Refrigeration & Air Conditioning

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Topic **Page**

28/11/2016

Book
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RAC

open system

① steady state

② $\Delta K.E. = 0$ & $\Delta P.E. = 0$

S.F.E.E.

$$h_1 + q = h_2 + W_{c.v.}$$

Adiabatic → Rev. / → irrv. $\}\ q = 0$

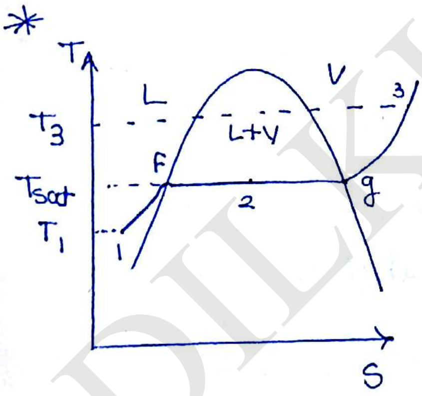
$$W_{c.v.} = h_1 - h_2$$

Polytropic ($PV^n = c$)

$$W_{cv} = -\int v\,dp$$

$$W_{c.v.} = \frac{n}{n-1}\left(P_1V_1 - P_2V_2\right)$$

*



① Sub cooled Region

$$h_f - h_1 = C_{p_{liq}}\left(T_{sat} - T_1\right)$$

$$s_f - s_1 = C_{p_{liq}} \ln \frac{T_{sat}}{T_1}$$

② Wet Region.

$$h_2 = h_f + x_2 h_{fg}$$

$$s_2 = s_f + x_2 s_{fg}.$$

L.H $Q_p = h_g - h_f$

LH $= h_g - h_f$

$$s_g - s_f = \frac{L.H.}{T_{sat}}$$

$$s_g - s_f = \frac{h_g - h_f}{T_{sat}}$$

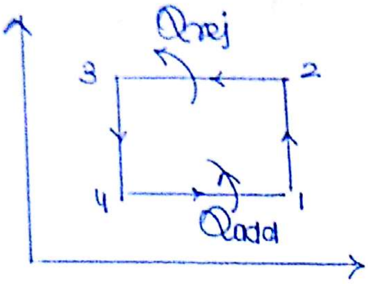
③ super heated (ideal gas)

$$h_3 - h_g = C_{p_v}\left(T_3 - T_{sat}\right).$$

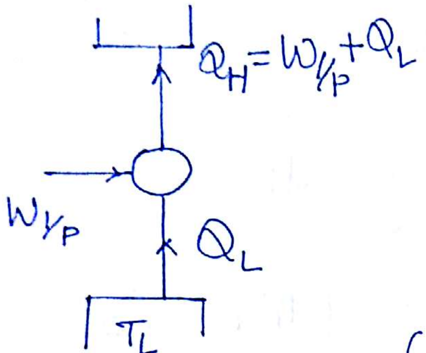
$$s_3 - s_g = C_{p_v} \ln \frac{T_3}{T_{sat}} \cancel{- R \ln \frac{P}{P}}$$

$$s_3 - s_g = C_{p_v} \ln\left(\frac{T_3}{T_{sat}}\right)$$

Ideal cycle for Refrigeration:-
(Reversed Carnot Cycle)



1-2 isentropic comp.
2-3 isoth heat rej
3-4 isentropic exp.
4-1 isoth. heat add.



$$(COP)_{Ref} = \frac{Q_L}{W_{I/P}}$$

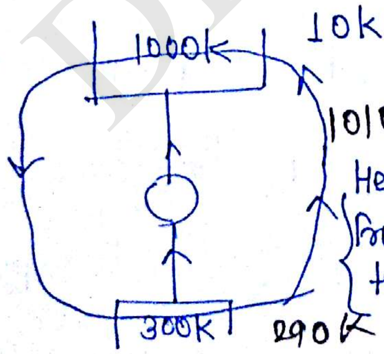
$$(COP)_{HP} = \frac{Q_H}{W_{I/P}}$$

$$(COP)_{ref} = (COP)_{HP} - 1$$

$$(COP)_{HP} - (COP)_{ref} = 1$$

* $$(COP)_{ref} = \frac{T_L}{T_H - T_L} \qquad (COP)_{H.P} = \frac{T_H}{T_H - T_L}$$

eg if 10K diff b/w temp. of working substance and sink
cop = ?



10K diff

1010K

Heat rej from high temp. to low temp

290K

$$(COP) = \frac{290}{1010 - 290} = 0.4027$$

$$\frac{1000}{1000 - 300} = 0.4285$$

* The expressions developed in term of temp. can be used when
  - The cycle is internally rev. (may or may not be externally rev.)
  - Heat add. and heat rej. should be isothermal.
  - Temp. should be temp. of working Fluid.

* The eff. (η) of an engine increases by increases T_H and by decreasing T_L. but increment is more when the T_L is decrease.

* COP of heat pump & ref. increases by decreasing T_H and by increasing T_L. Here increasing T_L is more benefesial.

* The COP of AC ~~and~~ is more than COP of ref. but the electrisity bill of AC is more because the total ~~to~~ heat removed i.e. Desired effect is more as compare to ref., since

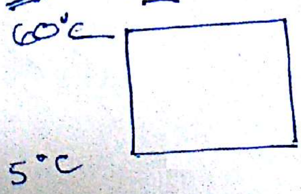
Reasons
  - total space to cooled is more
  - Heat gen. ~~sorces~~ sources are present (fan, light people)
  - ~~fan, li~~ Heat leakage from outside

Suppose

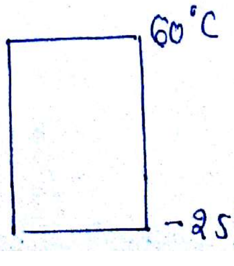
$$(COP)_{A/C} = 2 = \frac{D.E. \rightarrow 100}{W_{I/P}} \qquad W_{I/P} = 50$$

$$(COP)_{ref} = 1 = \frac{D.E. \rightarrow 10}{W_{I/P}} \qquad W_{I/P} = 10$$

eg A/C



Ref eg



Heat Capacity

* $(COP)_{ref} = \frac{R.E.}{W_{I/P}} = \frac{R.C}{W_{I/P}}$, $(COP)_{HP} = \frac{H.E.}{W_{I/P}} = \frac{H.C}{W_{I/P}}$

Ref. Capasity   Heat cap.

Q_L from lower temp.

- The amount of heat absorbed to maintain a space at a lower temp. is called refrigeration effect. The rate of heat absorption is called refrigeration capasity.
- The amount of heat rejected is called heating effect and the rate of heat rejection is called heating capacity.

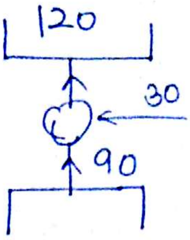
Imp
* 1 Ton of Refrigeration: (1TR)

$$\boxed{1\ TR = 3.5167\ KW}$$
$$= 211\ KJ/min$$
$$= 50.4\ kcal/min$$

It is the amount of heat which has to be removed to convert 1 ton of water at 0°C into 1 ton of ice at 0°C in 24 hrs. hence ton of refrigeration represents heat transfer rate.

Q 6
P.g.41
WB

$$\cancel{COP = \frac{30}{120-30} = \frac{1}{3}}$$



$$Cop = \frac{90}{30}$$

$$Cop = \underline{\underline{3}}$$

Q.10

$$\frac{T_L}{T_H} = 0.8$$

$$(COP)_{ref.} = \frac{T_L}{T_H - T_L}$$

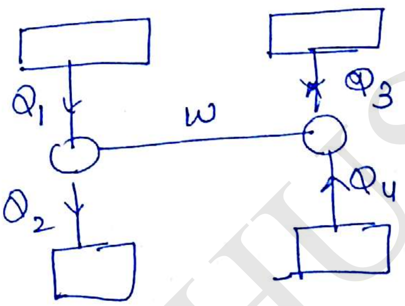
$$\left(\frac{1}{COP}\right)_{ref} = \frac{T_H}{T_L} - 1 = \frac{10}{0.8} - 1$$

$$\left(\frac{1}{COP}\right)_{ref} = 1.25 - 1$$

$$(COP)_{ref} = 4$$

$$(COP)_{HP} = 5$$

Q.17



$$\eta_{HE} = \frac{Q_1 - Q_2}{Q_1} = 0.4$$

$$1 - \frac{Q_2}{Q_1} = 0.4$$

$$Q_2 = 0.6\, Q_1$$

$$Q_2 + Q_4 = 3Q_1$$

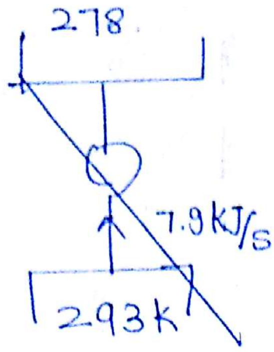
$$(COP) = \frac{Q_4}{Q_3 - Q_4} = \frac{3Q_1 - Q_2}{Q_1 - Q_2}$$

$$(COP) = \frac{3Q_1 - 0.6Q_1}{Q_1 - 0.6Q_1}$$

$$= \frac{2.4}{0.4}$$

$$\underline{COP} = 6$$

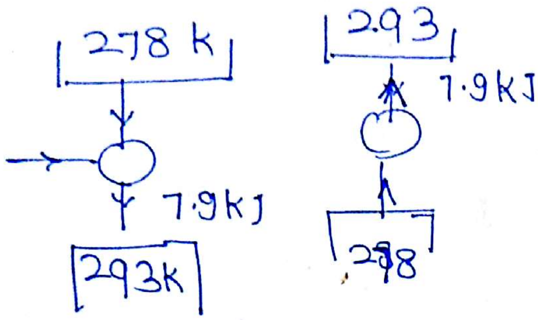
Q.17



$$\cancel{\frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L}}$$

$$\cancel{\frac{7.9}{293} \times 5 = W}$$

Heat pump

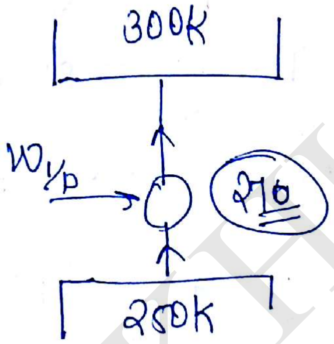


$$\frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L} = \frac{293}{15}$$

$$Q_H - Q_L = W = \frac{7.9}{293} \times 15$$

$$W = 0.4045 \text{ kJ}$$

Q.18



$m = 3600$ kg

$t = 10$ hrs

$C_{p_f} = 2.0$ kJ/kg K above $-3°C/270K$

$C_{p_f} = 0.5$ kJ/kg K below 270 K

$LH = 230$ kJ/kg

$$(COP)_{idea} = 2(COP)_{act}$$

Heat removed = $m(c\,dT + LH + c\,dT)$

Heat absorbe $Q = 3600(2 \times 30 + 230 + 0.5 \times 20)$

$$\frac{\cancel{250}\,5}{\cancel{50}} = 2(COP)_{act}$$

$$(COP)_{act} = 2.5 = \frac{Q_L}{Q_H - Q_L} = \cancel{\frac{3600 \times (0.5 \times 20 + 230 + 2 \times 30)}{W_{i/p}}}$$

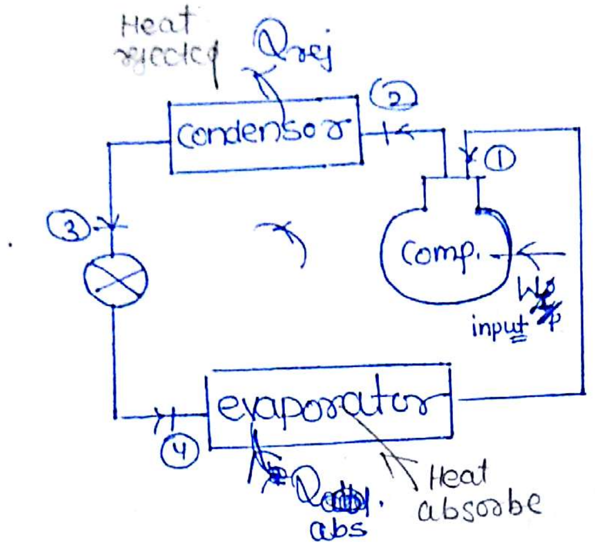
$$\dot{Q} = \frac{Q}{10 \times 3600} = \frac{1080000}{360000}$$

$$2.5 = \frac{30}{W_{i/p}}$$

$$\dot{Q} = 30 \text{ KW}$$

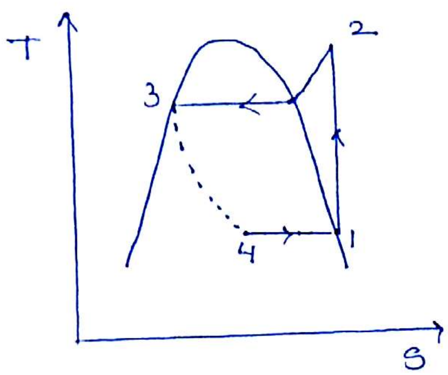
$$W_{i/p} = 12 \text{ kW} \quad \text{Ans}$$

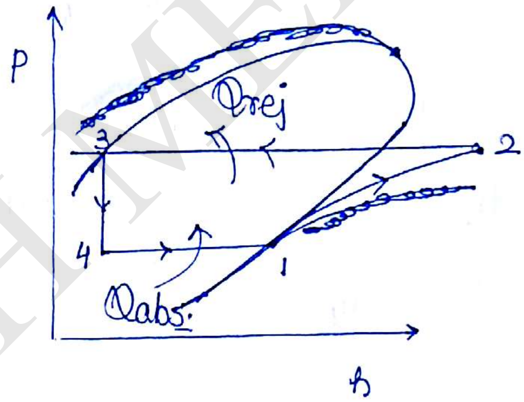
Vapour Compression Refrigeration System (VCRS)



1→2 isentropic Comp.
2→3 Isobaric heat rej.
3-4 throttling
4-1 Isobaric heat ab.

* In actual unit the ref. leaving the evaporator is superheated

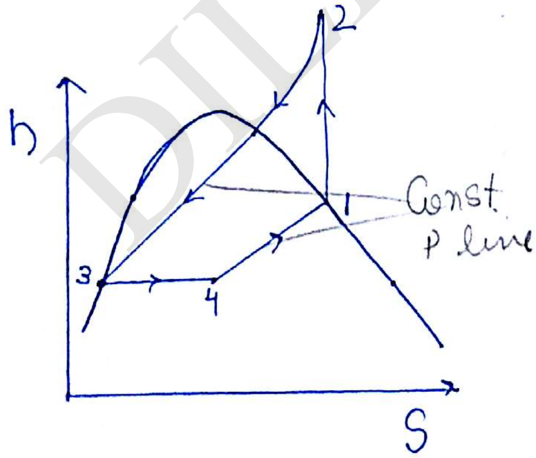




Simple V-C cycle
or ideal V-C cycle

Function is define so (3-4) throttling straigh line

1. Sat. ~~liq~~ Vap.
3. Sat. liq.



$$T ds = dh - \cancel{v dp}^{\,0}$$

$$\left(\frac{dh}{ds}\right) = T$$

1. Sat. Vapour
3 Sat. liquid

⇒ Appling steady ~~state~~ flow energy eqⁿ in various stages

- steady state
- $\Delta KE = \Delta P.E. = 0$

$$h_i + q = h_e + w_{c.v.}$$

① Compressor.

isentropic $(Q=0)$

$\therefore w_{c.v.} = h_i - h_e$

$w_{i/p} = h_e - h_i = h_2 - h_1$

$W_{i/p} = h_2 - h_1$

② Condensor $(w_{c.v.} = 0)$

$q = h_e - h_i$

$Q_{rej} = h_i - h_e = h_2 - h_3$

$Q_{rej} = h_2 - h_3$

③ throttling.

$h_3 = h_4$

④ Evaporater $w_{c.v} = 0$

$h_i + q = h_e$

$Q_{ab} = h_1 - h_4$

$$* \boxed{COP = \frac{R.E.}{w_{i/p}} = \frac{h_1 - h_4}{h_2 - h_1} = \frac{h_1 - h_3}{h_2 - h_1}}$$

Ref. Capacity, $\boxed{(R.C.) = \dot{m} \times (R.E.)}$

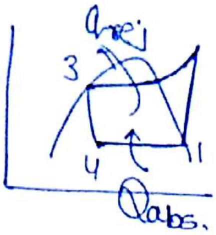
$$\boxed{\dot{W}_{i/p} = \dot{m} \times (w_{i/p})}$$

Q.16
P.g 45
WB

$RC = 5\ kW$

$h_3 = 75\ kJ/kg = h_4$

$COP = \frac{R.E}{W_{inp}} = \frac{h_4 - h_1}{h_2 - h_1}$



$h_1 = 183\ kJ/kg.$

$h_2 = 210\ kJ/kg.$

$$(COP) = \frac{183 - 75}{210 - 183} = 4$$

$W_{i/p} = \text{Power} = \dot{m}\,(W_{inp})$

$= \dot{m}\,(h_2 - h_1)$

$(RE) \times \dot{m} = RC.$

$(h_1 - h_4)\,\dot{m} = 5$

$\dot{m} = \frac{5}{108}\ kg/s.$

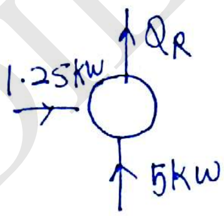
$$P_{i/p} = \frac{5}{108}(210 - 183)$$

$P_{i/p} = 1.25\ kW$

$$\text{Heat tran rate} = \frac{5}{108}(h_3 - h_2) = \frac{5}{108}(210 - 75)$$

$$= \underline{6.25\ kW}$$

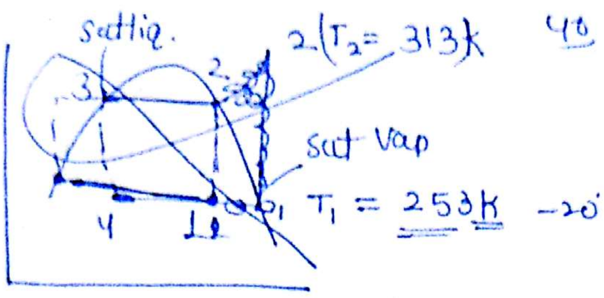
or $COP = \frac{R.C}{W_{inp}} \Rightarrow W_{inp} = \frac{5}{4} = 1.25\ kW.$

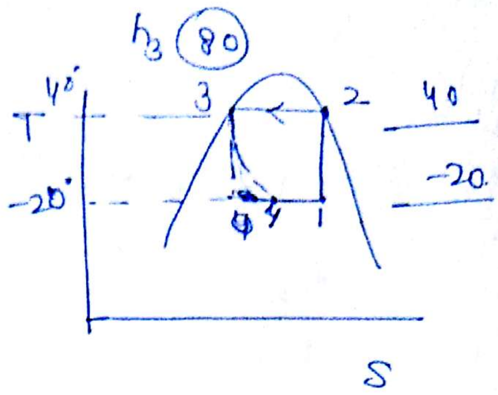


$$Q_R = 1.25 + 5$$

$$= \underline{6.25\ kW}$$

Q. 19





$$COP = \frac{h_1 - h_3}{h_2 - h_1} = \cancel{\frac{180 - 80}{200 - 180}} = \cancel{5}$$

or

$$COP =$$

$$S\big|_{40^\circ} = S_f + x(S_g - S_f)\big|_{-20^\circ C}$$

$$0.67 = 0.07 + x(0.04)$$

$$x = 0.9$$

$$h_1\big|_{-20^\circ} = h_f + x\, h_{fg}\big|_{-20^\circ}$$

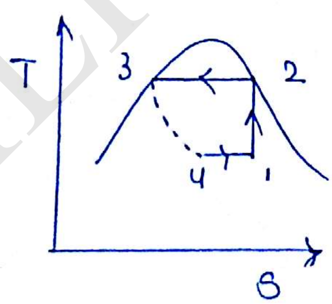
$$= 20 + 160 \times 0.9$$

$$h_1 = 164 \text{ kJ/kg}$$

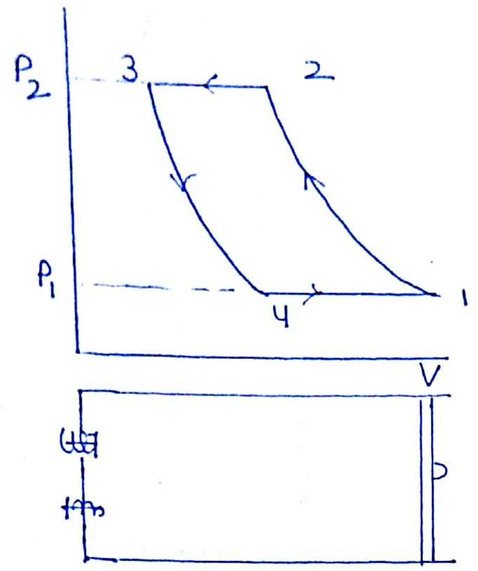
$$COP = \frac{164 - 80}{200 - 164} = 2.33$$

$$R.E. = \dot{m}(h_1 - h_4) = 0.025(164 - 80)$$

$$R.E. = 2.1 \text{ kW}$$



Volumetric efficiency in reciprocating Compression:–



$$\eta_v = \frac{\text{Vol. entering}}{\text{Vol. swept}}$$

$$\eta_v = \frac{V_1 - V_4}{V_1 - V_3}$$

Refer power plant notes for deriv.

