

* Air Conditioning *

Air conditioning :- it is the process of simultaneous control of temp., humidity, velocity and purity of Air.

Psychrometry:- it is the branch of science which deals with the properties of moist air.
 → Moist air is considered as two component hence three variables are required for our study.
 We have fixed total pressure equal to 1 atm
 therefore we are able to draw psychrometry chart in 2-D.

		v	mas.
		O ₂	21% 23%
		N ₂	79% 77%
Moist air	Dry air		
	Water Vapour		

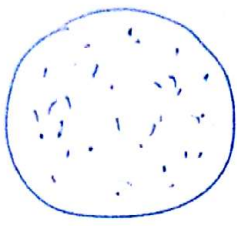
$$* P + F = C + 2$$

$$1 + F = 2 + 2 \Rightarrow \underline{F = 3}$$

$$\bar{P}_t = \bar{P}_{\text{vap}} + \bar{P}_{\text{air}}$$

$$P_{\text{total}} = 1 \text{ atm (const.)}$$

Psychrometric Properties:-


 P_t, V
 T, P_a, P_v
 m_v, m_a

$$P_v V = m_v R_v T \quad - (1)$$

$$P_a V = m_a R_a T \quad - (2)$$

① Specific humidity / Humidity Ratio / Absolute humidity (w)

$$w = \frac{m_v}{m_a}$$

from eqn ① & ②

$$\frac{P_v}{P_a} = \frac{m_v}{m_a} \times \frac{R_v \rightarrow \frac{\bar{R}}{18}}{R_a \rightarrow \frac{\bar{R}}{29}}$$

~~mass of water vapour in moist air~~

$$\frac{P_v}{P_a} = \frac{m_v}{m_a} \times \frac{29}{18}$$

* mass of water vapour present in moist air per kg of dry air

$$\therefore \frac{m_v}{m_a} = \frac{18}{29} \frac{P_v}{P_a}$$

$$\boxed{w = 0.622 \frac{P_v}{P_t - P_v}} \quad \text{kg v / kg dry air}$$

$$\boxed{m_t = Hw}$$

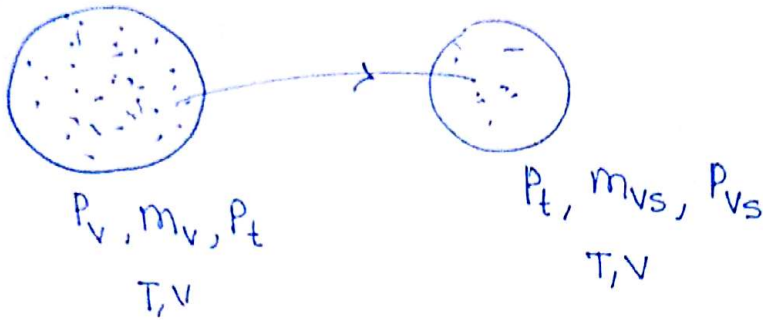
$$m_t = m_v + m_a$$

$$\frac{m_t}{m_a} = \frac{m_v}{m_a} + 1$$

$$\frac{m_t}{m_a} = w + 1$$

$$\boxed{m_a = \frac{m_t}{w + 1}}$$

② Relative humidity: (ϕ)



$$P_v V = m_v R_v T \quad - (1)$$

$$P_{vs} V = m_{vs} R_v T \quad - (2)$$

$$\frac{(1)}{(2)} \quad \frac{P_v}{P_{vs}} = \frac{m_v}{m_{vs}}$$

$$* \quad \boxed{\phi = \frac{P_v}{P_{vs}} = \frac{m_v}{m_{vs}}} \rightarrow \text{Saturated V.}$$

* Relative humidity represent vapour absorption capacity whereas specific humidity represent the actual mass of vapour.

* IF the relative humidity is 100%, air is called as saturated air

③ Dry bulb temp. (DBT):- It is the normal temp. measured by an ordinary thermometer.

③

④ Wet bulb temp. :- (WBT) :-

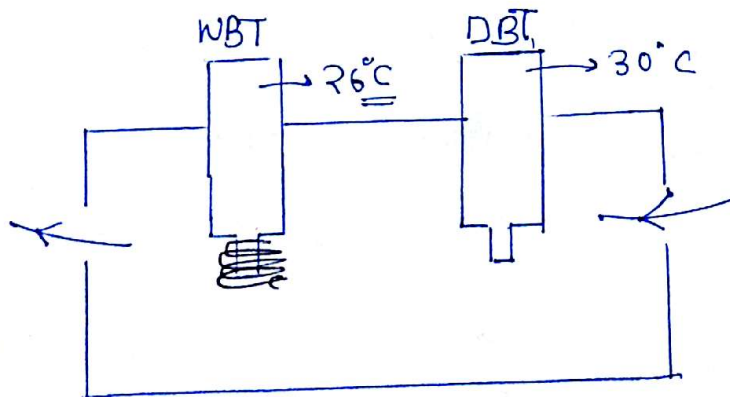
It is the minimum temp. achieved by a wet cloth due to evaporation of water.

- it is the temp. measured by a thermometer whose tip is covered with wet cloth.
- it is the temp. upto which air can be cooled in desert cooler.
- It is the temp. upto which water can be cooled in cooling towers
- It is the minimum temp upto which water can be cooled earth & pot.
- Wet bulb depression (WBD) = DBT - WBT

$$\boxed{WBD = DBT - WBT}$$

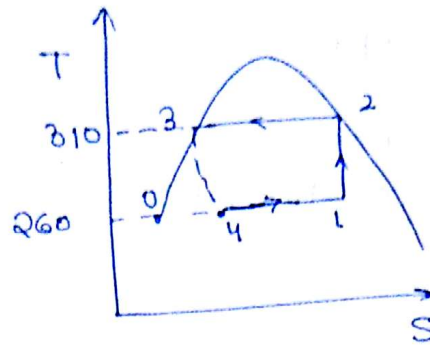
- Use of desert cooler is beneficial if the WBD is high.

- For saturated air $\boxed{DBT = WBT}$



Q1.17 Gate book

P-411



$$@ 310 \quad LH = 1054$$

$$C_{p\text{eq}} = 4.8$$

$$h_1 - h_0 = ?$$

$$\frac{h_1 - h_0}{260} = s_1 - s_0$$

$$s_2 - s_3 = \frac{h_2 - h_3}{310} = \frac{1054}{310} \quad \text{--- (1)}$$

$$s_3 - s_0 = C_{p\text{eq}} \log \frac{T_f}{T_i} = 4.8 \ln \frac{310}{260}$$

$$s_3 - s_0 = 4.8 \ln \frac{310}{260} \quad \text{--- (2)}$$

$$\text{Sum (1) + (2)}$$

$$s_2 - s_0 = 4.8 \ln \frac{310}{260} + \frac{1054}{310}$$

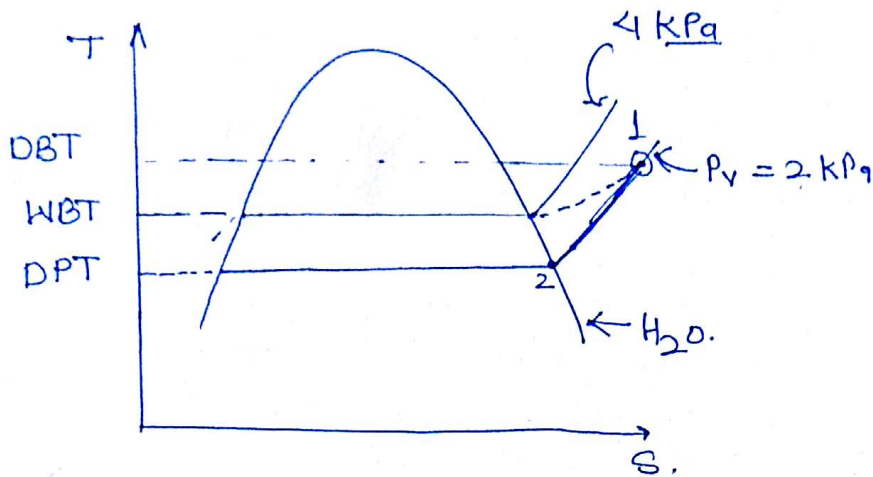
$$s_1 = s_2$$

$$s_1 - s_0 = 4.8 \ln \frac{310}{260} + \frac{1054}{310} = \frac{h_1 - h_0}{260}$$

$$h_1 - h_0 = 260 \left\{ 4.8 \ln \frac{310}{260} + \frac{1054}{310} \right\}$$

$$h_1 - h_0 = 1103.51 \text{ kJ/kg.}$$

⑤ Dew point temperature:-



{ unsaturated :- $DBT > WBT > DPT$
 { saturated :- $DBT = WBT = DPT$

• Dew point temp. is the temp. of air at which water vapour present in the air starts Condensing when cooled at Constant pressure

→ Air is saturated means water vapour is present in air is saturated.

→ Air is unsaturated means water vapour is present in the air is superheated.

★ Saturation pressure corresponding to dew point temp. is the partial pressure of vapour in air at DBT Conditions.

