Chapter - V

5.1 *What do you understand by dry bulb and wet bulb temperatures?*

Dry Bulb Temperature (or) DBT): (t_d) It is the temperature measured by ordinary thermometer.

Wet Bulb Temperature (or) (WBT): (t_w) It is the temperature measured by a thermometer when the bulb of thermometer is wrapped by a wet cotton wick and is exposed to a stream of moving air.

5.2 *Define Dew point temperature of humid air. How it is related to partial pressure of water vapour in the moist air?*

When air is cooled at constant pressure, the water vapour in air is condensed into water at particular temperature. This temperature is called Dew point temperature (DPT).

The saturation temperature (taken from steam table) corresponding to partial pressure of water vapour is called DPT.

5.3. *Define degree of saturation of moist air.*

It is defined as the ratio of amount of moisture present in 1 kg of dry air to the amount of moisture required to saturate 1kg of dry air at same dry bulb temperature.

Degree of saturation

$$\mu = \frac{\text{Amount of moisture present in 1 kg of dry air}}{\text{Amount of moisture required to saturate 1 kg of dry air at same DBT}} = \frac{\omega}{\omega_s}$$

where $\omega = 0.622 \dfrac{P_v}{P_b - P_v}$ and $\omega_s = 0.622 \dfrac{P_{vs}}{P_b - P_{vs}}$

P_v = Partial pressure of water vapour.

P_{vs} = Saturation pressure corresponding to DBT.

5.4. *Define Relative humidity of air.*

It is the ratio of the mass of water vapour in air in a given volume at a given temperature to the mass of water vapour contained in the same volume at same temperature when air is saturated.

$$\phi = \frac{m_v}{m_{vs}} = \frac{P_v}{P_{vs}} = \frac{\mu}{1 - (1 - \mu)\dfrac{P_{vs}}{P_b}}$$

5.5 *What is specific humidity and how do you calculate it?*

It is the mass of water vapour per kg of dry air.

$$\text{Specific humidity } (\omega) = \frac{\text{mass of water vapour}}{\text{mass of dry air}}$$

(ie) $$\omega = \frac{m_v}{m_a}$$

also

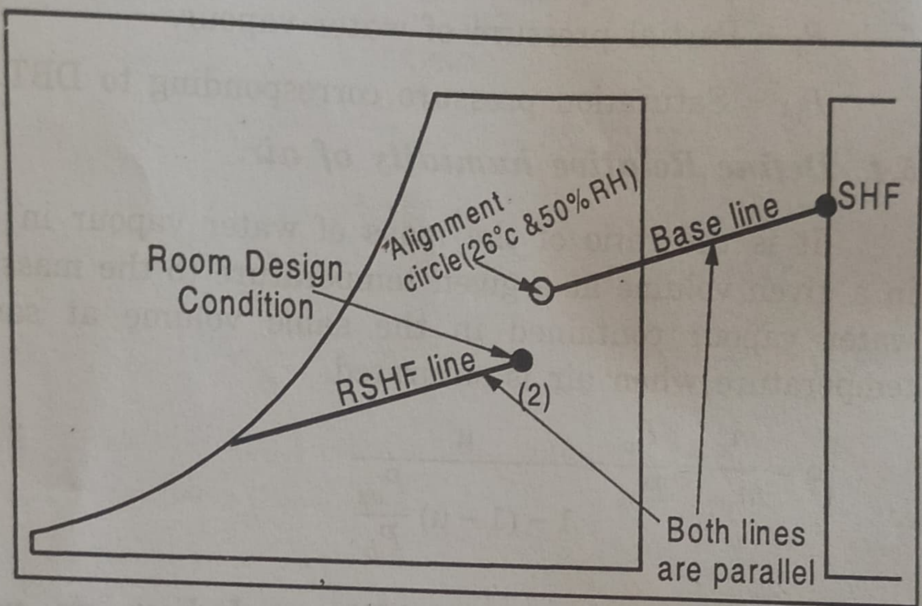
$$\omega = 0.622 \frac{P_v}{P_b - P_v}$$

where P_v = vapour pressure

P_b = barometric pressure

unit of ω is $\frac{\text{kg of water vapour}}{\text{kg of dry air}}$

5.6. *Define RSHF line?*



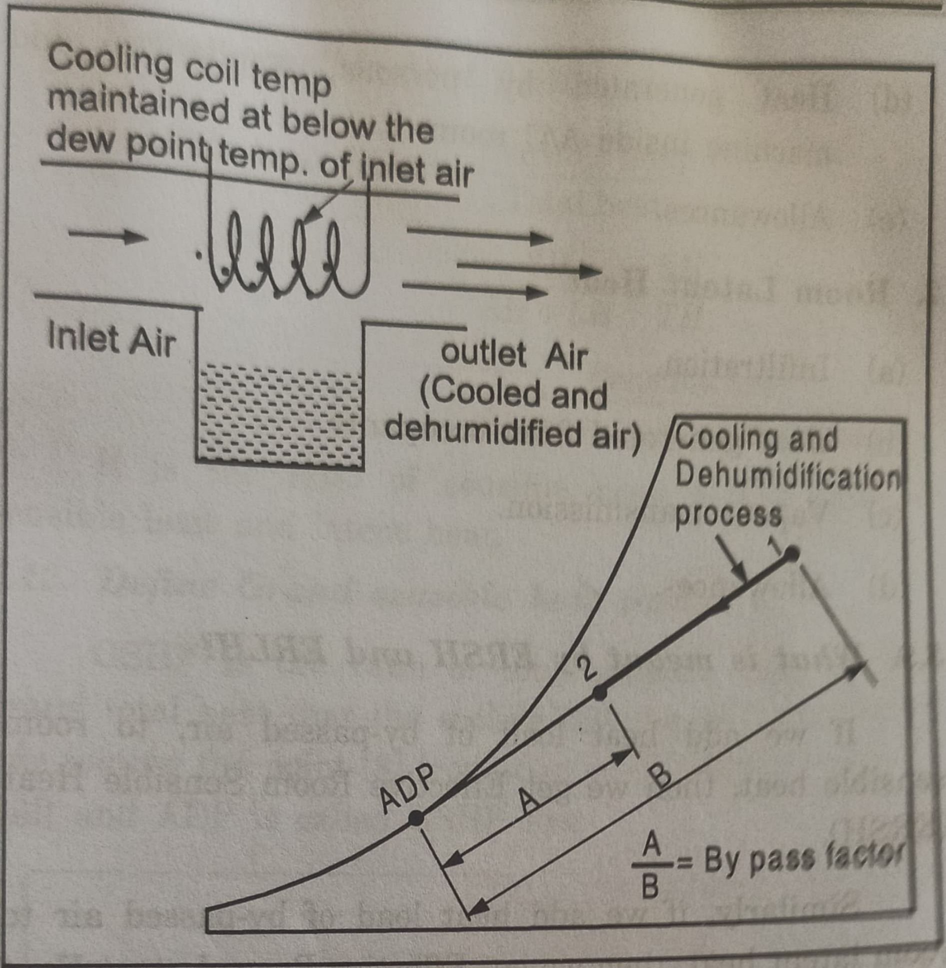
It is room sensible heat factor line. This line is drawn from a point (2) (Room design condition) parallel to base line. Refer psychrometric chart.