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

$C = \frac{V_3}{V_1 - V_3}$ clearance ratio.

n – polytropic index.

☆⇒

$$\eta_v = \frac{\overset{\text{kg/min}}{\dot{m} \times 60} \times \overset{\text{m}^3/\text{kg}}{v_1}}{\underbrace{\frac{\pi}{4} D^2 L}_{\text{m}^3/\text{rev.}} \times \underbrace{N}_{\text{rev/min}} \times \underbrace{K}_{\text{No. of Cylinder}}} = \frac{\dot{m} \times 60 \times v_1}{V_s \times N \times K}$$

Q.9
P.g 45
WB

~~$C = 0.03$~~

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

~~$= 1 + 0.03 - 0.03\left(\frac{7.45}{1.5}\right)^{1/1.5}$~~

~~$\eta_v = 0.942$~~

~~$0.942 = \frac{\dot{m} \times 60 \times 0.1089}{\quad}$~~

η 1TR = 3.561 kW
Q_1

Ques

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

$$\eta_v = 1 + 0.03 - 0.030\left(\frac{7.45}{1.5}\right)^{1/1.15}$$

$$\eta_v = 0.9091$$

$$\eta_v = \frac{\text{Vol. entring}}{\text{Vol swept} \rightarrow ?} = \dot{m} \times v_1$$

$$R.C. = \dot{m} \cdot R.E.$$

$$2 \times 3.5167 = \dot{m}(h_1 - h_4) = \dot{m}(176 - 65)$$

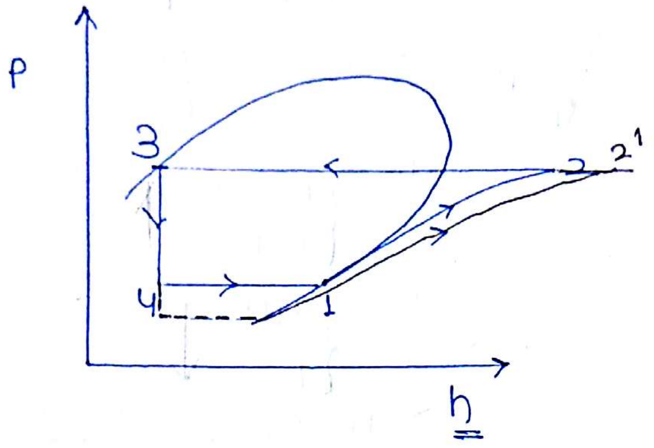
$$\dot{m} = 0.06336 \text{ kg/sec.}$$

$$(V)_{actue} = \frac{0.06336 \times 0.1089}{0.9091}$$

$$V_{act.} = 7.58 \times 10^{-3} \text{ m}^3/\text{s.}$$

Effect of Variation of various properties on the performance of VC cycle.

1) Reduction in evaporator pressure:-



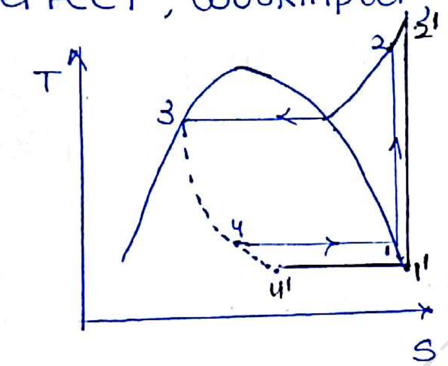
(i) R.E. ↓

(ii) $W_{i/p}$ ↑

(iii) ↓COP $= \dfrac{R.E.\downarrow}{W_{i/p}\uparrow}$

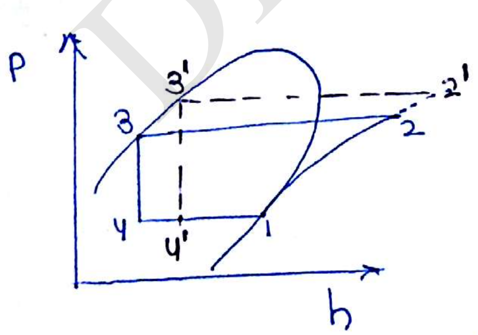
(iv) $\downarrow \eta_v = 1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}$

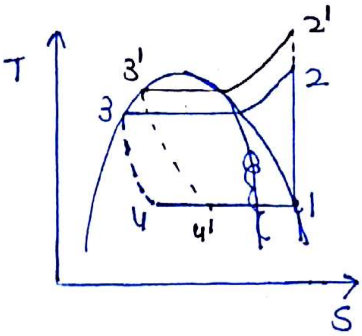
→ Reduction in evaporator pressure decrease the Refrigeration effect, workinput, COP and Volumetric efficiency.



→ The evaporator pressure depends on the temp. of the evaporator, which depends on the desired effect of the machine. (i.e. Air conditioning or ice making)

2) Increase in Condensor pressure:





(i) R.E. ↓

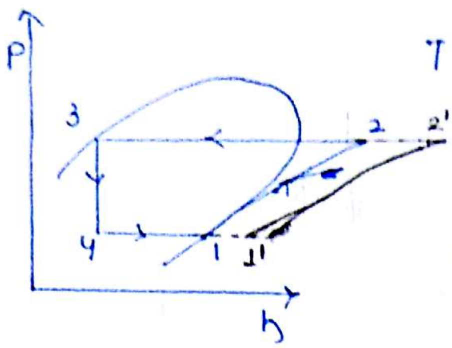
(ii) $W_{i/p}$ ↑

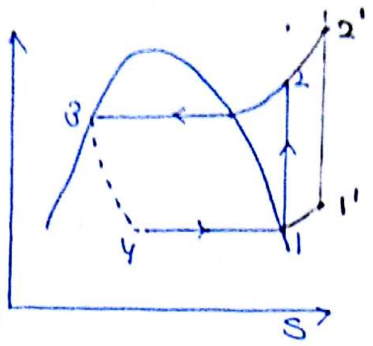
(iii) ↓COP $= \dfrac{R.E.\downarrow}{W_{i/p}\uparrow}$

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

→ The Condensor pressure depends on the Condensor temp. Which further depends on the ambient temperature

3) Superheating of the suction vapour to the compressor:-





→ (i) R.E. ↑

→ (ii) $W_{I/P}$ ↑

→ (iii) COP $= \frac{R.E.}{W_{I/P}}$

for $\left\{\begin{array}{l} R\text{-}134a \\ R\text{-}12 \end{array}\right.$ ↑

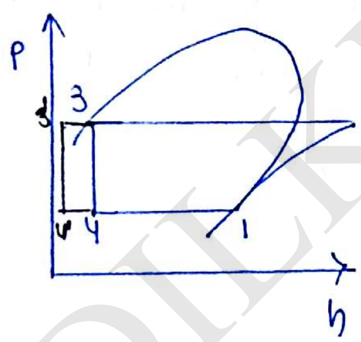
$\left\{\begin{array}{l} NH_3 \\ R\text{-}22 \end{array}\right.$ ↓

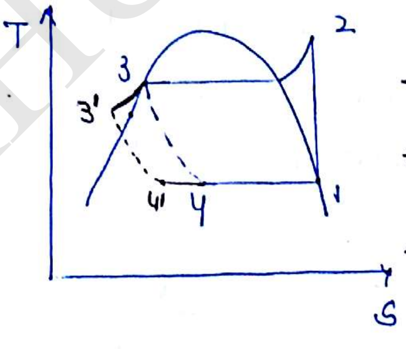
→ Work input increases due to superheating because superheating increase the volume of the fluid.

→ (iv) η_v = remain same

Since both R.E and $W_{I/P}$ increases hence COP may increase, decrease or remain constant. In case of R-134a and R-12 COP increases with superheating whereas in case of R-22 & NH_3 COP decrease with superheating.

4) Subcooling of liquid in the condensor:





→ (i) R.E. ↑

→ (ii) $W_{I/P}$ → Same

→ (iii) ↑ COP $= \frac{R.E↑}{W_{I/P}}$

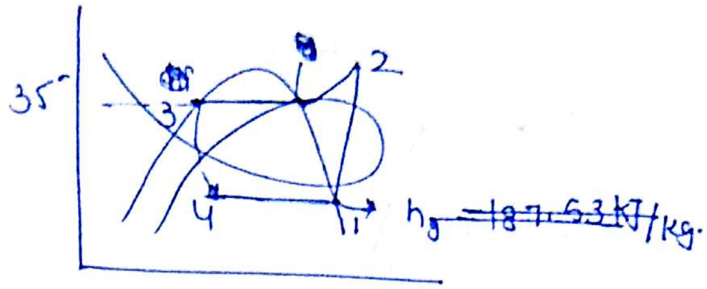
→ (iv) $\eta_v = 1 + c - c\left(\frac{P_2}{P_1}\right)^{1/n}$ → Same

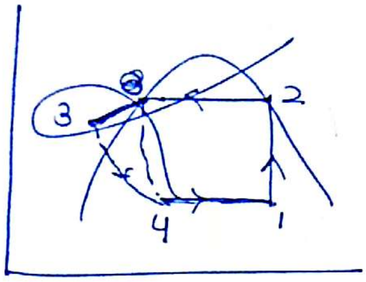
Q.18

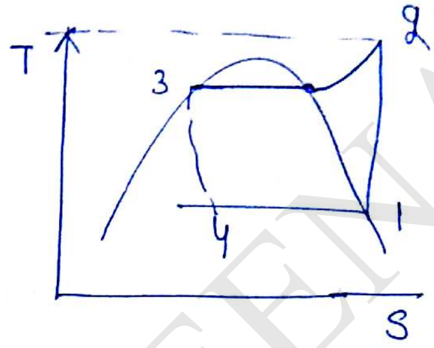
$COP = 6.5$

35°C $\begin{cases} h_f = 69.55 \text{ kJ/kg} \\ h_g = 201.50 \text{ kJ/kg} \end{cases}$

$C_p = 0.6155 \text{ kJ/kg}$







$$h_2 = h_g + C_p \cancel{\ln \frac{T_2}{T_3}} (T_2 - T_3)$$

$$h_2 = 201.5 + 0.6155 (T_2 - 308)$$

$$COP = \frac{R.E.}{W_{I/p}}$$

$$6.5 = \frac{h_1 - h_4}{h_2 - h_1}$$

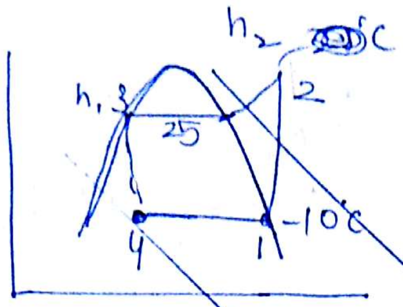
$$6.5 = \frac{201.5 - 69.55}{h_2 - 201.5}$$

$$h_2 = 205.68 \text{ kJ/kg.}$$

$$205.68 = 201.5 + 0.6155 (T_2 - \cancel{308}\ 35)$$

$$T_2 = 41.79\ °C$$

Q.17



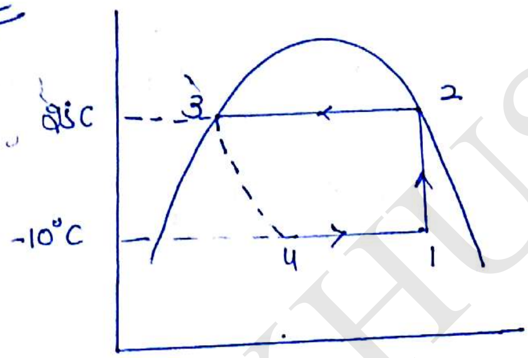
$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

$$COP = \frac{\cancel{1465.84} - \cancel{298.9}}{-\cancel{1465.84}} \qquad COP = \cancel{\frac{1433.05 - 298.9}{-1433.05}}$$

$$h_3 = \cancel{h_4 = h_f + x\, h_{fg}} \qquad \cancel{h_2 = h_g}$$

$$S_2 = S_g\Big|_{-10^\circ C} = S_g + C_v \ln\left(\frac{T_2}{T_3}\right)$$

Q 17



$$h_2 = 1465.84$$

$$h_3 = h_4 = 298.9$$

$$S_1 = S_2$$

$$S_f + x(S_g - S_f)\Big|_{-10^\circ C} = S_g\Big|_{25^\circ C}$$

@ 25°C

$$S_{fg} = \frac{h_g - h_f}{T_{sat}}$$

$$S_g - S_f = S_g - 1.125 = \frac{1465.84 - 298.9}{298}$$

$$S_g = 5.046 \quad \text{at } 25^\circ C$$

@ $-10^\circ C$ $\quad S_g - S_f = \dfrac{h_g - h_f}{T_{sat}} \Rightarrow S_g - S_f = \dfrac{1433.05 - 135.37}{263}$

$$S_{fg} = 4.934$$

Now

$$0.5443 + x(4.934) = 1.1242$$

$$x = 0.91$$

So $h_1 = h_f + x_1 h_{fg}$ at $-10°C$

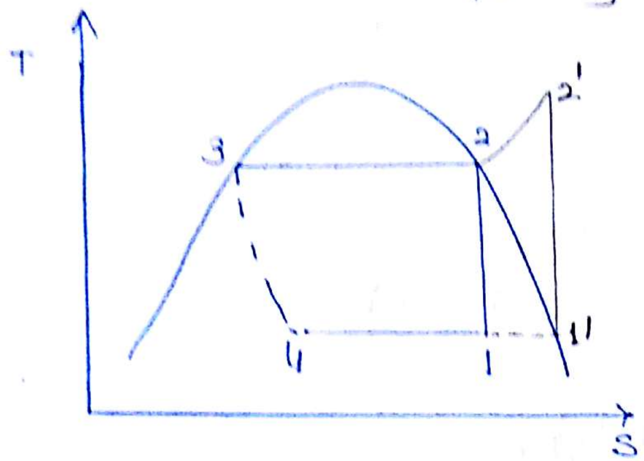
$$= 138.37 + 0.91(1433.5)$$

$$h_1 = 1317.57 \text{ KJ/kg}$$

$$COP = \frac{h_1 - h_4}{h_2 - h_1} = \frac{1317.54 - 298.9}{1465.84 - 1317.54}$$

$$COP = 6.8 \text{ Ans}$$

Wet Compression V/S Dry Compression:-



1-2. wet Comp.

1'-2' Dry Comp.

→ In wet compression the refrigeration effect is less than the dry compression due to incomplate vapourisation of refrigerant.

→ In wet compression the work input is also less as compared of dry comp. because of lower specific volume.

→ Generally the cop is more with wet comp. but whenever reciprocating Compressor is used wet compressor is not preferred because

(i) liquid particles in the refrigarent wash away the lubricating oil hence increase wear and tear of the Compressor

(ii) liq. particles damage the valves in the reciprocating Compressor.

Secondary Refrigerent and Primary Refrigerent:-

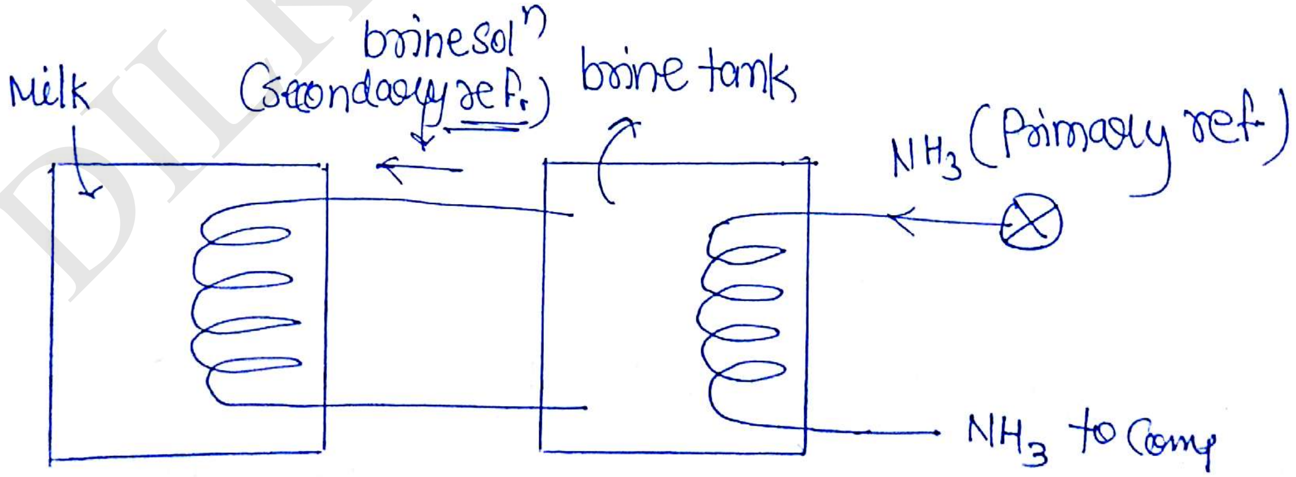
- The refrigerent which flows through the refrigeration equipment is called primary refrigerent.
- Secondary refrigerent which absorbs heat from the refrigerated space and rejects to the primary refrigerent.
- Secondary refrigerent used in milk chilling plants is brine solution. (water + salt)

In Air conditioning the secondary refrigerent is air.

Use of secondary refrigerent helps in

(i) Saving the Cost associated with the amount of primary refrigerent.

(ii) It facilitates the use of A primary refrigerent having good thermodynamic properties irrespective of it toxic nature. (eliminate direct mixing)



Q.20

water $35\,^\circ C \xrightarrow{w} 0_{w} \longrightarrow 0\,^\circ C_{ice} \longrightarrow -8\,^\circ C_{ice}$

$$Q = m\{C_w\,dT + L.H. + C_{ice}\,dT\}$$

$$= 8640(4.18 \times 35 + 334.72 + 2.26 \times 8)$$

$$Q = \cancel{49.91\,kW}\ 4312222.4\ kW$$

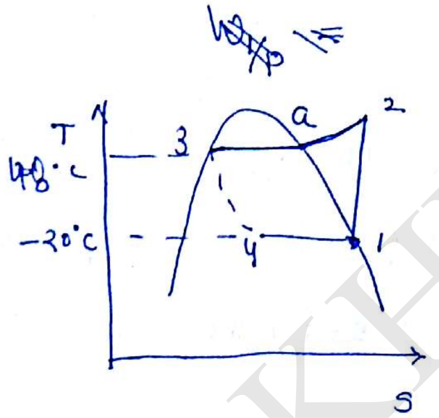
$$\dot{Q} = \frac{Q}{24 \times 3600} = 49.91\,kW \quad P$$

$$R.C. = \dot{Q} \times 1.1$$

$$= 49.91 \times 1.1$$

$$R.C = 54.901\ kW$$

primary ref. remove this amount of heat.



$$h_1 = 178.74\ KJ/kg$$

$$h_4 = h_3 = 82.83\ KJ/kg$$

$$S_1 = S_2$$

$$0.7087 = S_g + C_{p_v} \ln\left(\frac{T_2}{T_{sat}}\right)$$

$$0.7078 = 0.6802 + 0.82 \ln\left(\frac{T_2}{321}\right)$$

$$T_2 = 331.9\ K$$

$$h_2 - h_a = C_{pa}(T_2 - T_a)$$

$$h_2 = 205.83 + 0.82(331.9 - 321)$$

$$h_2 = 215.135\ KJ/kg.$$

$$COP = \frac{h_1 - h_4}{h_2 - h_1} = 2.63$$

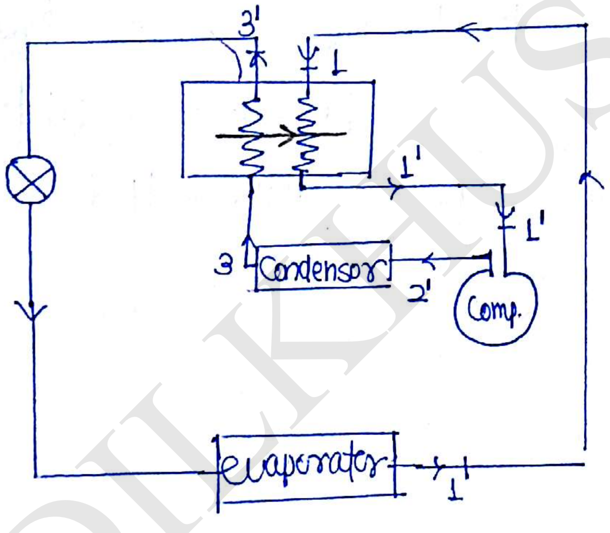
$$2.63 = \frac{R_c}{W_{I/P}}$$

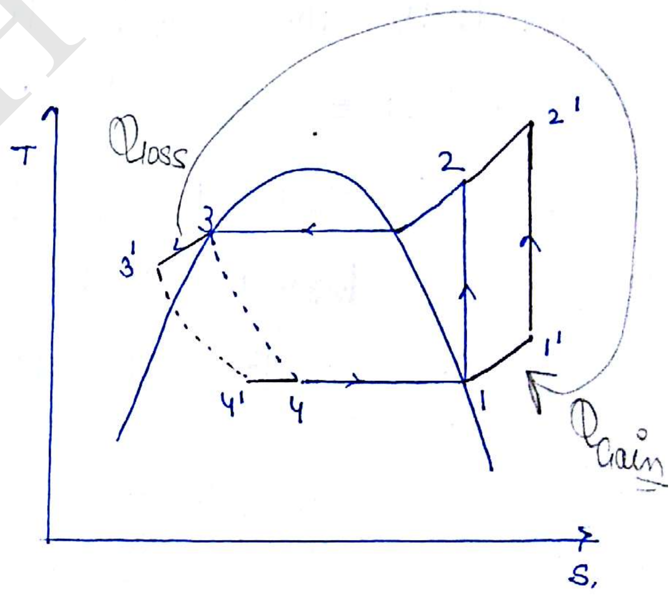
$$W_{I/P} = \frac{54,901}{2.63}$$

$$W_{I/P} = \cancel{2.63}\ 20.84\ \underline{kW}$$

Use of Regenrative heat exchanger

(liquid line heat exchanger or Sub Cooling H.E.)