Q.23
p.g.58

$$P_s = 0.6624 \text{ bar}$$

$$P_{\text{atm}} = 1 \text{ bar}$$

$$\omega = ?$$

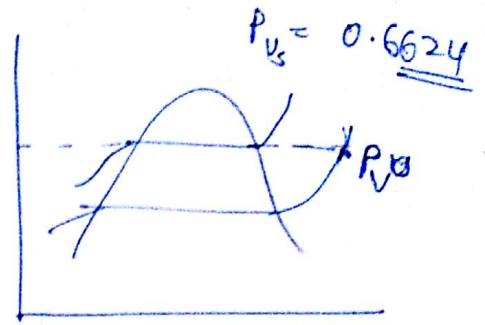
$$\phi = 72\%$$

$$\phi = \frac{m_v}{m_t} = \frac{P_v}{P_t - P_v} \quad P_v = 0.47692$$

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

$$\omega = 0.622 \frac{0.47692}{1 - 0.4762}$$

$$\omega = 0.56712 \text{ kg/kg dry} = 567.12 \text{ g/kg dry}$$



Q.24

$$\omega = 0.01$$

$$m_1 = 10.1 \text{ kg/s}$$

$$m_2 = 0.1 \text{ kg/s}$$

$$\omega = \frac{\dot{m}_1 \omega_1 + \dot{m}_2 \omega_2}{\dot{m}_1 + \dot{m}_2}$$

$$0.01 = 0.0162 \frac{P_v}{P_t - P_v}$$

$$0.0160 (P_t - P_v) = P_v$$

$$0.0160 = (1 + 0.016) P_v$$

$$P_v = 0.01582$$

① $m_{t1} = 10.1$
 $\omega_1 = 0.01$
 $\dot{m}_{v1} = ?$
 $\dot{m}_{a1} = ?$

② $\dot{m}_{v2} = 0.1 \text{ kg/s}$

$\dot{m}_t = \dot{m}_a$

$\dot{m}_3 = \dot{m}_{v1} + \dot{m}_{v2}$

$\dot{m}_a = \frac{10.1}{1.01} = 10 \text{ kg dry / sec}$

$\dot{m}_{v1} = 0.1$

$$\dot{m}_{v3} = 0.1 + 0.1$$

$$\dot{m}_3 = 10 = \dot{m}_a$$

$$\omega_3 = \frac{\dot{m}_{v3}}{\dot{m}_{v1}} = \frac{0.2}{10} = 0.02$$

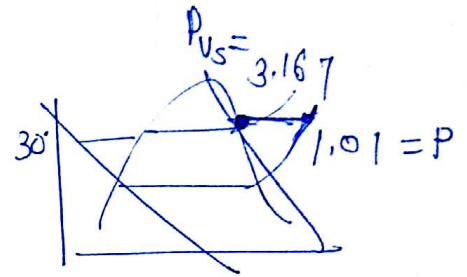
Ques Moist air at 1.013 bar & 30°C contains
log of water vapour per kg of dry air.

saturation pressure of water vapour at 30°C
is 3.167 kPa find relative humidity of
moist air

$$\Rightarrow \omega = ?$$

$$\omega = 0.1 \quad \hat{m}_v = \frac{\log v}{\text{kg dr.}}$$

$$P_{st} = 3.16$$

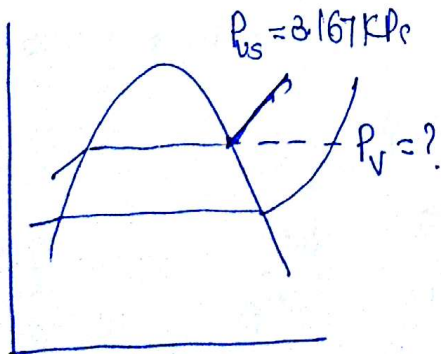


$$\omega = 0.622 \frac{P_v}{P_t - P_v}$$

$$\omega = 0.622 \frac{P_v}{P_t - P_v} = 0.01$$

$$0.622 \times \frac{P_v}{1.013 - P_v} = 0.01 \Rightarrow P_v = 1.6028$$

$$\omega = 10 \times 10^{-3} = 0.01 = 0.622 \frac{P_v}{P_t - P_v}$$



$$P_t = 1.013$$

$$0.01 = 0.622 \frac{P_v}{1.013 - P_v}$$

$$P_v = 1.6028$$

$$\phi = \frac{P_v}{P_{vs}} = \frac{1.6028}{3.167} \times 100 = 50.61\%$$

Q. Atmospheric air at 100 kPa & 30°C has a relative humidity of 70%. The saturation pressure of vapour at 30°C is 4.25 kPa. then find the partial pressure of dry air

$$\phi = \frac{P_v}{P_{vs}} = 0.70$$

$$P_v = 0.70 \times 4.25 = 2.975$$

$$P_t = P_v + P_a$$

$$P_a = 100 - 2.975$$

$$= 97.025$$

~~Ques~~

Enthalpy of Moist Air!—

Moist air

$$H = H_a + H_v$$

$$H = m_a h_a + m_v h_v \quad \text{--- (A)}$$

dry air

$$dh_a = C_{p_a} dt$$

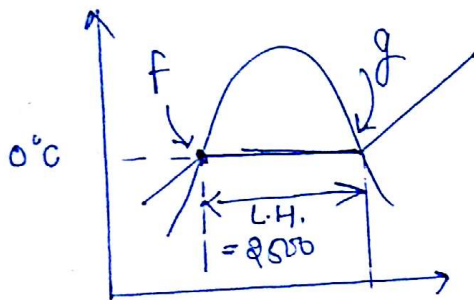
$$\text{at } t = 0^\circ\text{C} \quad \text{let } h_a = 0$$

$$t = t^\circ\text{C} \quad \text{let } h_a = h_a$$

$$(h_a - 0) = C_{p_a} (t - 0)$$

$$\boxed{h_a = C_{p_a} t}, \quad t \text{ is in } ^\circ\text{C}$$

water vapour



$$\text{at } 0^\circ\text{C}, h_f = 0$$

$$h_g = 2500 + C_{p_v} (t - 0)$$

$$h_v = 2500 + 1.88 t$$

from (A)

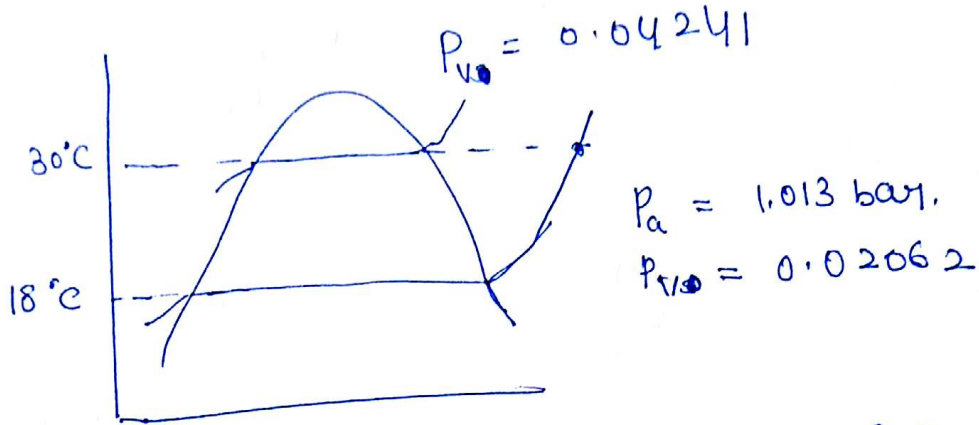
$$H = m_a \times C_{p_a} t + m_v (2500 + 1.88 t)$$