The sufficient supply air falling at any point on RSHF line will remove both room sensible heat and room latent heat.

$$\text{RSHF} = \frac{\text{Room sensible heat}}{\text{Room sensible heat} + \text{Room latent heat}}$$

5.7. *Define Apparatus dew point. Show the state in psychrometric chart for a typical moist air process.*

When air is passing through cooling coil whose effective surface temperature t_s is below the dew point



temperature of entering air, the water vapour in the air will condense into water and droplets may be formed around the cooling coil and drained. This temperature of cooling coil (t_s) is called Apparatus dew point temperature simply ADP.

5.8 *Name different heat loads considered during cooling load calculations.*

1. Room Sensible Heat Load

(a) Heat from sun light.

(b) Heat from partition walls, ceiling and floor.

(c) Infiltration.

(d) Heat generated by persons, appliances and machine inside A/C room.

(e) Allowances.

2. **Room Latent Heat**

(a) Infiltration.

(b) Heat generated from occupants.

(c) Vapour transmission.

(d) Allowances.

5.9. *What is meant by ERSH and ERLH?*

If we add heat load of by-passed air, to room sensible heat, then we get Effective Room Sensible Heat (ERSH).

Similarly, if we add heat load of by-passed air to room latent heat, then we get Effective Room Latent Heat (ERLH).

5.10. *Explain how air may be dehumidified.*

When air is passing through cooling coil whose temperature is maintained at below the dew point temperature of air, the water vapour in the air condenses into washer and droplets are formed around the cooling coil and the droplets are drained. So the water vapour is removed from air i.e air is dehumidified.

Similarly, when air is passing through air washer. [Air washer sprays water on it] in which spray water temperature is maintained at below the dew point temperature of air, the water vapour in the air condenses into water and air is dehumidified.

5.11. Define sensible heat factor.

$$\text{Sensible heat factor} = \frac{\text{Sensible heat}}{\text{Total heat}}$$

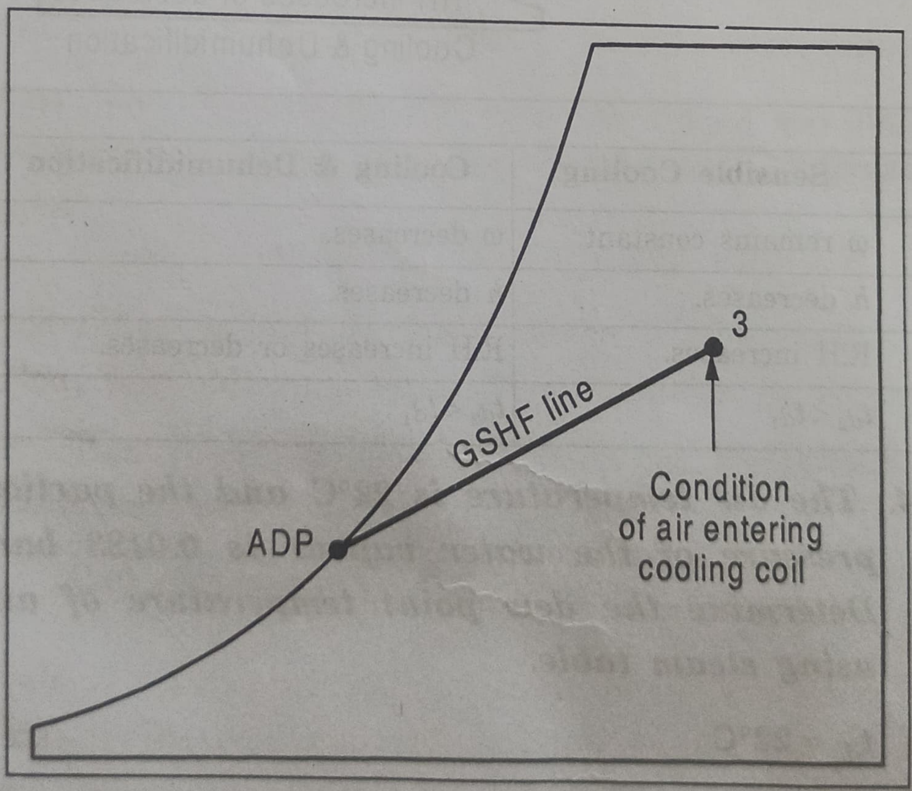
$$= \frac{SH}{SH + LH} = \frac{SH}{TH}$$

