# AIR CONDITIONING

→ It is the process of conditioning the air for human comfort by controlling temp., humidity, velocity & purity of air.

## Psychrometry-

It is the study of properties of the moist air.

Moist Air

Dry Air | Water Vapour

| | $O_2$ | $N_2$ |
|---|---|---|
| Mass | 23% | 77% |
| Vol | 21% | 79% |

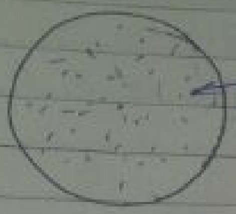
$$P + F = C + 2$$
$$1 + f = 2 + 2$$
$$\boxed{F = 3}$$

$$P_t = p_a + p_v$$
$$T$$

Assumption: $P_t = 1\,atm = $ Const → Psychometric Chart

→ While studying psychrometry we treat moist air as 2 components. Hence 3 variables are required for our study. Out of these 3 variables we assume $P_t = 1$ atm for our study. The psychrometric charts are drawn using $P_t = 1$ atm.

## Psychrometric properties –



$P_t, V, T.$

$$P_v V = m_v R_v T. \quad \text{--- (1)}$$
$$P_a V = m_a R_a T. \quad \text{--- (2)}$$

1 – Sp. humidity or humidity ratio or ~~Absolu~~ Absolute humidity ($\omega$) –

$$\omega = \frac{m_v}{m_a}.$$

(1) / (2)

$$\frac{P_v}{P_a} = \frac{m_v}{m_a} \times \frac{R_v}{R_a}.$$

$$\frac{P_v}{P_a} = \omega \times \frac{\bar{R}/18}{\bar{R}/29}.$$

$$\frac{P_v}{P_a} = \omega \times \frac{29}{18}.$$

$$\omega = \frac{18}{29} \times \frac{P_v}{P_a}.$$

***
$$\boxed{\omega = 0.622 \times \frac{P_v}{P_t - P_v}}$$ kg V/kg d.a

Vapour

dry air

$$m_t = m_v + m_a$$

***
$$\frac{m_t}{m_a} = \omega + 1 \Rightarrow \boxed{m_a = \frac{m_t}{1+\omega}}.$$

2- Relative Humidity ($\phi$) -

$$\phi = \frac{m_v}{m_{vs}}.$$

$$P_v V = m_v R_v T. \quad —(3)$$
$$P_{vs} V = m_{vs} R_v T. \quad —(4)$$

vs = Vapour at saturation

(3)/(4),

$$\frac{P_v}{P_{vs}} = \frac{m_v}{m_{vs}}$$

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

→ Sp. humidity represents the actual mass of vapour whereas relative humidity represents vapour absorbing capacity.

→ For saturated air, relative humidity is 1 or 100%.

3- Dry bulb temperature (DBT) -

→ It is the normal temp. measured by ordinary thermometer.

23- $\omega = \frac{m_v}{m_a} = 0.622 \times \frac{P_v}{P_t - P_a}$

$$\phi = \frac{m_v}{m_{vs}} = \frac{P_v}{P_{vs}} = 0.72$$

$$\frac{P_v}{P_{vs}} = 0.72.$$

DBT = 38°C.

$P_{vs} = 0.6624$. $\quad P_v = 0.4769$ bar.

Q - Moist air at 1.013 bar and 30°C temp. contains 10g of water vapour per kg of dry air. Assume air & water ~~pt~~ vapour mixture to behave as an ~~ideal gas~~ ideal gas & saturation pressure of vapour at 30°C is ~~gas and the streamline process saturation~~ 3.1676 Pa. Find the relative humidity of air.

$P_{vs} = 3.1676\, Pa.$

$P_t = 1.013 \times 10^5\, Pa.$

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

$DBT = 30°C.$

$\omega = 10 \times 10^{-3}\, kg\, v/kg\, d.a.$

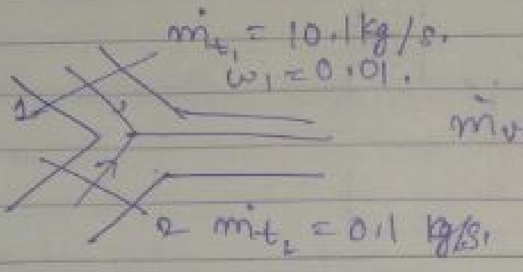
$\omega = 0.622 \times \frac{P_v}{P_t - P_v}$

$1.013$

$P_v = 0.016\, bar = 1.62028\, kPa.$

$\phi = \frac{P_v}{P_s} = 0.5081$

24-



$\dot{m}_{v3} = \dot{m}_{v1} + \dot{m}_{v2}.$

$\dot{m}_{a3} = \dot{m}_{a1}$

$\dot{m}_{a1} = \frac{\dot{m}_{t1}}{1+\omega_1} = \frac{10.1}{1.01} = 10\, kg\, d.a/s.$

$\dot{m}_{v1} = \dot{m}_{t1} - \dot{m}_{a1}$

$= 10.1 - 10 = 0.1.$

$\omega_3 = \frac{\dot{m}_{v1} + \dot{m}_{v2}}{\dot{m}_{a1}} = \underline{0.02}$

25- DBT = 35°C.

$\phi = 0.60$.

$P_t = 100$ kPa.

$P_{vs} = 5.63$ kPa.

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

$P_v = $ ✓.

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

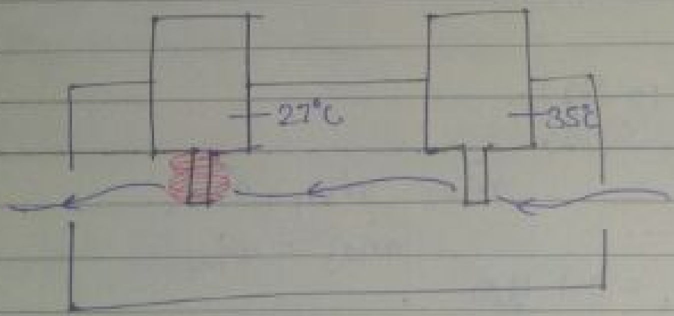
$= 0.0217$ kg V/ kg of dry air.

$= 21.7$ g V/ kg of dry air.

4- Wet Bulb temp. (WBT)-

It is the temp. measured by a thermometer whose tip is covered with wet cloth.

Psling Psychrometer.




→ It can be understood as the min temp. upto which water can be cooled in earthenpot.

→ It is the min. temp. upto which air can be cooled in a desert cooler.

Coz air is having less humidity than surrounding air

→ It is the min. temp. upto which water can be cooled in cooling towers.

Wet Bulb Depression (WBD) = ~~WBT = 1~~ DBT − WBT.

→ For saturated air WBT = DBT. Hence Wet bulb depression is zero.

→ For unsaturated air WBT $\leq$ DBT. Hence WBD = +ve.

5 - Dew Point Temp. (DPT) -

Class — Air

400 ← Chairs → Capacity (Temp.) → WBT 300/300

400/200

200 ← Students → Water Vapour. → DPT 200/200

→ It is the temp. upto which the air should be cool so that the water ~~temp. pres~~ vapour present in air starts condensing. (const. pressure cooling).