$$h = \frac{H}{m_a} = 1.005 t + \frac{m_v}{m_a} (2500 + 1.88 t)$$

$$h = 1.005 t + w(2500 + 1.88 t) \quad \frac{\text{kJ}}{\text{kg d.a.}}$$

$$\begin{aligned} m_a &= 1 \\ m_v &= w \end{aligned}$$

Q. 2



$$w = 0.622 \frac{0.02062}{1.013 - 0.02062}$$

$$w = 0.01291$$

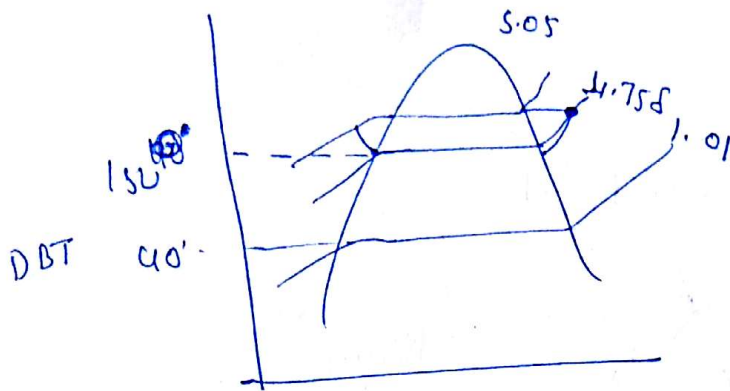
$$h = 1.005 t + 0.0129(2500 + 1.88 t)$$

$$= 1.005 \times 30 + 0.0129(2500 + 1.88 \times 30)$$

$$h = \underline{\underline{63.159}}$$

$$\underline{0.20}$$

$$\phi = 0.50 = \frac{P_v}{P_{vs}}$$



$$P_{sat}|_{15.0} = 7.38 \text{ kPa}$$

$$P_{sat}|_{40} = 4.758$$

$$\phi = \frac{P_v}{P_{vs}} = 0.50$$

$$P_v = 0.50 \times 7.38$$

$$P_v = 3.69 \text{ kPa}$$

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

$$\omega = \left(0.622 \times \frac{3.69}{101 - 3.69} \right) \times 1000$$

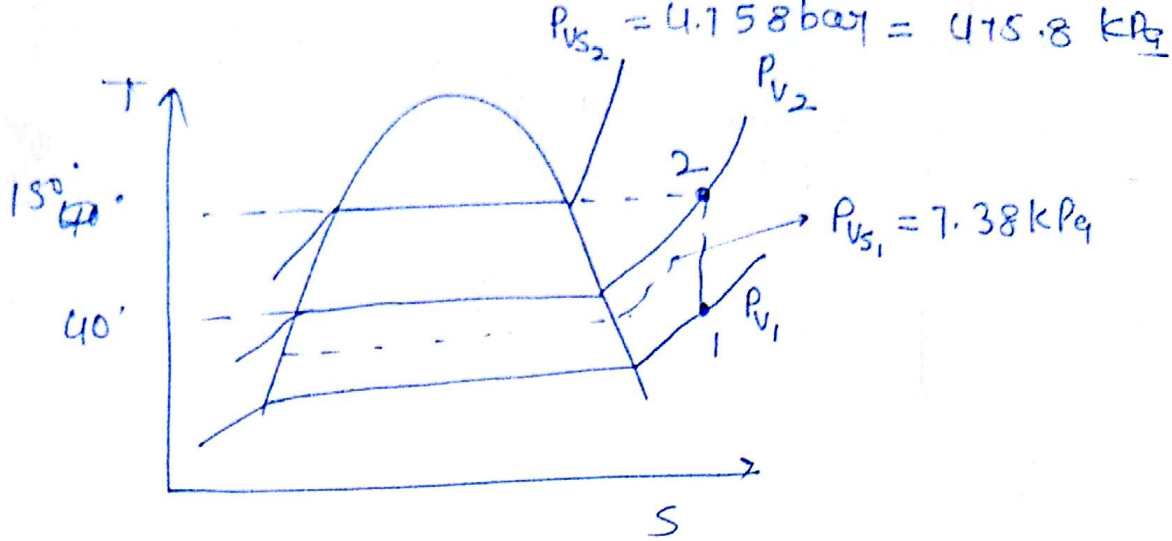
$$\omega = \underline{23.58} \text{ g/kg d.a.}$$

$$P_{vs} = 4.758 \text{ bar.}$$

$$\phi = \frac{P_v}{P_{vs}}$$

$$\omega = \frac{0.622 \times P_v}{P - P_v} = 0.236$$

$$P_v = 0.316$$



$$0.5 = \phi_1 = \frac{P_{v1}}{P_{vs1}} = \frac{P_v}{7.38}$$

$$P_v = 3.69 \text{ kPa}$$

$$\omega_1 = 0.622 \frac{P_{s1}}{P_{t1} - P_{v1}} = 0.622 \frac{3.69}{101 - 3.69}$$

$$\omega_1 = 23.6 \times 10^{-3} \text{ kgv/kgda}$$

$$\frac{P_{t2}}{P_{t1}} = \frac{P_{v2}}{P_{v1}} \Rightarrow \frac{505}{101} = \frac{P_{s2}}{3.69}$$

$$P_{s2} = 18.48 \text{ kPa}$$

$$\phi_2 = \frac{P_{v2}}{P_{vs2}} = \frac{18.48}{475.8} = 0.0388$$

$$\phi_2 = 0.0388$$

$$\phi_2 = 3.9\%$$

Degree of saturation:- (μ)
Percent humidity

$$\star \boxed{\mu = \frac{w}{w_s}} = \frac{0.622 \frac{P_v}{P_t - P_v}}{0.622 \frac{P_{vs}}{P_t - P_{vs}}}$$

$$\therefore \mu = \frac{P_v}{P_{vs}} \left(\frac{P_t - P_{vs}}{P_t - P_v} \right)$$

$$\mu = \phi \left(\frac{P_t - P_{vs}}{P_t - P_v} \right)$$

* Ap John Formula :-

$$\boxed{P_v = P_{v'} - \frac{1.8 P (t - t')}{2700}} \star$$

- P_v = Partial pressure of vap.
- $P_{v'}$ = Sat. pressure corresponding to WBT
- P = total pressure
- t = DBT
- t' = WBT.

• Alignment circle is a pt on psychrometric Chart

$$\text{DBT} = 26^\circ \text{C}$$

$$\phi = \underline{50\%}$$

$$\mu = \frac{P_v}{P_{vs}} \left(\frac{P_t - P_{vs}}{P_t - P_v} \right)$$

$$0.24 = \frac{P_v}{4} \left(\frac{100 - 4}{100 - P_v} \right)$$

$$0.24 \times 4 (100 - P_v) = P_v \times 96$$

$$P_v = 0.990 \quad \frac{12.9}{91.2} = P_v = 1230 \text{ kPa}$$

$$\phi = \frac{P_v}{P_{vs}} = \frac{0.990}{4} \times 100$$

$$\phi = \underline{24.75}$$

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

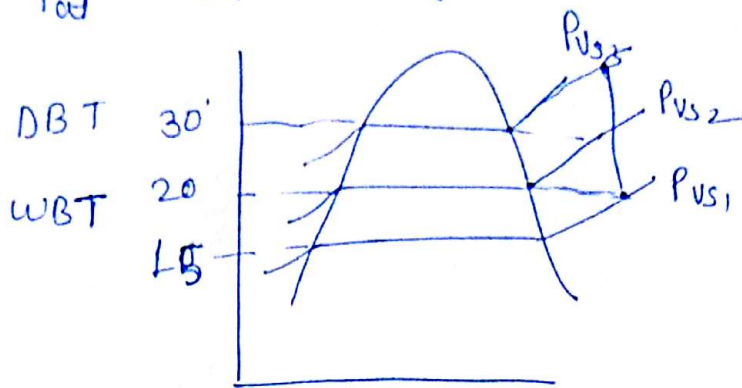
$$\omega = 0.622 \frac{1}{99}$$

$$\omega = \underline{\underline{0.0062}}$$

Q26

67

$$p_{at} = 740 \text{ mm Hg.} = \cancel{100.6} \text{ mm Hg.}$$



$$P_{v3} = 0.04242$$

$$P_{vs2} = 0.02337$$

$$P_{vs1} = 0.01679$$

$$p = 740 \text{ mm of Hg}$$

$$760 \rightarrow 1.013$$

$$740 \rightarrow \frac{1.013}{760} \times 740$$

$$p = 0.9869$$

be

$$(i) \quad P_v = P_v' - \frac{1.8 p (t - t')}{2700}$$

$$P_v = 0.02337 - \frac{1.8 \times 0.9869 (30 - 20)}{2700}$$

$$P_v = \underline{0.01679} \quad \text{DPT} = 15^\circ\text{C}$$

$$(ii) \quad \omega = 0.622 \times \frac{0.01679}{0.9869 - 0.01679}$$

$$\omega = \underline{0.01077}$$

$$(iii) \quad R_h = \phi = \frac{P_v}{P_{vs} \text{ at DBT}} = \frac{0.01679}{0.04242} = \underline{39.5\%}$$

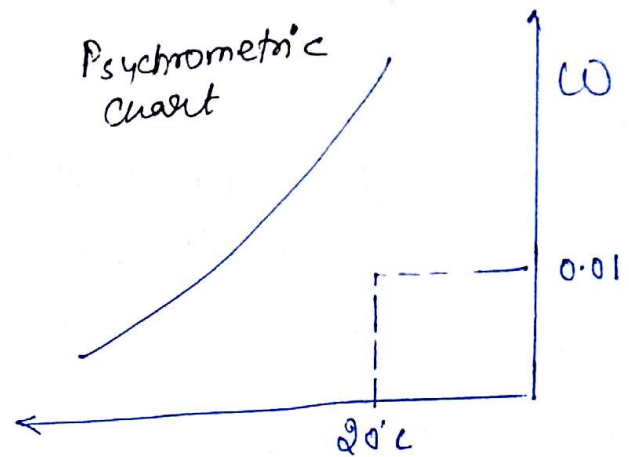
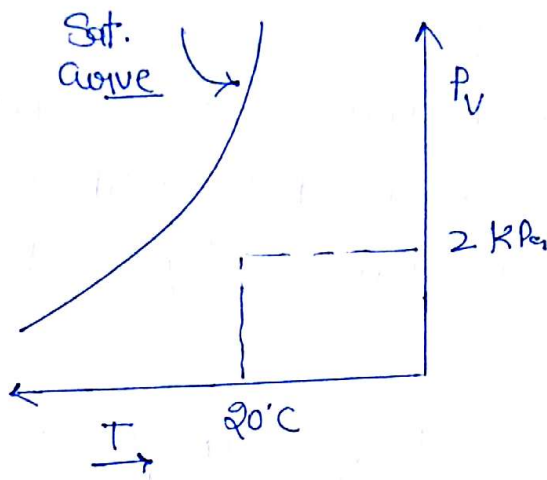
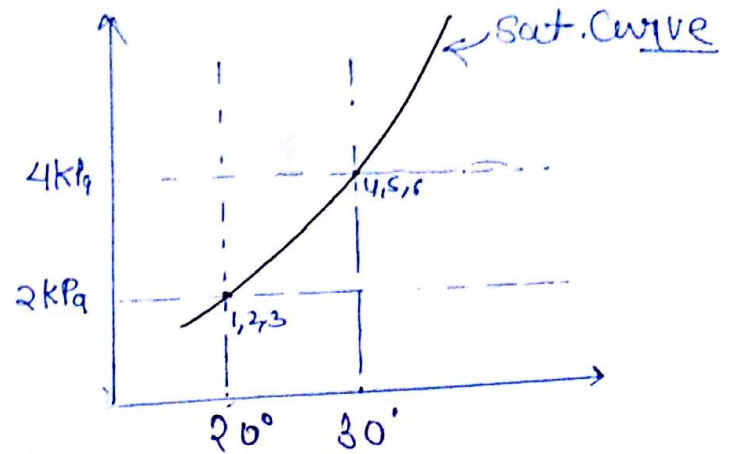
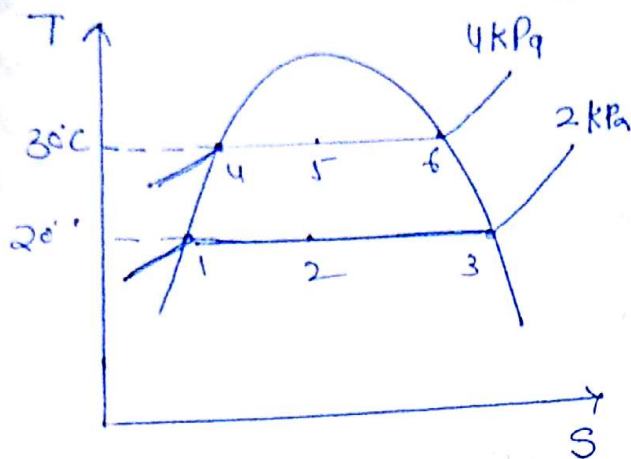
$$(iv) \quad P_v V = m_v R T$$

