IN THIS PDF UNIT 2 AND UNIT 3 MATERIALS

① A simple evaporative cooling system is used for an aeroplane for 20 tons of refrigeration load the ambient load air 20°c and 0.9 bar the ambient air is ~~lacked~~ rammed isentropically to a pressure of 1 bar the air leaving the Main Compressor at pressure 3.5 bar, is first cooled in the heat exchanger having effectiveness of 0.6 and then in the evaporatour where its Temperature reduced by 5°C The air from the evaporator is passed Through the Cooling turbine. and Then it is supplied to the Cabin. where the Temp of 25°c and a pressure of 1.05 bar $\eta_c = 80\%$; $\eta_T = 75\%$

(i) ma - mass of air in Main Compressor

(ii) power (iii) cop.

Sol →

$T_1 = 20^\circ + 273 = 293\ K$

$P_1 = 0.9$ bar

$Q = 20\,TR$

$P_2 = 1$ bar ; $P_3 = 3.5$ bar $= P_4$

$T_4' = T_4 - T_5 = 5^\circ + 273 = 278\ K$

$T_6 = 25^\circ C + 273 = 298\ K.$

$P_5 = P_6 = 1.05$ bar , $\eta_c = 80\%$, $\eta_T = 75\%$

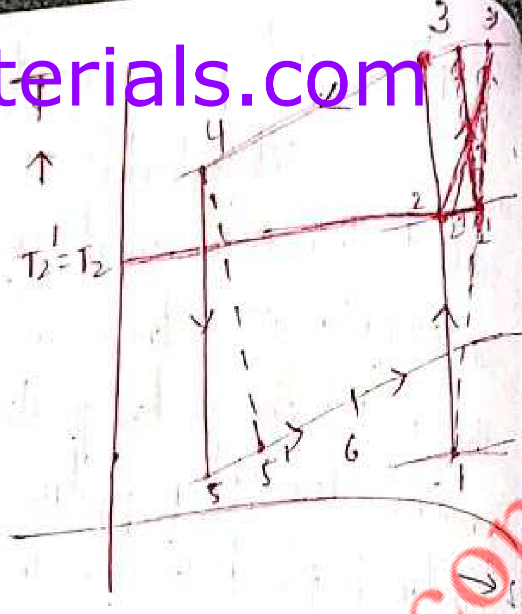
effectiveness $\varepsilon = 0.6$

process 1-2

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = T_1 \left[\frac{P_2}{P_1}\right]^{\frac{1.4-1}{1.4}}$$

$$T_2 = 301.8\ K$$



Isentropic Compression process 2-3

$$\frac{T_3}{T_2} = \left(\frac{P_3}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_3 = 431.6\ K.$$

$$\eta_c = \frac{\text{Isentropic increase in Temp}}{\text{Actual increase in Temp.}}$$

$$0.8 = \frac{T_3 - T_2'}{T_3' - T_2'}$$

$$\boxed{T_3' = 464\ K.}$$

if pressure line is Actual pressure line

Then $\epsilon = \dfrac{T_3' - T_4}{T_3' - T_2'}$

Note – effectiveness of heat exchanger $\epsilon = \dfrac{T_3' - T_4}{T_3' - T_2'}$

$$0.6 = \frac{464 - T_4}{464 - 301.8}$$

$$T_4 = 93.7^\circ C = 366.7\ K$$

$$T_4' = \cancel{88.7^\circ C}$$

$$= 367.7\ K$$

Isentropic expansion process 4'-5

$$\frac{T_4'}{T_5} = \left[\frac{P_4}{P_5}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\boxed{T_5 = 256.42\ K}$$

$$\eta_T = \frac{\text{Actual increase in Temp}}{\text{Isentropic increase in Temp}} = \frac{T_4' - T_5'}{T_4' - T_5}$$