→ It is the saturation temp. corresponding to partial pressure of vapour.

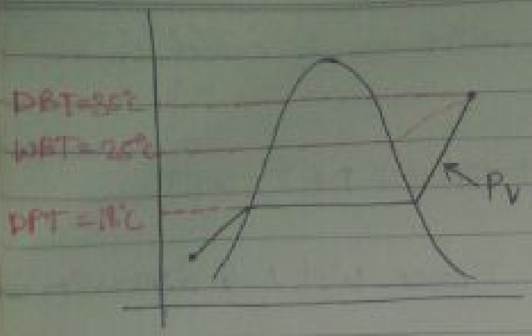
***Unsaturated:***

DBT > WBT > DPT.

***Saturated:***

DBT = WBT = DPT.

$H_2O \rightarrow 18$
$O_2 \rightarrow 32$
$N_2 \rightarrow 28$

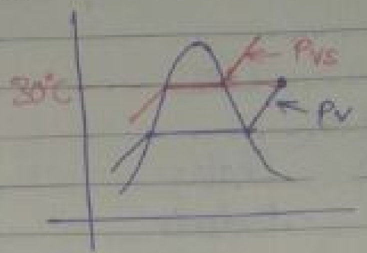



Q- Atmospheric air at 100 kPa & 30°C has a relative humidity of 70%. The saturation pressure of vapour at 30°C is 4.25 kPa. Find the partial pressure of dry air.

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

$$0.70 = \frac{P_v}{4.25}$$

$$P_v = 2.975\ kPa.$$




$$\underset{100}{\overset{\parallel}{P_t}} = P_v + P_a.$$

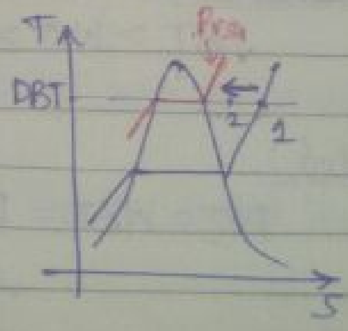
$$\boxed{P_a = 97.025\ kPa}$$

** Q- If the vol. of moist air with 50% relative humidity is isothermally reduced to half of its original volume then the relative humidity of moist air will become ____.

$$\phi_1 = 0.5 = \frac{P_{v_1}}{P_{vs_1}}$$

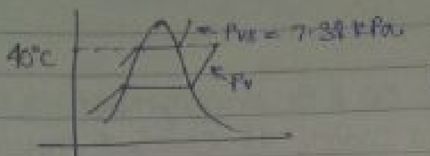
$$P_{v_1} \cdot V_1 = P_{v_2} \cdot \underset{V_1/2}{\overset{\parallel}{V_2}}$$

$$\therefore P_{v_2} = 2P_{v_1}.$$



$$\phi_2 = \frac{P_{v_2}}{P_{vs_2}} = \frac{2P_{v_1}}{P_{vs_1}} = 2\times0.5 = 1.$$

20-




$P_t = 1.01\times10^5$
$= 101\ kPa.$

$P_t = P_v +$

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

$P_v = 0.5\times 7.38$
$= 3.69\ kPa.$

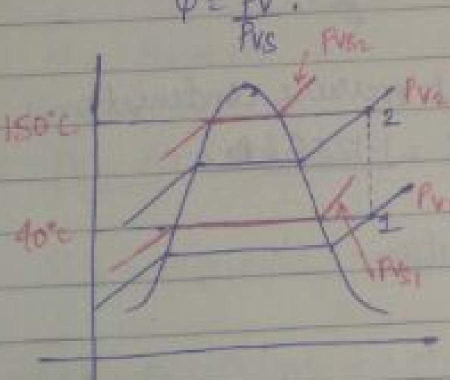
$$\omega = 0.622\times\frac{P_v}{P_t - P_v}$$

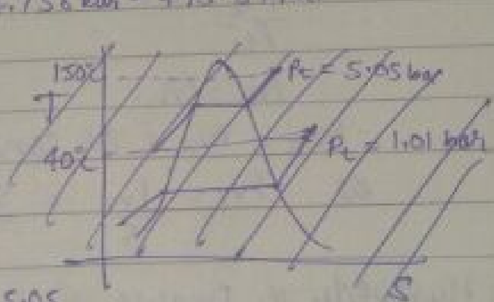
$$= 0.622\times\frac{3.69}{101-3.69}$$

$= 23.586\ g/kg$ dry air.

21- $P_t = 5.05$ bar $= 505\ kPa.$
$P_{vs} = 4.758$ bar $= 475.8\ kPa.$

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




$$\frac{P_{t_2}}{P_{t_1}} = 5$$ ($P_{t_2} = 5.05$, $P_{t_1} = 1.01$)

→ Total pressure is 5 times. Hence partial pressures of all constituents will also be 5 times.

OR

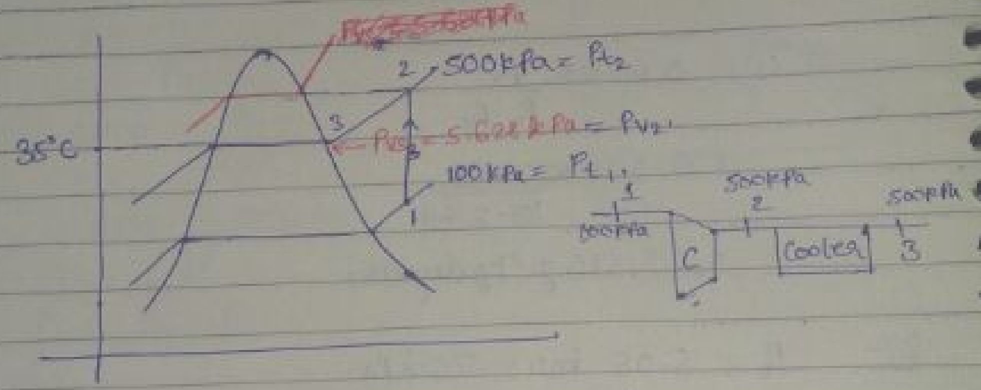
Specific humidity will not change as condensation is not happening.