$$P_v = \rho R T$$

$$\rho = \frac{P_v}{R T} = \frac{0.01679 \times 100}{\frac{8.314}{18} \times 303} \text{ kPa}$$

$$\rho = \underline{0.0119 \text{ kg/m}^3}$$

Development of Psychrometric chart :-



$$W = 0.622 \frac{P_g}{P_t - P_v} = \underline{\underline{f(P_g)}}$$

let $P_t = P_{atm}$

$$W @ P_v = 2 \text{ kPa} \quad \text{let } \underline{\underline{0.01}}$$

* humidity Ratio is the function of P_g

25

$$\phi = 60\% = \frac{P_v}{P_{vs}}$$

$$P_{atm} = 0.1 \text{ MPa} = 0.1 \times 10^6 \text{ Pa} = 100 \text{ kPa}$$

$$P_v = 0.60 \times 5.63$$

$$\omega = 0.622 \times \frac{0.60 \times 5.63}{100 - 0.60 \times 5.63} \times 1000$$

$$\omega = 21.24 \text{ gram/kg dry air}$$

Ques if the volume of moist air with 50% relative humidity is isothermally reduced to half of the original vol the relative humidity of moist air will become?

solⁿ

$$\phi = 0.50 = \frac{P_v}{P_{vs}}$$

$$P_v V_1 = m R_v T$$

$$P_v = \frac{m R_v T}{V_1}$$

$$P_{vs} = \frac{P_v}{0.5}$$

$$P_{v2} = 2 \left(\frac{m R_v T}{V_1} \right)$$

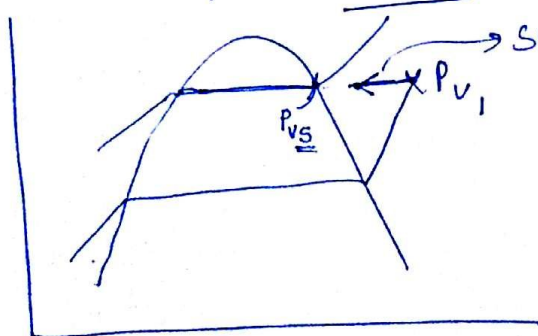
$$V_2 = \frac{V_1}{2}$$

Now

$$\phi = \frac{2 P_{v1}}{P_{vs}/0.5}$$

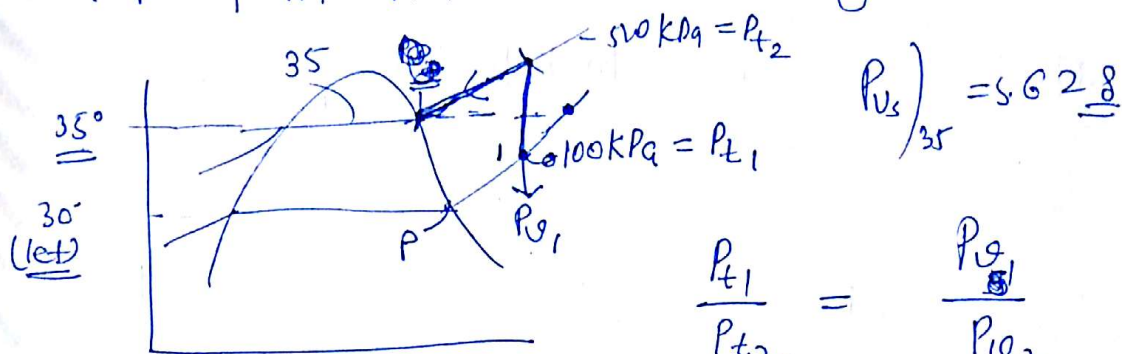
$$\frac{P_{v1}}{P_{v2}} = \frac{P_{vs}}{2 P_{v1}}$$

$$\phi = 100\%$$



P_{vs} const. (isothermally)

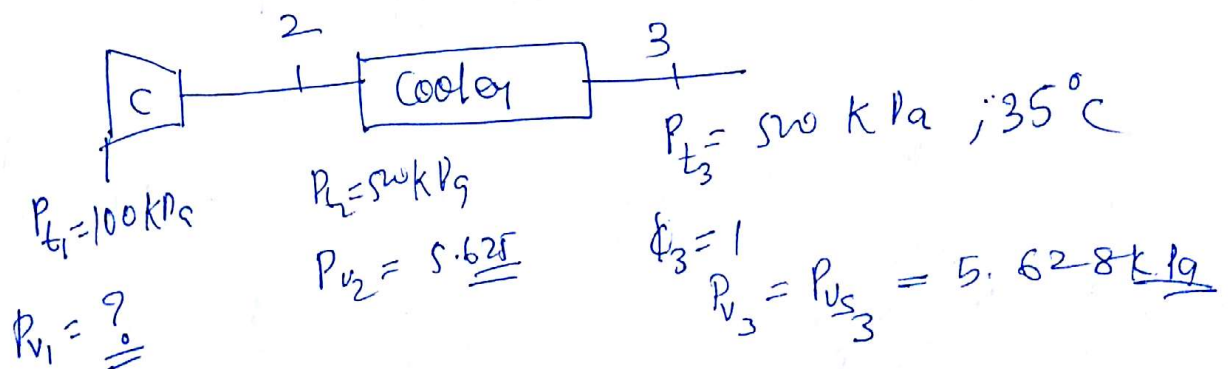
Q Moist air at a pressure of 100 kPa is compressed to 500 kPa and then cooled to 35°C in a cooler at const. pressure (there is no condensation the air at the entry to the cooler is unsaturated and becomes just saturated at the exit of cooler. The saturation pressure of vapour at 35°C is 5.628 kPa, find partial pressure of vapour in moist air entering the compressor



$$\frac{P_{t1}}{P_{t2}} = \frac{P_{v1}}{P_{v2}}$$

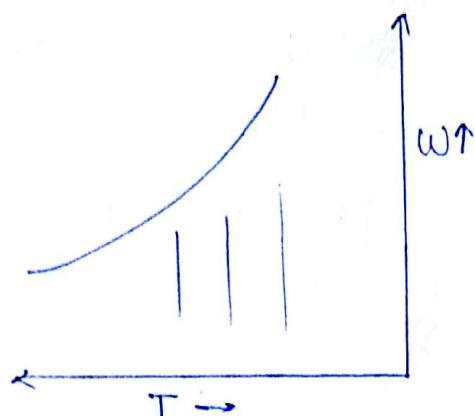
$$\frac{100}{500} = \frac{P_{v1}}{5.628}$$

