[redacted]/2016

Book
P.L. Ballaney.

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 $\begin{cases} \to \text{Rev.} \\ \to \text{irrv.} \end{cases}$ $q = 0$

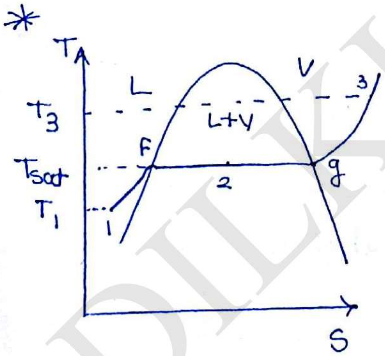
$W_{c.v.} = h_1 - h_2$

Polytropic$(pv^n = c)$

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

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

*



① Sub cooled Region

$h_f - h_1 = C_{P_{liq}}(T_{sat} - T_1)$

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

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)

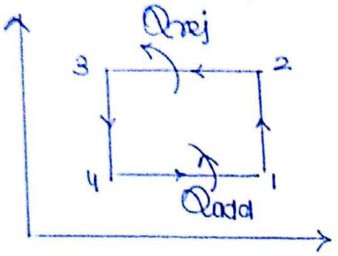
$h_3 - h_g = C_{P_v}(T_3 - T_{sat})$.

$s_3 - s_g = C_{P_v} \ln \frac{T_3}{T_{sat}} - \overset{0}{\cancel{R \ln \frac{P}{P_s}}}$

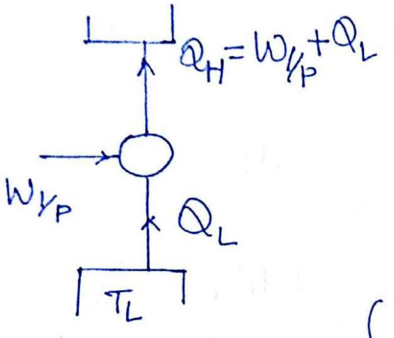
$s_3 - s_g = C_{P_v} \ln\left(\frac{T_3}{T_{sat}}\right)$

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.



$$(COP)_{Ref} = \frac{Q_L}{W_{i/p}}$$

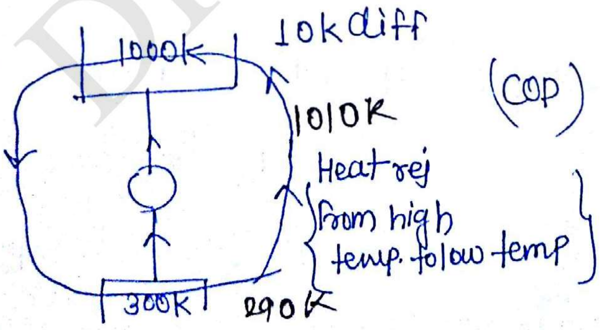
$$(COP)_{HP} = \frac{Q_H}{W_{i/p}}$$

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

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

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

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



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

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

* 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~~ ~~r~~ 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

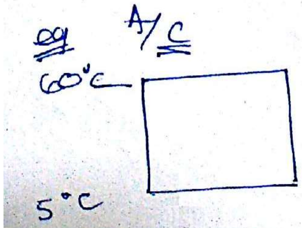
Reasons
- total Space to cooled is more
- Heat gen. ~~sorces~~ sources are present (Fan, light people)
- ~~fan, li~~ Heat leakage from outside

Suppose

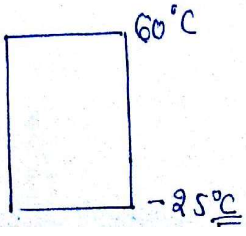
$$(COP)_{A/C} = 2 = \frac{\overset{\to 100}{D.E.}}{W_{I/P}} \qquad W_{I/P} = 50$$

