

Where, Q_S = Relative sensible heat

Q_L = Relative latent heat

$$\text{Number of air flow changes/hr} = \frac{\text{Cmm}\left(\text{m}^3/\text{hr}\right)}{\text{Volume of room}\left(\text{m}^3\right)}$$

CMM: It is the volume flow rate of air taken in m^3/min.

7.5.8 Sensible Heat Factor (SHF)

$$\text{SHF} = \frac{Q_S}{Q_S + Q_L} = \frac{h_B - h_A}{h_C - h_A}$$

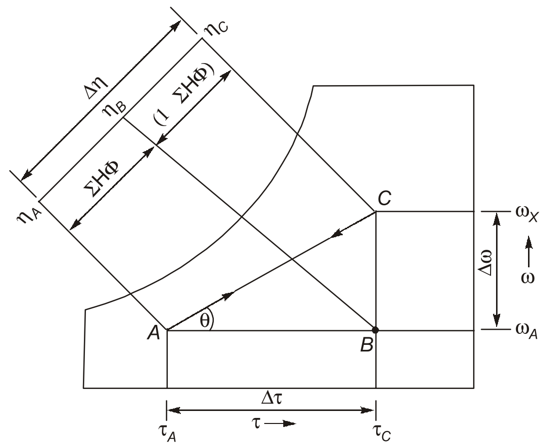
$$= \frac{0.0204\Delta t}{0.0204\Delta t + 50\Delta\omega}$$

- SHF = 1

$\Rightarrow$ Sensible Heating or Cooling

- SHF = 0

$\Rightarrow$ Humidification or Dehumidification

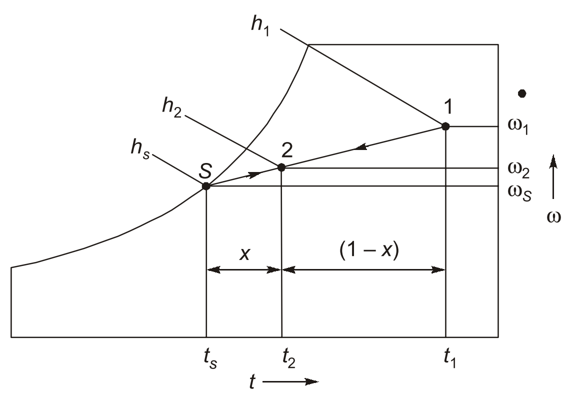


7.5.9 By Pass Factor (x)

- By pass factor is defined as the fraction of air which doesn't come in contact with or which by passes the cooling surface.
- Due to bypass factor, the exit state of air is a complex mixture of contacted and uncontacted air.

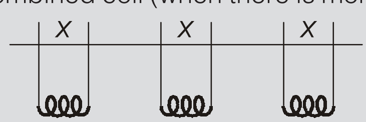
$$X = \frac{t_2 - t_s}{t_1 - t_s} = \frac{\omega_2 - \omega_s}{\omega_1 - \omega_s} = \frac{h_2 - h_s}{h_1 - h_s}$$

- By pass factor represents how much effective the coil is high by pass factor coil implies less effective and vice-versa.



NOTE

By pass factor in case of combined coil (when there is more than one row of coils)



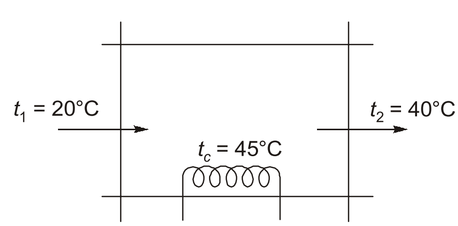
BPF = X^n

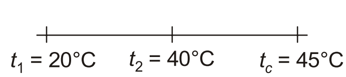
Where 'n' is total number of coils.

Example - 7.12 Air at 20°C DBT and 40% RH is heated upto 40°C using an electric heater, whose surface temperature is maintained uniformly at 45°C. The bypass factor of the heater is

(a) 0.2
(b) 0.25
(c) 0.88
(d) 1

Solution: (a)





By pass factor of heater,

$$\text{BPF} = \frac{t_c - t_2}{t_c - t_1} = \frac{45 - 40}{45 - 20}$$

$$X = 0.2$$

7.5.10 Adiabatic Mixing of Air Streams

Mixing of two moist air streams is a common process in air-conditioning systems. For the purpose of analysis the mixing of two such streams is assumed to be an adiabatic process and is shown in figure (a).

The pipelines carrying air streams are assumed to be perfectly insulated so that no heat enters of leaves the system figure (b).