$$P_{v1} = 1.1256 \text{ kPa}$$

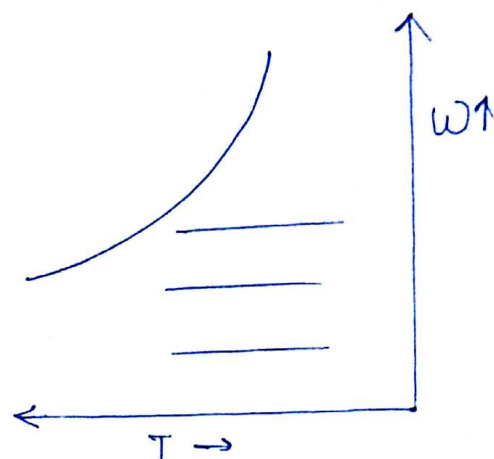


Various lines on Psychrometric chart:-

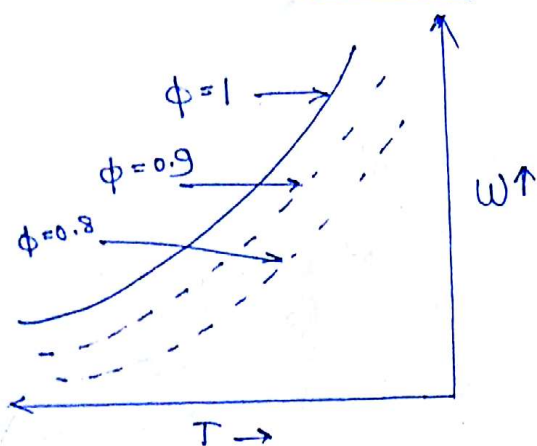
① Constant DBT lines



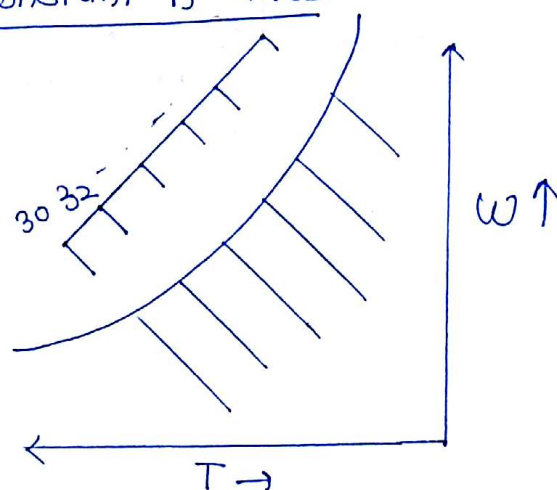
② Constant 'w' lines



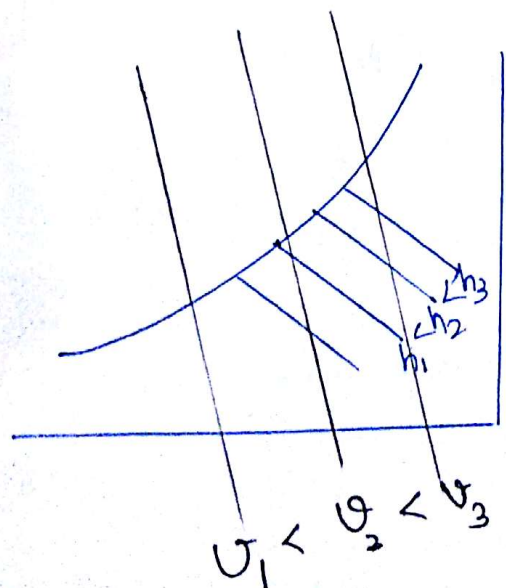
③ Constant R.H. (φ) lines



④ Constant 'h' lines



⑤ Const (v) lines;



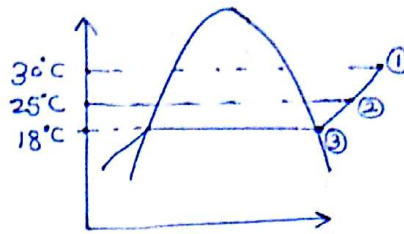
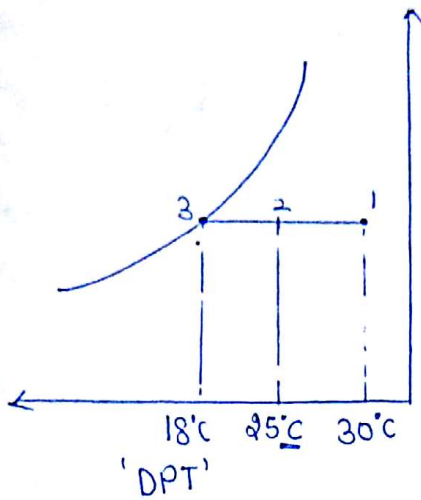
specific Vol.

$$v = \frac{V}{m_a} \left(\frac{m^3}{kg \text{ d.a.}} \right)$$

$$m_a = \frac{V}{v}$$

↓
dry air mass remain same

⑥ Constant 'DPT' lines



→ if ' P_o ' is same, 'DPT' is same

→ $w = f(P_o \text{ only})$

if ' P_o ' is same

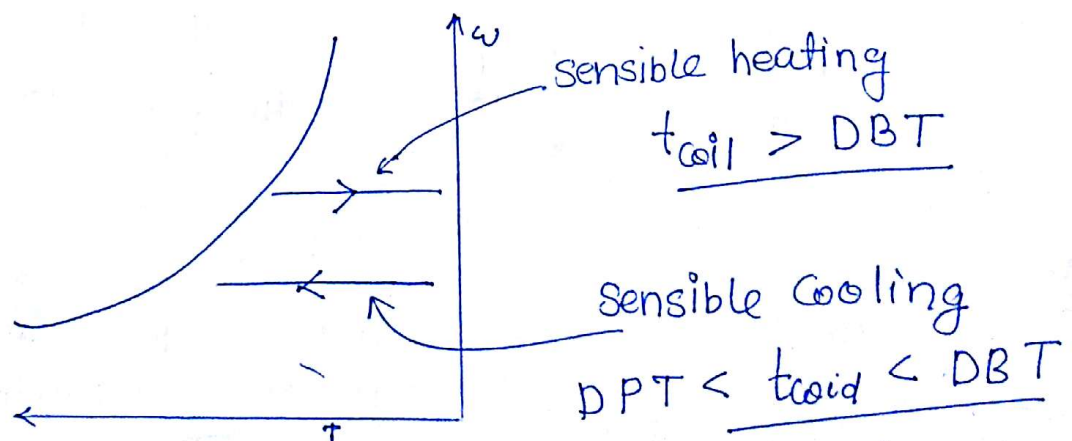
$\therefore w$ is same

* Constant DPT lines follow constant ' w ' line and are horizontal lines on psychrometric chart.

⑦ WBT line: Though there is slight deviation between constant WBT lines and constant enthalpy lines but for all practical purposes these lines are taken to be same.

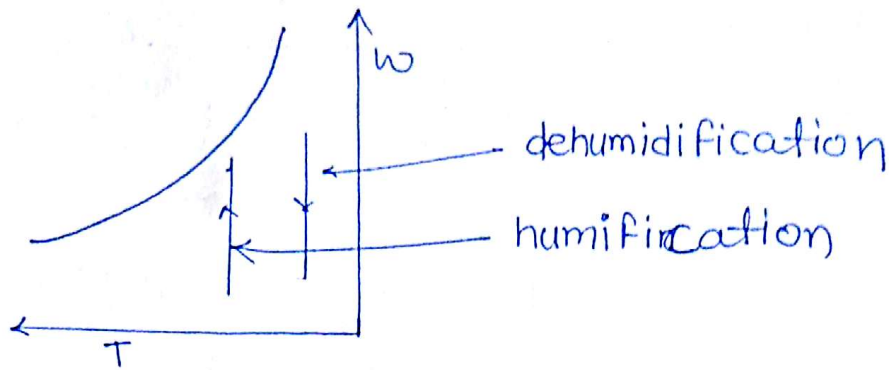
Various processes on psychrometric chart:-

① Sensible Cooling & sensible Heating:-

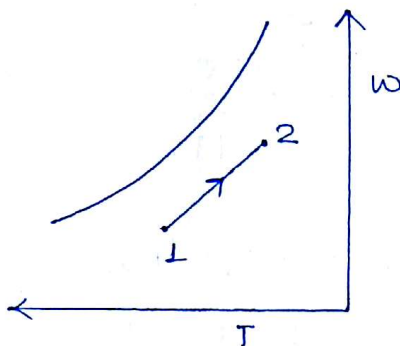


The process followed in the electrical room heater is sensible heating

② Humidification & Dehumidification:-



③ Heating and Humidification:-

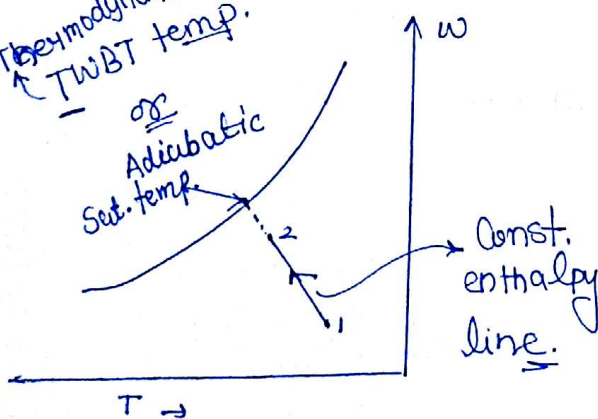


eg: steam spray in air

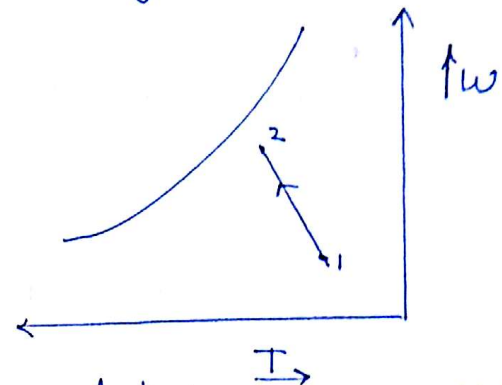
★ Adiabatic saturation

Thermodynamic
TWBT temp.

or
Adiabatic
Sat. temp.



④ Cooling & humidification



eg:- Desert cooler follow adiabatic saturation process.