$$= \frac{\text{Sensible heat}}{\text{Sensible heat} + \text{Latent heat}}$$

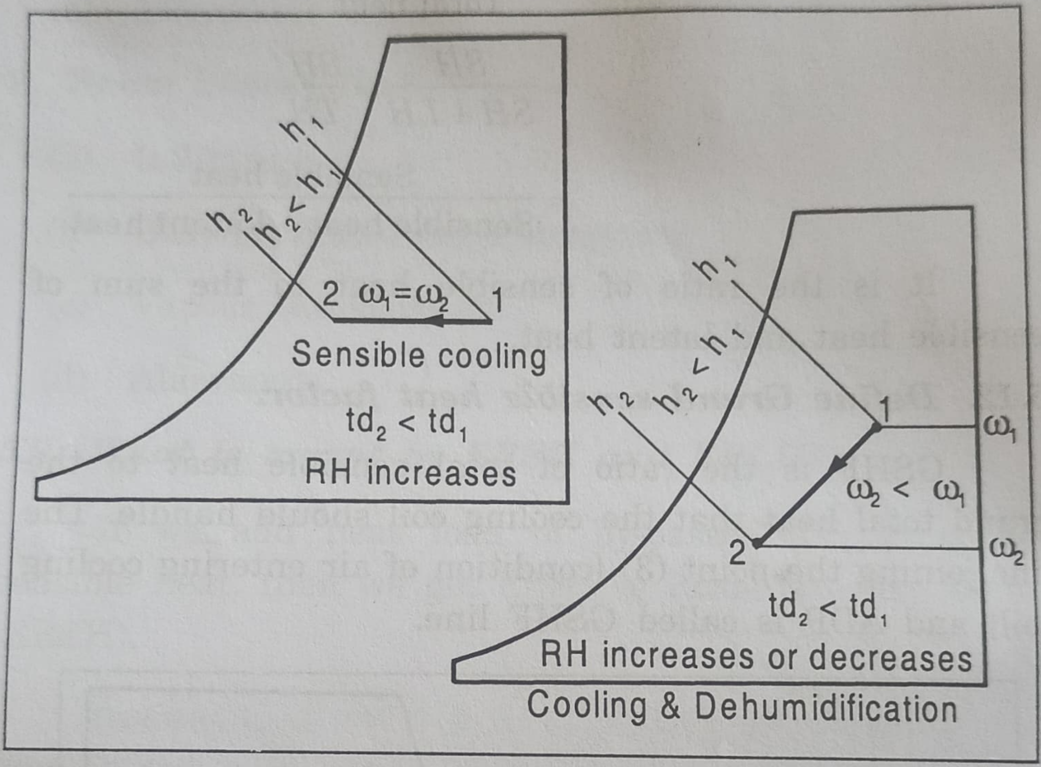
It is the ratio of sensible heat to the sum of sensible heat and latent heat.

5.12. Define Grand sensible heat factor.

GSHF is the ratio of total sensible heat to the grand total heat that the cooling coil should handle. The line joining the point (3) [condition of air entering cooling coil] and ADP is called GSHF line.



5.13. Compare Sensible cooling with Cooling and Dehumidification process.



	Sensible Cooling	Cooling & Dehumidification
1.	ω remains constant.	ω decreases.
2.	h decreases.	h decreases.
3.	R.H increases.	R.H increases or decreases.
4.	$td_2 < td_1$	$td_2 < td_1$

5.14. The air temperature is 22°C and the partial pressure of the water vapour is 0.0123 bar. Determine the dew point temperature of air using steam table.

$t_{d_1} = 22°C$

$P_v = 0.0123$ bar

DPT (Dew point temperature) is the saturation temperature corresponding to P_v.

Using steam table,

$t_{sat} = 10°C$ for $P_v = 0.0123$ bar

So, $DPT = 10°C$

5.15. *Define coil efficiency and write the relationship between coil efficiency and by pass factor. What is 'By-pass factor' of a cooling coil.*

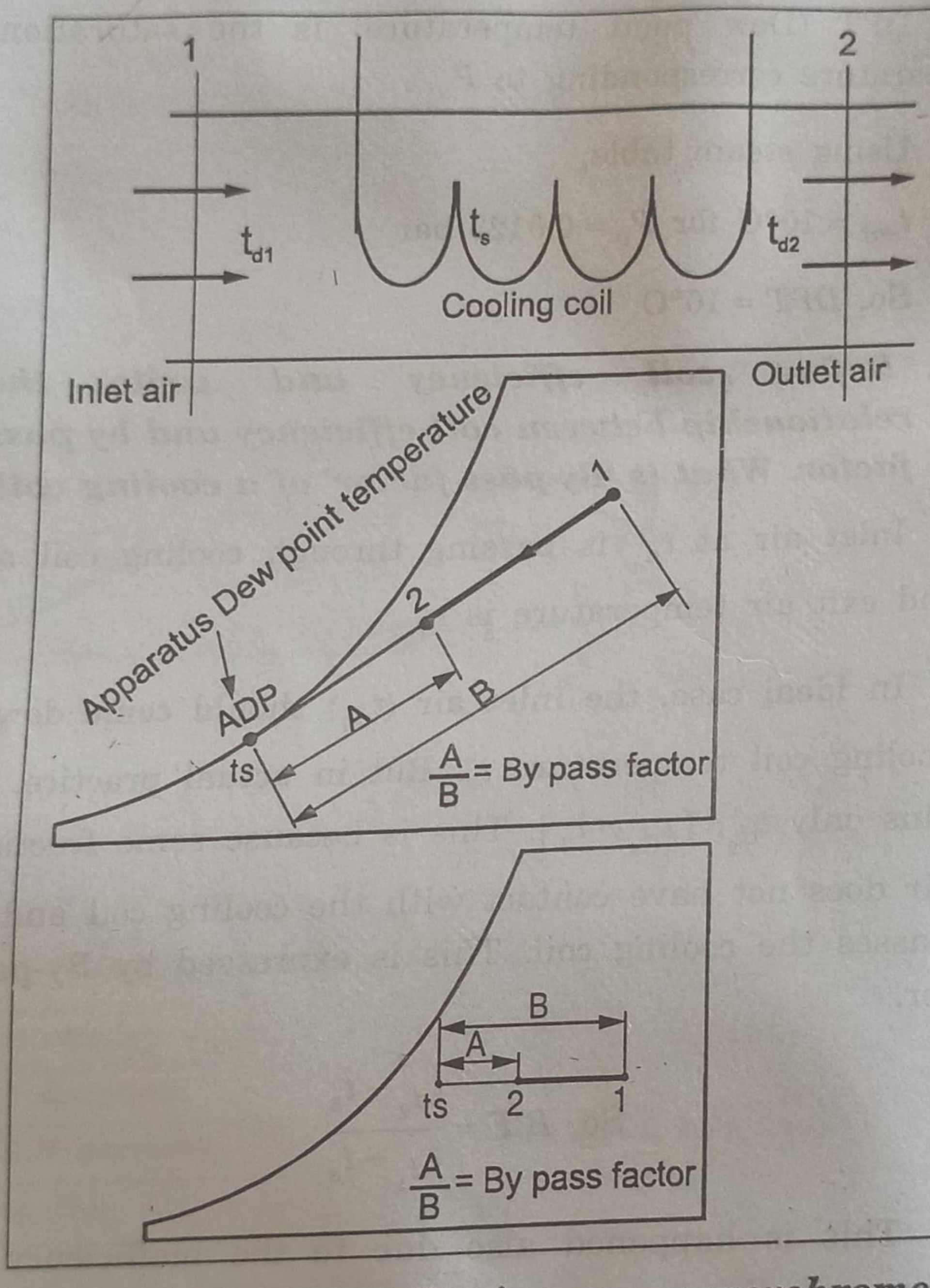
Inlet air at t_{d_1} is passing through cooling coil at t_s and exit air temperature is t_{d_2}.