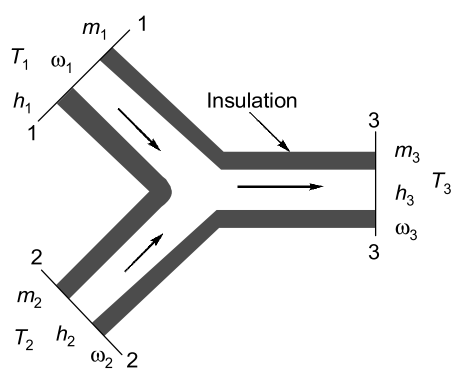
Heat balance gives $m_1h_1 + m_2h_2 = m_3h_3$

Mass balance gives $m_1 + m_2 = m_3$

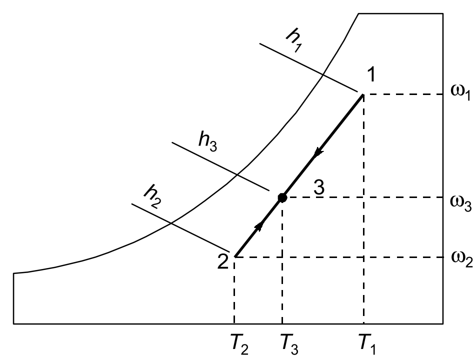
Replacing the value of m_3 from equation (6.43) in equation (6.42)

$$m_1h_1 + m_2h_2 = (m_1 + m_2)h_3$$

Rearranging the terms, $$\frac{m_1}{m_2} = \frac{h_3 - h_2}{h_1 - h_3}$$



(a): Adiabatic mixing of two moist streams



(b): Adiabatic mixing of two air streams

Similarly, during mixing, water vapour is neither added nor removed.

So, $m_1\omega_1 + m_2\omega_2 = m_3\omega_3$

Substituting the value of m_3 and rearranging, we get

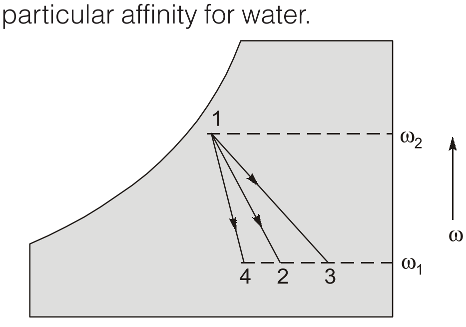
$$\frac{m_1}{m_2} = \frac{\omega_3 - \omega_2}{\omega_1 - \omega_3}$$

The symmetry also gives

$$\frac{m_1}{m_2} = \frac{T_3 - T_2}{T_1 - T_3}$$

7.5.11 Chemical Dehumidification or Sorbent Dehumidification

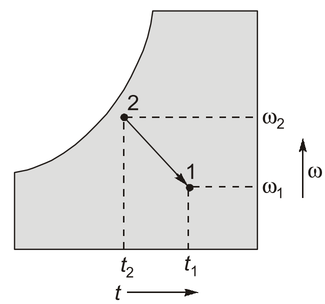
- Sorbents are materials that have an ability to attract and hold gases and liquids, other than water vapour. Desiccants are a subset of sorbents; they have a particular affinity for water.
- The chemical dehumidification process takes place along constant enthalpy or WBT line from 1 - 2. Ideally the latent heat is released by condensation of moisture in the solid adsorbent from the air and picking up by air as sensible heat raising its temperature. Thus it is an adiabatic process.
- Solid sorbents includes silica gel, zeolites, synthetic zeolites.



Example - 7.13 During the chemical dehumidification process of air

(a) DBT and specific humidity decreases.
(b) DBT increases and specific humidity decreases.
(c) DBT decreases and specific humidity increases.
(d) DBT and specific humidity increases.

Solution: (a)



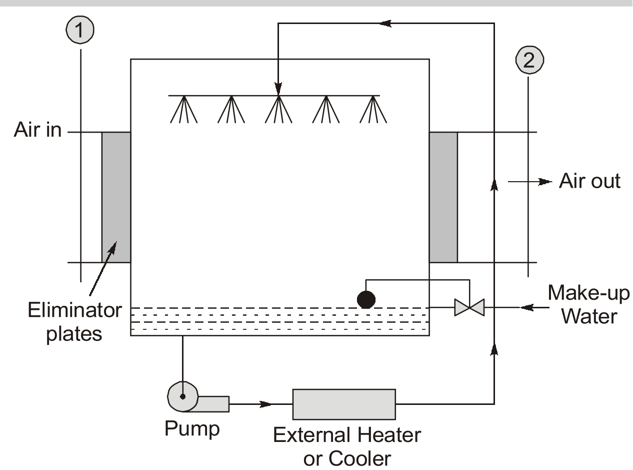
Clearly, $\omega_2 > \omega_1$

and $t_2 < t_1$

∴ DBT ↑ and ω ↓

7.6 Air Washer

- It is a device used in conditioning of air for large spaces. Air is passed through spray of water and following processes can take place depending upon the relative temperature of water droplets and air.
  1. Heating and dehumidification ($t_s > t_1$)
  2. Humidification ($t_s = t_1$)
  3. Cooling and humidification ($t_1' < t_s < t_1$)
  4. Adiabatic saturation ($t_1' = t_s$)
  5. Cooling and humidification ($t_d < t_s < t_1'$)
  6. Cooling ($t_s = t_d$)
  7. Cooling and dehumidification ($t_s < t_d$)