$$0.75 = \frac{367.7 - T_5'}{367.7 - 256.42}$$

$$\boxed{T_5' = 283.8\ K}$$

Mass of air $M_a = \frac{210Q}{c_p \times [T_6 - T_5']}$

$$m_a = 276\ kg/min$$

power $P = \frac{m_a \times c_p (T_2' - T_2)}{60} = \frac{276 \times 1 \times (464 - 301.8)}{60}$

$$\boxed{P = 746\ kW}$$

$$C.O.P = \frac{T_6 - T_5}{T_3 - T_4}$$

$$C.O.P = \frac{298 - 256.42}{431.6 - 366.7} = 0.64$$

$\cancel{C.O.P} = \frac{N}{W_c} = \frac{210 \times 2}{\cancel{\ }}$

Refrigerating effect, $N = 1 \times [\text{[illegible]}]$

$$= 1 \times [296 - 280.8]$$

$$N = 15.2$$

Work of Compression $W_c = c_p \times [T_2' - T_2]$

$$W_c = 162.2$$

$$C.O.P = \frac{N}{W} = \frac{15.2}{162.2} = \underline{\underline{0.092}}$$

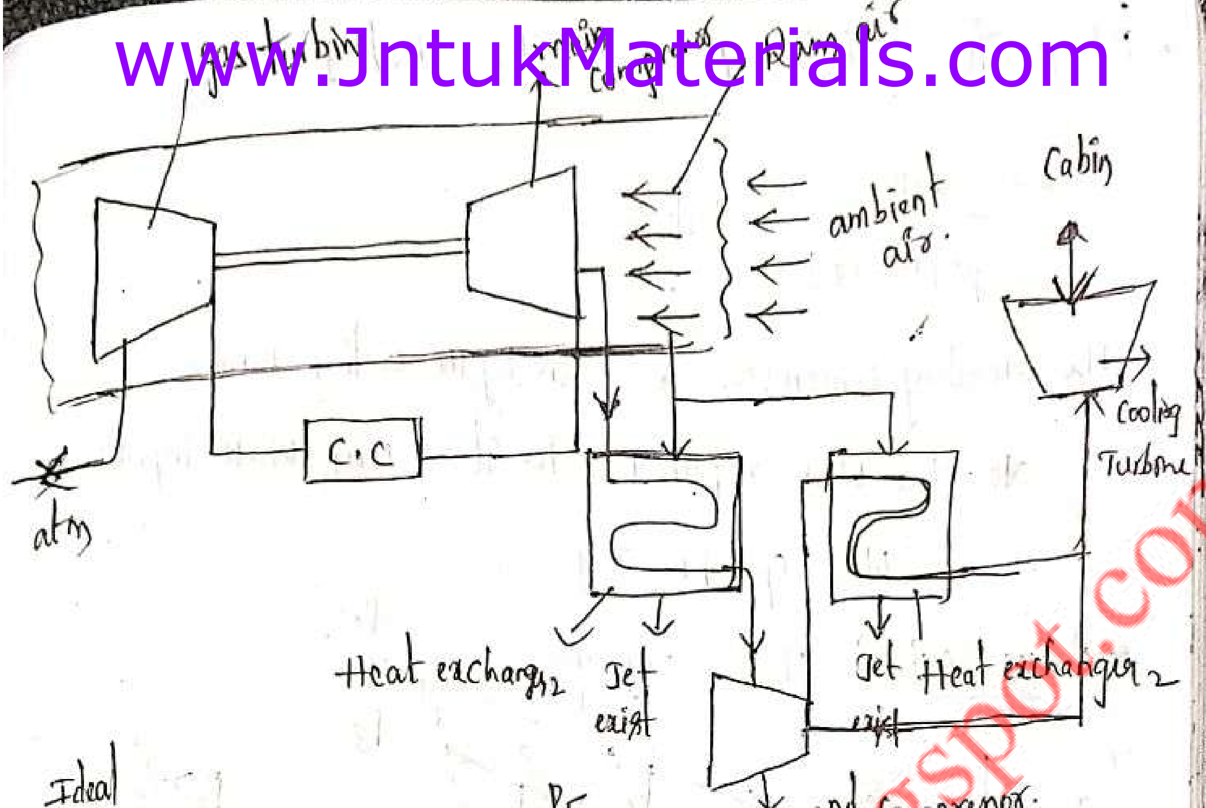
power $P = m_a \times c_p \times [T_2' - T_2] / 60$