$P_{v_2} = 5\,P_{v_1} = 5 \times 0.0369 = 0.1846\,bar.$

$$\phi_2 = \frac{P_{v_2}}{P_{vs_2}} = \frac{0.1846}{4.758} \times 100 = 3.87\%.$$

**

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




$$\frac{P_{t_2}}{P_{t_1}} = 5.$$

$P_{v_2} = 5P_{v_1}.$

$P_{vs_3} = P_{v_2}$ (As constant pressure condensation)

$$P_{v_1} = \frac{P_{v_2}}{5} = \frac{5.628}{5} = 1.1256\,kPa.$$

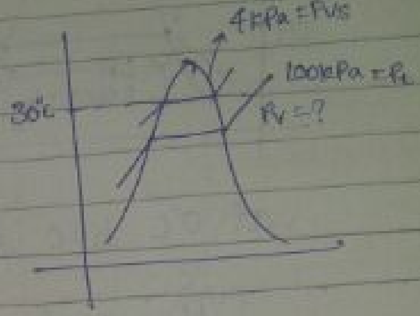
## Percent Humidity or Degree of Saturation-

$$\mu = \frac{\omega}{\omega_s}.$$

$$\mu = \frac{0.622 \times \frac{P_v}{P_t - P_v}}{0.622 \times \frac{P_{vs}}{P_t - P_{vs}}}$$

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

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




1- $\mu = \frac{P_v \cancel{\phi}}{4} \times \left(\frac{100 - 4}{100 - P_v}\right) = 0.24.$

$$\frac{P_v}{\cancel{4}} \times \frac{\overset{24}{\cancel{96}}}{100 - P_v} = 0.24$$

$$24 P_v = 24 - 0.24 P_v.$$

$$24.24 P_v = 24.$$

$$P_v = \frac{24}{24.24} = 0.99.$$

$$\phi = \frac{P_v}{P_{vs}} = \frac{0.99}{4} = 0.2475 \text{ or } 24.75\%.$$

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

$$= 0.622 \times \cancel{\frac{0.2475}{100 - 0.2475}} \left(\frac{0.99}{100 - 0.99}\right) = 0.0062.$$

Enthalpy of Moist Air-

$$H = H_a + H_v.$$

→ Dry Air

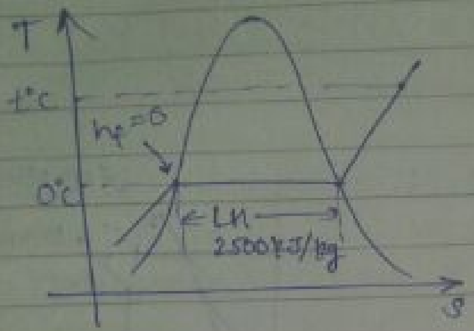
$$dH_a = m_a C_{pa} dt.$$

Let $H_a = 0$ at $t = 0°c$.

$\therefore H_a = H_a$ at $t = t°c$.

$$(H_a - 0) = m_a C_{pa}(t - 0) \Rightarrow \boxed{H_a = m_a C_{pa} t}.$$

## → Water Vapour -




at 0°C $h = 0$ for saturated water.

$$H_v = m_v \left[ \underbrace{2500}_{LH} + C_{pv} \times t \right]$$

$$H_v = m_v \left( 2500 + C_{pv} t \right).$$

$$H_v = m_v \left( 2500 + 1.88t \right).$$

$$\therefore \quad H = H_a + H_v.$$

$$H = m_a C_{pa} t + m_v (2500 + 1.88t).$$

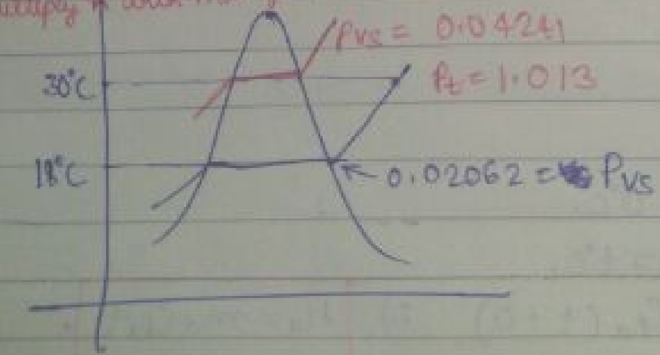
$$h = \frac{H}{m_a} = C_{pa} t + \omega (2500 + 1.88t).$$

** Air के mass से divide किया है. So whenever total enthalpy need to find we will multiply 'h' with mass of air.

$$\boxed{h = 1.005t + \omega (2500 + 1.88t) \quad kJ/kg\ d.a}$$

current temp. in(°C)

2 -




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

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

$$\omega = 0.012921$$

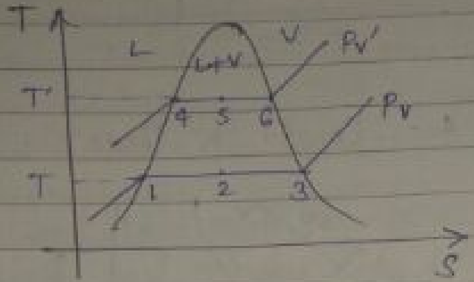
$h = 1.005 \times t + \omega(2500 + 1.88 t)$.

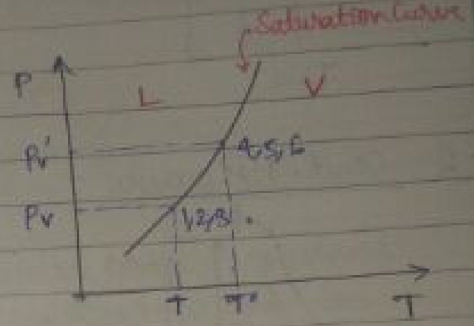
$\cancel{= 1.005 \times 303 + 0.01292(2500 + 1.88 \times 285)}$

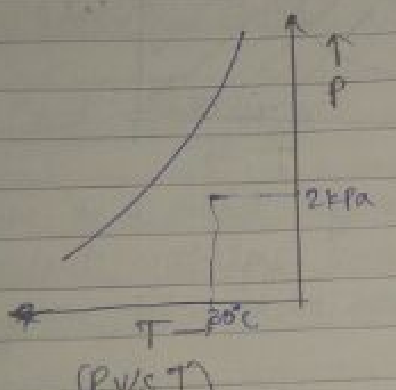
$= 1.005 \times 30 + 0.01292(2500 + 1.88 \times 30)$

$= 63.17$ kJ/kg.

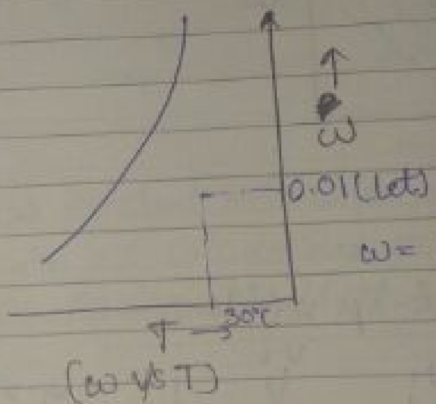
Psychrometric Chart-




(Pv/s T)




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

(ω v/s T)

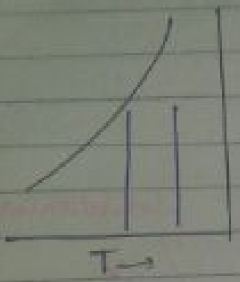
→ Air is saturated means water vapour present in air is saturated.