$\therefore$ $Q_{lost} = Q_{gain}$ $\quad$ R.E $= (h_1 - h_4) + (h_4 - h_{4'})$

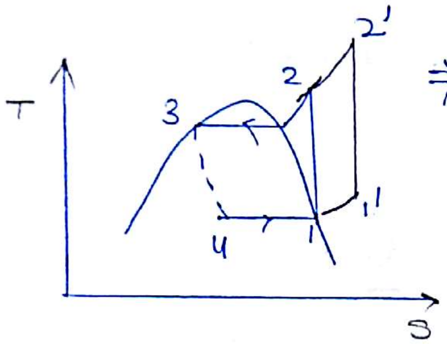
$$h_3 - h_{3'} = h_{1'} - h_1$$

$$C_{P_{liq.}} \underbrace{(T_3 - T_{3'})}_{\text{Degree of subcooling}} = C_{P_v} \underbrace{(T_{1'} - T_1)}_{\text{Degree of super heating}}$$

Degree of ~~Super~~ subcooling $\neq$ Degree of super heating

→ In regerative heat exchanger Heat loss is equal to heat gained by degree of subcooling is not equal to Degree of superheating because specific heat of liquid & vapour is different.

Use of Regenrative heat exchanger V/s superheating in evaporator



$\Rightarrow$ R.E. $= (h_1 - h_4) + (h_{1'} - h_1)$ — x

↓ in evap. super heating

$\Rightarrow$ R.E. $= (h_1 - h_4) + (h_{4'} - h_4)$ — x

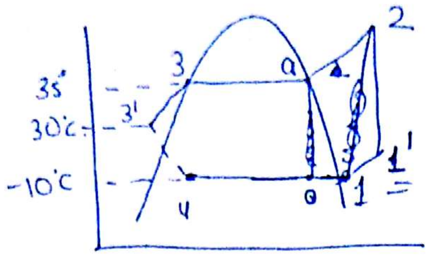
↓ in regenrative HE

$=$

* In both the cases the ~~refe~~ R.E., work input and hence COP comes out to be same but the increased refrigaration effect is obtain at a lower temp. in regenrative H.E. compare to evaporator.

(22)

R.C. = 50 kW



$RC = \dot{m}(RE)$

$= \dot{m}(h_1 - h_4)$

$h_a = 1488.57$ KJ/kg.

$h_3 = 366.07$ KJ/K.

$h_3' = h_3 - C_p \cancel{\ln\left(\frac{T_3}{T_3'}\right)} (T_3 - T_{3'})$

273 / 35 / 0.8

$h_3' = 366.07 - 4.556 \cancel{\ln\left(\frac{308}{303}\right)} (308 - 303)$

$h_4 = h_3' = 343.29$ KJ/kg

$\cancel{s_2|_{35} = s_f + x\, s_{fg}.|_{-10}}$

$\cancel{5.2086 = 0.82965 + x(\quad)}$

$\cancel{x = 0.88}$

$\cancel{h_1 = h_f + x\, h_{fg}}$

$\cancel{h_1 = 1294.68}$

$\cancel{50\ kJ/s = \dot{m}(1294.68 - 343.29)}$

$\cancel{\dot{m} = 9}$

$\cancel{W = 0.0525(1488.57 - 1294.68)}$

$\cancel{= 10.18\ kW}$

$v_1 = v_f + x\, v_{fg}$

=

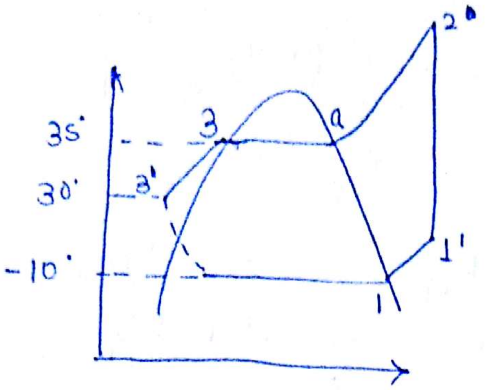
L = 1.2 D

$V = \frac{\pi}{4} D^2 L$

$\cancel{= \frac{\pi}{4}(D^2)\, 1.2 D}$

$\cancel{D = 0.67\ m}$

Q.22



$h_1 = 1450.22$

$h_3 = 366.07$

$h_a = 1488.07$

$h_3 - h_{3'} = \underbrace{C_{pl}}_{4.556}\underbrace{(T_3 - T_{3'})}_{5}$

$h_3' = 343.29 \text{ kJ/kg}.$

$Q_{loss} = Q_{gain}$

$h_3 - h_{3'} = h_{1'} - h_1$

$366.07 - 343.29 = h_1' - 1450.22$

$h_1' = 1473.$

$h_{1'} - h_1 = C_{pv}(T_{1'} - T_1)$

$C_{pv} = 2.492$, $T_1 = 263$

$T_{1'} = 272.14 K.$

$S_{1'} = S_1 + C_{pv} \ln \frac{T_1'}{T_1} = 5.755 + 2.492 \ln \frac{272.14}{263}$

$S_{1'} = 5.840 \text{ KJ/kgK}$

$S_1' = S_{2'} = S_a + C_{pv} \ln \frac{T_{2'}}{T_a}$

$5.2086 = 5.2086 + 2.903 \ln \frac{T_2'}{308}$

$T_2' = 382.84 \text{ K}$

$$h_{2'} - h_a = C_{p_v}(T_{2'} - T_a)$$

$$h_{2'} = 1488.57 + 2.903(382.84 - 308)$$

$$h_2' = 1705.86$$

$$COP = \frac{R.E.}{w/p} = \frac{h_1 - h_{4'}}{h_2' - h_1'}$$

$$COP = 4.75$$

$$COP = \frac{R_c}{W_{i/p}} = 4.75 = \frac{50}{W_{i/p}}$$

$$W_{i/p} = 10.51\ kW$$

$$\eta_v = \frac{(\dot{m} \times 60)\, v_1'}{\frac{\pi}{4} D^2 L \times N \times K} \qquad \eta_v = \underline{\underline{1}}\ (\underline{\underline{let}})$$

$$R.C. = \dot{m} \times R.E.$$

$$\dot{m} = \frac{50}{(h_1 - h_{4'})}$$

$$\dot{m} = 0.045\ kg/s.$$

$L = 1.2D$, $K = \underline{\underline{1}}$

$\underline{\underline{1 \to 1'}}$

$$\boxed{\frac{v_1}{T_1} = \frac{v_1'}{T_1'}}$$

$$\frac{0.41749}{263} = \frac{v_1'}{272.14}$$

$$v_1' = 0.4319$$

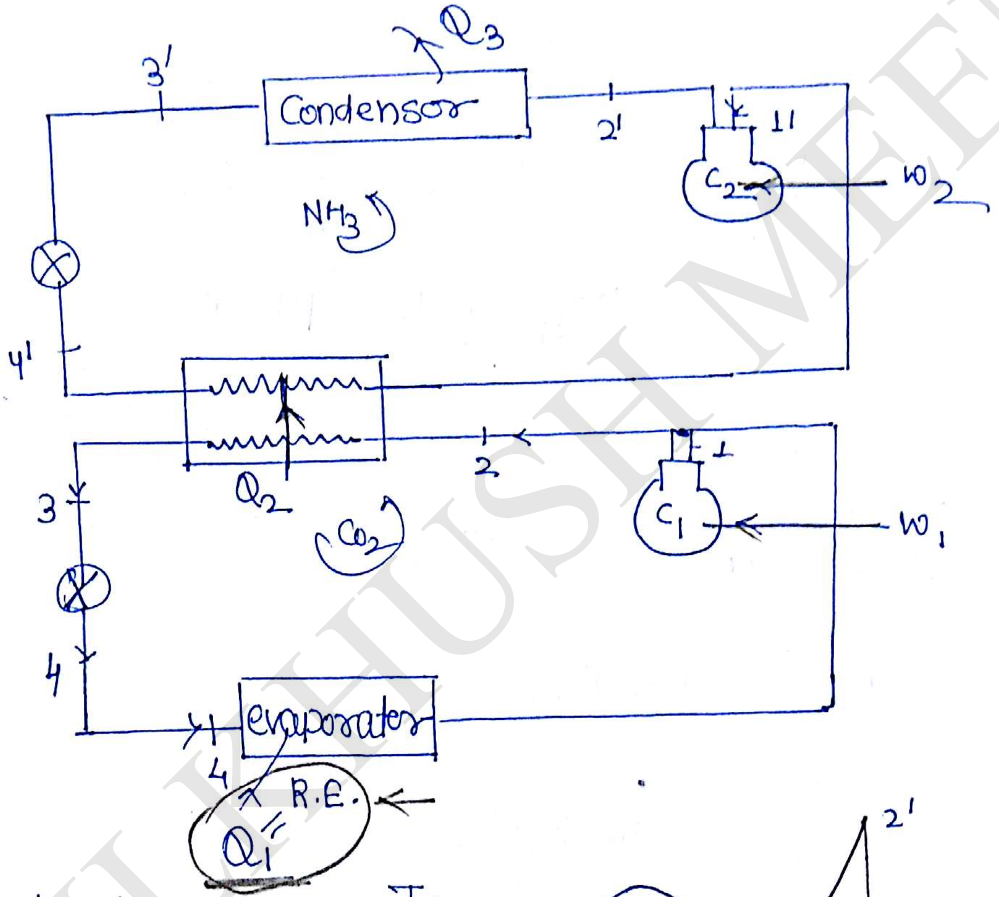
$$\frac{(0.045 \times 60) \times 0.4319}{\frac{\pi}{4} D^2 \, 1.20 \times 1000 \times 1} = 1$$

$$D = 107.49\ mm$$

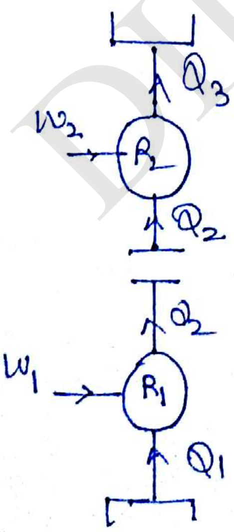
$$L = 128.9\ mm$$

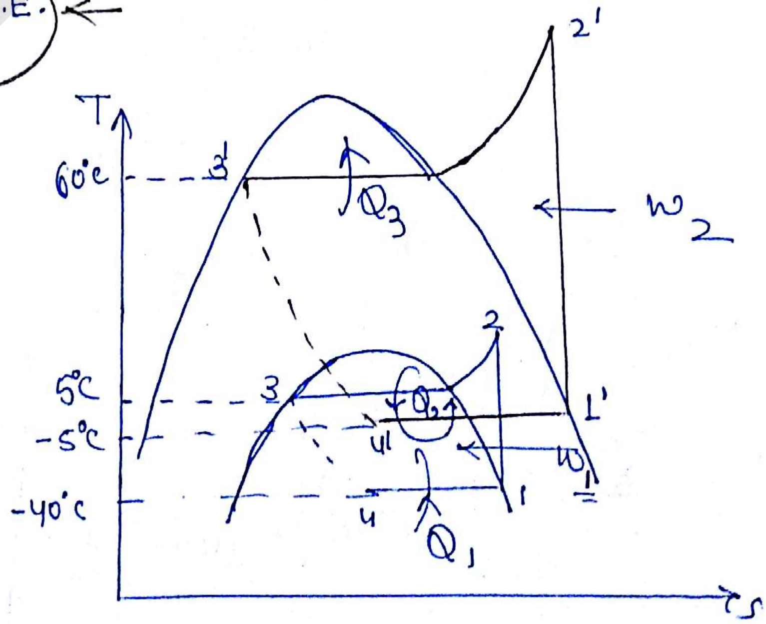
Cascade Refrigeration System:-

* For producing very low temp. the corresponding pressure ratio becomes very high hence the volumetric efficiency becomes very low therefore cascading of refrigeration system is done.
* It is ~~CI~~ used in medical industry.



eq





$$COP_1 = \frac{Q_1}{W_1}, \quad COP_2 = \frac{Q_2}{W_2}$$

$$\boxed{COP = \frac{Q_1}{W_1 + W_2}}$$

To prove $$COP = \frac{COP_1 . COP_2}{1 + COP_1 + COP_2}$$

$$COP = \frac{Q_1}{W_1 + W_2} = \frac{Q_1}{\frac{Q_1}{COP_1} + W_2} = \frac{COP_1 \times Q_1}{Q_1 + W_2 COP_1}$$

$$COP = \frac{COP_1}{1 + \frac{W_2}{Q_1} \times COP_1}$$

$$\boxed{Q_1 + W_1 = Q_2}$$

$$1 + \frac{W_1}{Q_1} = \frac{Q_2}{Q_1}$$

$$COP_2 = \frac{Q_2}{W_2}$$

$$1 + \frac{1}{COP_1} = \frac{Q_2}{Q_1}$$

$$COP = \frac{COP_1}{1 + \frac{COP_1}{Q_1} \times \frac{Q_2}{COP_2}} = \frac{COP_1}{1 + \frac{COP_1}{COP_2} . \frac{Q_2}{Q_1}}$$

$$\boxed{COP = \frac{COP_1 \cdot COP_2}{1 + COP_1 + COP_2}}$$

Q. A cascade refrigeration system of 100 TR capacity used NH_3 & CO_2 The evaporating & Condensing temp. of CO_2 are $-40°C$ and $5°C$ respectively. The evaporating temp. for NH_3 is $-7°C$ Power supplied to NH_3 compressor is 96.5 kW Both CO_2 and NH_3 cycles are simple VC cycles. Calculate

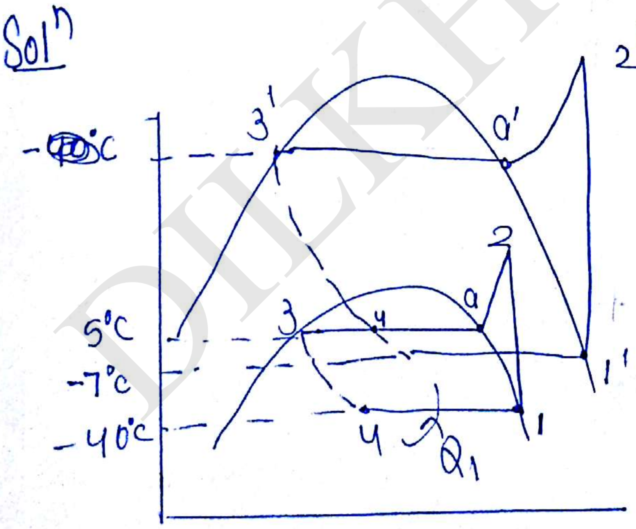
(i) Mass flow rate of refrigerant CO_2 (kg/s)

(ii) COP of the ref. system.

For CO_2 $C_{pv} = 0.85$ kJ/kgK

t_s (°C)	P (bar)	h_f	h_g	s_f	s_g
-40°C	10.05	332.7	652.8	3.8531	5.2262
5°C	39.7	431.0	649.8	4.2231	5.0037

Sol^n



Q_1 = R.E. = 100 TR

R.E = 351.67 kW

$h_1 = 652.8$ kJ/kg.

$h_3 = 431.$ kJ/kg $= h_4$

$RC = \dot{m}(h_1 - h_4)$

$351.67 = \dot{m}(652.8 - 431)$

$\dot{m} = 1.58$ kJ/s

$$(COP)_1 = \frac{h_1 - h_4}{h_2 - h_1}$$

$$h_2 = h_a + C_{pv}(T_2 - T_a)$$

$$s_2 = s_1$$

$$s_1 = s_a + C_{pv} \ln \frac{T_2}{T_a}$$

$$\cancel{5.0037} = 5.2262 = 5.0037 + 0.85 \ln \frac{T_2}{278}$$

$$T_2 = \cancel{374.17\,K}\ 361.18\ K$$

$$h_2 = 649.8 + 0.85(\cancel{374.17}\ 361.18 - 278)$$

$$\cancel{h_2 = 712\ kJ/kg} \quad h_2 = 720.503\ k$$

$$(COP)_1 = \frac{\cancel{625.}652.8 - 431}{\cancel{702.}\ 720.50 - 652.8} = \cancel{3.74}\ 3.27$$

$$\frac{Q_1}{W_1} = 3.27 \Rightarrow W_1 = \frac{1.58(652.8 - 431)}{\cancel{3.74}\ 3.27}$$

$$\cancel{W_1 = 93.70\ kW}.\ W_1 = 106.97$$

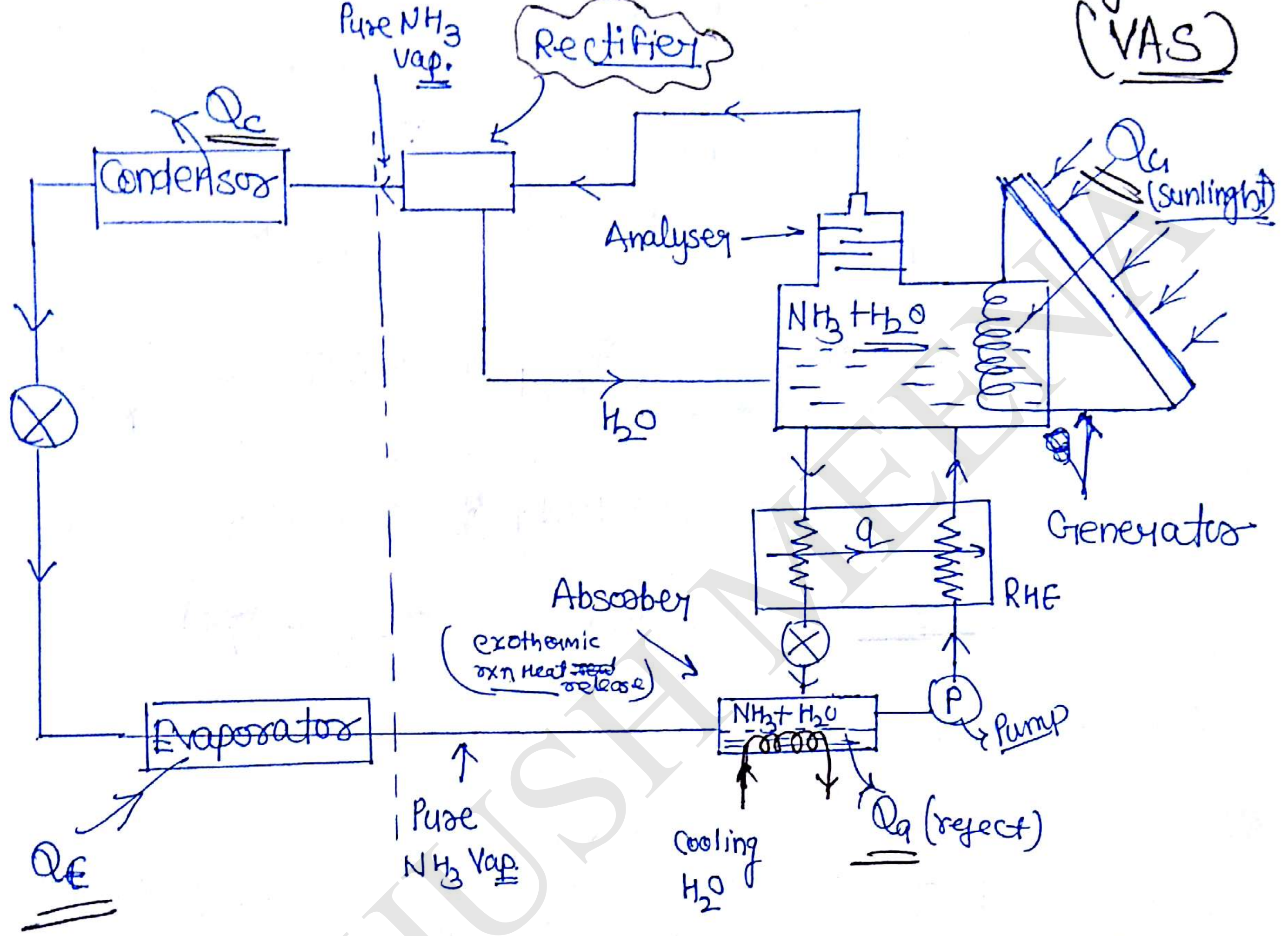
$$W_2 = 96.5\ kW$$

$$\boxed{COP = \frac{Q_1}{W_1 + W_2}} = \frac{1.58(652.8 - 431)}{203.47}$$

$$COP = 1.72\ \text{Ans}$$

Imp

* Vapour Absorption Refrigeration System (VAS)



→ Pure NH_3 vapour enters the absorber where it is absorbed in water (H_2O). The reaction is exothermic and tho solibility of NH_3 is inversaly perportional to temp. of solution. Cooling water is continuosly circulat~~ing~~ed to maintain a low temp of solution to facilitate absorption of NH_3. Solution rich in NH_3 is pumped to Generator via Regerative heat exchanger in Generator this solution absorbs heat and NH_3 separate forming high pressure of NH_3 vapour.