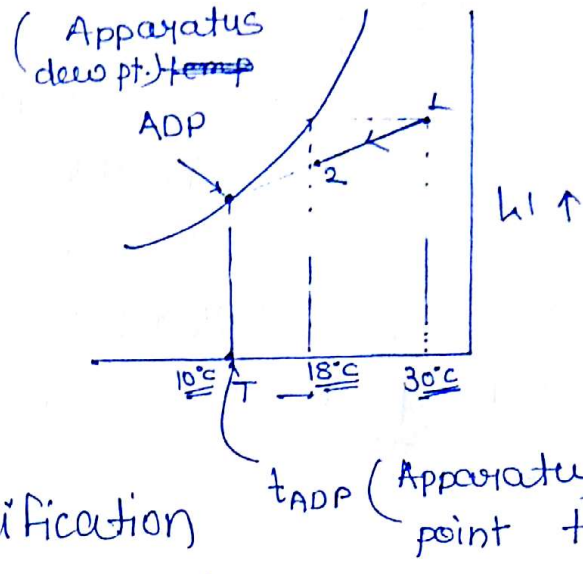
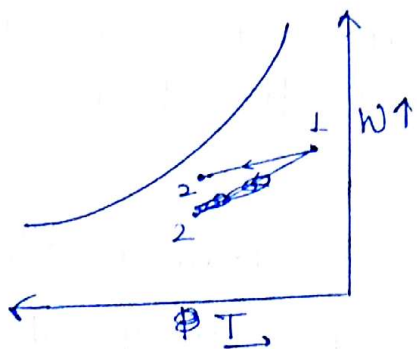
⇒ If cooling and humidification occurs when air interact with water in the absence of a cooling coil then the process is called Adiabatic saturation.
Adiabatic saturation lines are isenthalpic lines and also const. WBT lines.

★ Temp. corresponding to the point where adiabatic sat. line when produced intersects the saturation curve is called Thermodynamic wet bulb temp (TWBT) or adiabatic Sat. temp.

→ TWBT is a property of the air, whereas WBT is not the property of the air.

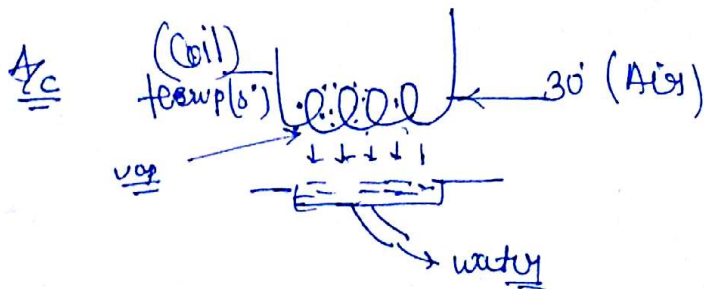
$$\Rightarrow * \boxed{TWBT \leq WBT}$$

⑤ Cooling and dehumidification:

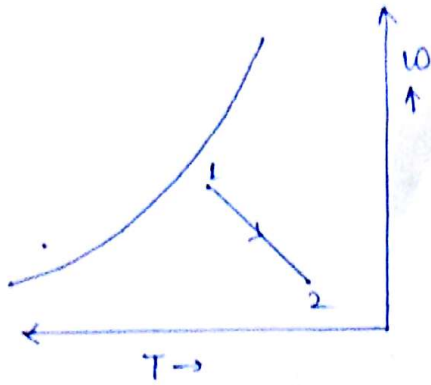


→ The cooling and dehumidification lines when produced intersects the saturation curve at the point called as apparatus dew point. The temp. corresponding to this point is the temp of the cooling coil, called as apparatus dew point temp.

→ The process followed in summer A/c is Cooling and dehumidification.



(6) Heating and dehumidification:-



This process is carried out with the help of chemicals like alumina (Al_2O_3). These chemicals absorb water vapour from the air and ~~water~~ water vapour while leaving the air, condenses and reject latent heat of condensation in the air, hence the temp of air increases.

→ This process is called as adiabatic chemical dehumidification and enthalpy of air remains const during the process.

Ques 5 gram of W. vapour per kg of dry air from atmospheric air is removed and temp of air after removing water vapour become $25^\circ C$ Find

(i) Relative humidity & enthalpy of air after removal of moisture

(2) Cooling load on the cooling coil.

Sol Assume the atmospheric condition are $35^\circ C$ DBT and $\phi = 60\%$. Take the mass flow rate of air to 5 kg/sec . (dry air basis) and Condensate leaving

the Coil at $25^\circ C$

Sat^n	W	$t(^{\circ}C)$	$P_{vs} (\text{bar})$
	5 5	35	0.05733
	100	25	0.03229

Solⁿ

$$w = \frac{5}{1000} = 0.005$$

$$w = 0.622 \frac{P_v}{P_t - P_v}$$

$$w = 0.622 \frac{P_v}{1.013 - P_v} = 0.005$$

$$P_v = 8.07 \times 10^{-3} \text{ bar}$$

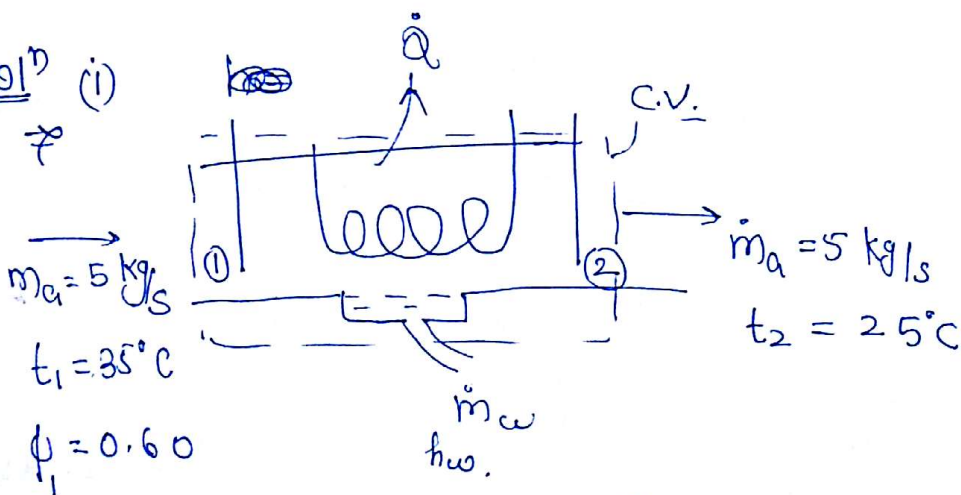
$$P_v = 8.07 \text{ kPa}$$

$$\phi = \frac{P_v}{P_{vs}}$$

$$\phi = \frac{8.07 \times 10^{-3}}{0.05733} = 25.01$$

$$\phi = 14.09\% \quad \phi = 25.01\%$$

$$h = 1.005 t + w(2500 + 1.88 t)$$

Solⁿ (i)

$$\phi_1 = 0.60 = \frac{P_{v1}}{P_{vs1}} = \frac{P_{v1}}{0.05733}$$

$$P_{v1} = 0.03439$$

$$w_1 = 0.622 \frac{P_{v1}}{P_{t1} - P_{v1}}$$

$$w_1 = 0.622 \frac{(0.03439)}{1.013 - 0.03439}$$

$$w_1 = 21.86 \times 10^{-3} \text{ kgv / kg d.a.}$$

$$\begin{aligned} h_1 &= 1.005 \times t_1 + w_1 (2500 + 1.88 t_1) \\ &= 1.005 \times 35 + 21.86 \times 10^{-3} (2500 + 1.88 \times 35) \end{aligned}$$

$$h_1 = 91.36 \text{ kJ / kg d}$$

Now $w_2 = w_1 - w \rightarrow \text{removed}$

$$w_2 = 21.86 \times 10^{-3} - 5 \times 10^{-3}$$

$$w_2 = 16.86 \times 10^{-3} \text{ kgv / kg d.a.}$$

$$h_2 = 1.005 t_2 + w_2 (2500 + 1.88 t_2)$$

$$h_3 = 1.005 \times 25 + 16.86 \times 10^{-3} (2500 + 1.88 \times 25)$$

$$\boxed{h_3 = 68.07 \text{ kJ / kg d.a.}} \text{ An}$$

$$w_2 = 0.622 \frac{P_{v2}}{P_{t2} - P_{v2}} = 0.622 \frac{P_{v2}}{1.013 - P_{v2}} = 16.86 \times 10^{-3}$$

$$P_{v2} = 0.0268 \text{ bar.}$$

$$p = \frac{0.0268}{0.03229} = 82.8 \%$$

(ii)

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}_a \times h_1 = \dot{m}_a h_2 + \dot{Q} + \dot{m}_w h_w$$

$\uparrow$
 Cooling
 Coil

$$5 \times 91.36 = 5 \times 68.07 + \dot{Q} + \dot{m}_w h_w$$

$$\dot{m}_w = (\omega_1 - \omega_2) \frac{\text{kg v}}{\text{kg d.a}} \times 5 \frac{\text{kg d.a}}{\text{s}}$$

$$= 5 \times 10^{-3} \times 5 = 25 \times 10^{-3} \text{ kg/s}$$

$$h_w = C_{pw} \times t_w \leftarrow \text{latent}$$

$$= 4.18 \times 25 \quad (\text{in system C.V.})$$

$$5 \times 91.36 = 5 \times 68.07 + \dot{Q} + 25 \times 10^{-3} \times 4.18 \times 25$$

$$\dot{Q} = 113.8 \text{ kW}$$

Ques 5
W.B. 5b

$\xrightarrow{\text{air}} \quad \xrightarrow{\text{water}} \quad \xrightarrow{\text{coil}} \quad \xrightarrow{\text{out}}$