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

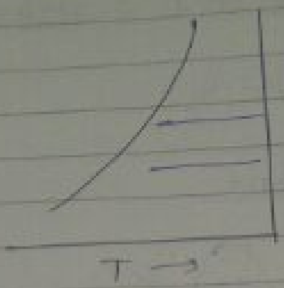
~~→ Various lines on Psychrometric chart-~~

## Various Lines on Psychrometric Chart -

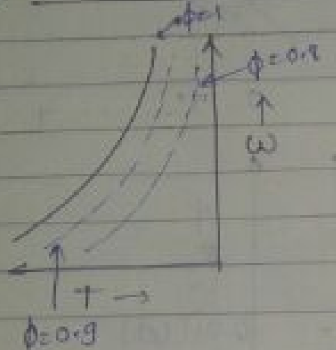
1- Const. DBT lines -



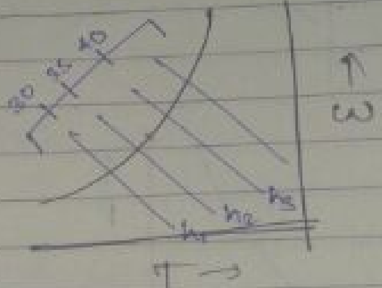

2- Const. 'ω' lines -



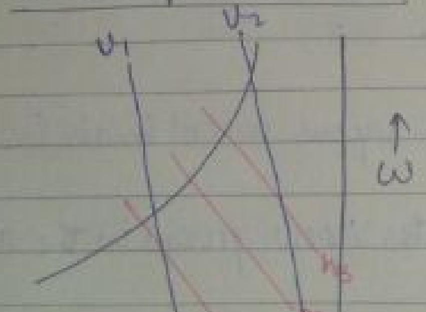

3- Const. RH curves -




4- Const. 'h' lines -




5- Const. 'sp. vol' lines -



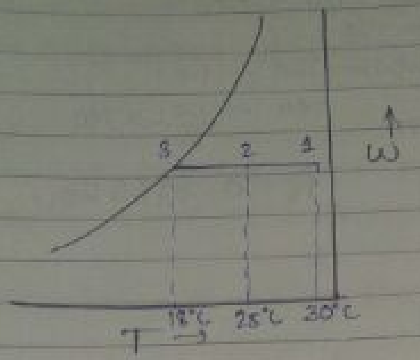

$v_2 > v_1$

$$v = \frac{V(m^3)}{m_a(kg\ da)}$$

$(m^3/kg\ da)$

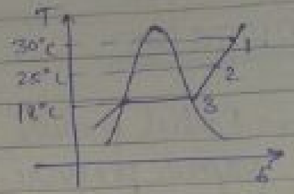
* When total vol. is needed to Cal., multiply the sp. vol. with mass of air.

6- Const. DPT Lines -




If $P_v$ is same,
DPT is same.

but,
If $P_v$ is same
$\omega$ is also same.




→ Constant Dew point temperature lines follow constant $P_v$ lines and therefore they follow constant '$\omega$' lines on Psychrometric chart.

7- Const. WBT lines -

There is a slight difference b/w constant WBT lines and constant enthalpy lines but for all calculations purposes they are taken to be same on Psychrometric chart.

Ap John Formula -

$$P_v = P_v' - \frac{1.8P(t - t')}{2700}$$

$P_v$ → Partial pressure of vapour

$P_v'$ → Sat. pressure corresponding to WBT.

$P$ → Total pressure

$t$ → DBT.

$t'$ → WBT.

Ch3-

1-c, 2-c, 3-d, 4-d, 5-a, 6-d, 7-b, 8-c, 9-d, 10-a.

11-1.5, 12-0.529, 13-80

Ch4-

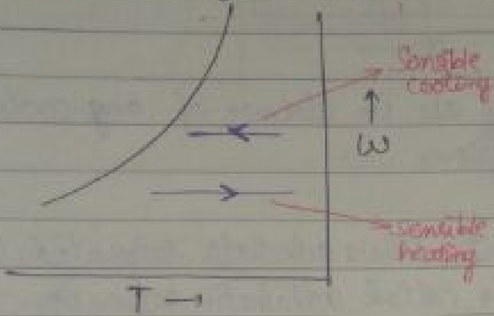
b&c (both are correct)

1-b, 2-d, 3-c, 4-a, 5-d, 6-b, 7-b, 8-c, 9-d, 10-b, 11-a, 12-c, 13-a,

14-a, 15-a, 16-c, 17-3.5167.

## Representation of Various Processes on Psychrometric Chart-

(i) Sensible heating & Sensible cooling-



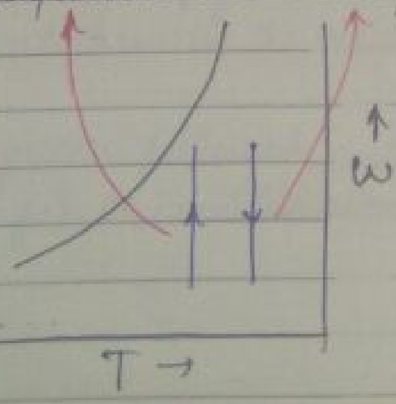

S.C. → DPT < $t_{coil}$ < DBT.

S.H. → $t_{coil}$ > DBT.

→ Heating or cooling of air w/o without changing specific humidity is called sensible heating and sensible cooling.

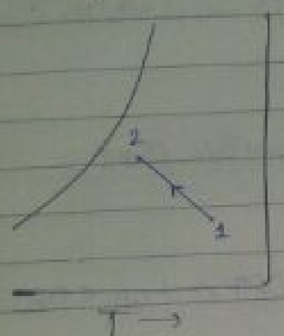
→ Sensible heating process is followed in electrical room heater.

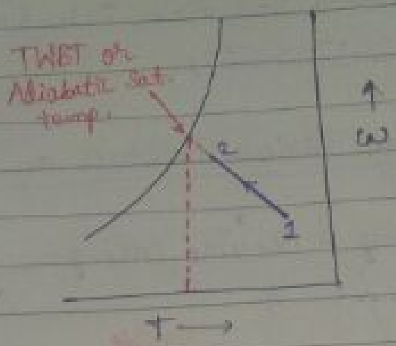
(ii) Humidification & de-humidification-



→ Changing of 'ω' without changing temp. is not possible practically. Hence pure humidification & de-humidification processes are not possible practically.

(iii) Cooling & Humidification -




$\boxed{TWBT \leq WBT}$

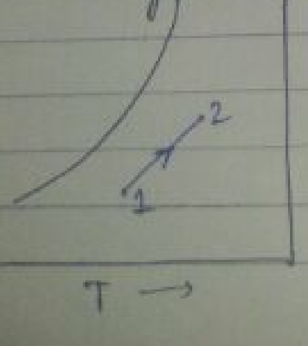
→ Cooling and Humidification of air in absence of any cooling coil is called adiabatic saturation.

→ Temp. corresponding to the point where adiabatic saturation lines intersects the saturation curve is called adiabatic saturation temp. or thermodynamic wet bulb temp.

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

→ Desert cooler follows adiabatic saturation process.