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

eg A/C



Ref eg



Heat Capacity

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

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)

$$\boxed{1TR = 3.5167\ KW}$$

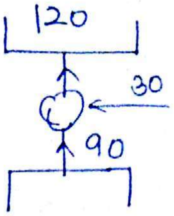
$$= 211\ KJ/min$$

$$= 50.4\ kcal/min$$

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

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



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

$COP = \underline{\underline{3}}$

Q.10

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

$(COP)_{ref.} = \frac{T_L}{T_H - T_L}$ 10

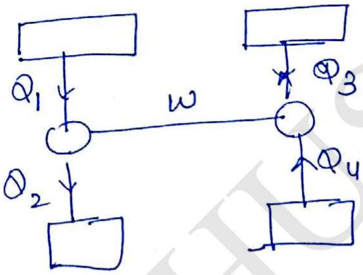
$\left(\frac{1}{COP}\right)_{ref} = \frac{T_H}{T_L} - 1 = \frac{10}{0.8} - 1$

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

$(COP)_{ref} = 4$

$(COP)_{HP} = 5$

Q.17



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

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

$Q_2 = 0.6\, Q_1$

$Q_2 + Q_4 = 3Q_1$

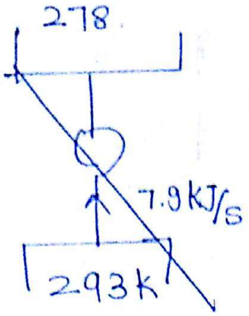
$(COP) = \frac{Q_4}{Q_3 - Q_4} = \frac{3Q_1 - Q_2}{Q_1 - Q_2}$

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

$= \frac{2.4}{0.4}$

$\underline{COP} = 6$

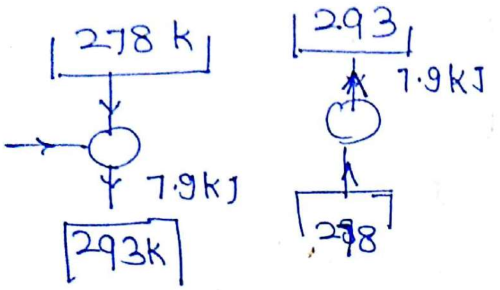
Q.17



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

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

Heat pump

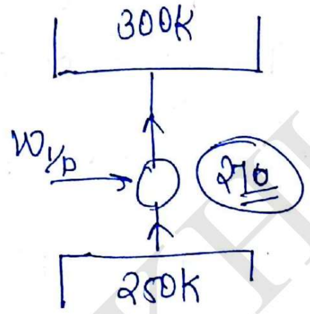


$$\frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L} = \frac{293}{15}$$

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

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

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

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

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

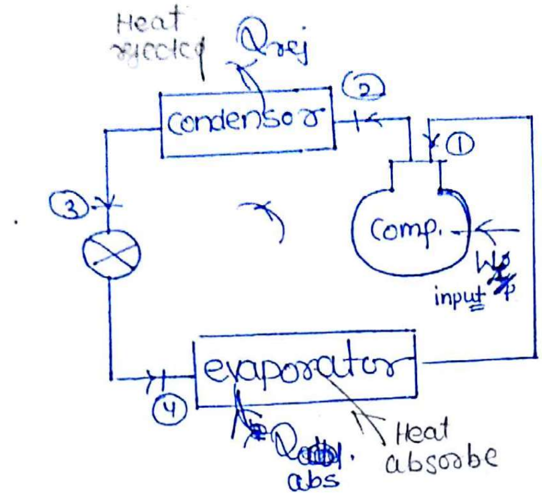
$$\overset{\circ}{Q} = \frac{Q}{10 \times 3600} = \frac{1080000}{360000}$$

$$\overset{\circ}{Q} = 30 \text{ KW}$$

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

$W_{i/p} = 12$ KW Ans

Vapour Compression Refrigeration System (VCRS)



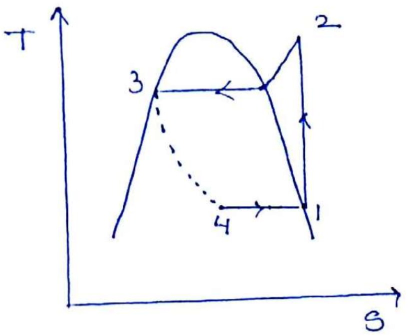
1→2 isentropic Comp.