$\dot{m}_a = 3 \text{ kg/s} \quad \dot{E}_{in} = \dot{E}_{out}$
 $h_1 = 85 \text{ kJ/kg} \quad h_2 = 43 \text{ kJ/kg}$
 $\omega_1 = 19 \times 10^{-3} \quad \omega_2 = 8 \times 10^{-3}$
 $h_w = 67 \text{ kJ/kg}$
 $\dot{m}_w = (\omega_1 - \omega_2) \times \frac{\text{kg v}}{\text{kg d.a}} \times 3 \frac{\text{kg d.a}}{\text{s}}$

$$\dot{m}_a h_1 = \dot{m}_a h_2 + \dot{m}_w h_w + \dot{Q}$$

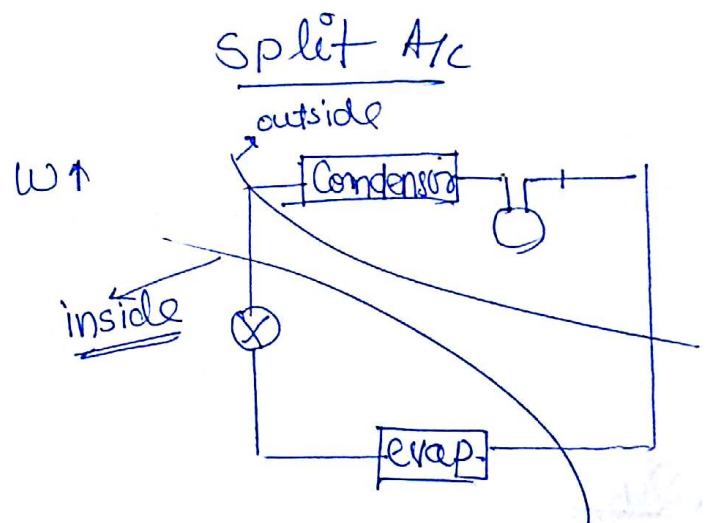
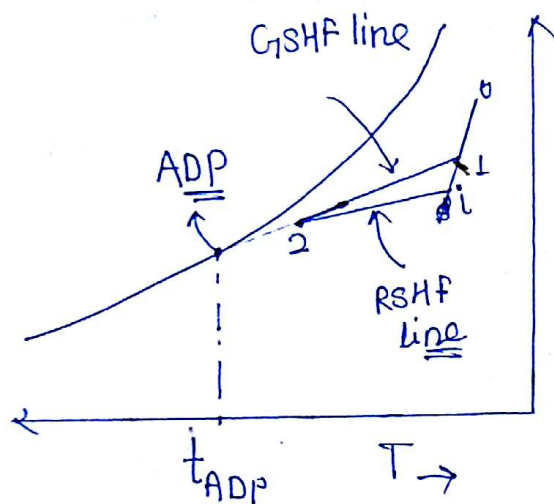
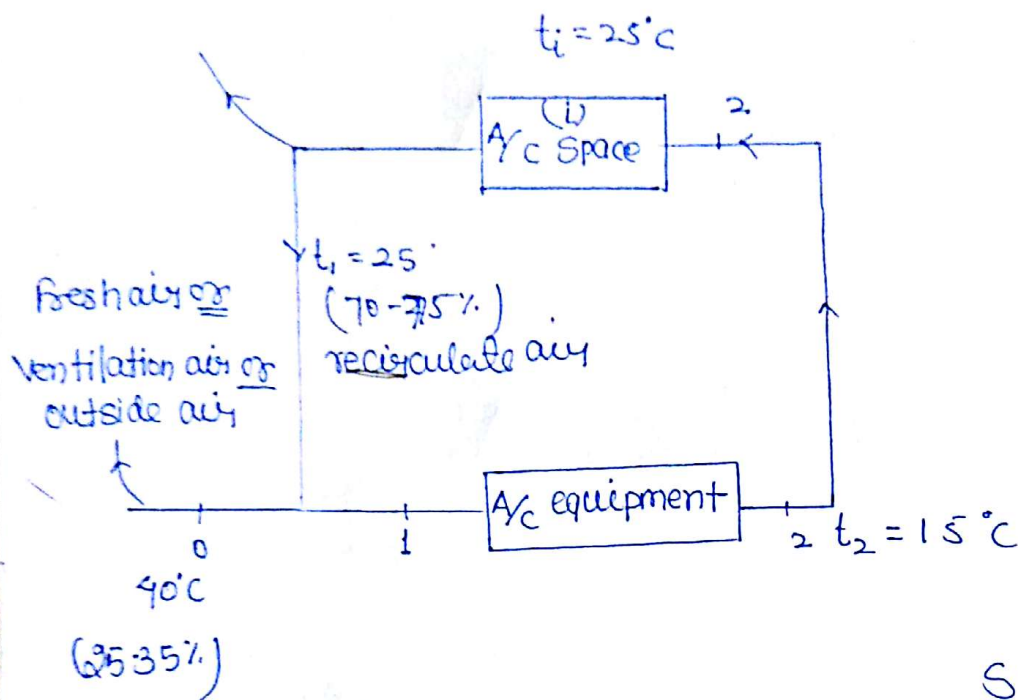
$$3 \times 85 = 3 \times 43 + \dot{Q} + 3 \times (19 - 8) \times 10^{-3} \times 67$$

$$\dot{Q} = 123.78 \text{ kW}$$

★

$$\dot{m}_w = \text{Condensate rate}$$

Summer Air Conditioning with Ventilation A/c



→ line joining the inlet and exit Conditions of A/c equipment is called Grand sensible heat Factor line.

→ line joining the supply Condition to the room with the room inside Condition is called Room sensible heat Factor line RSHF.

- The intersection of RSHF & GS HF gives the supply conditions to the room.
- The outside air supplied in order to maintain purity of air is called ventilation air or fresh air.
- In hospitals the recirculated air should be zero and ventilation air/fresh should be 100%.

Air changes:-

$$\text{Air changes per hour (ACH)} = \frac{V_o (\text{m}^3/\text{hr})}{V (\text{m}^3)}$$

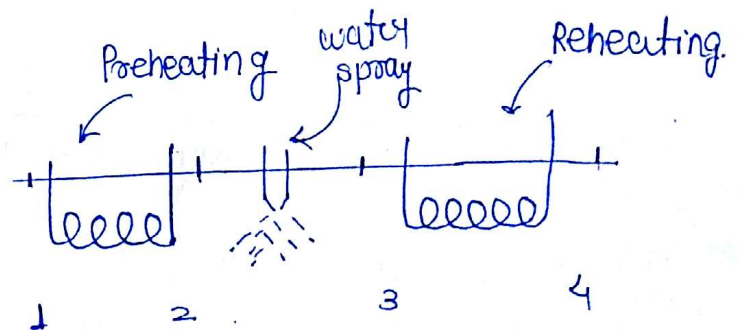
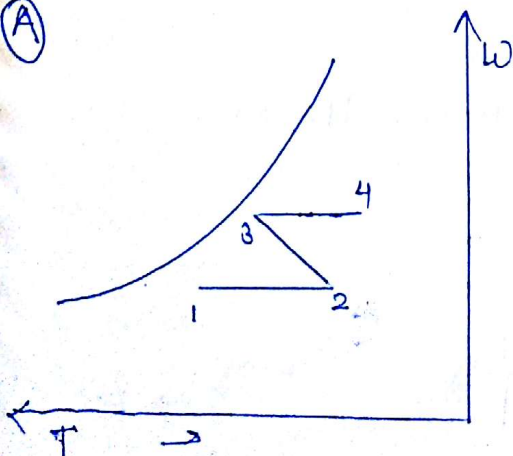
$$\text{Air changes per min} = \frac{V_o (\text{m}^3/\text{min})}{V (\text{m}^3)}$$

$\left\{ \begin{array}{l} V_o - \text{outside air} \\ V \rightarrow \text{Vol. of A/c space.} \end{array} \right.$

(MM - Cubic meter per min (m^3/min))

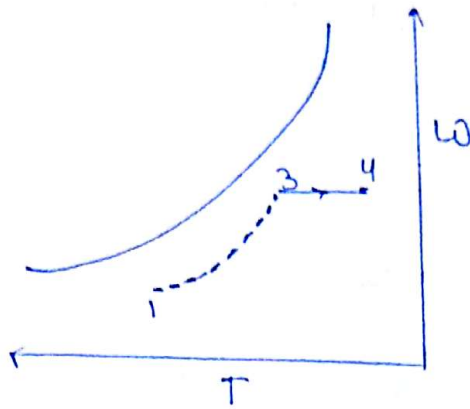
Winter Air Conditioning:

(A)



$1 \rightarrow 2$ sensible heating
 $2 \rightarrow 3$ Adiabatic sat.
 $3 \rightarrow 4$ sensible heating.