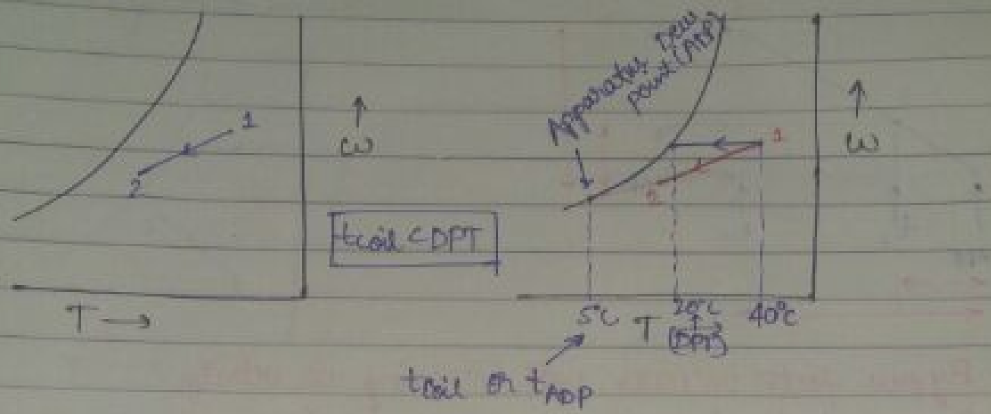
(iv) Heating & Humidification -

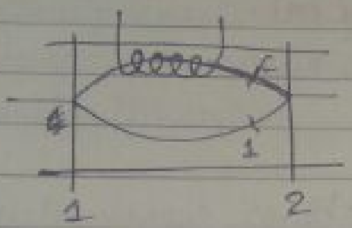


→ Heating and humidification can be obtained by steam spray in air.

→ Heating and humidification is followed in winter air conditioning ~~operation~~ equipment.

(V) Cooling & De-humidification-



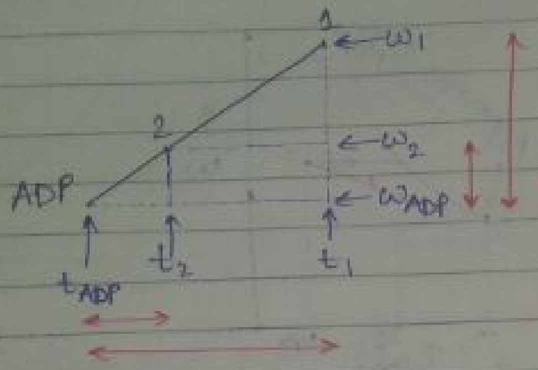

→ The point where cooling and de-humidification line intersects the saturation curve is called apparatus dew point (APD) & the temp. corresponding to the point is called as Apparatus Dew Point temp. which is also the coil temp.

→ The process followed in summer air conditioning equipment is cooling & de-humidification.

By pass Factor (BPF), $X = \frac{t_2 - t_{ADP}}{t_1 - t_{ADP}} \approx \frac{h_2 - h_{ADP}}{h_1 - h_{ADP}}$.

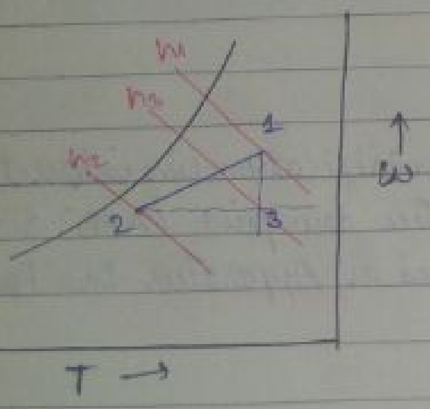
$\eta$ (Contact factor or coilefficiently) $= \frac{t_1 - t_2}{t_1 - t_{ADP}}$.

$$\boxed{BPF + \eta = 1}$$




Note: 1- Bypass factor increases with increasing air velocity.
2- By pass factor depends on placing of coil.

(ii) Sensible Heat Factor & latent Heat Factor-




$TH = h_1 - h_2$.
$L.H = h_1 - h_3$.
$S.H = h_3 - h_2$.

$SHF = \frac{SH}{TH}$

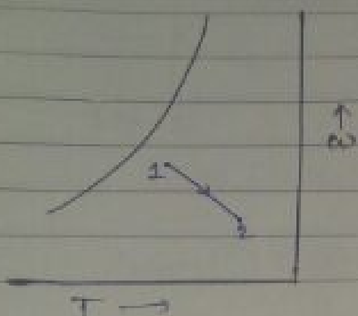
$LHF = \frac{LH}{TH}$.

$$\boxed{SHF + LHF = 1}$$

→ Latent heat load is high when the relative humidity is high (Rainy season).

→ Latent heat factor is also high in places of high occupancy. eg., Movie halls & auditoriums.

(vii) Heating & de-humidification-



→ This process is also called as adiabatic chemical de-humidification because it is carried out with the help of chemicals like silica gel & alumina ($Al_2O_3$).

→ Water vapour condenses in the process while rejecting heat in the air hence the temp. of the air increases. Adiabatic chemical de-humidification lines follows isenthalpic lines because enthalpy of the air almost remains constant during the process.

Q- Air at 20°C DBT and 40% relative humidity is heated to 40°C using electric heater. The surface temp. of the coil is 45°C. Then the BPF is ______

$$X = \frac{t_2 - t_{ADP}}{t_1 - t_{ADP}} = \frac{5}{25} = 0.2.$$

Q- In an air conditioning process 5kJ/min of heat is extracted from the room. If the SHF is 0.8 then what is the latent heat load.

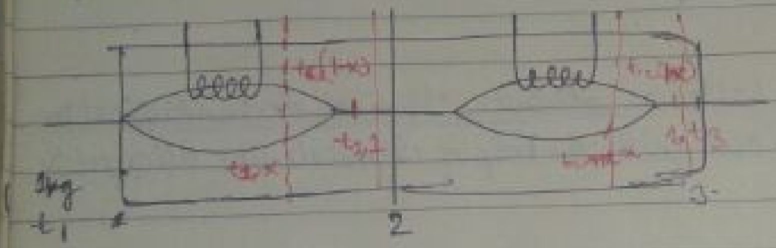
$$\underset{0.8}{SHF} + LHF = 1.$$

$$LHF = 0.2.$$

$$\underset{0.2}{LHF} = \frac{LH}{\underset{=5kJ}{TH}}$$

$$\boxed{LH = 1kJ/min}.$$

Effective Bypass factor-



Dry Air - Energy Conversion-

$$(1-x) h_c + x \cdot h_1 = 1 \cdot h_2.$$

$$(1-x) C_{pa} \times t_c + x \cdot C_{pa}\, t_1 = 1 \times C_{pa} \times t_2.$$

$$(1-x)\, t_c + x \cdot t_1 = t_2 \quad — (1)$$

Similarly,

$$(1-x) t_c + x\, t_2 = t_3. \quad — (2)$$

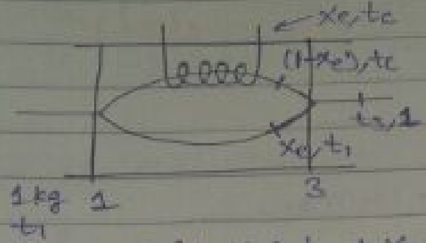
$(1) \Rightarrow t_2 \rightarrow$ in $(2)$,

$$(1-x) t_c + x \{ (1-x) t_c + x t_1 \} = t_3.$$

$(1-x)t_c + (x-x^2)t_c + x^2 t_1 = t_3$.