$$= 746.12$$

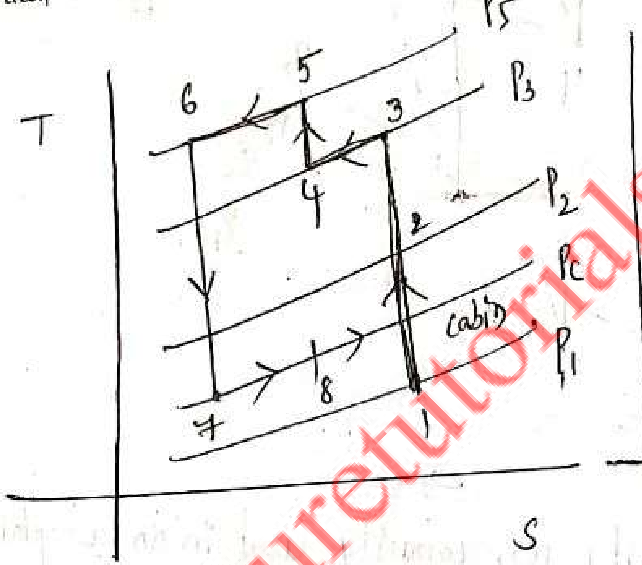
Boot strap air cooling system :-

Here two heat exchangers, and the pressure of the air is increased to higher level by using secondary compressor. ~~But~~ for two heat exchangers the ram air provides a coolant. The air bled from the main compressor is initially cooled in the first heat exchanger, further compressed in second compressor (turbo), Then the air is cooled further in the second heat exchanger, finally the expanded air pass through the cooling turbine and then passes into the cabin

→ Boot strap air cooling system widely used in Transport type air crafts



Ideal



1-2 → isentropic compression of ambient air due to ramming effect

2-3 → Isentropic compression of rammed air in the Main Compressor.

3-4 → Cooling of air in the first heat exchanger by rammed air

4-5 → Isentropic ~~expansion~~ Compression of air in the second compressor

5-6 → Cooling of air in the 2nd heat exchanger by ram air

6-7 → Isentropic expansion of cooling air in the cooling turbine.