(B)



Steam spray

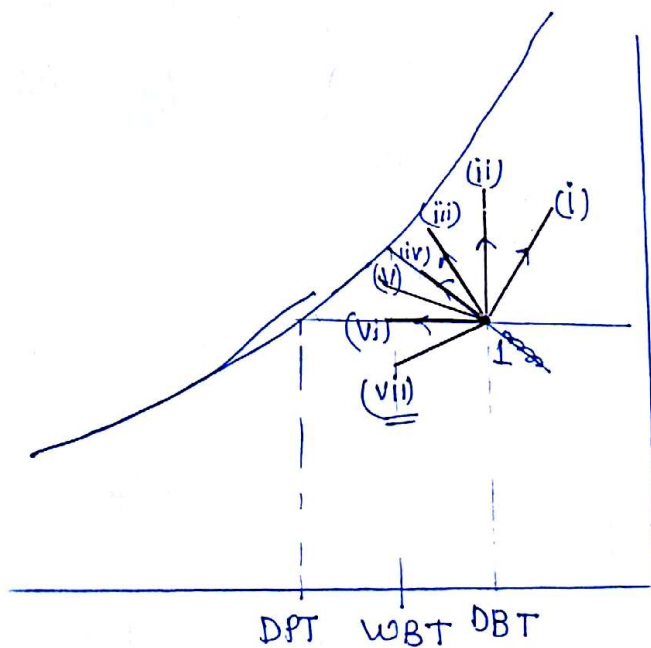
Reheat Coil

1-3 → heat-humidification

3-4 → sensible heating

→ In winters the outside air is at low w and low temp. hence heating and humidification of air is required. This can be achieved by one of the above methods

Air washer:-



① $t_w > \text{DBT}$ → heating & humidification
→ heating coil
→ $t_{a} \uparrow$

(ii) $t_w = \text{DBT}$ → humidification
→ heating coil
→ $t_{a} \uparrow$

(iii) $WBT < t_w < DBT$

- cooling and humidification
- heating coil
- $h_a \uparrow$

(iv) $t_w = WBT$ → cooling & humidification

- No coil
- $h_a = \text{const.}$

(v) $DPT < t_w < WBT$

- cooling & humidification
- cooling coil
- $h_a \downarrow$

(vi) $t_w = DPT$

- sensible cooling
- cooling coil
- $h_a \downarrow$

(vii) $t_w < DPT$

- cooling & dehumidification
- cooling coil
- $h_a \downarrow$

Human Comfort and Effective temperature:-

- The physical comfort of a human being which can be affected by adjusting the temp., humidity, air velocity & purity of air.
- Effective temp is the temp. of a saturated envt. where the person feel same level of comfort as in the normal ~~envt~~ environment.
- According to the study conducted by American society for heating refrigeration and air condition engineers (ASHRAE), 99% of the ~~adults wearing light cloths~~ ~~adults wearing light cloths~~ adults wearing light cloths involved in light activity (eg. office work) will experience comfort at

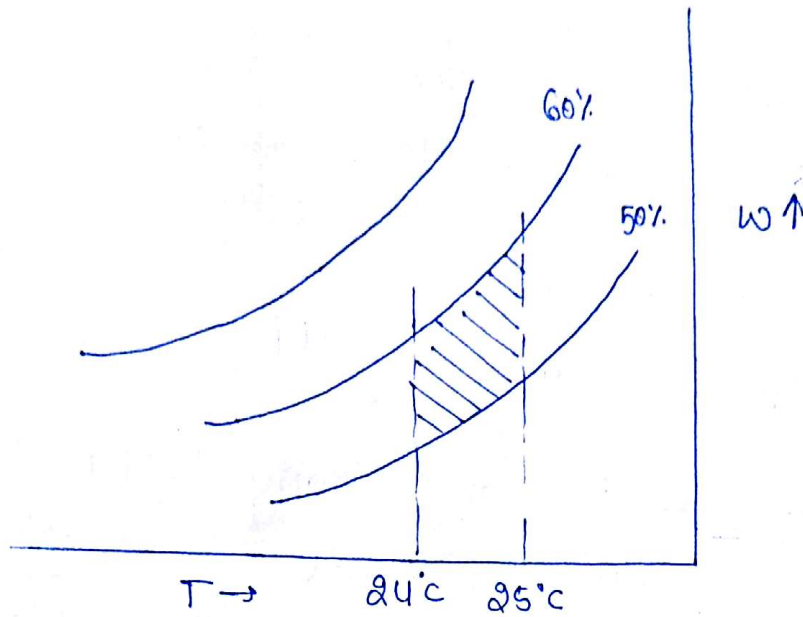
→ DBT → 24-25°C & RH → 50-60%

Effective temp 21.6°C (summer)
 20°C (winter)

Factors affecting human Comfort:-

- ① Gender:- man experience comfort at a lower temp. compare to woman.
- ② Age:- Adult experience comfort at a lower temp. compare to children & old age people.
- ③ kind of clothing:- Person wearing light cloths will experience comfort at a relatively higher temp. compare to people wearing heavy cloths.
- ④ kind of activity:- Person involved in heavy physical activity (for ex. gym) will experience comfort at a lower temp. compared to person involved in light activities (office work)
- ⑤ climatic condition: people habitual to cold climate experience comfort at lower temp. & compare to people living in hot climatic condition.
- ⑥ Seasons:- People experience comfort at a lower temp. in winters compare to summer.

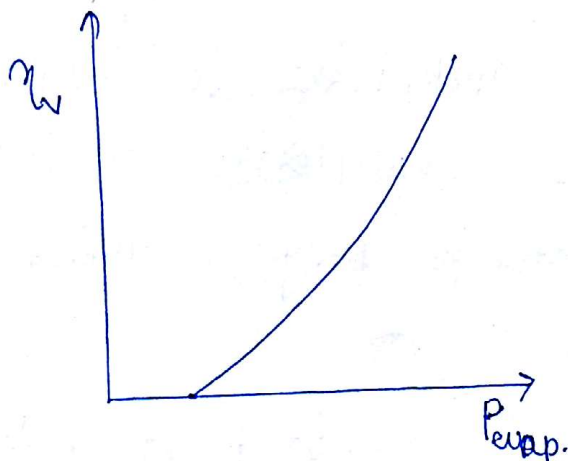
Comfort chart:-



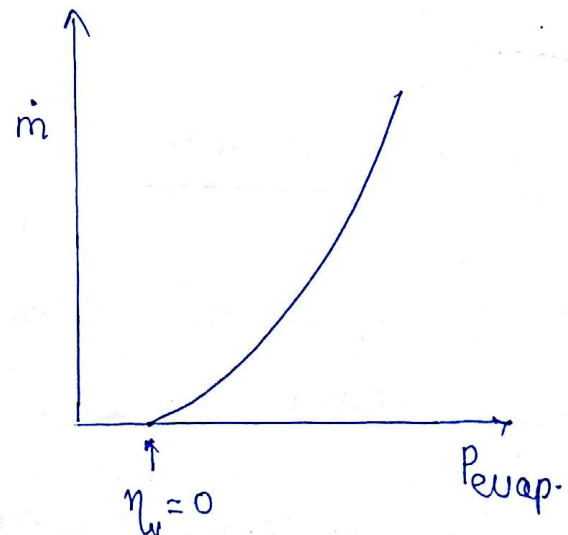
* The chart representing the year round comfort condition is called as comfort chart.

* Performance Curve!:-

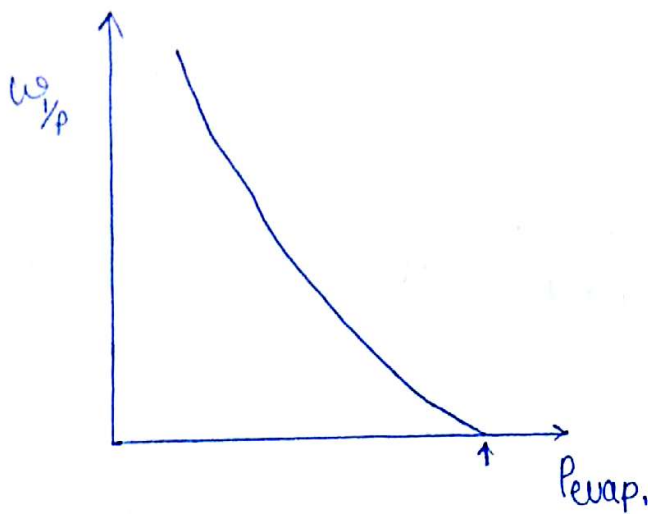
(i) η_w Vs P_{evap}



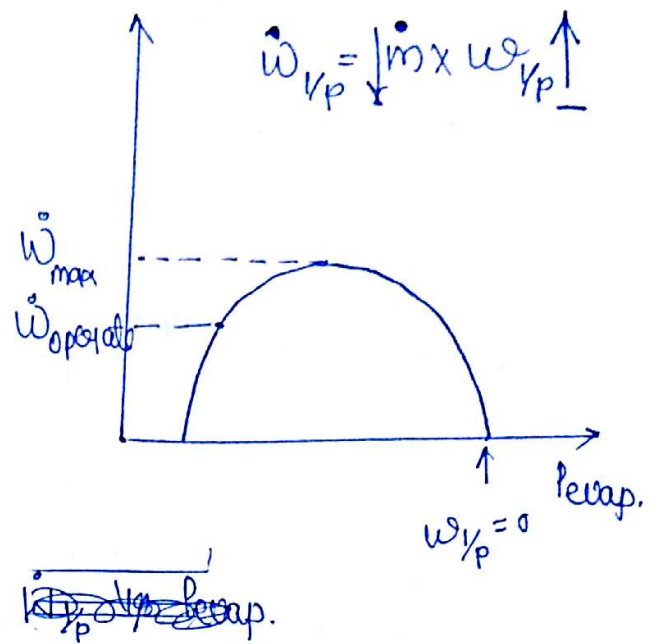
(ii) $\dot{m}$ Vs P_{evap}



(iii) $\omega_{1/p} \propto V_g P_{\text{evap.}}$



(iv) $\dot{\omega}_{1/p} \propto V_g P_{\text{evap.}}$



* The operating is less than the maximum power but the compressor motors are designed for maximum power conditions because for reaching the operating power we have to cross the max. power condition.