$t_c - x^2 t_c + x^2 t_1 = t_3$.

$(1-x^2)t_c + x^2 t_1 = t_3$ — (3).




$\Rightarrow (1-x_e)t_c + x_e t_1 = t_3$ — (4)

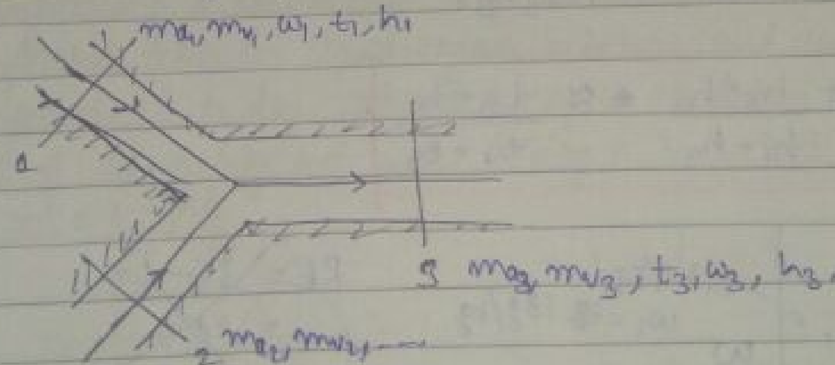
from (3) & (4),

$$\boxed{x_e = x^2}$$

for 'n' coils,

$$\boxed{x_e = x^n}.$$

## Adiabatic mixing of Air Streams –



(I) Conservation of mass,

(1) **Dry air:**

$$m_{a_1} + m_{a_2} = m_{a_3}.$$

(2) **Water vapour:**

$$m_{v_1} + m_{v_2} = m_{v_3}.$$ (No Condensation)

$$\omega = \frac{m_v}{m_a}.$$

$$\omega_1 m_{a_1} + \omega_2 m_{a_2} = \omega_3 m_{a_3}.$$

$$\therefore \omega_1 m_{a_1} + \omega_2 m_{a_2} = \omega_3 (m_{a_1} + m_{a_2}).$$

$$m_{a_1}(\omega_1 - \omega_3) = m_{a_2}(\omega_3 - \omega_2).$$

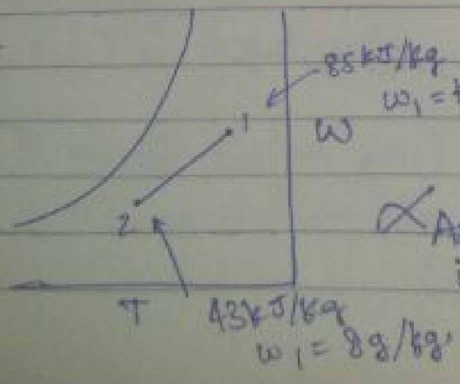
$$\boxed{\frac{m_{a_1}}{m_{a_2}} = \frac{\omega_3 - \omega_2}{\omega_1 - \omega_3}}.$$

(II) Conservation of energy,

$$m_{a_1} h_1 + m_{a_2} h_2 = m_{a_3} h_3.$$

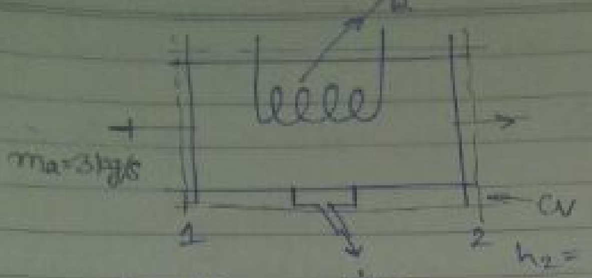
$$\therefore \boxed{\frac{m_{a_1}}{m_{a_2}} = \frac{h_3 - h_2}{h_1 - h_3} \approx \frac{t_3 - t_2}{t_1 - t_3}}.$$

S-




~~RE = 85 - 43~~
~~= 42~~
~~RC = 42×3 = 126.~~

$\propto$ As Condensation is also taking place.




$h_1 = 85$ $h_2 = 43$

$\omega_1 = 19 g/kgda$ $\omega_2 = 8$.

$h_w = 67 kJ/kg$

Energy conservation:-

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

$\dot{m}_{a_1} \times h_1 = \dot{m}_{a_2} h_2 + \dot{Q} + \dot{m}_w \times h_w$.

$\dot{m}_w = m_{a_2}(\omega_1 - \omega_2)$

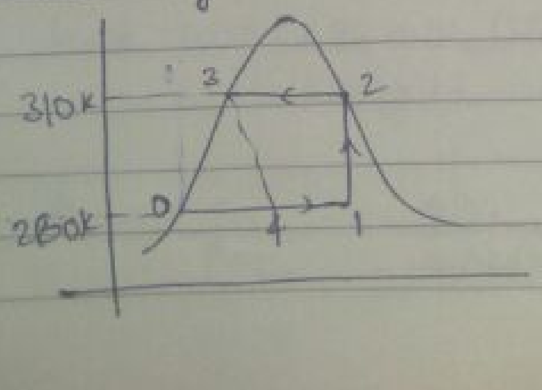
$= 3 \times (19-8) \times 10^{-3} kg/s$.

$= 33 \times 10^{-3} kg/s$.

$\therefore \dot{Q} = 123.8 kW$.

***

Q- In the vapour compression cycle shown in the diagram, the evaporating & condensing temp are 260K and 310K. The compressor takes in liquid-vapour mixture and isentropically compresses it to dry saturated vapour condition. The specific heat of liq. refrigerant is 4.8 kJ/kg K & latent heat at 310K is 1054 kJ/kg.




$h_1 - h_0 = ?$

$h_2 - h_3 = 1054$

$h_1 = h_0 + x(h_{fg})$.

$h_1 - h_0 = x(h_{fg})$.

$$\frac{h_1 - h_0}{260} = s_1 - s_0$$
$$\quad\quad\quad\quad\quad\ \ \Vert$$
$$\quad\quad\quad\quad\quad\ \ s_2$$

$$\frac{h_1 - h_0}{260} = s_2 - s_0 \quad — (1)$$

$$s_2 - s_3 = \frac{1054}{310} \quad — (2)$$

$$s_3 - s_0 = C_{liq} \ln\left(\frac{310}{260}\right) \quad — (3)$$

ये expression constant pressure में applicable होता है but यहाँ apply इसलिए हुआ coz specific heat of liq. is ~~same~~ almost same in const. volume & const. pressure.

(2) + (3)

$$s_2 - s_0 = 4.8 \ln\left(\frac{310}{260}\right) + \frac{1054}{310}.$$

∴ (1) ⇒

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

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

***

Q- 5g of water vapour per kg of dry air from the atmospheric air ( $P_0 = 1.013$ bar, DBT = 35°C and 60% relative humidity) is removed and temp. of air after removing water becomes 25°C. Find the relative humidity & enthalpy of air after removal of water vapour.