In ideal case, the inlet air (t_{d_1}) should come down to cooling coil temperature t_s. But in actual practice, it attains only t_{d_2}. [$t_{d_2} > t_s$]. This is because some fraction of air does not have contact with the cooling coil and it by-passes the cooling coil. This is expressed by By-pass factor.

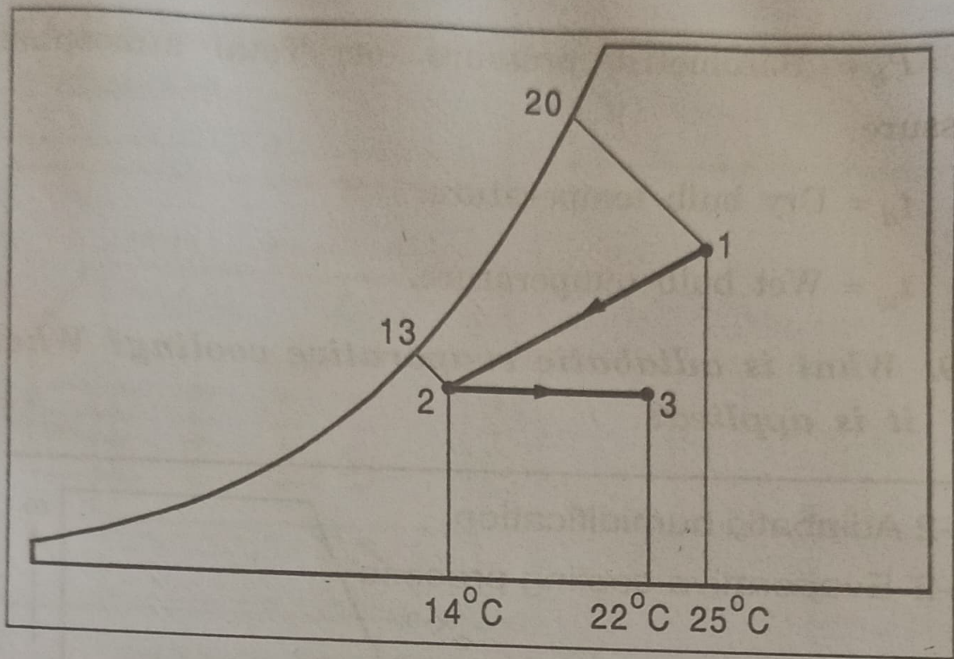
$$\text{So, } B.F = \frac{t_{d_2} - t_s}{t_{d_1} - t_s}$$

This is happened also due to the inefficiency of cooling coil. So,

Coil efficiency $= 1 - B.F$



5.16. *Represent the following on a psychrometric chart. Air at 25°C DBT and 20°C WBT cooled to 14°C DBT and 13°C WBT and heated to 22°C DBT.*



5.17. *What are the factors influence the by-pass of a coil.*

- Temperature of entering air.
- Temperature of the cooling coil (or) heating coil.
- Speed of air.
- Turbulence of air.

5.18. *Write the Carrier's equation to calculate partial pressure of water vapour in atmospheric air.*

$$P_v = P_{sw} - \frac{[P_b - P_{sw}][t_d - t_w]}{1527.4 - 1.3t_w}$$

where P_v = Partial pressure of water vapour in air.

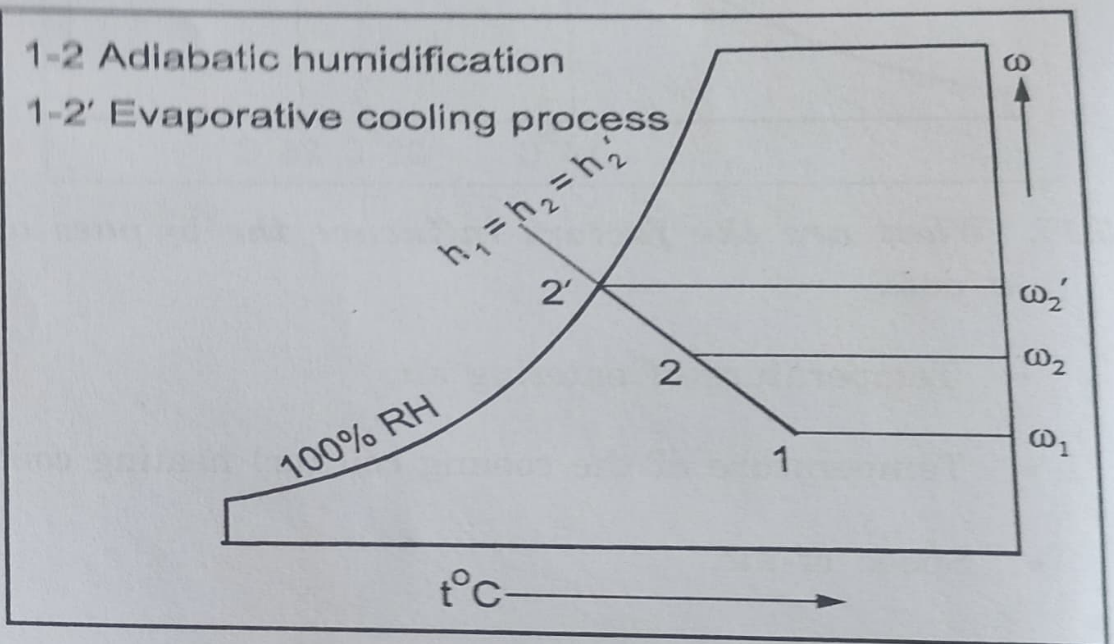
P_{sw} = Saturation pressure corresponding to WBT (t_w) wet bulb temperature.