→ In RHE solution absorbs some heat from the water moving towards absorber. This reduceses the need for heat absorption in generator.

→ High pressure NH_3 vapour is passed through analyser where water vapour condenses. for complete removal of water vapour present with NH_3 vapour ractifier is installed.

* Water vapour ~~is~~ presence is undesirable because it may freeze at the exit of the throatling ~~va~~ valve because of low temp. thus chocking the system.

* Important Points.

① VAS works on low grade energy (Heat) whereas VCRS works on high grade energy (work). hence COP of VAS is very less (0.3 to 0.5).

② Most popular VAS is $NH_3 - H_2O$ system. In this H_2O water is absorbent and NH_3 is refrigerant. Other popular system are H_2O - LiCl & H_2O - LiBr. in these two water is ~~a~~ the refrigerant hence used for Air Conditioning purpose.

③ VAS are used where large waste heat is available or the cost of electricity is very high. Solar refrigeration system and Geothermal refrigeration system are based on VAS.

④ Heat is absorbed in generator and evaporator and heat is rejected in condensor & absorber.

⑤ Electrolux Refrigeration system is a VAS. It is three fluid system. ($NH_3 - H_2O - H_2$).

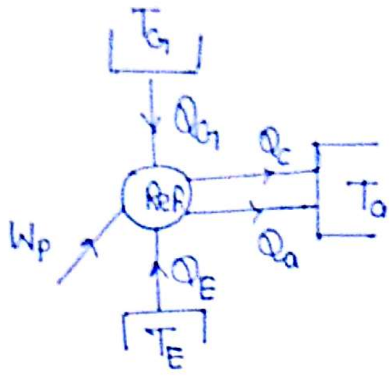
⑥ Here NH_3 is the refrigerant, H_2O is absorbent and H_2 is used to create low partial pressure of NH_3.

⑦ No pump is used in this system and the fluid flows under the action of gravity due to density differance.

$$COP = \frac{Q_{Evaporator}}{Q_G + W_p} \qquad Q_G >> W_p$$

$$\boxed{COP = \frac{Q_E}{Q_G}}$$

For $(COP)_{max}$ Refrigerator — Reversible.



energy consv.

$$Q_G + Q_E + W_p = Q_c + Q_a$$

neglecting W_p

$$\Rightarrow Q_G + Q_E = Q_c + Q_a \quad -(1)$$

2nd law $\Rightarrow \oint_{rev.} \frac{dQ}{T} = 0$

$$\Rightarrow \frac{Q_G}{T_G} + \frac{Q_E}{T_E} - \frac{Q_a + Q_c}{T_o} = 0 \quad -(2)$$

from eq^n (1) & (2)

$$\frac{Q_G}{T_G} + \frac{Q_E}{T_E} - \frac{Q_G + Q_E}{T_o} = 0$$

$$Q_E\left(\frac{1}{T_E} - \frac{1}{T_o}\right) = Q_G\left[\frac{1}{T_o} - \frac{1}{T_G}\right]$$

$$Q_E\left(\frac{T_o - T_E}{T_o T_E}\right) = Q_G\left[\frac{T_G - T_o}{T_o T_G}\right]$$

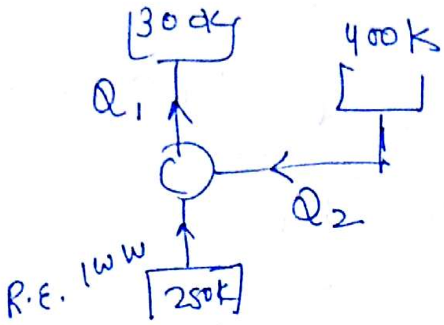
$$\frac{Q_E}{Q_G} = \frac{T_E(T_G - T_o)}{T_G(T_o - T_E)}$$

$$\boxed{(COP)_{max} = \frac{T_E(T_G - T_o)}{T_G(T_o - T_E)}}$$

P.9.49

Q.13

WB



$$\frac{Q_1}{300} = \frac{Q_2}{400} + \frac{\cancel{100}^{\,2}}{\cancel{250}_{\,5}}$$

$$Q_1 = 100 + Q_2$$

$$\frac{100+Q_2}{300} = \frac{Q_2}{400} + \frac{2}{5}$$

$$\frac{1}{3} + \frac{Q_2}{300} = \frac{Q_2}{400} + \frac{2}{5}$$

$$\frac{1}{3} - \frac{2}{5} = Q_2\left(\frac{400-300}{400\times 300}\right)$$

$$\frac{5-6}{15} = Q_2 \frac{\cancel{100}}{\cancel{120000}_{\,8}}$$

rej. $Q_2 = -\underline{80\,W}$

T1

$T_G = 360\,K$

$T_0 = 310\,K$

$T_E = 260 \rightarrow \underline{250K}$

$$COP = \frac{T_E(T_G - T_0)}{T_G(T_0 - T_E)}$$

$$COP = \frac{260(\cancel{50})}{360 \times \cancel{50}} = \frac{250(T_G - 310)}{T_G(310 - 250)}$$

$$\frac{13}{18} = \frac{250\,T_G - 250\times 310}{T_G \times 310 - T_G\, 250}$$

$$T_G = 374.9\,\underline{K}$$

(12) $COP = \frac{T_E(T_G - T_0)}{T_G(T_0 - T_E)} =$

$$COP = \frac{258(383-328)}{383(328-258)} = 0.529$$

(11) $$COP = \frac{270(360-300)}{360(300-270)} = \frac{270 \times \cancel{60}^{2}}{360 \times \cancel{30}}$$

$$COP = 1.5$$

Ques In $NH_3 - H_2O$ absorption system heat is supplied to generator by condensing steam at 0.2 MPa the initial state of steam is at a dryness fraction of 0.9 and the final state of the steam after condensing is saturated liquid. The temp. to be maintained in evaporator is $-10^\circ C$ and the surrounding temp is $30^\circ C$ (i) Find $(COP)_{max}$

(ii) if the actual COP is 40% of max COP and refrigeration load is 20 TR, what will be the required steam flow rate (kg/se)

at 0.2MPa $T_{sat.}$ $120.2^\circ C$ $h_{fg} = 2201.9$ kJ/kg.

Sol^n

$$(COP)_{max} = \frac{T_E(T_G - T_0)}{T_G(T_0 - T_E)}$$

$$= \frac{263(120.2 - 30)}{\cancel{120}\cdot 393.2(30+10)}$$

$$(COP)_{max} = 1.508$$

$$R.E. = RE \times \dot{m}$$

$$\cancel{20 \times 3.51 = (h_1 - h_4) \times \dot{m}}$$

$$(COP)_{act} = 0.4\,(COP)_{max}$$

$$\cancel{Q_1}\ \frac{RE}{W_{I/P}} = 0.4 \times 1.508 = 0.603$$

$$\cancel{RE = 42.34 = \dot{m}(h_1 - h_4)}$$

$$\cancel{42.34 = \dot{m}(h_f + x\,h_{fg} - h_f)}$$

$$\cancel{\dot{m} =}$$

$$\frac{RC}{\dot{Q}_G} = 0.603 = \frac{20 \times 3.5167}{\dot{m} \times x \times h_{fg}}$$

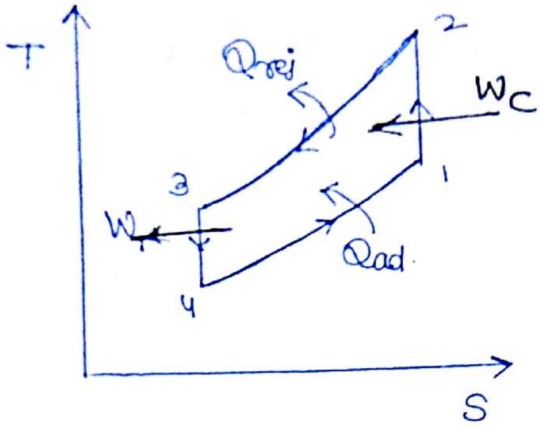
$$\dot{m} = 0.058\ kg/s$$

29/11/2016

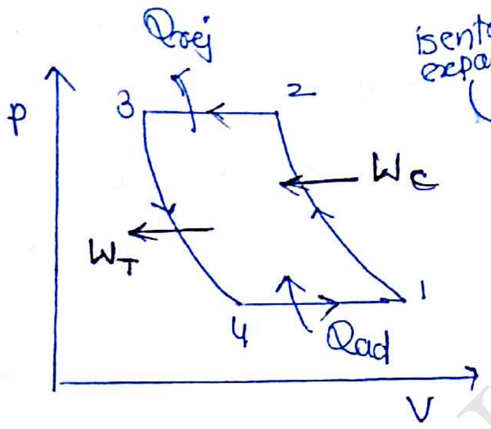
* Gas Refrigeration Cycle (Reversed brayton)

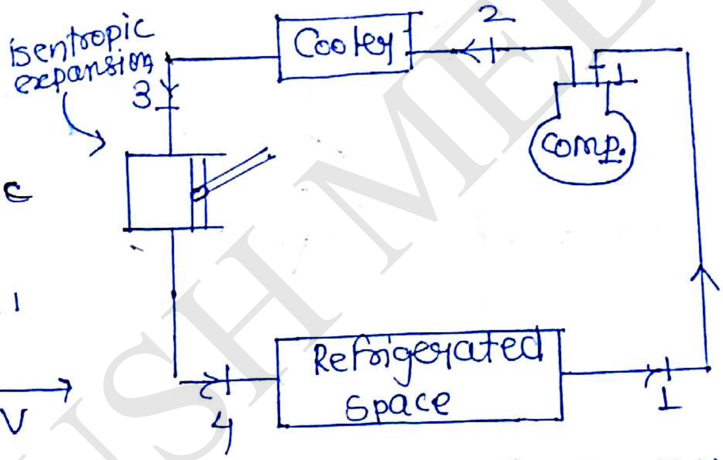
→ (Air craft - air Conditioning cycle)

- Gas l'quification cycle
- Bell Colemann cycle.



1 → 2 isentropic comp.
2 → 3 isobaric heat rej
3 → 4 isentropic exp.
4 − 1 isobaric heat addition





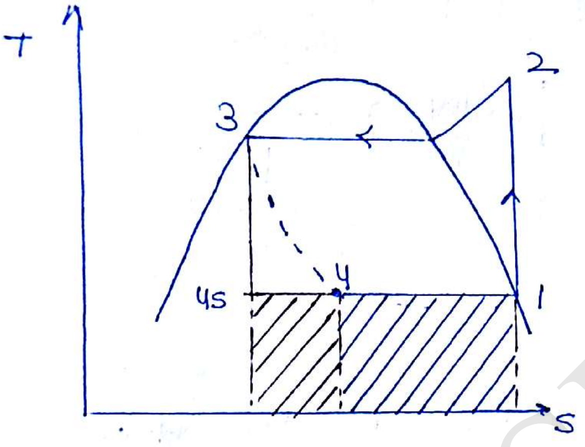
→ This cycle is used for air craft air conditioning because of it's low weight per ton of refrigeration.

→ Air conditioning is done for the cooling of the air-craft because since the air craft moves at high velocity due to skin friction a lot of heat is generated.

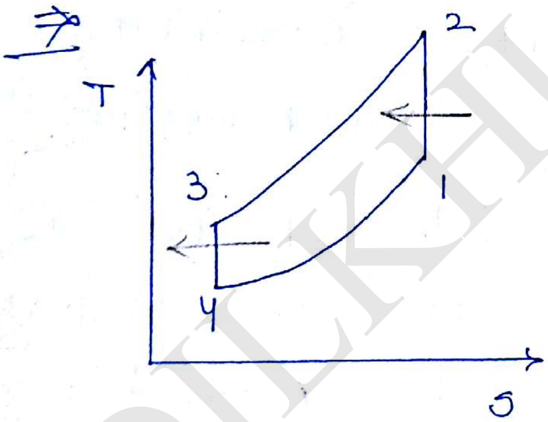
→ Isentropic expander v/s throttling :-

→ In gas refrigeration cycle since air is used as refrigerent which behaves as ideal gas hence throttling doesnot result in any temp. drop. More over use of isentropic expander gives some work output which reduces the work input from outside.

→ In VCRS we don't use isentropic expander because the refrigerent remain liquid during most of it's expansion hence the work obtain is very less this does not justify the cost of the isentropic expander. Hence throttling is used since it is very cheap device.



(Area) $_{4s-4}$ → extra R.E. due to isentropic expande



expression for COP = ?

$$COP = \frac{R.E.}{W_c - W_T}$$

$$R.E. = h_1 - h_4$$

$$= C_p(T_1 - T_4)$$

$$W_c = h_2 - h_1 = C_p(T_2 - T_1)$$

$$W_T = h_3 - h_4 = C_p(T_3 - T_4)$$

$$COP = \frac{(T_1 - T_4)}{(T_2 - T_1) - (T_3 - T_4)}$$

$$COP = \frac{T_1 - T_4}{(T_2 - T_3) - (T_1 - T_4)}$$

$$COP = \frac{1}{\frac{T_2 - T_3}{T_1 - T_4} - 1} = \frac{1}{\frac{T_2\left(1 - \frac{T_3}{T_2}\right)}{T_1\left(1 - \frac{T_4}{T_1}\right)} - 1} \quad (1)$$

$\because$ comp & exp. are isentropic

$$\therefore \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma - 1}{\gamma}} = \gamma_p^{x} \qquad \text{let } \frac{\gamma - 1}{\gamma} = x$$

$$\rightarrow \quad \frac{T_3}{T_4} = \gamma_p^{x}$$

Since $T_2/T_1 = T_3/T_4 \Rightarrow \frac{T_4}{T_1} = \frac{T_3}{T_2}$

$$1 - \frac{T_4}{T_2} = 1 - \frac{T_3}{T_2}$$

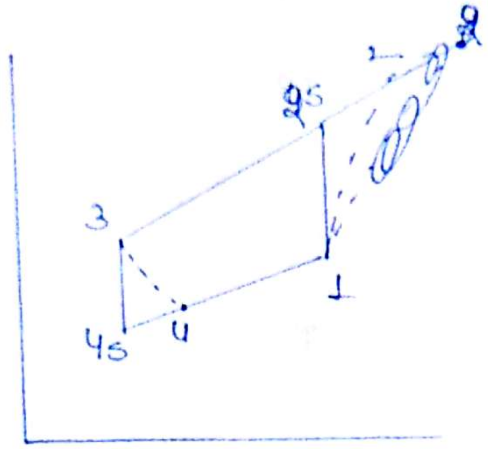
from (1)

$$COP = \frac{1}{T_2/T_1 - 1}$$

$$COP = \frac{1}{\cancel{10}\ \gamma_p^{x} - 1}$$

$$COP = \frac{1}{\gamma_p^{x} - 1}$$

$$\boxed{COP = \frac{1}{(\gamma_p)^{\frac{\gamma - 1}{\gamma}} - 1}}$$



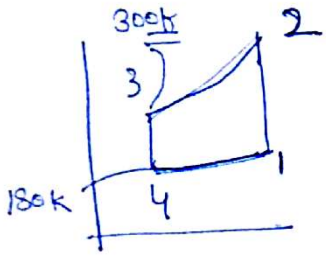
$$\eta_{isc,C} = \frac{T_{2s} - T_1}{T_2 - T_1}$$

$$\eta_{isc,T} = \frac{T_3 - T_4}{T_3 - T_{4s}}.$$

Q.3

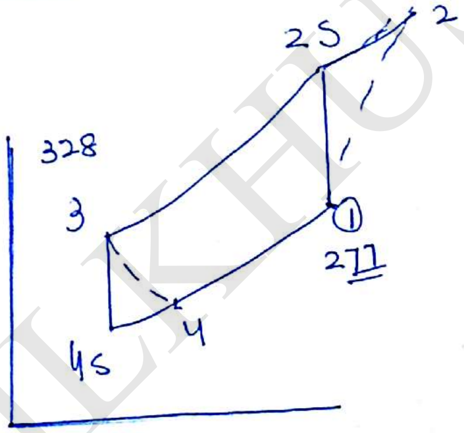
$$COP = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1} = \frac{1}{\frac{T_2}{T_1} - 1}$$

$$COP = \frac{1}{\frac{300}{180} - 1} = 1.5$$



$$\left(\frac{P_3}{P_4}\right)^x = \frac{T_3}{T_4} = \left(\frac{P_2}{P_1}\right)^x = \frac{T_2}{T_1} = \frac{300}{180}$$

Q.20



$P_1 = 0.1$ MPa

$P_2 = 0.3$ MPa.

$W_{ise,c} = 72\%$, $W_{ise,T} = 78\%$

$T_1 = 277$ K

$T_3 = 328$

$$\frac{T_3}{T_{4s}} = \frac{T_{2s}}{T_1}$$

$T_{2s} = 379.14$

$$0.72 = \frac{T_{2s} - T_1}{T_2 - T_1}$$

$$0.72 = \frac{379.14 - 277}{T_2 - 277} \Rightarrow T_2 = 418.86 \text{ K}$$

$$W_{isc,T} = 0.78 = \frac{T_3 - T_4}{T_3 - T_{4s}} \qquad \frac{T_3}{T_{4s}} = (3)^{2/7}$$

$$T_{4s} = 239.63$$

$$0.78 = \frac{328 - T_4}{328 - 239.63}$$

$$\underline{T_4 = \cancel{141.08}\ 259.07\ K}$$

$$COP = \frac{T_1 - T_4}{(T_2 - T_1) - (T_3 - T_4)}$$

$$= \frac{277 - 259.07}{(418.86 - 277) - (328 - 259.07)}$$

$$COP = \underline{0.245}$$

$$RC = 3\ TR = \dot{m} \times R.E.$$

$$3 \times 3.51 = \dot{m} \times (1.005\,(T_1 - T_4))$$

$$3 \times 3.51 = \dot{m}\,(1.005\,(277 - 259.071))$$

$$\dot{m} = 0.584\ kg/s.$$

$$COP = \frac{RC}{W_{input}}$$

$$W_{i/p} = \frac{3 \times 3.51}{0.245} = \underline{\underline{42.97\ kW}}$$

Refrigerants :-

Naming of Refrigerants :-

① saturated hydrocarbon :- (single bond)

$$C_m H_n F_p Cl_q$$

$$2m+2 = n+p+q \quad \text{(saturated)}$$

$$\boxed{R\,(m-1)(n+1)\,p}$$

eg (i) CCl_2F_2

$m=1,\ m-1=0$

$n=0,\ n+1=1$

$p=2$

R012 or R12

(ii) R11

R011 → $(m-1)$ $(n+1)$ p

$CH_0F_1Cl_3$

$CFCl_3$

(iii) R22

R022 → $(m-1)$ $(n+1)$ p

CHF_2Cl

(iv) C_2F_3Cl

$m=2$

$n=0$

$p=3$

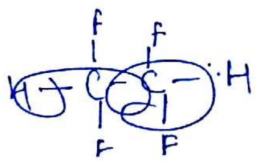
~~R2~~ R113

(v) R134

$m-1=1,\ m=2$

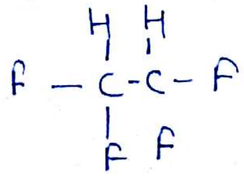
$n+1=3\ \ n=2$

$p=4$



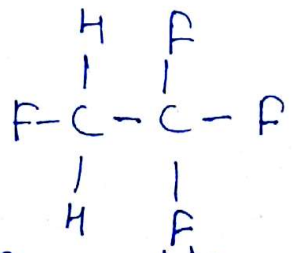
$C_2H_2F_4Cl_0$

↙ $C_2H_2F_4$



Symmetric

or



asymmetric R134a

② Unsaturated hydrocarbon (double bond)

$C_m H_n F_p Cl_q$

$2m = n + p + q$

$\rightarrow \boxed{R1(m-1)(n+1)P}$

eg C_2H_4

$R1(2-1)(4+1)(0)$

$R1150$

③ Inorganic

$\boxed{R(700 + \text{mol. mass})}$

$NH_3 \rightarrow R717$

$H_2O \rightarrow R718$

Air $\rightarrow R729$

$SO_2 \rightarrow R764$

$CO_2 \rightarrow R744$.

④ Azetrope:-

(as a pure substance)

$\boxed{R - (500 + \text{randon No.})}$

R 502

↳ ingredient (Sec bw ts)

* The mixture of refrigerent behaving as pure substance is called azetrope.

Properties of the Refrigerent

Properties of the Refrigerent.

1) Normal Boiling Point (NBP):-

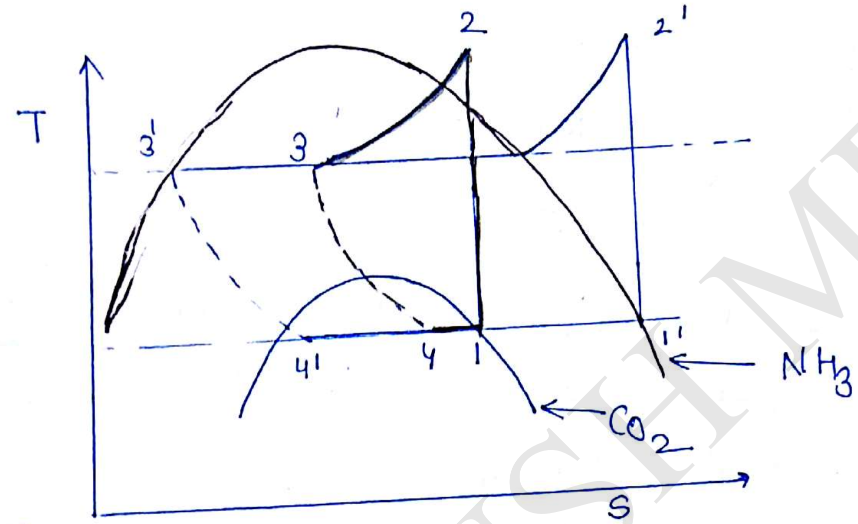
→ The minimum pressure in the cycle is desired to be above atmospheric pressure. This is because if the leakage occurs, we dont want air to leak inside the system because it will bring water vapour with it self which may freeze at low temp. hence chocking the system.