Assuming the condensate leaves at 15°C. Calculate cooling load per kg of dry air.

| t (°C) | $P_{vs}$ (bars) |
|---|---|
| 35 | 0.05733 |
| 25 | 0.03229 |

~~$\omega_1 = 5 g/kg\ d.a$~~ $\omega_1 - \omega_2 = 5 g/kg\ da.$

$\phi_1 = \frac{P_{v_1}}{P_{vs_1}} = 0.6$

$P_{v_1} = 0.6 \times 0.05733$

$= 0.034398$ bar.

~~$\dot{m}_{a_1} h_1 = \dot{m}_{a_2} h_2 + \dot{m}_w$~~

$\omega_1 = 0.622 \times \frac{P_{v_1}}{P_t - P_{vs_1}}$

$= 0.622 \times \frac{0.034398}{1.013 - 0.034398}$

$= 21.86 g/kg\ d.a.$

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

$h_1 = 1.005 \times 35 + \omega_1(2500 + 1.88 \times 35)$

$= 91.26\ kJ/kg\ da.$

$\omega_2 = \omega_1 - 5 \times 10^{-3}$

$= 16.86 \times 10^{-3}\ kg/kg da$

$\omega_2 = 0.622 \times \frac{P_{v_2}}{1.013 - P_{v_2}}$

$P_{v_2} = 0.02672$ bar.

$h_2 = 1.005 \times 25 + \omega_2(2500 + 1.88 \times 25)$

$= 68.06\ kJ/kg\ da.$

$\phi_2 = \frac{P_{v_2}}{P_{vs_2}} = \frac{P_{v_2}}{0.03229} = 0.828 = 82.8\%.$

* Hospitals में recirculated air की percentage zero percent and fresh air की 100%. as germs/virus need to be treated and thrown out of the room.

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

$$m_{a_1} \cdot h_1 = m_{a_2} h_2 + q + m_w h_w .$$

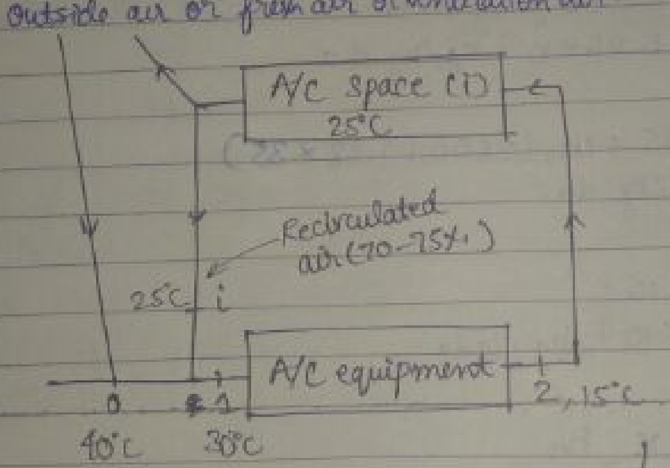
(As water vapour is removed).

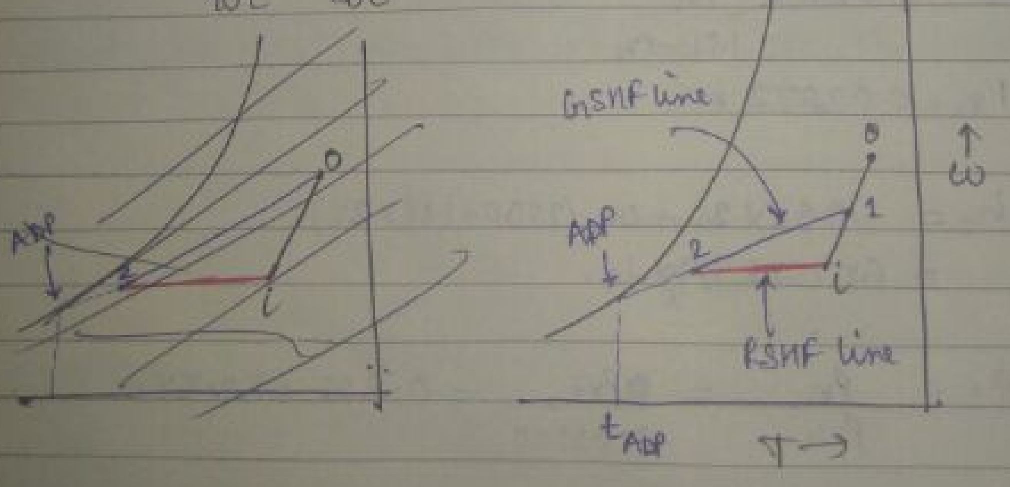
$m_w = 5 \times 10^{-3}$ kg/kg da.

$h_w = C_w \times t = 4.18 \times 15 = 62.7$

$q = 22.87$ kJ/kg da.

Summer air conditioning with ventilation air and non-zero by pass factor-



Air changes = $\frac{\dot{Q} \text{ (Vol. flow of fresh air)}}{V \text{ (Vol. of A/C space)}}$

$\dot{Q} \rightarrow m^3/hr \rightarrow$ ACH (Air changes per hour)

$\dot{Q} \rightarrow$ (cmm = Cubic metre per min) AC $\Rightarrow$ /min.

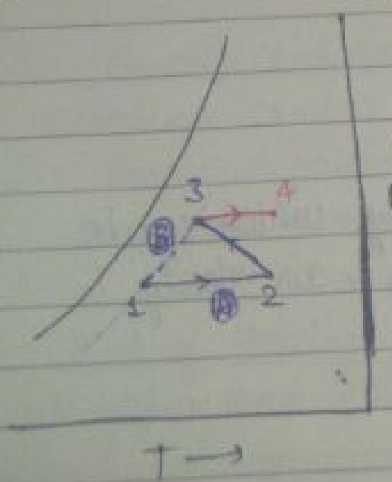
→ The outside ~~air~~ air supplied to maintained the purity of air is called ventilation air. In ~~emer~~ emergency wards and hospitals the fresh air supply is 100% and recirculated air is 0.

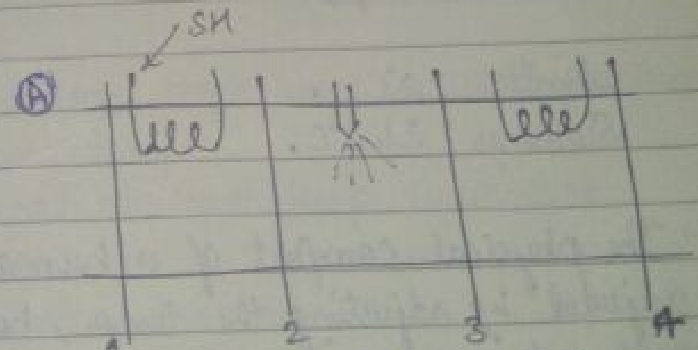
→ Line joining inlet condition ~~to~~ the A/C equipment with the exit condition is called Grand Sensible Heat Factor Line (GSHF)

→ Line joining the supply conditions to the room with the inside conditions is called room sensible heat factor line (RSHF).