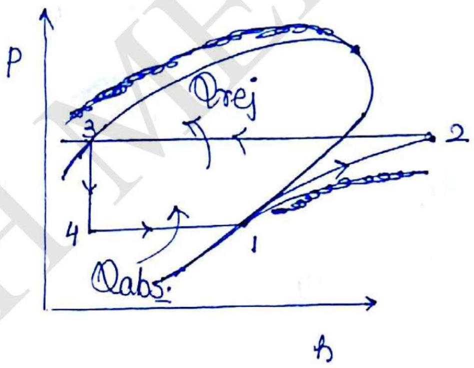
2→3 Isobaric heat rej.

3-4 throttling

4-1 Isobaric heat ab.

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

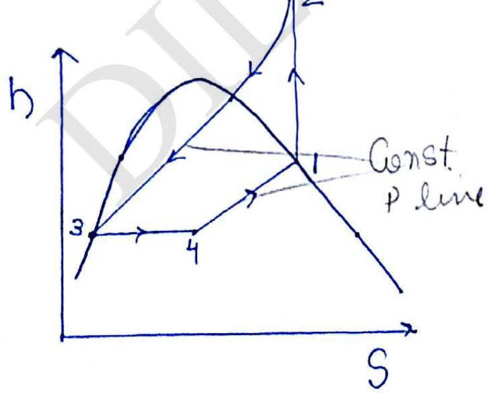




Simple V-C cycle
or ideal V-C cycle

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

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



$$T ds = dh - \cancel{V dp} \to 0$$

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

1. Sat. Vapour
3 Sat. liquid

⇒ Appling steady ~~state~~ flow energy eq^n 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 $w_{c.v} = 0$

$h_i + q = h_e$

$Q_{ab} = h_1 - h_4$

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

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

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

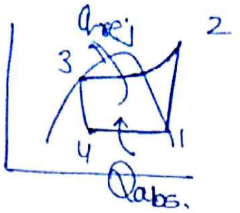
Q.16

P.g 45
WB

$RC = 5 \text{ kW}$

$h_3 = 75 \text{ kJ/kg} = h_4$

$COP = \frac{R.E}{W_{i/p}} = \frac{h_4 - h_1}{h_2 - h_1}$



$h_1 = 183 \text{ kJ/kg.}$

$h_2 = 210 \text{ kJ/kg.}$

$$(COP) = \frac{189 - 75}{210 - 183} = 4$$

$W_{i/p} = \text{Power} = \dot{m}(W_{inp})$ $\quad (RE) \times \dot{m} = RC.$

$= \dot{m}(h_2 - h_1)$ $\quad (h_1 - h_4)\dot{m} = 5$

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

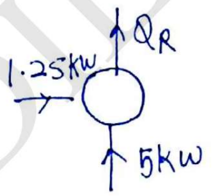
$P_{i/p} = \frac{5}{108}(210 - 183)$

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

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

$= 6.25 \text{ kW}$

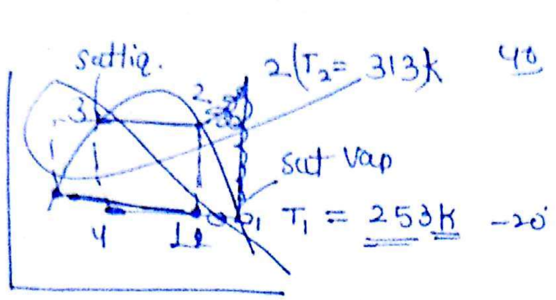
or $\quad COP = \frac{R.C}{W_{inp}} \Rightarrow W_{inp} = \frac{5}{4} = 1.25 \text{ kW.}$