→ If the evaporator pressures are close to atmospheric pressure then for the refrigerent to boil at very low temp. the normal boiling point should be lower than the desired temp. Hence low NBP refrigerent are desirable.

→ low NBP refrigerent are high pressure refrigerents & high NBP refrigerents are low pressure refrigerents.

<u>Note:</u> The air if enters in the system get trapped in the condensor. It increase condensor pressure, compressor power and cooling water temp. ~~The~~ The removal of trapped air in the condensor is called '<u>purging</u>.'

(2) <u>Critical Point temprature</u>:-



$R.C. = \dot{m}\uparrow \times R.E\downarrow$

$T_{cr}\downarrow$, $\dot{m}\uparrow$, $R.E.\downarrow$, $\dot{W}\uparrow$, $COP\downarrow$, $Vol\uparrow$

The critical temp. of the refrigerent should be sufficient-ly more than the condensor temp., to facilitate heat transfer during phase change. CO_2 and ethylen have very low critical temp hence they are unidesirable.

→ Water has one of the highest critical temp. among the commonly used refrigerent.

Note :- Since heat transfer in Bell Colemann Cycle is sensible hence the COP of this cycle is less than VCRS.

③ Latent heat and Specific heat :-

latent heat of the refrigerant should be high as it result in lower mass flow rate
specific heat should be low in liquid phase and high vapour phase.

$$R.C. = \dot{m}\downarrow(\underbrace{R.E\uparrow}_{\uparrow LHT})$$

④ Freezing point :- Freezing point should be lower than the required temp. to avoid freezing of refrigerent.

⇒ water has good thermodynamic property but because of it's high freezing point it is not used for refrigeration.

⑤ Viscosity: The viscosity of refrigerent should be low to eliminate viscous loss.

⑥ Pressure Ratio :- we should select a refrigerent which gives low pressure ratio corrospounding to the required evaporator and condenser temp. $\eta_v \downarrow$ $\eta_v = 1 + C - C\left(\frac{P_2}{P_1}\right)^{1/n}$

(7) Specific Volume at the inlet to the Compressor:-

The specific Volume at the Compressor inlet ~~Volume result~~ should be less because high specific ~~to larger size comp~~ Volume result in large size Compressor. ~~R~~

→ R11 & R113 have high specific Volume hence they are used with centrifugal Compressor.

(8) Compressor discharge temprature:-

Compressor discharge temp. should be low. high compressor discharge temp. increase Compressor damage.

→ Since NH_3 has high Compressor discharge temp. hence NH_3 Compressor are water Cooled..

Note :- NH_3 has a high latent heat of Vapourisatio

(9) Toxicity and Flammability :- The refrigerent should be non toxicity and non Flammable.

→ NH_3 has very good thermodynamic properties but is not used in domestic application because of it's toxic and Flammable nature.

(10) Action with the lubricating oil :-

(i) Complately immiscible :- refrigerents like NH_3 and CO_2 which are complately immissible with the lubricating oil are seprated with the help of an oil seprature installed b/w compressor and condensor. The seprated oil brough back to the compressor.

(ii) Complately miscible: Refrigerent like R11 & R22 which are complately missible with the lubricating oil do not present much problem because the ~~seprated oil is brough~~ the oil which is washed away by the refrigerent is brought back in the compressor.

(iii) partialy miscible :- The refrigerent like R22 present problem because the lubricating oil is washed away by the refrigerent Gets deposite it in the evaporator this leads to reduction in lubricating oil in the compresser hence wear & tear of compressor.

→ In such cases we use synthetic oil in place of lubricating oil.

(11) Action with material of Construction:-

→ NH_3 reacts with copper hence whenever NH_3 is used as refrigerent copper is not used as material of construction instead wrought iron or steel is used.

→ Freon's react with Al hence whenever Freon's are used as refrigerent Al is not used instead Cu is used as material of Construction

leak detection test:-

(1) Halide torch test: it is used to detect the leakage of Freon's. In presence of Freon' the blue Flame of hydrocarbon changes to bluish green.

(2) Sulphur Stick or Sulphur ribbon method:- it is used to detect the leakage of NH_3. White flumes of $(NH_4)_2S$ Amonium sulphide are formed when sulphure stick brought close to leaking NH_3.

(3) Ammonia swab test:- A cloth dibbed in NH_3 is passed over leaking sulphur dia oxide (SO_2) white flumes of $(NH_4)_2S$ are formed.

(4) Soap bubble test:- Soap water is used to identify the leakage of hydrocarbon.

Recent trend in Refrigeration:–

Cl element present in the refrigrent dissociates in presence of sunlight and reacts with O_3 which is situated in stratosphere.

→ ozone layer filters the harmful ultraviolet ray from the sun. hence it's depletion is undesirable.

→ There for the use of refrigrent containing clorine (cl) has need discourage and we have replaced R12 in domestic refrigerator with R134a.

→ The substitute for cloroflorocarbon (CFC) is

a) hydro carbon

b) Florocarbon

c) hydro floro carbon

d)

	Name of Ref.	use
1)	R-12 →	Domestic Ref. (Earlier)
2)	R134a →	Domestic ref. (Now) & car A/c's
3)	R-22 →	window A/c
4)	R-11 →	Central A/c
5)	NH_3 →	Industrial Application (ice making)
6)	Air →	Air craft + A/c
7)	CO_2 →	transport refrigeration and direct Contact food refrigeration

* Air Conditioning *

Air conditioning :- it is the process of simuteneous contool 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
Moist air — water vapour

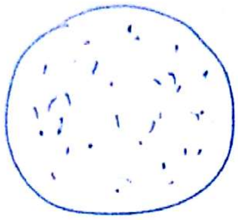
* $P + F = C + 2$

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

$P_t = P_{vap} + P_{air}$

$P_{total} = 1$ 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 (ω)

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

~~mass of water vapour in moist air~~

from eqn (1) & (2)

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

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

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

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

* $$\boxed{\omega = 0.622 \frac{P_v}{P_t - P_v}} \qquad \frac{kg\ v}{kg\ dry\ air}$$

$m_t = HW$

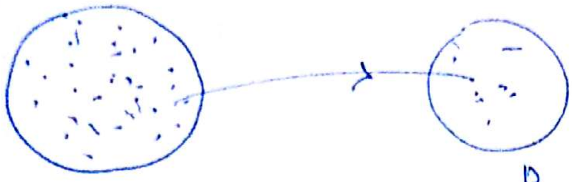
$$m_t = m_v + m_a$$

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

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

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

(2) Relative humidity :- (ϕ)



P_v, m_v, P_t

T, V

P_t, m_{vs}, P_{vs}

T, V

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

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

(1)/(2)

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

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

* 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 coolar.

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

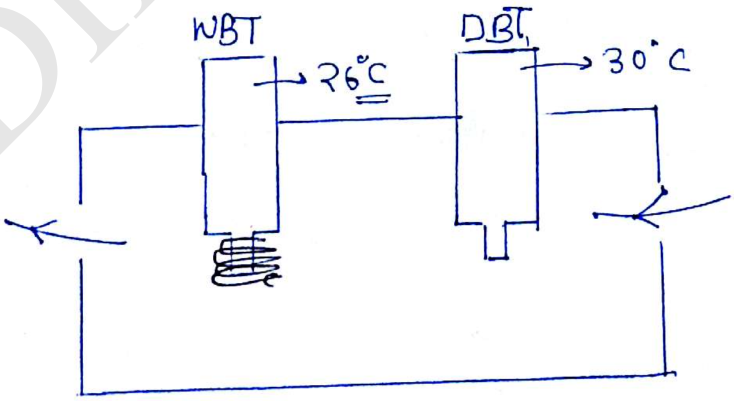
→ It is the minimum temp upto which water can be cooled earth & pot.

→ Wet bulb depression (WBD) = DBT − WBT

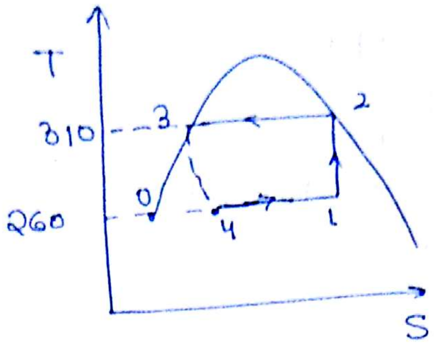
$$\boxed{WBD = DBT - WBT}$$

→ Use of desert coolar is benifecial if the WBD is high.

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



Q 1.17 Gate book
P- 411



@ 310 LH = 1054

$C_{liq} = 4.8$

$h_1 - h_0 = ?$

$$\frac{h_1 - h_0}{260} = S_1 - S_0$$

$$S_2 - S_3 = \frac{h_2 - h_3}{310} = \frac{1054}{310} \quad -(1)$$

$$S_3 - S_0 = C_{P_\ell} \log \frac{T_f}{T_i} = 4.8 \ln \frac{310}{260}$$

$$S_3 - S_0 = 4.8 \ln \frac{310}{260} \quad -(2)$$

(1) + (2)

$$S_2 - S_0 = 4.8 \ln \frac{310}{260} + \frac{1054}{310}$$

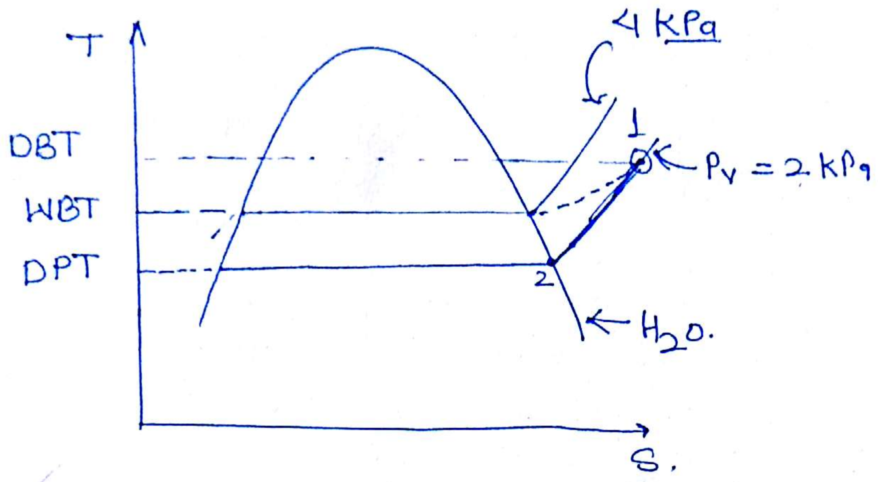
$$S_1 = S_2$$

$$S_1 - S_0 = 4.8 \ln \frac{310}{260} + \frac{1054}{310} = \frac{h_1 - h_0}{260}$$

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

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

(5) Dew point temprature :-



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

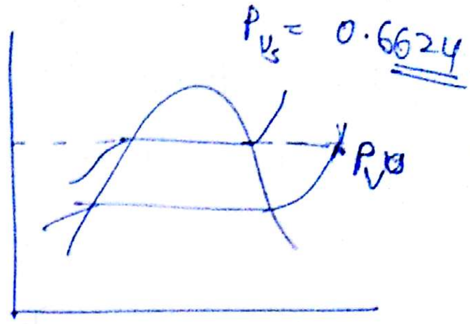
- Dew point temp. is the temp. of air at which water vapour present in the air starts condensing when cooled at constant pressure

→ 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



$P_s = 0.6624$ bar

$P_{atm} = 1$ bar.

$\omega = ?$

$\phi = 72\%$

$\overset{0.72}{\phi} = \frac{m_v}{m_t} = \frac{P_v}{P_{vs}} \leftarrow 0.6624$ $\qquad P_v = 0.47692$

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

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

$\omega = 0.56712$ kg/kgda $= 567.12$ g/kgde

Q.24

$\omega = 0.01$

$m_i = 10.1$ kg/s. $\qquad m_2 = 0.1$ kg/s.

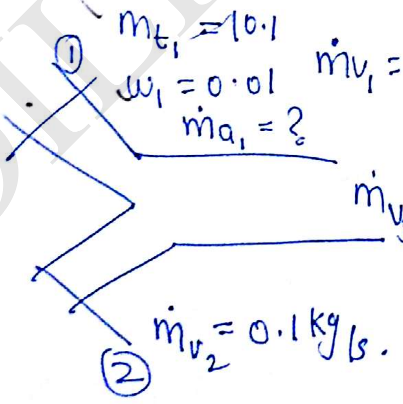
$\cancel{\omega = \frac{\dot m_1 \omega_1 + \dot m_2 \omega_2}{\dot m_1 + \dot m_2}}$

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

$\cancel{0.0160 (P_t - P_v) = P_v}$

$\cancel{0.0160 = (1 + 0.016) P_v}$

$\cancel{P_v = 0.01582}$



$\frac{\dot m_t}{1 + \omega} = \dot m_{a_1}$

$\dot m_{a_1} = \frac{10.1}{1.01} = 10$ kg d.a/se.

$\dot m_{v_1} = 0.1$

$\dot m_{v_3} = 0.1 + 0.1$

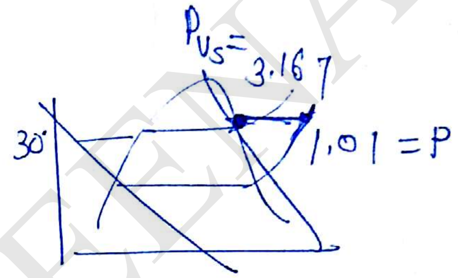
$\dot m_{a_3} = 10 = \dot m_{a_1}$

$\omega_3 = \frac{\dot m_{v_3}}{\dot m_{v_1}} = \frac{0.2}{10} = 0.02$

Ques Moist air at 1.013 bar & 30°c Contains 10 g of water vapour per kg of dry air. saturation pressure of water vapour at 30° is 3.167 KPa find relative humidity of moist air

$\Rightarrow$ $\omega = ?$

$\omega = 0.1$ $\qquad \dot{m}_v = 10\,g\,v/kg\,dr.$



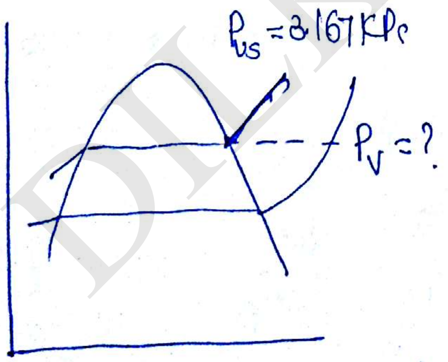
$P_{st} = 3.16$

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

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

$$0.622 \times \frac{\cancel{3.167}P_v}{1.013 - P_v} = 0.01 \Rightarrow P_v = 1.6028$$

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



$P_t = \underline{1.013}$

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

$P_v = \underline{1.6028}$

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

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

$\underline{S/n}$

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

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

$$P_t = P_v + P_a$$

$$P_a = 100 - 2.975$$

$$= 97.025$$

Enthalpy of Moist Air :—

Moist air

$$H = H_a + H_v$$

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

dry air

$$dh_a = C_{pa}\, dt$$

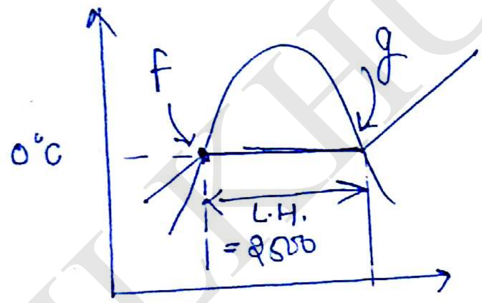
at $t = 0^\circ C$ let $h_a = 0$

$t = t^\circ C$ let $h_a = h_a$

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

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

water vapour



at $0^\circ C$, $h_f = 0$

$$h_v = 2500 + C_{pv}(t - 0)$$

$$h_v = 2500 + 1.88t$$

from (A)

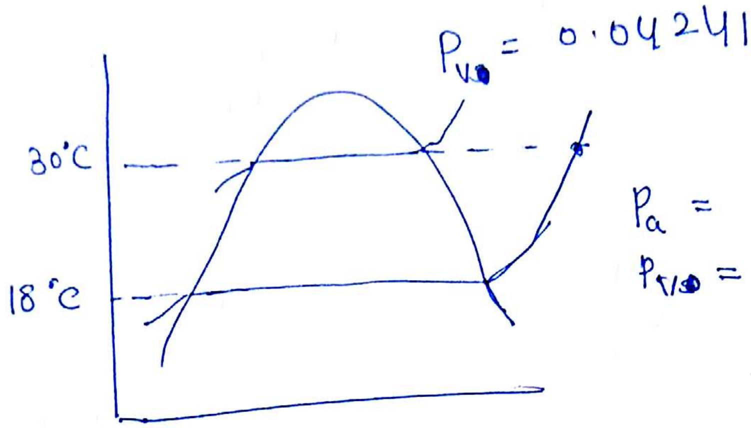
$$H = m_a \times C_{pa} t + m_v (2500 + 1.88t)$$

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

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

$m_a = 1$
$m_v = \omega$

Q.2



$P_a = 1.013$ bar.
$P_v = 0.02062$

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

$$\omega = 0.01291$$

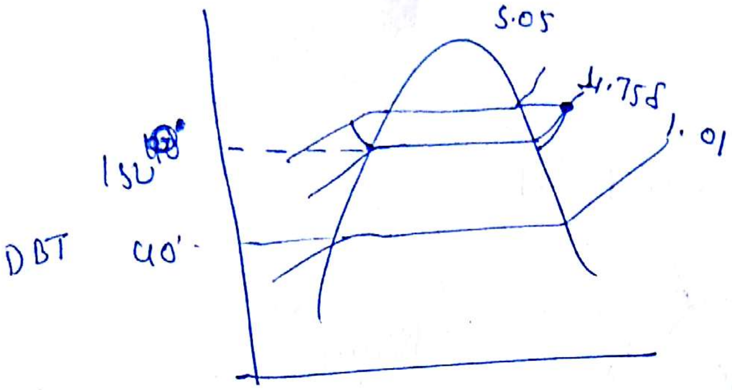
$$h = 1.005t + 0.0129(2500 + 1.88t)$$

$$= 1.005 \times \cancel{18}\ 30 + 0.0129(2500 + 1.88 \times \cancel{18}\ 30)$$

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

Q.20

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



$P_{sat}|_{150} = 7.38$ KPa

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

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

$P_v = 0.50 \times \cancel{4.758}\ 7.38$

$P_v = \cancel{2.379}\ 3.69$ kPa

$$\omega = 0.622 \frac{\cancel{2.379}}{}$$

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

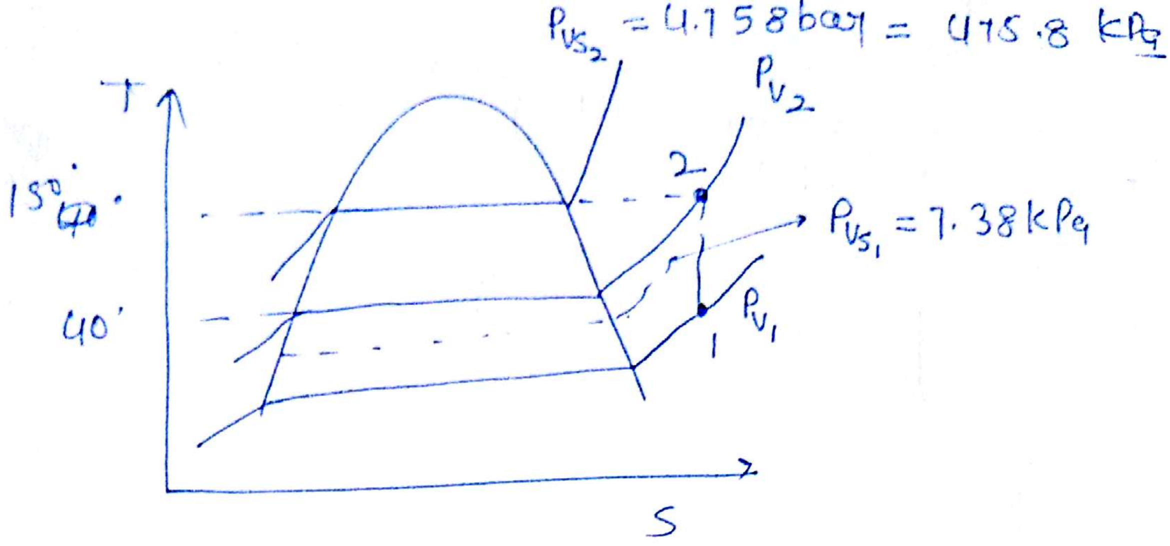
$$\omega = \underline{23.58 \text{ g/kg da}}$$

$\cancel{\omega = 0.622 \frac{P_v}{5.05 - P_v} = 0.236}$

$\cancel{P_v = 0.316}$

$P_{vs} = 4.758$ bar.