→ Intersection of RSHF & GSHF lines gives supply conditions to the room.

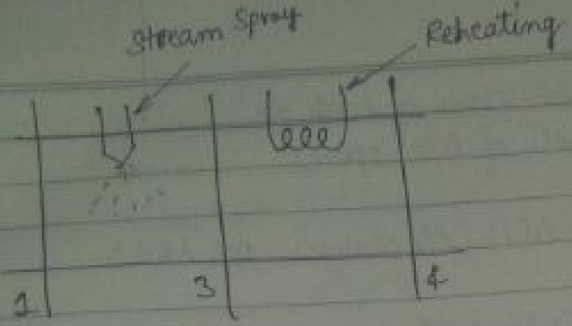
<u>Winter air conditioning</u> -




1→2 : SH (Pre-heating)
2→3 : Adiabatic saturation
3→4 : SH (Reheating)

(B)



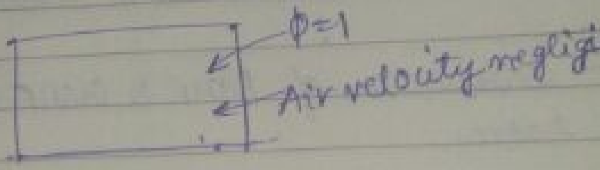

1 → 3 : Heating & humidifying.
3 → 4 : Reheating.

→ In winters the outside air is at low temp. and low 'ω'. Hence winter air conditioning requires heating as well as humidification of air.

Human Comfort & Effective Temp.:-

According to ASHRAE,

DBT → 24-25°C
R.H. → 50-60%.



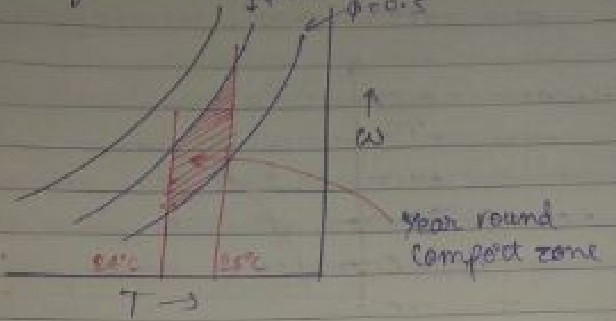

Effective Temp.

Winter : 20°C .
Summer : 21.6°C.

→ The physical comfort of a human being which can be adjusted by adjusting the temp., humidity, air velocity is reffered as human comfort.

→ The temp. of the saturated environment at which a person experiences same level of comfort as in the normal environment is called effective temp.

→ The psychrometric chart showing the comfort region is called as comfort chart.




Factors Affecting human comfort & effective temp.–

1- Age: Adults experience comforts at a lower temp. compared to children and old-age people.

2- Gendre: Men experience comfort at a lower temp. compared to women.

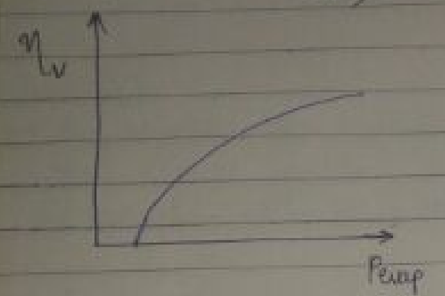
3- Climatic Condition and Season– People living in colder countries experience comfort at lower temp.
→ People experience comfort at lower temp. in winters compared to summer.

4- Kind of clothing– People wearing light clothes will experience comfort at higher temp. compared to people wearing heavy clothes.

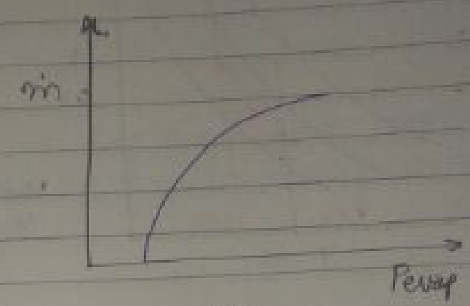
5- Physical Activity : People involved sedantry work (office work) experience comfort at higher temp compared to people involved in heavy physical activity.

Performance Curves- Doubt??

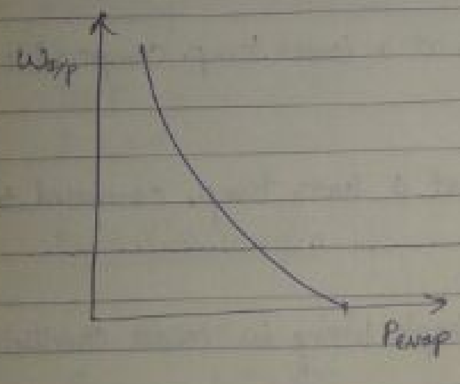
1- $\eta_v = 1+C-C\left(\frac{P_2}{P_1}\right)^{1/n}$




2-

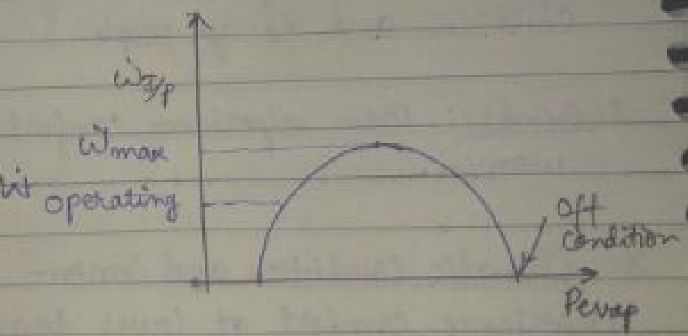



3- $W_{I/P}$ vs Pevap.




4- $\dot{W}_{I/P}$ v/s ~~and~~ Pevap.

$\dot{W}_{I/P} = \dot{m} \times \dot{w}_{I/P}$.




The power input to the refrigeration unit first increases because of ~~in~~ increasing $w_{I/P}$ but then decreasing because mass flow rate reduces drastically. The operating power is less than max. power but the compressor motors are designed for max. power because they have to cross maximum power condition for reaching operating power.

Pull down Period -

→ It is the time required by refrigeration machine to reduce the temp. of evaporator to the designed value from the starting of machine.

Compressor -

1- Hermetic sealed Compressor -

→ In this motor and compressor are mounted on common shaft & the entire assembly is sealed in ~~casun~~ steel casing.
→ Occupies less space and low noise generation, hence used for domestic purposes.
→ Maintanence is difficult and motor cools while rejecting heat to the suction vapour to compressor. This results in super heating of vapour, increasing work input in the compressor and therefore reducing COP.

2- Open type Compressor -

→ In this motor and compressor are mounted on a separate shaft & joined with belt & pulley arrangement.
→ Occupies large space & noise is generated.
→ Maintanance is easier and COP is high. Hence used for industrial purposes.

3- Semi-hermetic -

→ Compressor and motor are sealed separately and joined with belt & pulley arrangement.