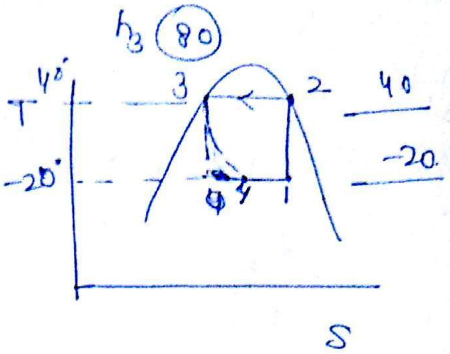


$Q_R = 1.25 + 5$

$= 6.25 \text{ kW}$

Q. 19





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

a

$$S_4\big|_{40^\circ} = S_f + x(S_g - S_f)\big|_{-20^\circ C}$$

COP =

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

$$x = 0.9$$

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

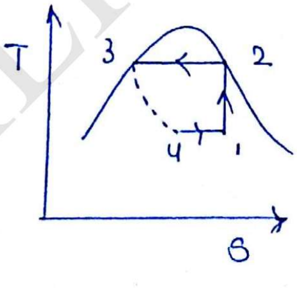
$$= 20 + 160 \times 0.9$$

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

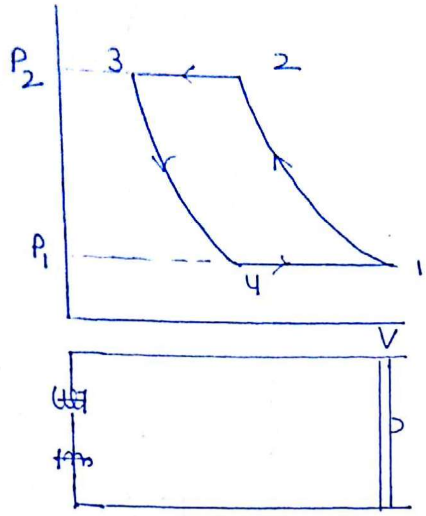
$$COP = \frac{164 - 80}{200 - 164} = 2.33$$

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

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



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.

☆

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

Q.9
p.g 45
NB

$C = 0.03$

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

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

$$\eta_v = 0.942$$

1TR = 3.561 KW

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

Ques

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

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

$$\eta_v = 0.9091$$

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

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

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

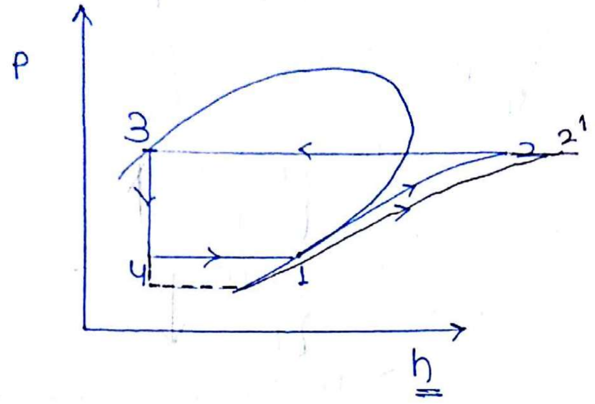
$$\dot{m} = 0.06336 \text{ kg/sec.}$$

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

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

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

1) Reduction in evaporator pressure:-



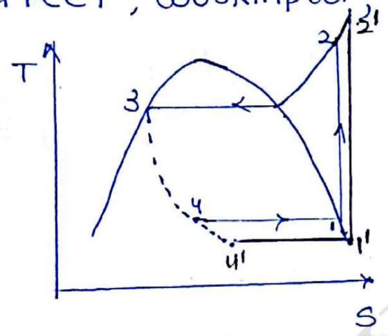
(i) R.E. ↓

(ii) $W_{I/P}$ ↑

(iii) ↓COP = $\frac{R.E.\downarrow}{W_{I/P}\uparrow}$

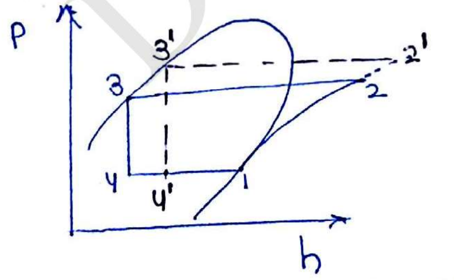
(iv) $\downarrow\eta_v = 1+C-C\left(\frac{P_2}{P_1}\right)^{1/n}$