P_b = Barometric pressure (or) Total atmospheric pressure.

t_d = Dry bulb temperature.

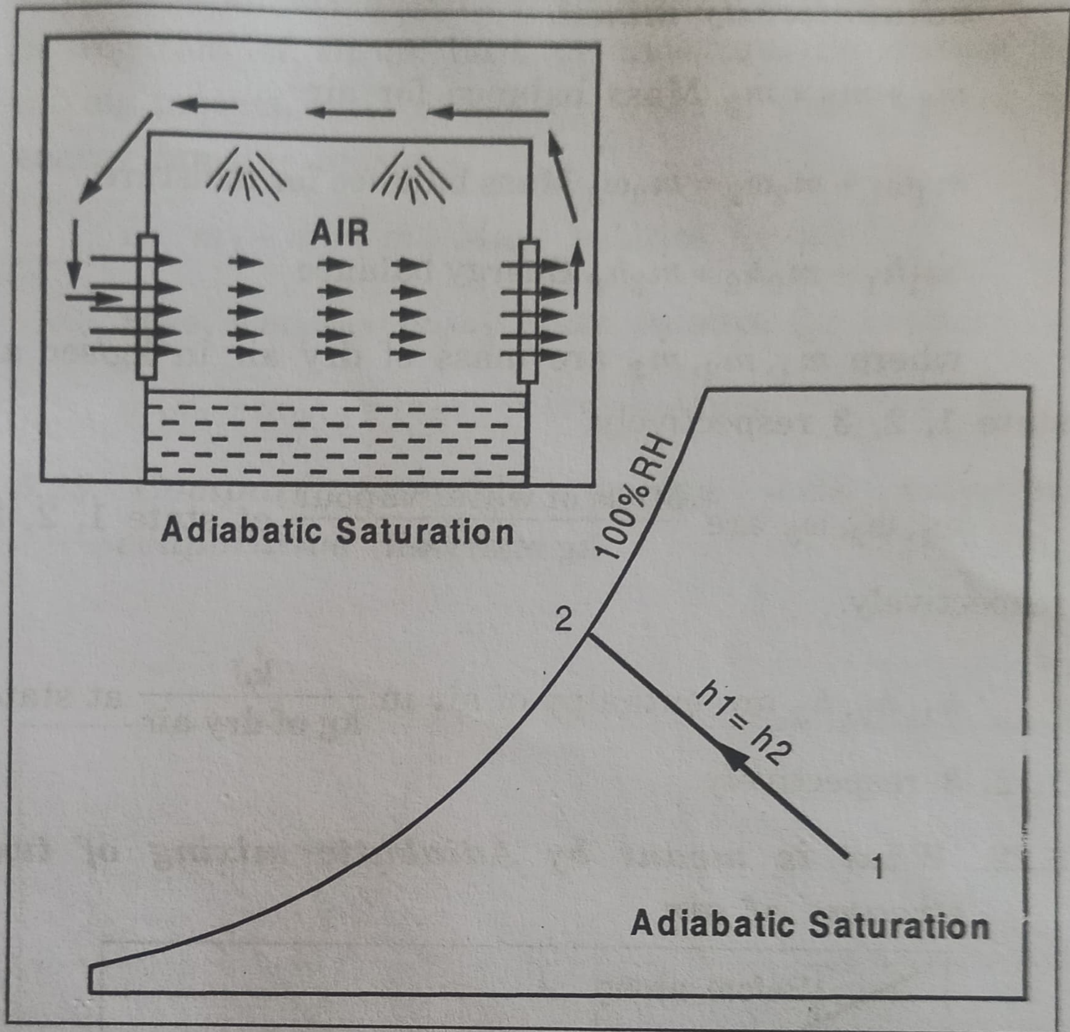
t_w = Wet bulb temperature.

5.19. *What is adiabatic evaporative cooling? Where it is applied?*



Air is passing through spray chamber, water is added to the air. This process is humidification. If no heat transfer occurs during this process, then it is adiabatic humidification. If the same air is humidified until the air is saturated, (until R.H = 100%) then the process is called adiabatic saturation process (or) Evaporative cooling process.

5.20. *Explain adiabatic saturation process with sketches.*



Air is passing through adiabatic saturator where water vapour is added and also its relative humidity is added until it attains the 100%. R.H. During the process, enthalpy of air remains constant. i.e. No heat transfer from system to surroundings or surroundings to system. This process is called adiabatic saturation process. [This is also called cooling and humidification process].

5.21. *Write the equations for finding the condition of mixture when two streams of air are adiabatically mixed.*

$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$ Mass balance for air

$\dot{m}_1\omega_1 + \dot{m}_2\omega_2 = \dot{m}_3\omega_3$ Mass balance for moisture

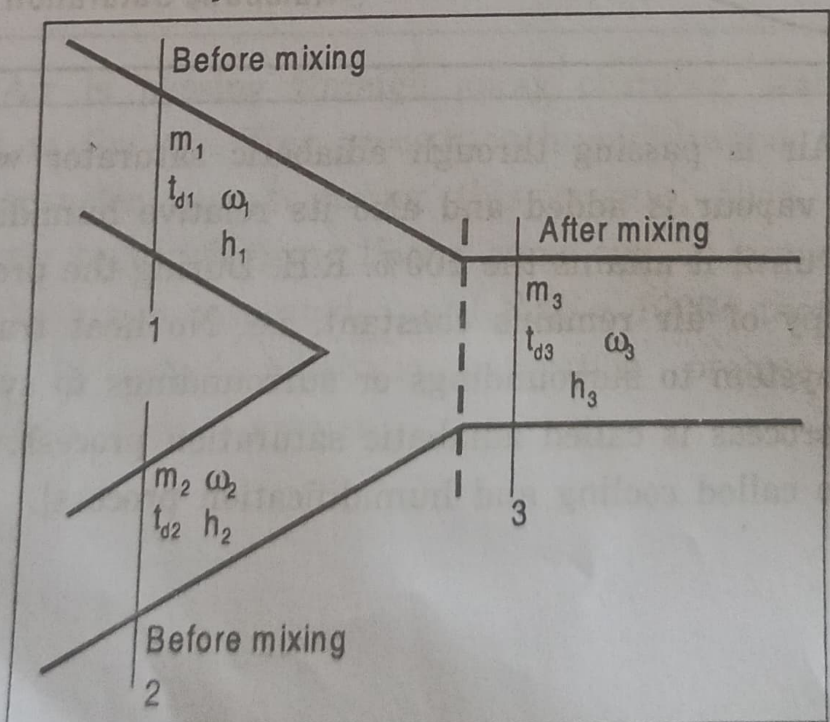
$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$ Energy balance