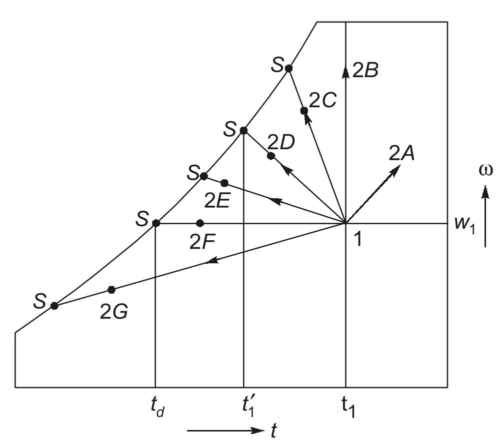


- Humidifying efficiency of air washer

$$h_H = \frac{h_2 - h_1}{h_s - h_1} = \frac{\omega_2 - \omega_1}{\omega_s - \omega_1}$$

By pass factor,

$$X = \frac{\omega_s - \omega_2}{\omega_s - \omega_1} = 1 - \eta_H$$



Example - 7.14 Air washer can work as

1. humidifier only
2. Dehumidifier only
3. Filter only

Which of these statements are correct?

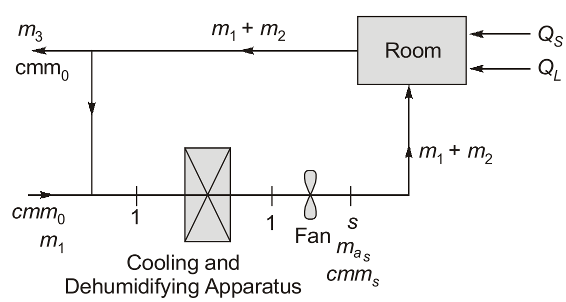
(a) Only 1 (b) 2 and 3

(c) 1 and 3 (d) 1, 2 and 3

Solution: (d)

Air washer can perform any psychrometric process depending upon temperature of spraying water.

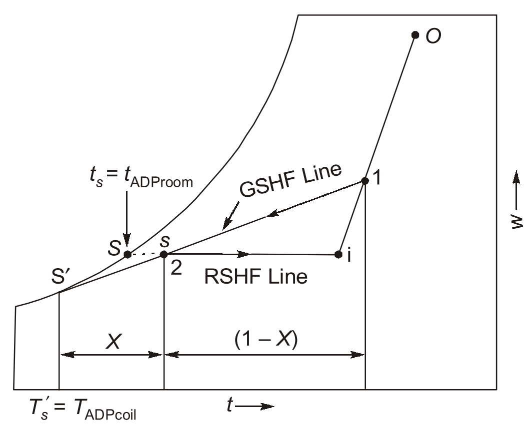
7.7 Summer Air-Conditioning System



m_1 – fresh air inducted in the room

m_2 – recirculated air

m_3 – air rejected from the room = m_1



$$\text{Room SHF} = \frac{\text{RSH}}{\text{RSH}+\text{RLH}} = \frac{\text{RSH}}{\text{RTH}}$$

Minimum quantity of air to be supplied is

$$(\text{CMM}) = \frac{\text{RSH}}{0.0204(t_i - t_{ADP})}$$

$$= \frac{\text{RLH}}{50(\omega_i - \omega_{ADP})} = \frac{\text{RTH}}{0.02(h_i - h_{ADP})}$$

- RSH = Room Sensible Heat; RLH = Room Latent Heat; RTH = Room total heat
- When ventilation air is used, another load, that of bringing a ventilation air from outside condition to inside condition, comes on apparatus. This is called ventilation load.

  OASH = Outside air sensible heat

  OALH = Outside air latent heat
- Air conditioning equipment load

  Total sensible TSH = RSH + OASH

  Total latent TLH = RLH + OALH

$$\text{Grand sensible heat factor} \quad \text{GSHF} = \frac{\text{TSH}}{\text{TSH}+\text{TLH}} = \frac{\text{TSH}}{\text{GTH}}$$