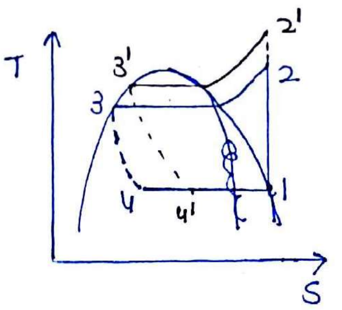
→ Reduction in evaporator pressure decrease the Refrigeration effect, workinput, COP and Volumetric efficiency.



→ 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. ↓

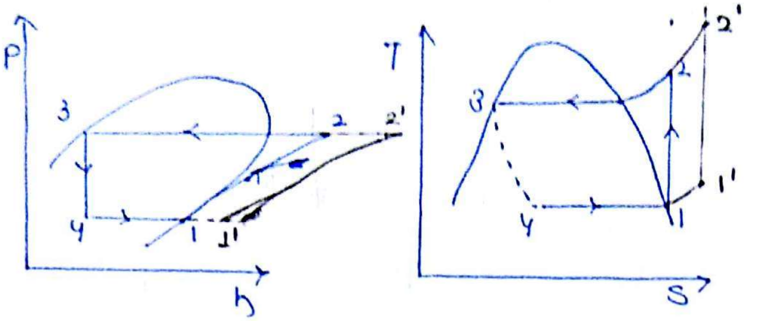
(ii) $W_{I/P}$ ↑

(iii) ↓COP = $\frac{R.E.\downarrow}{W_{I/P}\uparrow}$

(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 {R-134a, R-12} ↑

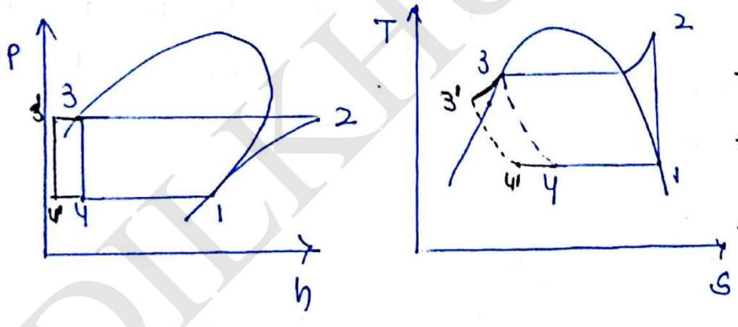
{NH_3, R-22} ↓

→ (iv) η_v = remain same

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

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

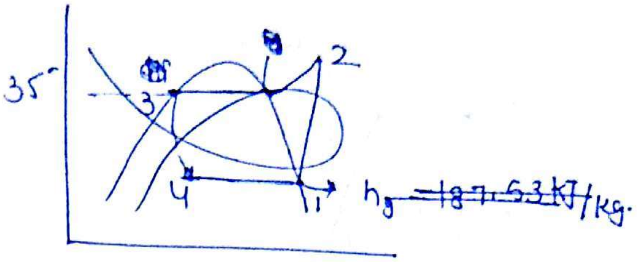
→ (iv) $\eta_v = 1 + c - c\left(\frac{P_2}{P_1}\right)^{1/n}$ → Same

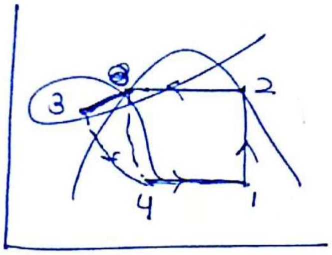
Q.18

COP = 6.5

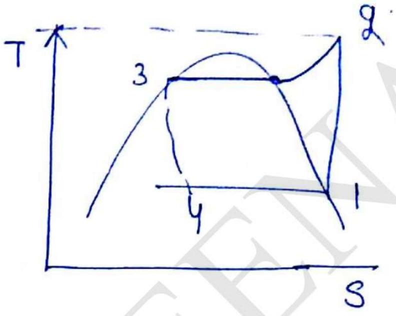
35°C $\left\{ \begin{array}{l} h_f = 69.55 \text{ KJ/kg} \\ h_g = 201.50 \text{ KJ/kg} \end{array} \right.$

$C_p = 0.6155$ KJ/kg.