where $\dot{m}_1, \dot{m}_2, \dot{m}_3$ are mass of dry air in kg/sec at state 1, 2, 3 respectively.

$\omega_1, \omega_2, \omega_3$ are $\dfrac{\text{Mass of water vapour}}{\text{kg of dry air}}$ at state 1, 2, 3 respectively.

h_1, h_2, h_3 are enthalpy of air in $\dfrac{\text{kJ}}{\text{kg of dry air}}$ at state 1, 2, 3 respectively.

5.22. *What is meant by Adiabatic mixing of two streams of air.*



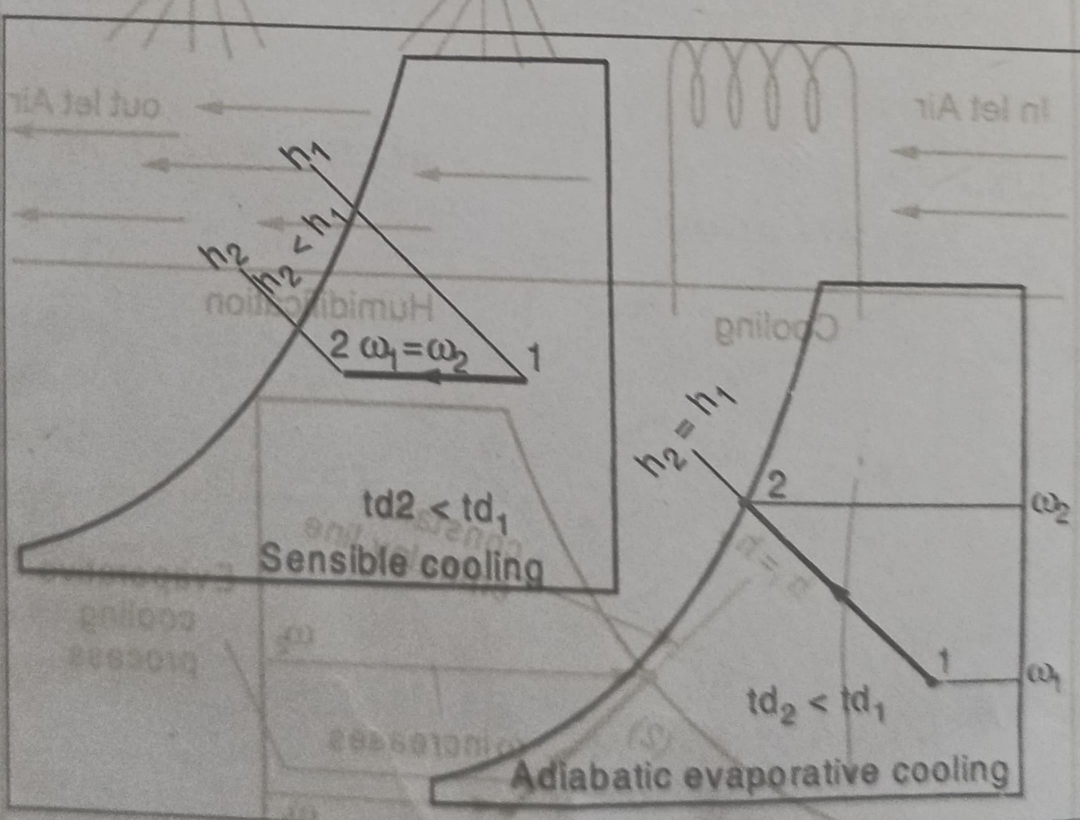
There is no heat transfer from system to surroundings (or) surroundings to system during mixing process. Two streams of air are mixed adiabatically i.e. without addition or rejection of either heat or moisture. So during this mixing process, mass of dry air, mass of water vapour and energy remains constant.