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



$$0.5 = \phi_1 = \frac{P_{v_1}}{P_{vs_1}} = \frac{P_v}{7.38}$$

$$P_v = 3.69\ kPa$$

$$\omega_1 = 0.622\ \frac{P_{v_1}}{P_{t_1} - P_{v_1}} = 0.622\ \frac{\times 3.69}{101 - 3.69}$$

$$\omega_1 = 23.6 \times 10^{-3}\ kgv/kg\,da$$

$$\frac{P_{t_2}}{P_{t_1}} = \frac{P_{v_2}}{P_{v_1}} \Rightarrow \frac{505}{101} = \frac{P_{v_2}}{3.69}$$

$$P_{v_2} = 18.48\ kPa.$$

$$\phi_2 = \frac{P_{v_2}}{P_{vs_2}} = \frac{18.48}{475.8} = 0.0389$$

$$\phi_2 = 0.0388$$

$$\phi_2 = 3.9\%$$

Degree of saturation :- (μ)
Percent humidity

$$\boxed{\mu = \frac{\omega}{\omega_s}} = \frac{0.622 \dfrac{P_v}{P_t - P_v}}{0.622 \dfrac{P_{vs}}{P_t - P_{vs}}}$$

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

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

* Ap John Formula :-

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

- 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

DBT = 26°C

ϕ = 50%

CP. 6 WB

Q.1 Pg. 57

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

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

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

$$P_v = 0.990 \qquad \cancel{\frac{120}{97.2} = P_v = 1.230\ kPa}$$

$$\phi = \frac{P_v}{P_{vs}} = \frac{0.99009}{4} \times 100$$

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

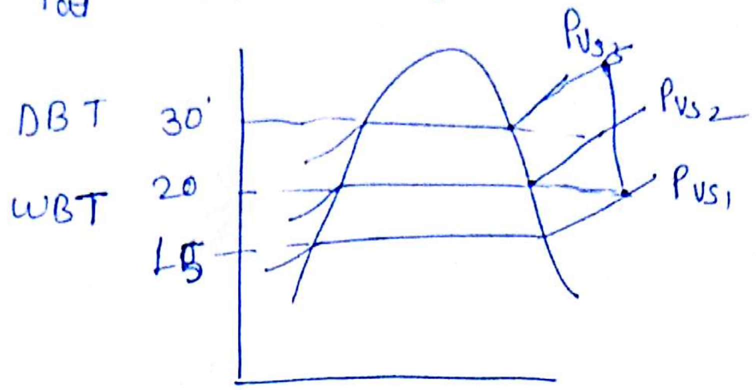
$$\omega = 0.622\,\frac{P_v}{P_t - P_v}$$

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

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

Q 26

$P_{at} = 740 \text{ mm Hg.}$



$P_{vs_3} = 0.04242$

$P_{vsg} = 0.02337$

$P_{vs_1} = 0.01679$

$P = 740 \text{ mmofHg}$

$760 \rightarrow 1.013$

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

$P = 0.9869$ bc

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

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

$P_v = 0.01679$ DPT = 15 °C

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

$\omega = 0.01077$

(iii) $RH = \phi = \frac{P_v}{P_{vs}|_{at\ DBT}} = \frac{0.01679}{0.04242} = 39.5\%$

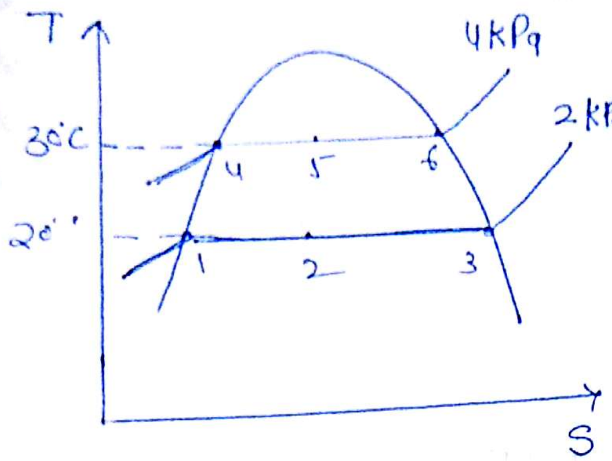
(iv) $P_v V = m_v R T$

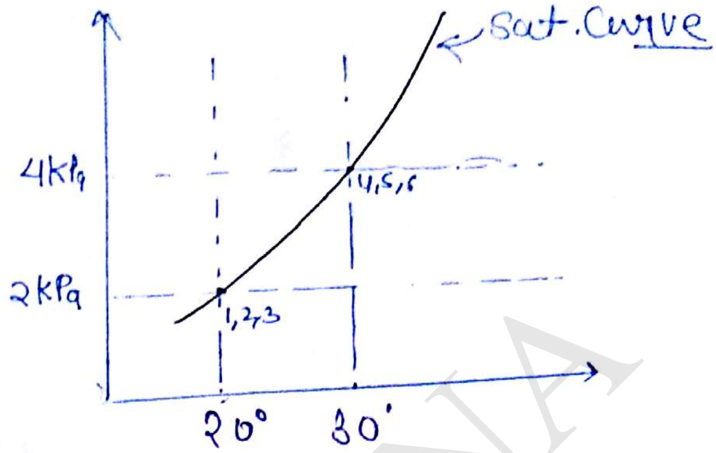
$P_v = \rho R T$

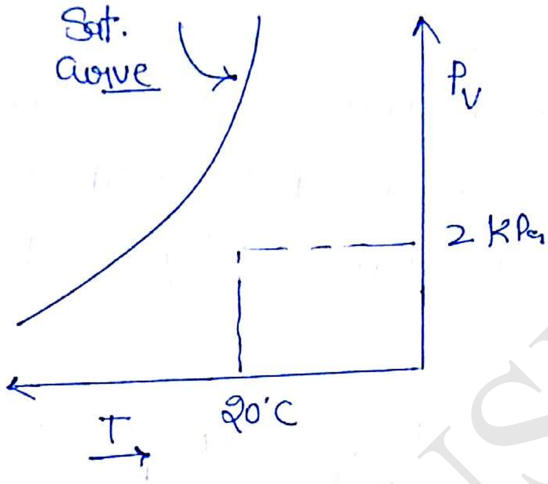
$\rho = \frac{P_v}{RT} = \frac{0.01679 \times 100 \text{ kPa}}{\frac{8.314}{18} \times 303}$

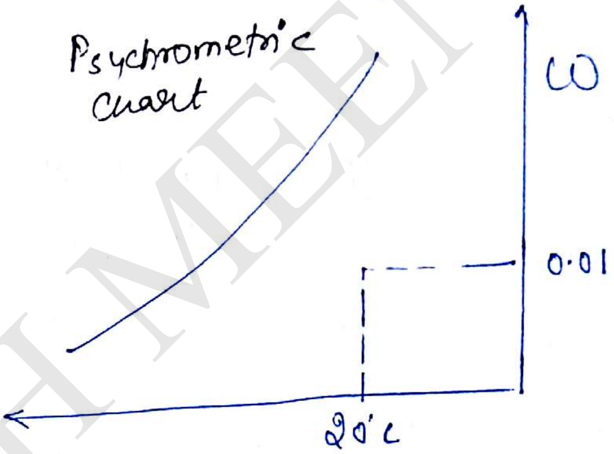
$\rho = 0.0119 \text{ kg/m}^3$

Development of Psychrometric chart :-









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

let 1 atm

ω @ $P_v = 2$ kPa let $\underline{\underline{0.01}}$

* humidity Ratio is the function of $\underline{\underline{P_v}}$

~~29~~ 30|11|

25

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

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

$P_v = 0.60 \times 5.63$

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

$\omega = 21.24\ gram/kg\ dry\ A$

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

Sol^n

$\phi = 0.50 = \frac{P_{v_1}}{P_{vs}}$

$P_{v_1} V_1 = m R_{v_1} T$

$P_{v_1} = \frac{m R_{v_1} T}{V_1}$

$P_{vs} = \frac{P_{v_1}}{0.5}$

$V_2 = V_1/2$

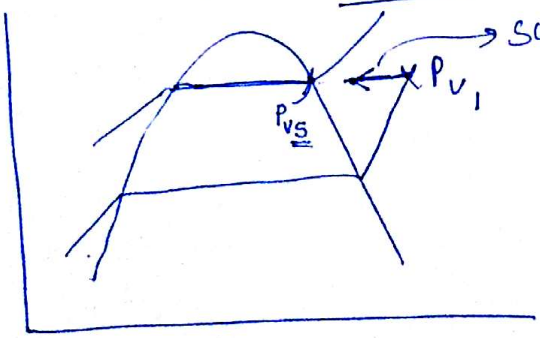
Now

$P_{v_2} = 2\left(\frac{m R_v T}{V_1}\right)$

$\phi = \frac{2 P_{v_1}}{P_{v_1}/0.5}$

$P_{v_2} = 2 P_{v_1}$

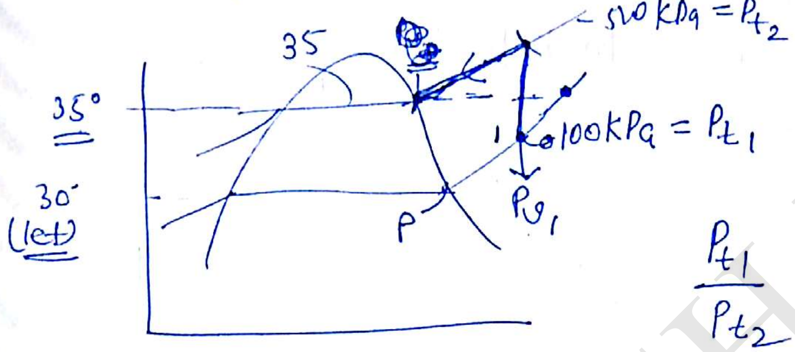
$\phi = 100\%$



same temp

P_{vs} cost. (isothermaly)

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 saturate 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

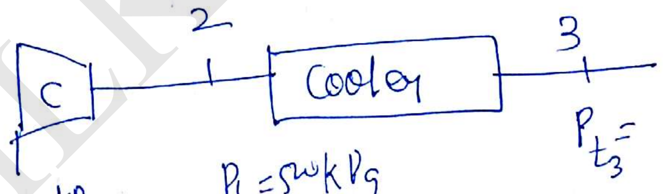


$P_{vs})_{35} = 5.628$

$$\frac{P_{t1}}{P_{t2}} = \frac{P_{v_1}}{P_{v_2}}$$

$$\frac{100}{500} = \frac{P_{v_1}}{5.625}$$

$$P_{v_1} = 1.1256 \text{ KPa}$$



$P_{t_1} = 100$ KPa

$P_{v_1} = ?$

$P_{t_2} = 500$ KPa

$P_{v_2} = 5.625$

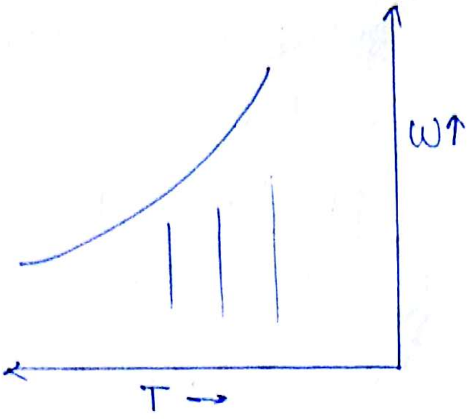
$P_{t_3} = 500$ KPa ; 35°C

$\phi_3 = 1$

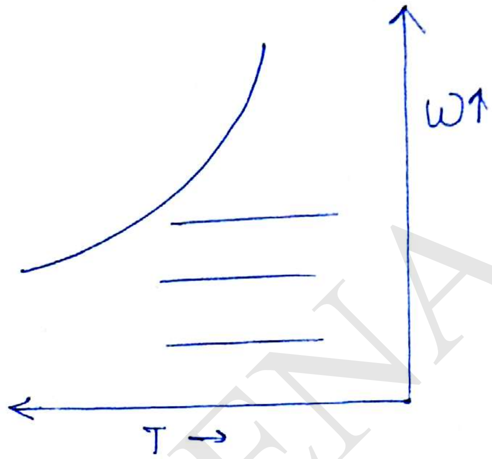
$P_{v_3} = P_{vs_3} = 5.628$ KPa

Various lines on Psychrometric chart:-

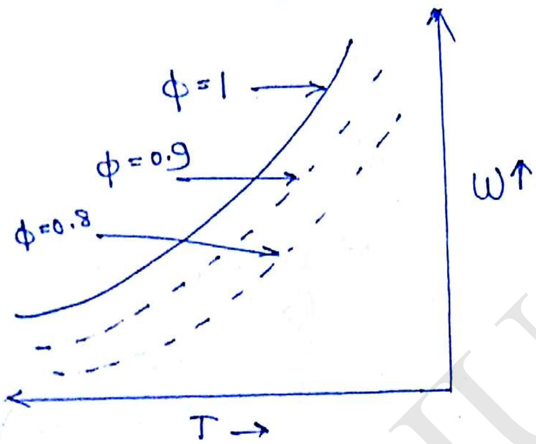
① Constant DBT lines



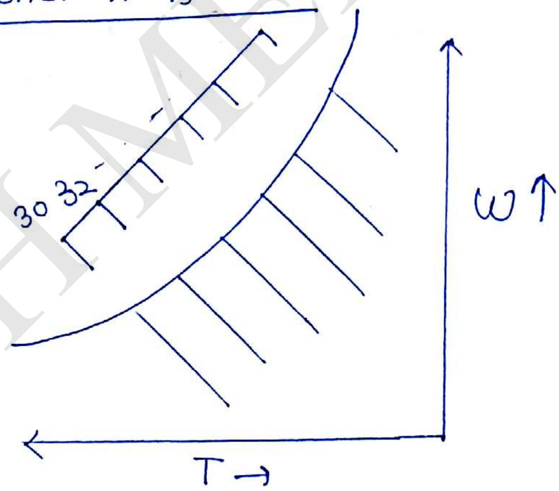
② Constant 'ω' lines



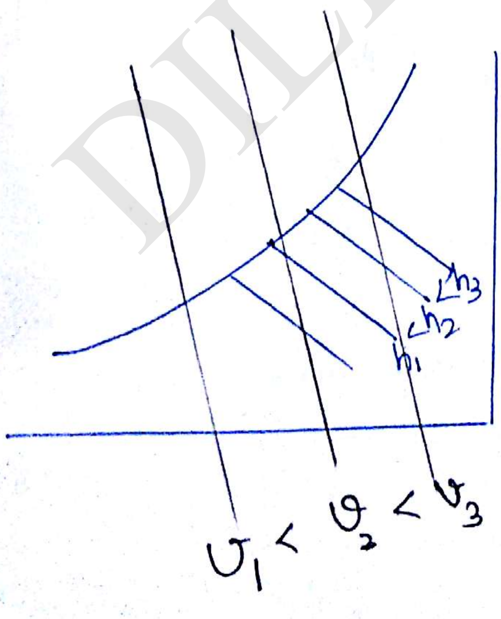
③ Constant R.H.(φ) lines



④ Constant 'h' lines



⑤ Const 'v' lines:



Specific Vol.

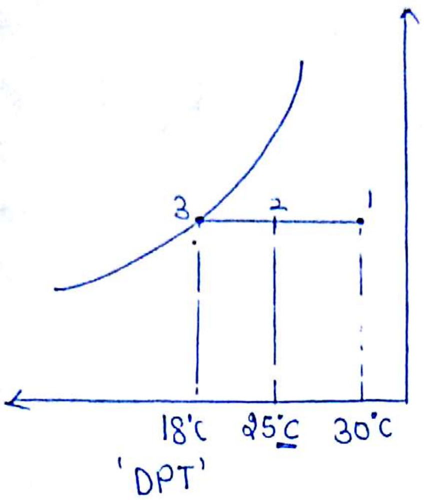
$$v = \frac{V}{m_a} \left(\frac{m^3}{kg\,d.a} \right)$$

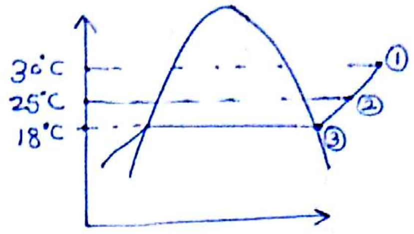
$$m_a = \frac{V}{v}$$

↓

dry air mass remain same

⑥ Constant 'DPT' lines





→ if 'P_v' is same, 'DPT' is same

→ $\omega = f(P_v \text{ only})$

if 'P_v' is same

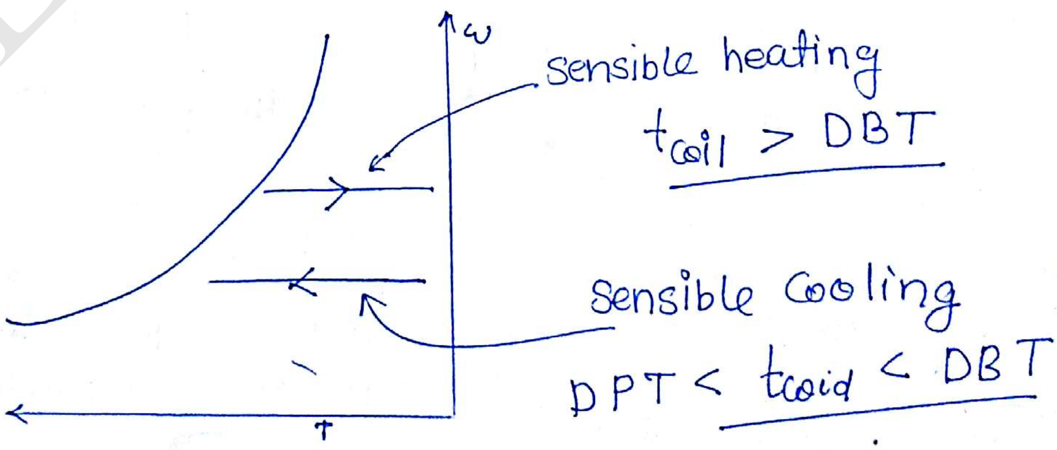
∴ ω is same

* Constant DPT lines follow constant 'ω' 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 practicles purposes these lines are taken to be same.

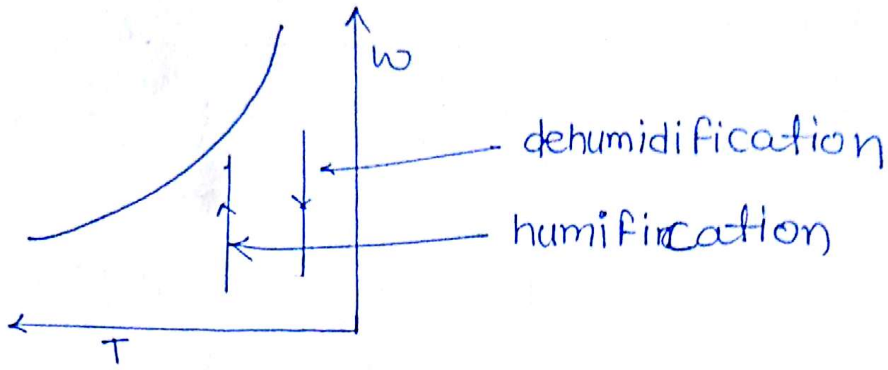
Various processes on psychrometric chart:-

① Sensible Cooling & sensible Heating:-

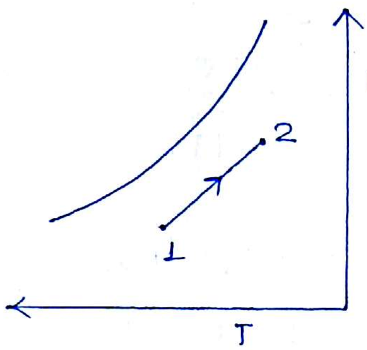


The process followed in the electrical room heater is sensible heating

(2) Humidification & Dehumidification :-

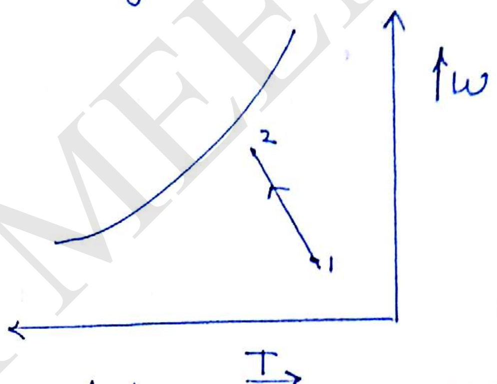


(3) Heating and Humidification :-



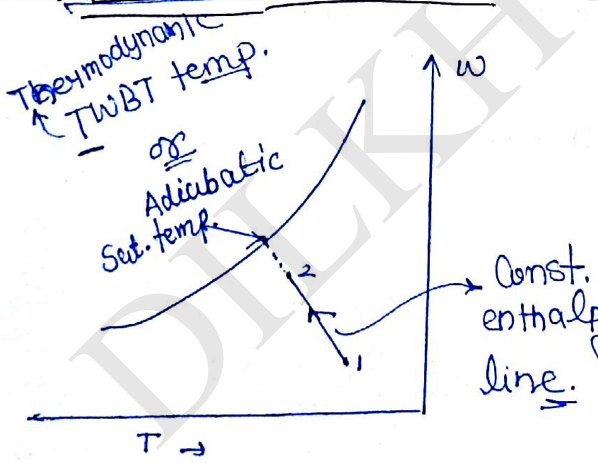
eg: steam spray in air

(4) Cooling & humidification



eg:- Desert cooler follow adiabatic saturation process.