$\cancel{Q_e} =$



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

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

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

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

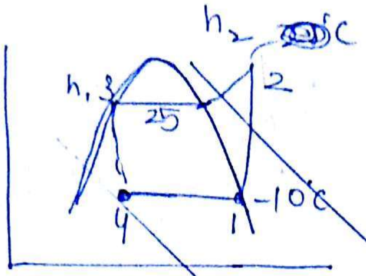
$$6.5 = \frac{201.5 - 69.55}{h_2 - 201.5}$$

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

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

$$T_2 = 41.79\,°C$$

Q.17



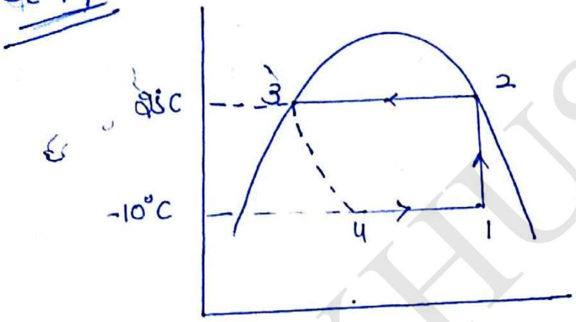
$$COP = \frac{h_1 - h_4}{h_2 - h_1}$$

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

h_3 ~~$= h_4 = h_f + x h_{fg} x$~~ ~~$h_2 = h_g$~~

$$S_2 = S_g\Big|_{-10°C} = S_g + C_{p_v} \ln\left(\frac{T_2}{T_3}\right)$$

Q 17



$h_2 = 1465.84$

$h_3 = h_4 = 298.9$

$S_1 = S_2$

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

@ 25°C

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

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

$S_g = 5.046$ at 25°C

@ -10°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 $-10°C$

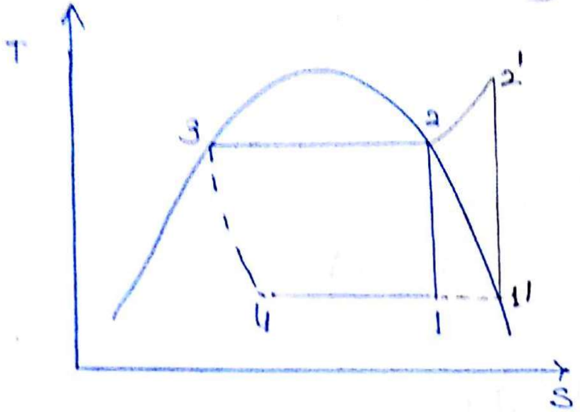
$$= 138.37 + 0.91(1433.5)$$

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

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

$$COP = 6.8$$ 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.
$V = V_f + x V_{fg}$

-> 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 values 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.