i.e. $m_1 + m_2 = m_3$ Mass balance for air

$m_1\omega_1 + m_2\omega_2 = m_3\omega_3$ Mass balance for vapour

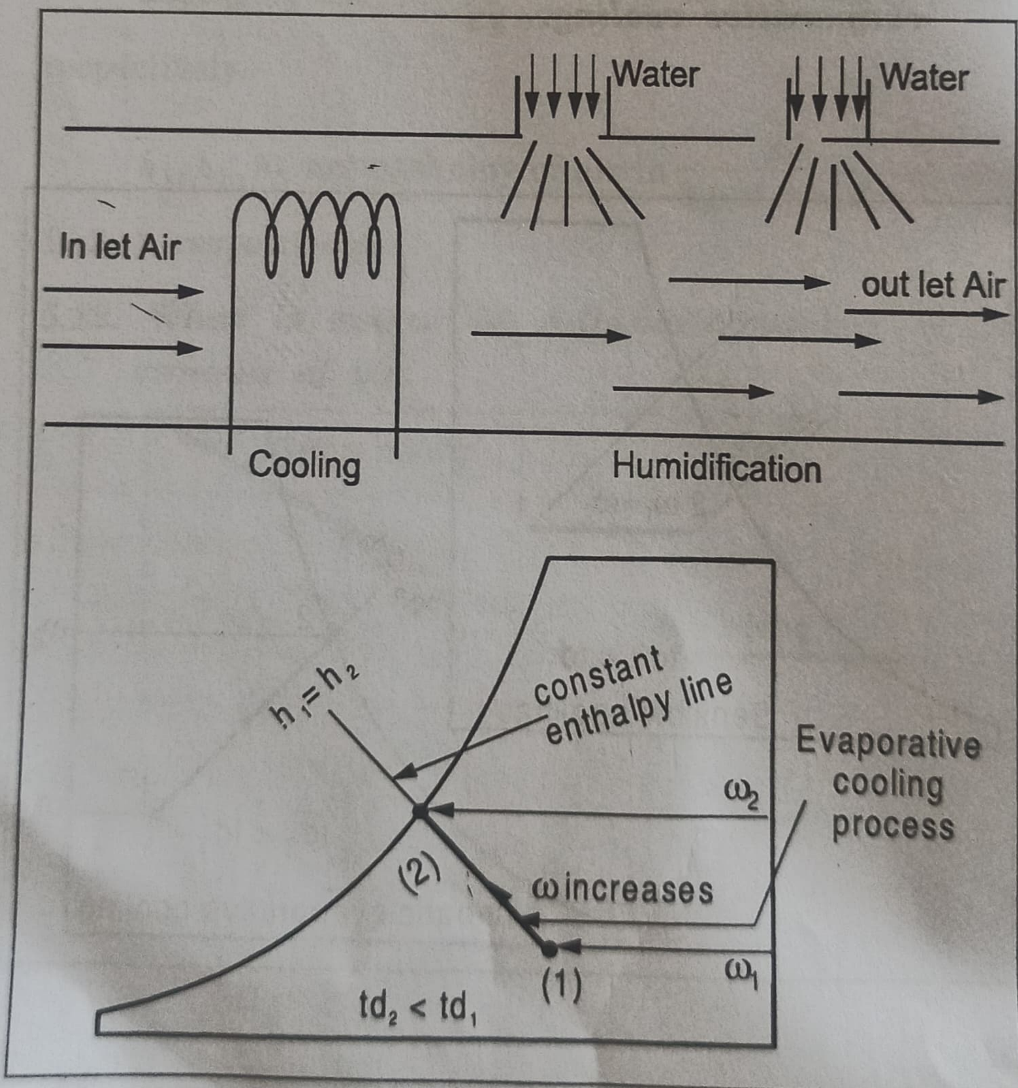
$m_1h_1 + m_2h_2 = m_3h_3$ energy balance.

5.23. *Compare Sensible cooling with adiabatic evaporative cooling.*



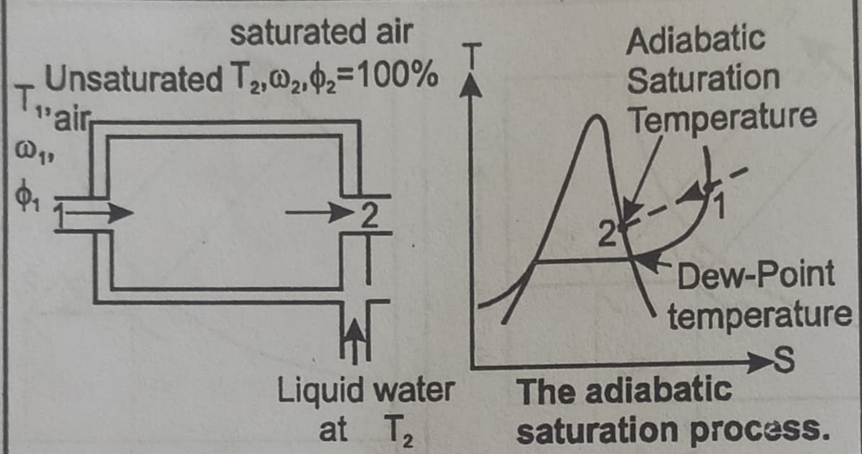
	Sensible cooling	Adiabatic Evaporative cooling
1.	Absolute humidity (ω) remains constant.	ω increases. [$\omega_2 > \omega_1$]
2.	Enthalpy decreases [$h_2 < h_1$]	Enthalpy remains constant.
3.	R.H. increases.	R.H. increases.
4.	Air is not humidified.	Air is humidified.

5.24. *Sketch the evaporative cooling process in a flow diagram and in psychrometric chart.*



Evaporative cooling means, air is cooled with enthalpy remains constant. It is also called adiabatic humidification process, or adiabatic saturation process.

5.25 *What is meant by adiabatic saturation temperature?*



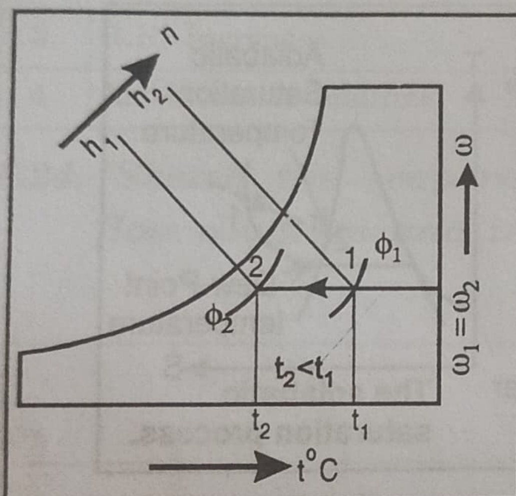
The adiabatic saturation process.

The adiabatic saturation process is another way of determining the absolute or relative humidity. The process is illustrated in fig. A steady stream of unsaturated air at ω_1 and T_1 passes through the channel.

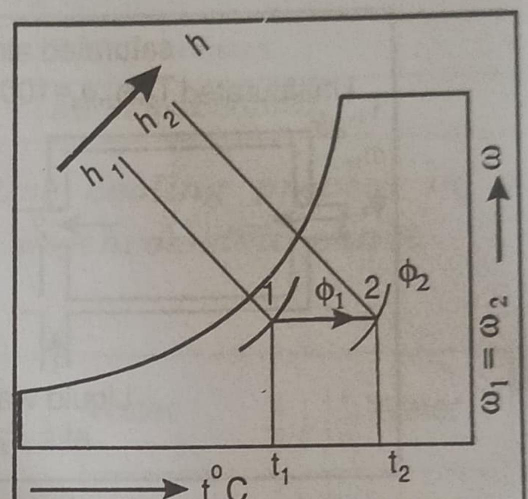
The moisture content of air will increase during the process, and its temperature will decrease, since part of the latent heat of vaporization of the water that evaporates will come from the air. If the channel is too long enough, the air stream will exit as saturation air with relative humidity $\phi = 100\%$ at T_2 which is called the adiabatic saturation temperature (or) thermodynamic wet bulb temperature.