Imp
Adiabatic saturation:-



→ if cooling and humidification occurs when air intract 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.

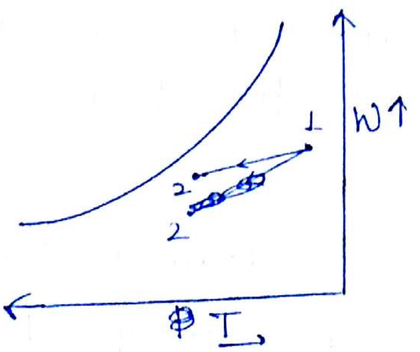
→ Temp. Corresponding to the point where adiabatic sat. line when produced intersects the saturation curve is called Thermodynamic wet bulb temp (TWBT) or adiabatic sat. temp.

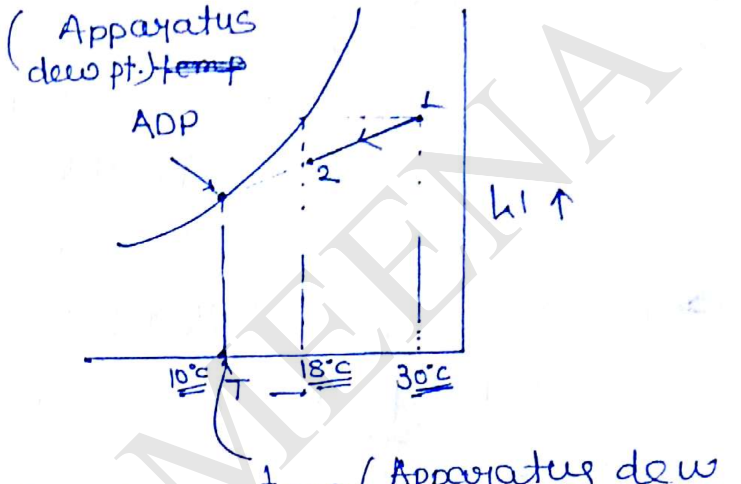
→ TWBT is a property of the air whereas WBT is not the property of the air.

★ ⇒ * $\boxed{TWBT \le WBT}$

★

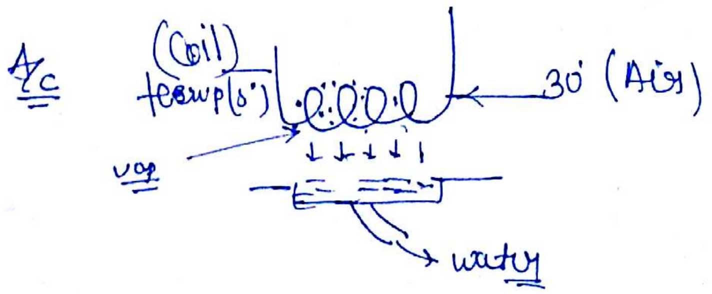
⑤ Cooling and dehumidification:-



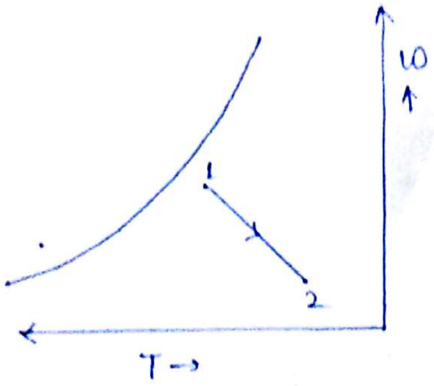


* The cooling and dehumidification lines when produced intersects the saturation curve at the point called as apparatus due point. The temp. corresponding to this point is the temp of the cooling coil. called as apparatus dew point temp

→ 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 absorbe water vapour from the air and ~~vat~~ 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 enthapy of air remain 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 °C. Find

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

(2) Cooling load on the cooling coil.

Assume the atmospheric condition are 35 °C DBT and $\phi = 60\%$. Take the mass flow rate of air to 5 kg/per sec. (dry air basis) and condensate leaving the coil at 25 °C

Soln: e $\omega = 5/100$

t (°C)	P_{vs} (bar)
35	0.05733
25	0.03229

Sol^n

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

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

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

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

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

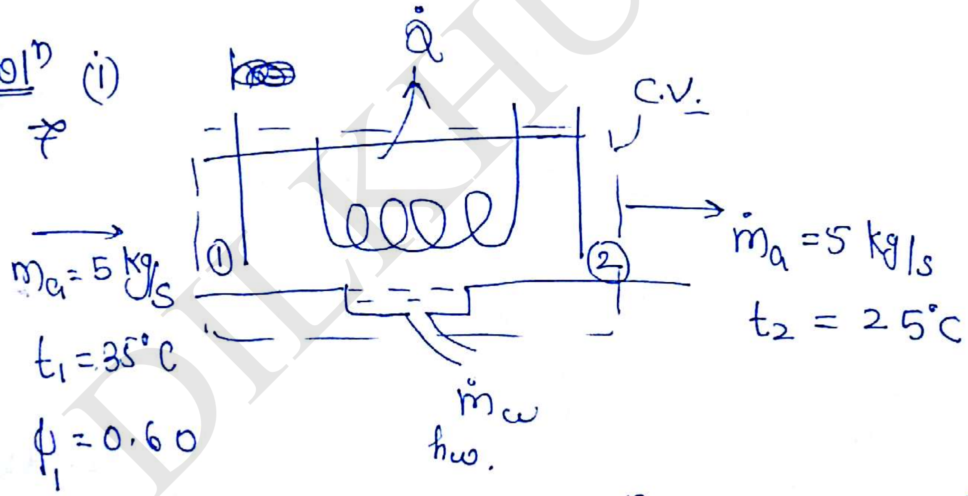
$$\phi = \frac{P_v}{P_{vs}} =$$

$$\phi = \frac{8.07 \times 10^{-3}}{\cancel{0.05733}\ 0.03229} = 25.01$$

~~$\phi = 14.09$~~ %. $\phi = 25.01\%$

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

Sol^n (i)
7



$$\phi_1 = 0.60 = \frac{P_{v_1}}{P_{vs_1}} = \frac{P_{v_1}}{0.05733}$$

$$P_{v_1} = 0.03439.$$

$$w_1 = 0.622 \frac{P_{v_1}}{P'_{t_1} - P_{v_1}}$$

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

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

$$h_1 = 1.005 \times t_1 + w_1 (2500 + 1.88 t_1)$$

$$= 1.005 \times 35^\circ + 21.86 \times 10^{-2} (2500 + 1.88 \times 35)$$

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

<u>Now</u> $w_2 = w_1 - \underline{w} \rightarrow$ removed

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

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

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

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

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

$$w_2 = 0.622 \frac{P_{v_2}}{P_{t_2} - P_{v_2}} = 0.622 \frac{P_{v_2}}{1.013 - P_{v_2}} = 16.86 \times 10^{-3}$$

$$P_{v_2} = 0.\underline{0268} \text{ bar.}$$

$$\phi = \frac{0.0268}{0.03229} = \underline{82.8\ \%}$$

(ii) $\dot{E}_{in} = \dot{E}_{out}$

$$\dot{m}_a \times h_1 = \dot{m}_a h_2 + \underset{\substack{\uparrow \\ \text{Cooling Coil}}}{\overset{?}{\dot{Q}}} + \dot{m}_w h_w$$

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

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

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

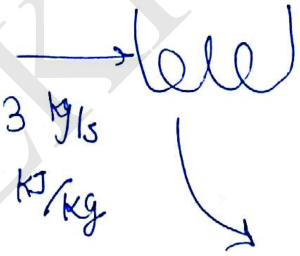
$$h_w = C_{pw} \times t_w \leftarrow \text{latent}$$

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

$$5 \times 91.36 = 5 \times 68.07 + \dot{Q} + 25 \times 10^{-3} \times 4.18 \times 28$$

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

Ques 5
W.B. 5b



$m_a = 3\ kg/s$ $\quad$ $E_{in} = E_{exit}$

$m_a = 3\ kg/s$ $\quad$ $h_2 = 43\ kJ/kg$

$h_1 = 85\ kJ/kg$ $\quad$ $\omega_2 = 8 \times 10^{-3}$

$\omega_1 = 19 \times 10^{-3}$ $\quad$ $h_w = 67\ kJ/kg.$ $\quad$ $\dot{m}_w = (\omega_1 - \omega_2) \times \frac{kg\,v}{kg\,d.a} \times 3 \frac{kg\,d.a}{s}$

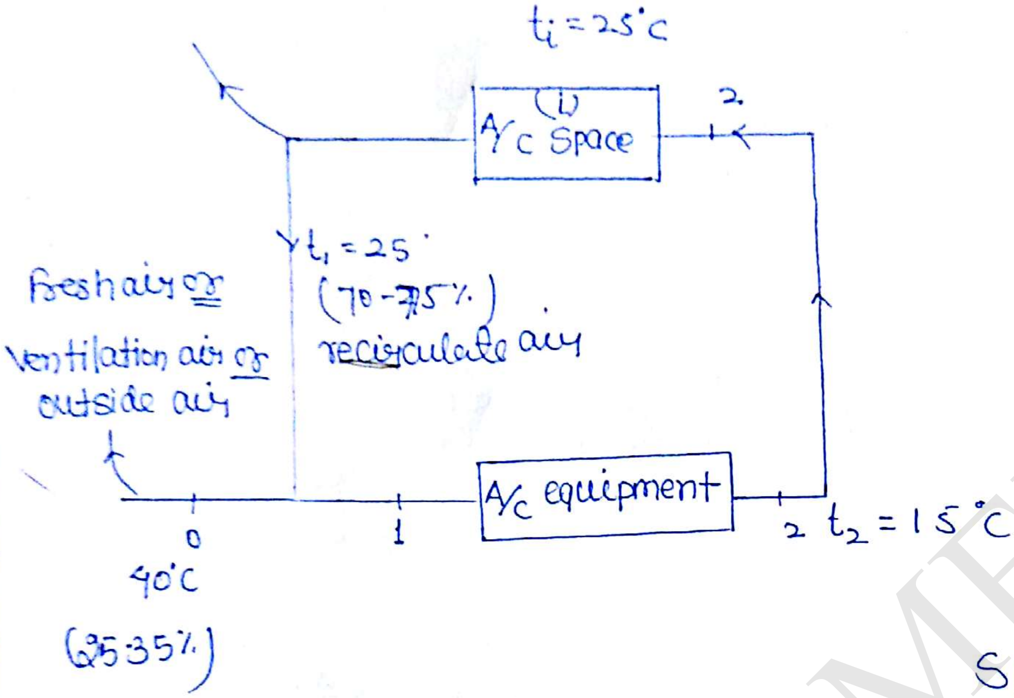
$$m_1 h_1 = m_2 h_2 + m_w h_w + \dot{Q}$$

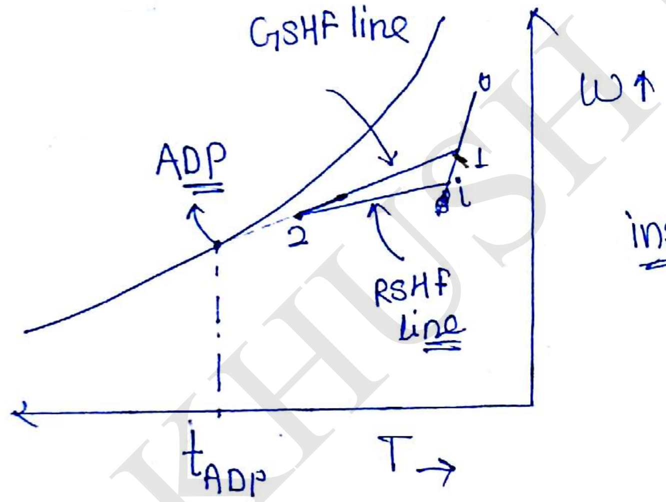
$$3 \times 85 = 3 \times 43 + \dot{Q} + 3 \times (19 - 8) \times 10^{-3} \times 67$$

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

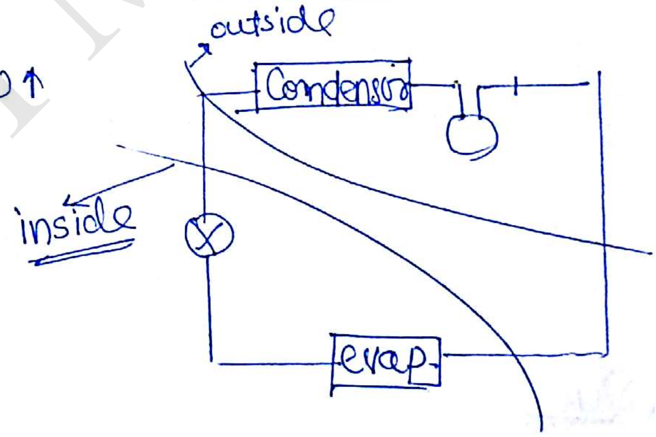
★ $\boxed{\dot{m}_w = \text{Condenset rate}}$

Summer Air Conditioning with Ventilation Air





Split 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 & GSHF 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:-

$$\text{Air changes per hour (ACH)} = \frac{V_0 \,(m^3/hr)}{V\,(m^3)}$$

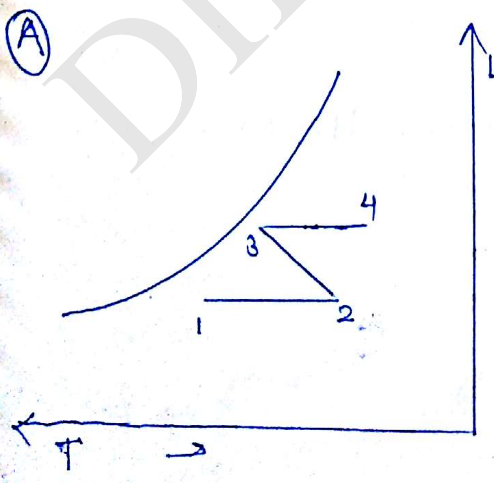
V_0 - outside air
V → Vol. of A/c space.

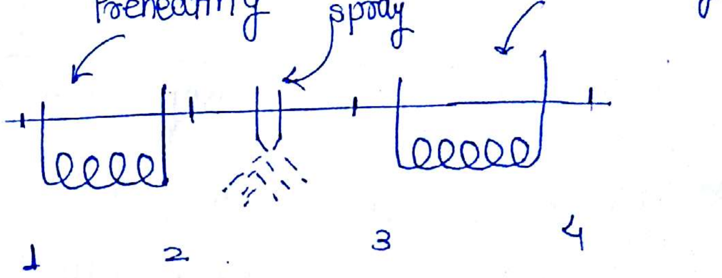
$$\text{Air changes per min} = \frac{V_0\,(m^3/min)}{V\,(m^3)}$$

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

Winter Air Conditioning:

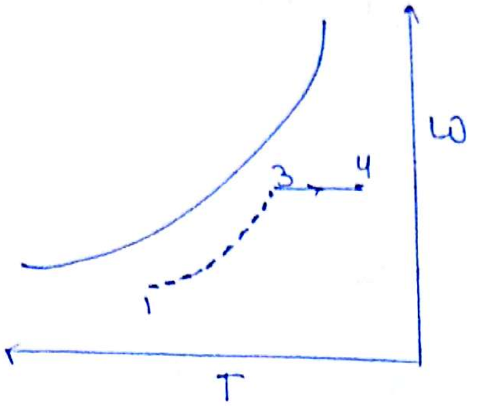
(A)

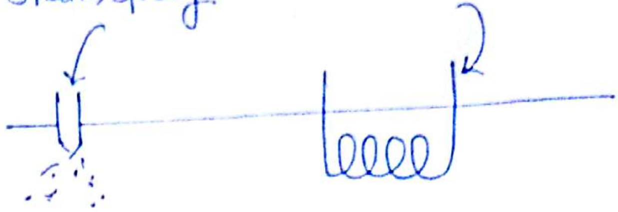




1 → 2 sensible heating
2 → 3 Adiabatic Sat.
3 → 4 sensible heating.

(B)

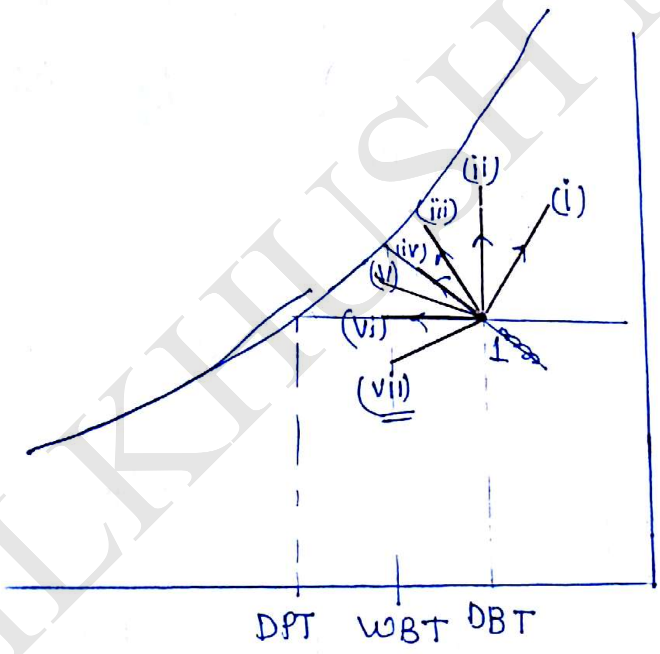




1-3 → heat humidification
3-4 → sensible heating

→ In winters the outside air is at low ω and low temp. hence heating and humidification of air is required. This can be acheived by one of the above method.

Air washer :-



(1) $t_w > DBT$ → heating & humidification
→ heating Coil
→ $h_a \uparrow$

(ii) $t_w = DBT$ → humidification
→ heating Coil
→ $h_a \uparrow$

(iii) WBT < t_w < DBT

→ Cooling and humidification
→ heating Coil
→ $h_a \uparrow$

(iv) t_w = WBT
→ cooling & humidification
→ No Coil.
→ h_a = 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 temprature :-

→ The physical comfort of a human being which can be ~~af~~ adjected by adjecting the temp., humidity, air velocity & purity of air.

- Effective temp is the temp. of a saturated envt. where the person feel same level of confort as in the normal ~~envt~~ environment.

- According to the ~~sy~~ study conducted by american society for heating refrigeration and ~~air~~ air condition engineers (ASHRAE), 99% of the ~~adults~~ ~~wearing~~ ~~little~~ ~~cloth~~ & ~~light~~ adults wearing light cloths involved in ligth activity (eg. office work) will experiance 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 experiance comfort at a lower temp. compare to woman.

2) Age:- Adult experiance comfort at a lower temp. comfake to children & old age people.

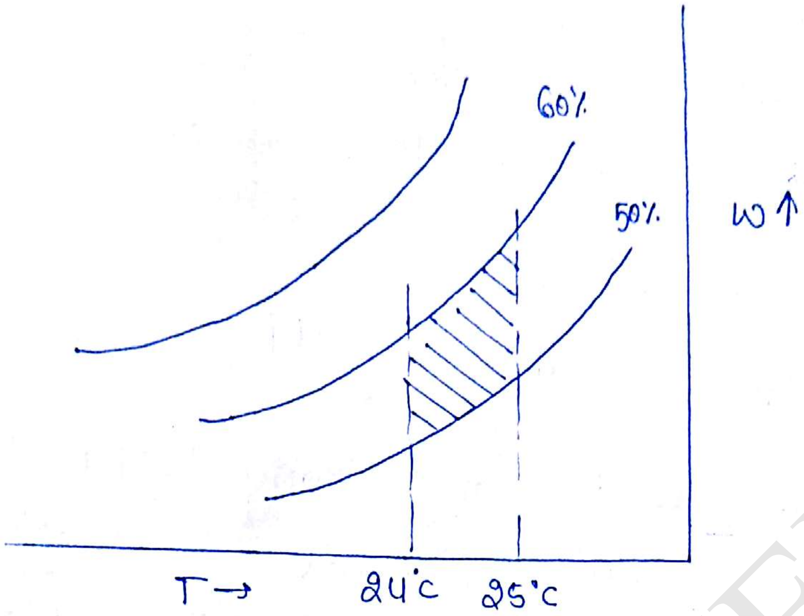
3) kind of clothing:- Person wearing light Cloths will experiance comfort at a relatively higher temp. compare to people wearing heavy cloths.

4) kind of activity:- Person involved in heavy physical activity (for ex. gym) will experiance comfort at a lower temp. Compared to person involved in light activities (offic work)

5) climatic Condition: people habitual to cold climate experiance comfort at lower temp compare to people living in hot climatic condition

6) Seasons:- People experiance Comfort at a lower temp. in winters compare to summer.