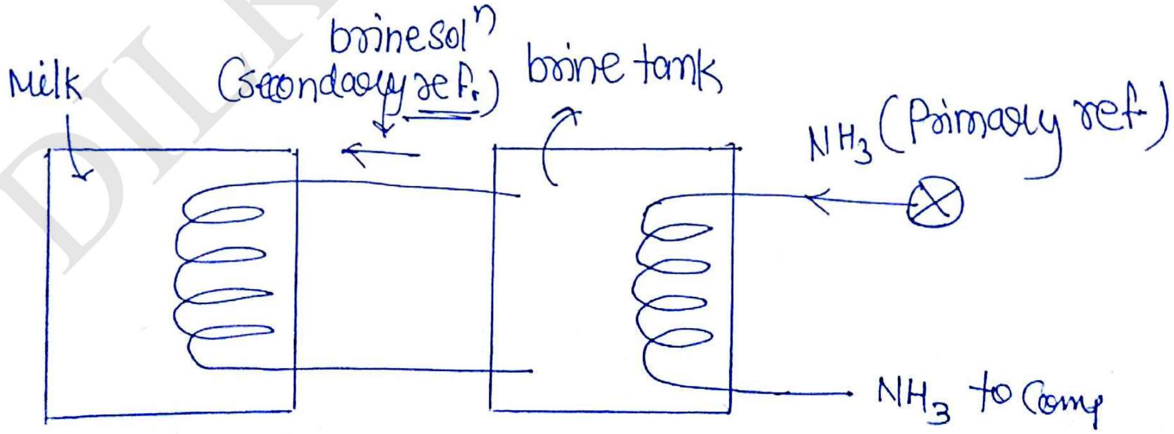
secondary refrigerent used in milk chilling plants. is brine solution. (water + salt)

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 $35\,^\circ C \xrightarrow{w} \underset{w}{0} \longrightarrow \underset{ice}{0\,^\circ c} \longrightarrow \underset{ice}{-8\,^\circ C}$

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

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

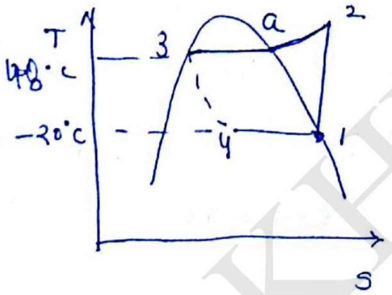
$Q =$ ~~49.91 kw~~ 4312222.4 kw

$\dot{Q} = \frac{Q}{24 \times 3600} = 49.91 kw$ 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.