5.26 *Draw a psychometric chart and show the following processes on it:*

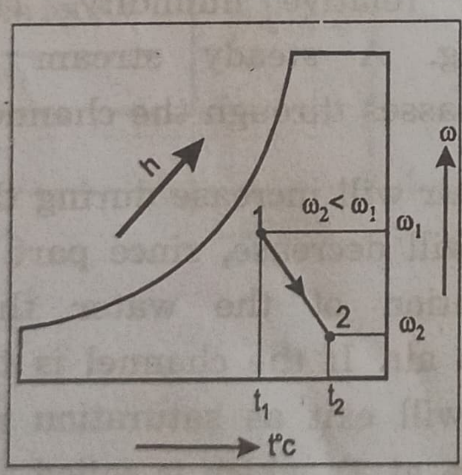
(a) Sensible cooling, (b) Senside heating, (c) heating and dehumidification and (d) cooling and humidification.



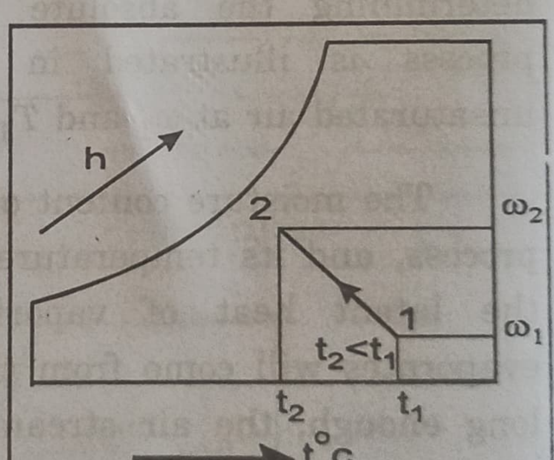
(a) Sensible Cooling Process.



(b) Sensible Heating Process.



(c) Heating and De-humidification.



(d) Cooling and Humidification.

5.27. *If the relative humidity of air is 60% at 30°C, what is the partial pressure of water vapour?*

we know that

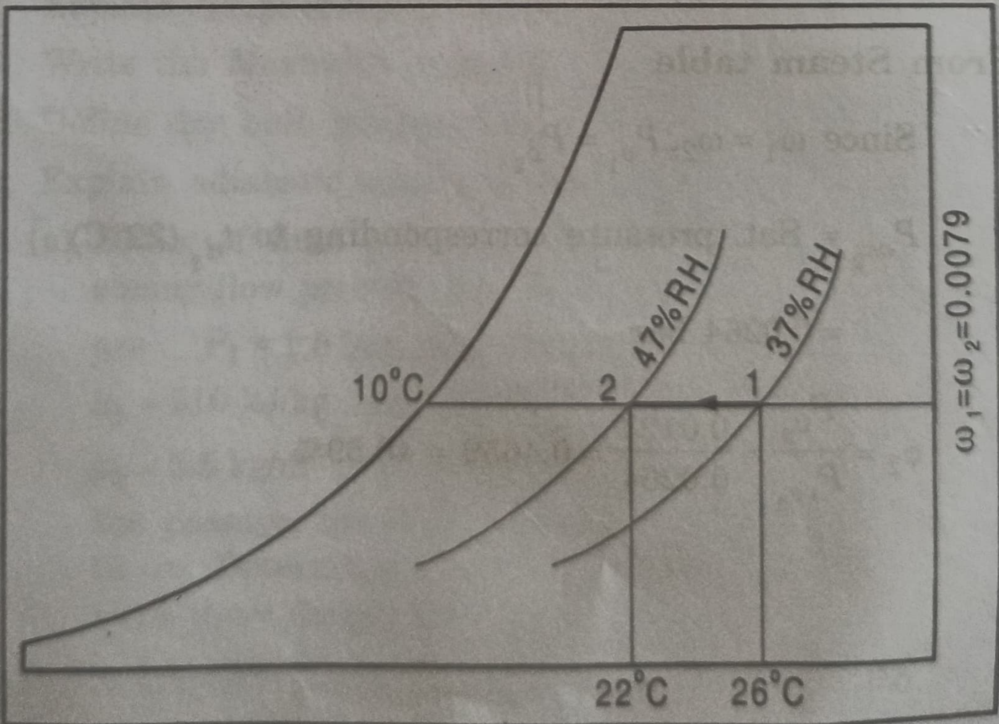
$$\text{Relative humidity } \phi = \frac{P_v}{P_{vs}}$$

given that $\phi = 60\%, t_d = 30°C$

$\therefore P_{vs} =$ saturation pressure corresponding to $t_d = 30°$ C. $\therefore$ $P_{vs} = 0.04242$ bar

$$\therefore P_v = \phi \times P_{vs} = 0.6 \times 0.04242 = 0.02545 \text{ bar}$$

5.28. *The air temperature at noon is found to be 26°C and dew point temperature is 10°C. Later in the day, the temperature drops to 22°C. Find the relative humidity of the air at both condition if the absolute humidity of the air remains constant.*



Solution

State 1

From Steam table

Saturation pressure corresponding to DPT (10°C) = P_{v_1}

[∵ DPT = sat. temp corresponding to P_v]

= 0.0123 bar

P_{vs} = sat. pressure corresponding to t_d (26°C) = 0.0336 bar

$$\phi_1 = \text{Relative humidity at (1)} = \frac{P_{v_1}}{P_{vs_1}}$$

$$= \frac{0.0123}{0.0336} = 0.3661 = 36.61\%$$

State 2

From Steam table

Since $\omega_1 = \omega_2, P_{v_1} = P_{v_2}$

P_{vs_2} = Sat. pressure corresponding to t_{d_2} (22°C)

= 0.0264 bar

$$\phi_2 = \frac{P_{v_2}}{P_{vs_2}} = \frac{0.0123}{0.0264} = 0.4659 = 46.59\%$$