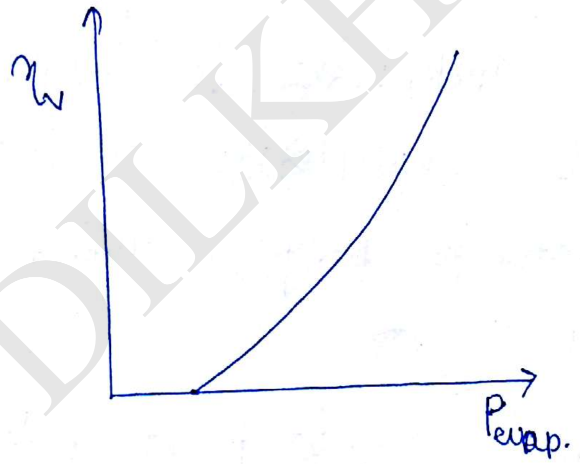
Comfort chart :-



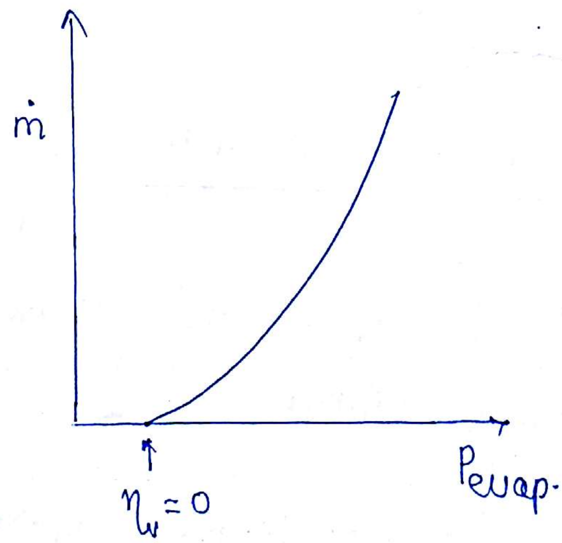
* The chart representing the year round comfort condition is called as comfort chart.

* Performance curve :-

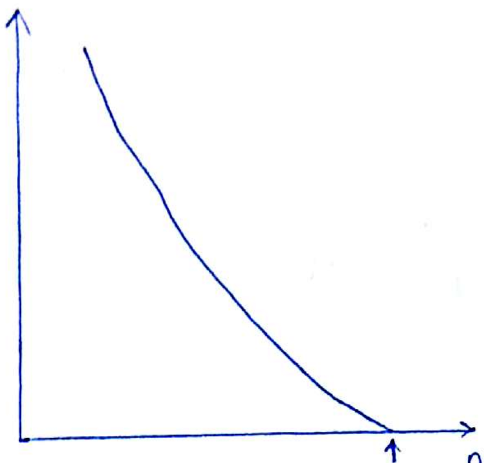
(i) η_v Vs $P_{evp.}$



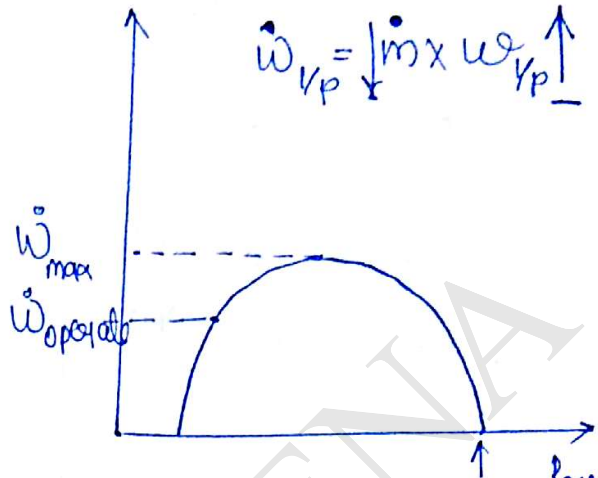
(ii) $\dot{m}$ Vs $P_{evap.}$



(iii) $w_{i/p}$ Vs P_{evap}.



(iv) $\dot{W}_{i/p}$ Vs P_{evap}.



~~$\dot{W}_{i/p}$ Vs P_{evap}.~~

* The operating is less than the maximum ~~ba~~ 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.

· Refrigeration Equipments ·

Compressor:-

① Hermitically shield compressor:-

→ In this the compressor and motor are installed on a steel shell.

→ occupies less space and noise generation is low.
→ Used in domestic application.
→ Maintenance is difficult and Motor cooling is achieved by rejecting heat to the suction vapour to compressor. This results in super heating of vapour hence increasing work input and decreasing COP of unit

② Open type Compressor:-

→ Compressor and motor are install on seprate shafts and joined by a belt and pulley arrangment
→ Maintenance is easy and Motor cools by itself
→ Used in Industrial application.
→ occupies large space & Noise generation is high.

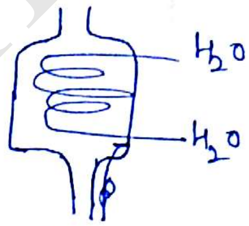
③ Semi hermitic Compressor :-

Motor and Compressor are install on seprate shaft and shield seprately they are Connected by belt and pulley arrangment. The merit and demerit are in b/w the above two Compressor.

Condensor

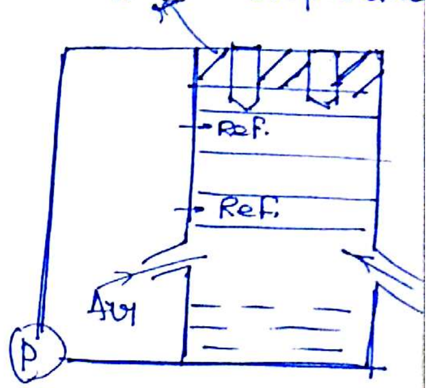
Condensor

- Air Cooled
  - < 5TR
  - → Window A/c
  - → Domestic Ref.
- water Cooled
  - Shell & tube
  - Shell & Coil
  - Evoporative



→ used when pure water available

baffels



→ use when water Shortage

* In both Shell and tube and Shell & Coil type Condenser the refrigerant flows through the Shell. The flow through tube is avoided to avoid the pressure loss of refrigerant.

→ Shell and Coil type condensor can be used only when pure water is available because of scaling problem in the coil.

* Evaporative condensor is used where there is shortage of water. Water absorbs heat from the refrigerent and is further cooled due to evaporative action as it comes in contact with the ~~air~~ air.

Heat rejection Factor / Heat rej. ratio :-

$$\text{Heat rejection ratio} = \frac{\dot{Q}_{rej}}{R.E.} = \frac{Q_{Rej}}{R.E.}$$

$$= \frac{W_{i/p} + R.E.}{R.E.}$$

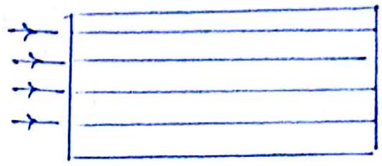
Heat rejection ratio

$$\boxed{HRR = \frac{1}{COP} + 1}$$

Heat rejection Ratio signifies the size of the condensor. In hermitically shield unit since COP is less, HRR is high hence larger size condensor are required.

Evaporators :-

Coil type :-  window A/c.

Plate type : Domestic Ref. 

Expansion devices

expansion devices.

- Const. Area type
  - → capillary tube
    - Domestic ref.
    - window A/c
- Variable Area.
  - Automatic exp. valve
  - Thermostatic expansion Valve (TEV)

Automatic expansion Valve :-

→ maintain const. pressure in the evaporator

→ used when load is almost constant. (For eq. Milk chilling plants)

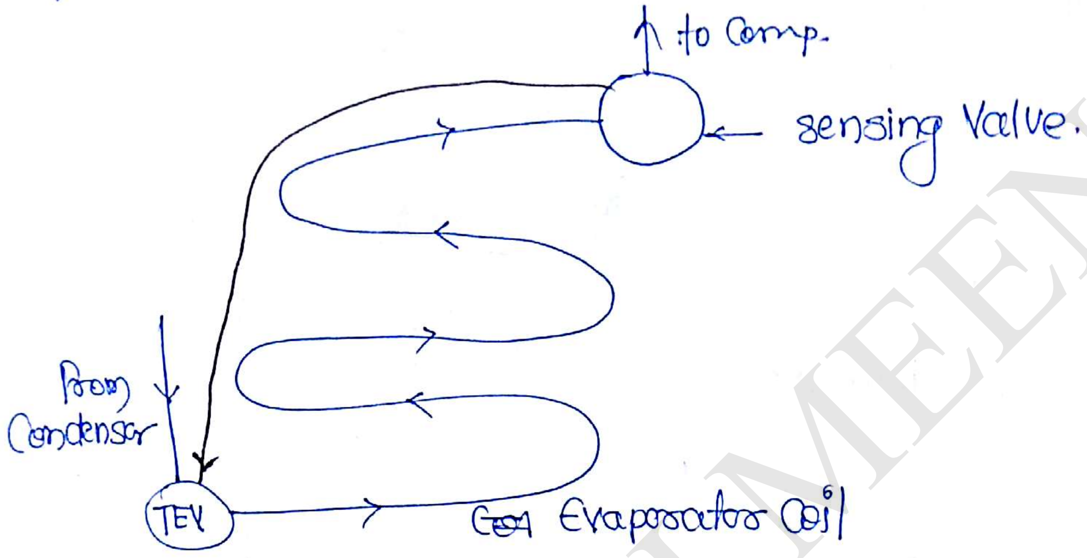
Thermostatic expansion Valve.

→ Maintain Constant degree of superheat in evaporator.

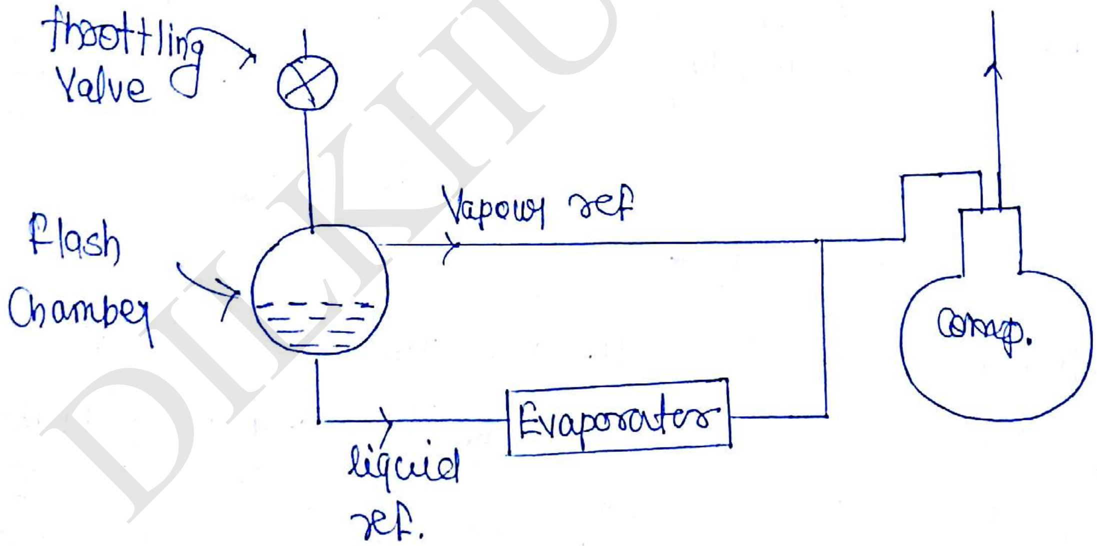
→ used when load is variable (

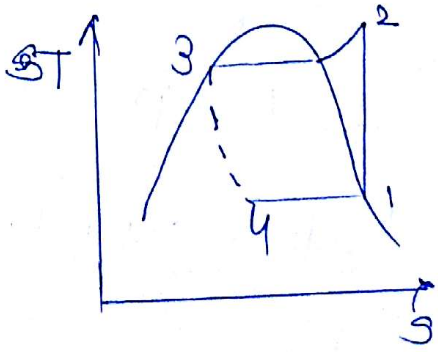
* → sensing bulb is locating at the exit of evaporator.

- Alternative overfeeding & starving of refrigerant in the evaporator coil leads to hunting in the thermostatic expansion valve.



Flash chamber:—



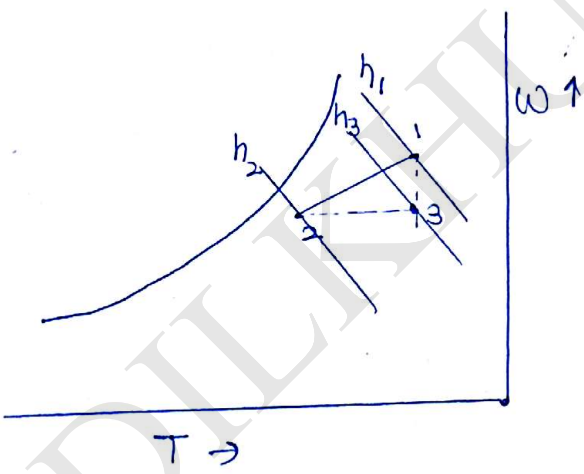


Theoretically there is no improvement in COP but practically as the vapour is bypass the pressure loss during the flow reduces hence COP improve ~~slightly~~ slightly.

Float Valve:-

These valves are used for regulating the level of liquid refrigerant. It is called as high side float valve if used on high pressure side i.e. condensor. and called as low side flot valve if used on low pressure side i.e. evaporator.

Sensible Heat factor & latent heat factor:-



Total heat removed

$$TH = h_1 - h_2$$

latent heat $LH = h_1 - h_3$

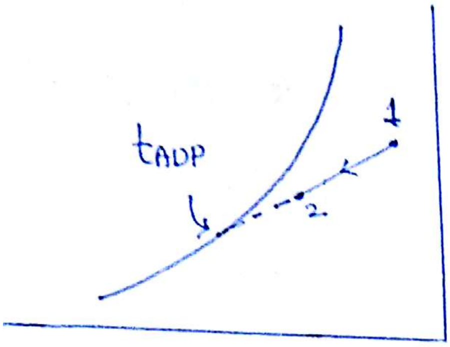
Sensible heat $SH = h_3 - h_2$

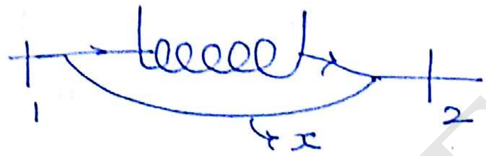
$$SHF = \frac{h_3 - h_2}{h_1 - h_3} \qquad LHF = \frac{h_1 - h_3}{h_1 - h_3}$$

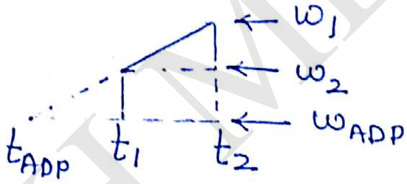
$$\boxed{SHF + LHF = 1}$$

~~Q.27 P.g.54 outside $\dot{m}_a = 50$ kg/sec. DBT = 45 °C $\phi = 30\%$ inside $t = 25$°C $\phi = 50\%$~~

By pass Factor & Contact Factor (η)
(Coil eff.)







*

$$BPF = \frac{t_2 - t_{ADP}}{t_1 - t_{ADP}} = \frac{\omega_2 - \omega_{ADP}}{\omega_1 - \omega_{ADP}} \simeq \frac{h_2 - h_{ADP}}{h_1 - h_{ADP}}$$

Contact Factor

$$* \quad \eta = \frac{t_1 - t_2}{t_1 - t_{ADP}} = \frac{\cancel{\omega_1 - \omega_2}}{}$$

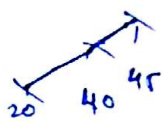
$$\boxed{BPF + \eta = 1}$$

Note ① The by pass factor depands on the placing of the coil. it also depands on the air velocity, as the air velocity increases by pass Factor increases.

Q.29
Pg 159

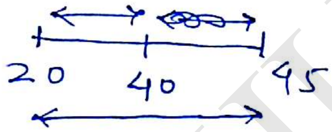
(2) latent heat factor is high when the relative humidity is high eg. during rainy season LHF is also high for the place of high occupancy like movie hall, auditorium.

Que Air at 20°c DBT and 40% RH is heated to 40°c using electric heater. The surface temp. of the coil is 45°c, the bypass factor will be.



$$BF = \frac{45-40}{45-20}$$

$$BF = \frac{5}{25} = \frac{1}{5} = 0.2$$



Ques In an air conditioning process 5 KJ/min of heat is extracted from the room if the SHF = 0.8, ten the latent heat load is

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

$SH = \cancel{5 \times 0.8} = 4$

$\cancel{LH = 1 - 5 \times 0.8}$

SHF + LHF = 1

LHF = 0.2

LH

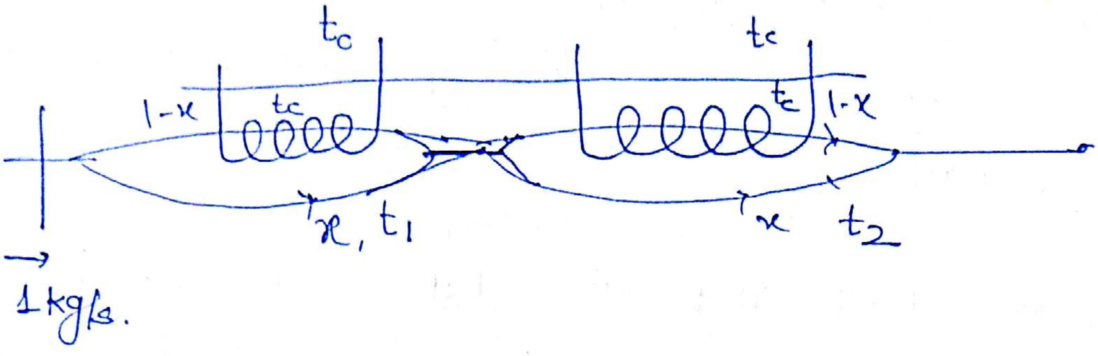
SH = 4 KJ/min

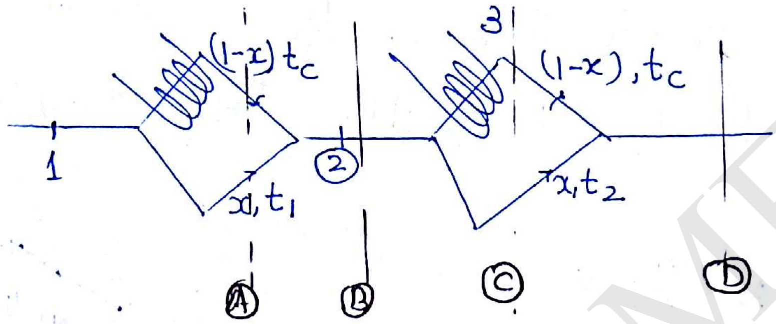
LH = 1 KJ/min

LH = 0.2 × 5 = 1 KJ/min

Effective bypass Factor:-

Note: for calculation of effective BF Dry Air is Considered





energy Consv. A → B

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

$$(1-x)C_{pa} t_c + x C_{pa} t_1 = C_{pa} t_2$$

$$(1-x)t_c + x t_1 = t_2 \quad \text{--- (1)}$$

Similarly C & D

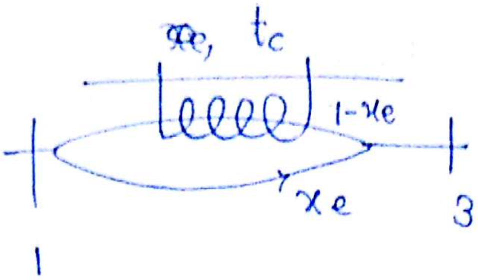
$$(1-x)t_c + x t_2 = t_3 \quad \text{--- (2)}$$

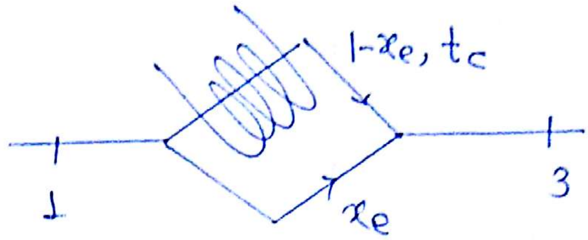
from (1) & (2)

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

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

$$(1-x^2)t_c + x^2 t_1 = t_3 \quad \text{--- (3)}$$





$$(1-x_e)\,t_c + x_e\,t_1 = t_3 \qquad -(4)$$

$$(1-x^2)\,t_c + x^2\,t_1 = t_3 \qquad -(3)$$

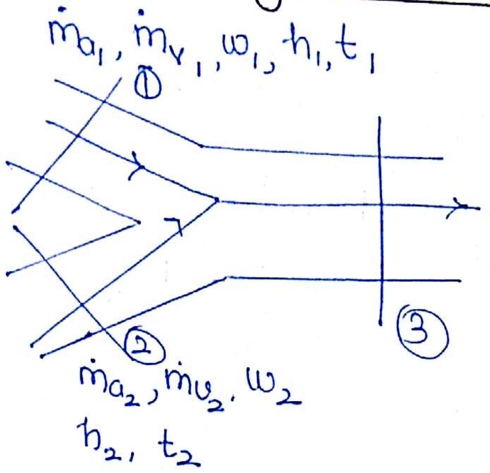
from (3) & (4)

$$\therefore \; x_e = x^2$$

For 'n' coils

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

Adiabatic Mixing of Air streams:-



(1) Consv. of mass

(a) dry air $\quad m_{a_1} + m_{a_2} = m_{a_3} \quad -(a)$

(b) water vapour

$$m_{v_1} + m_{v_2} = m_{v_3} \quad -(b)$$

∴ (No Condensation)

$$\Rightarrow \quad \omega = \frac{m_v}{m_a}$$

from (b)

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

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

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

Similarly (2) energy consv.

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

$$\Rightarrow \quad \boxed{\frac{m_{a_1}}{m_{a_2}} = \frac{h_3 - h_2}{h_1 - h_3}}$$