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

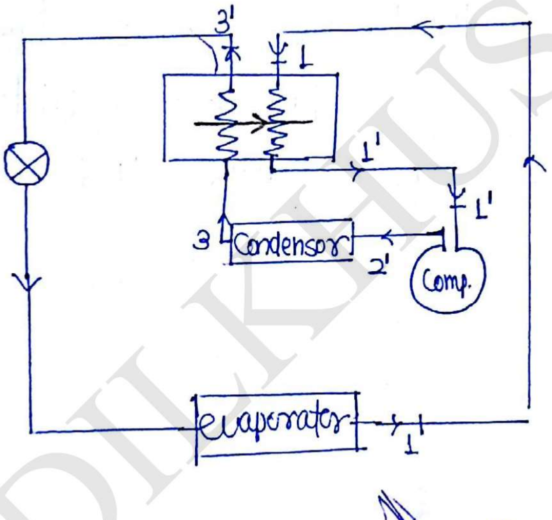
$$2.63 = \frac{R_c}{W_{I/P}}$$

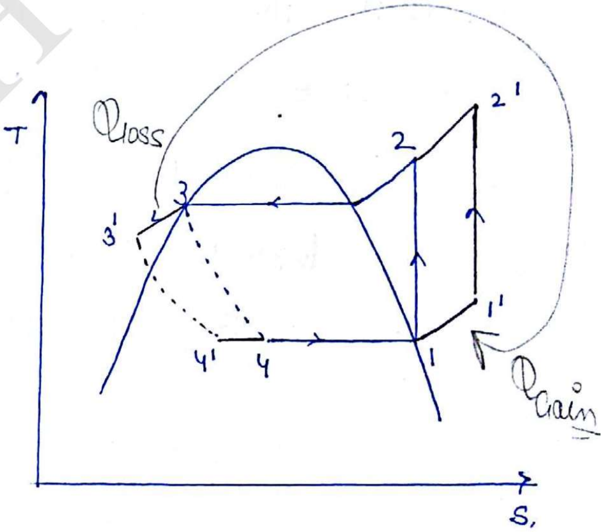
$$W_{I/P} = \frac{54,901}{2.63}$$

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

Use of Regenrative heat exchanger

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





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

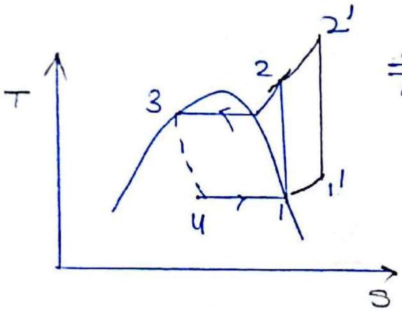
$$h_3 - h_{3'} = h_{1'} - h_1$$

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

Degree of ~~Super~~ subcooling ≠ Degree of super heating

→ In regerative heat exchanger Heat loss is equial 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 evaporato



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

↓ in evap. super heating

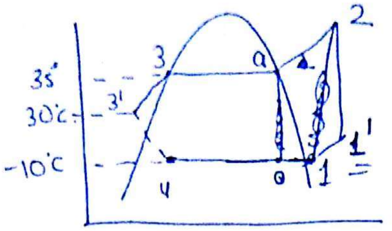
$$\Rightarrow R.E. = (h_1 - h_4) + \underbrace{(h_{4'} - h_4)}_{x}$$

↓ in regenrative HE

* In both the cases the 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.

$h_3 = \underline{366.07}$ KJ/k

$h_3' = h_3 - C_p \cancel{\ln\left(\frac{T_3}{T_3'}\right)} (T_3 - T_{3'})$ 273 35 ‾‾ 08

$h_3' = 366.07 - 4.566 \cancel{\ln\left(\frac{308}{303}\right)} (308 - 303)$

$\underline{h_4} = \underline{h_3'} = \underline{\underline{343.29}}$ KJ/kg

~~$S_2|_{35} = S_f + x\, S_{fg}.|_{-10}$~~

~~$5.2086 = 0.82965 + x(\quad)$~~

~~$x = 0.88$~~

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

$h_1 = \underline{1294.68}$

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

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

$W = 0.0525\,(1488.57 - 1294.68)$

$= \underline{10.18\ kW}$

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

[illegible]

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

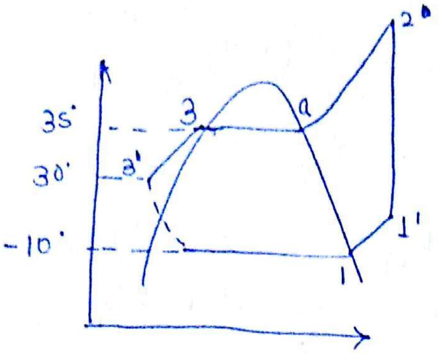
$=$

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

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

$D = 0.67\ \underline{\underline{m}}$

Q.22



$h_1 = 1450.22$

$h_3 = 366.07$

$h_a = 1488.07$

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

$h_3' = 343.29$ kJ/kg.

$Q_{loss} = Q_{gain}$

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

$366.07 - 343.29 = h_1' - 1450.22$

$h_1' = 1473.$

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

$\quad\quad\quad\quad \downarrow \quad\quad\quad \downarrow$

$\quad\quad\quad\quad 2.492 \quad\quad 263$

$T_{1'} = 272.14K.$

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

$S_{1'} = 5.840$ kJ/kgK

$S_1' = S_2' = S_a + C_{p_v} \ln \frac{T_2'}{T_a}$

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

$T_2' = 382.84$ K

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

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

$$h_2' = 1705.86$$

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

$$COP = 4.75$$

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

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

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

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

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

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

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

$\underline{\underline{1 \to 1'}}$ $$\boxed{\frac{v_1}{T_1} = \frac{v_1'}{T_1'}}$$

$$\frac{0.041749}{263} = \frac{v_1'}{272.14}$$

$$v_1' = 0.4319$$

$$\frac{(0.045 \times 60) \times 0.4319}{\frac{\pi}{4} D^2\, 1.2D \times \cancel{1000} \times 1} = 1$$

$$D = 107.49\ mm$$

$$L = 128.9\ \underline{\underline{mm}}$$