After this expansion cooling air is supplied to the cabin

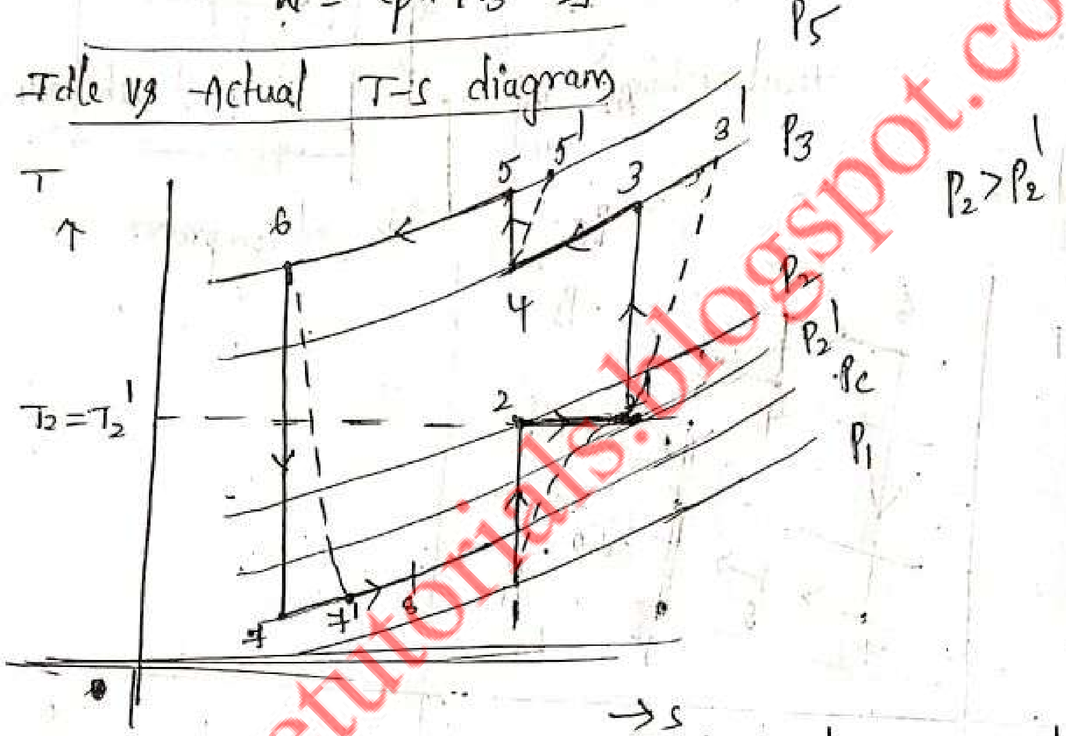
· Refrigeration effect $N = T_8 - T_7$ kJ/kg

$$m_a = \frac{210}{c_p \times [T_8 - T_7]} \text{ kg/min}$$

The Secondary compressor is driven by the cooling Turbine. Then work input
∴ No extra work required for it.

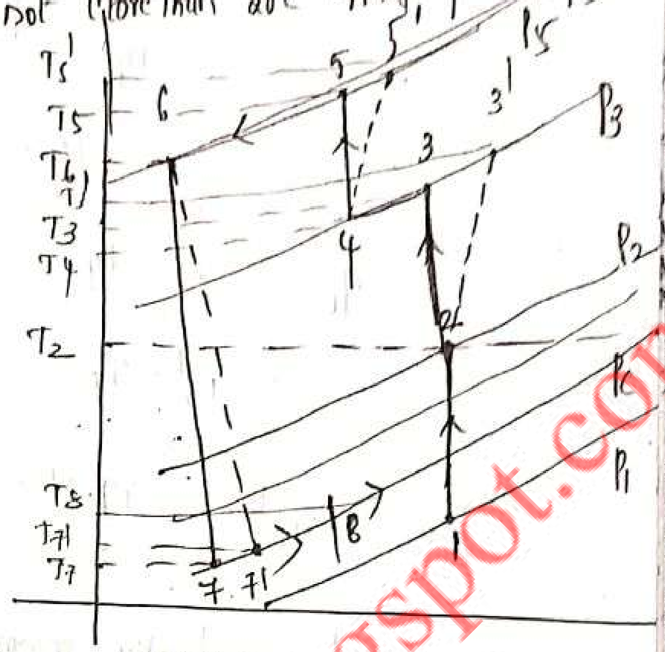
$$W = c_p \times [T_3 - T_2]$$

Idle vs Actual T-s diagram



Q) A boot strap cooling capacity 10Tr capacity used in an aeroplain the ambient air pressure and Temperature are 0.85 bar, 20°C the pressure of air increases from 0.85 to 1 bar due to ramming action of air the pressure of air discharged from the main compressor is 3 bar.

the discharge pressure of air from the auxilary compressor 4 bar The isentropic efficiency of each compressor is 80%, Turbine is 85% 50% of enthalaphy of air discharged from the Main compressor is removed in the first heat exchanger, 30% of enthalaphy of air discharged from the auxilary compressor is removed in the secondary heat exchanger using rammed air. Assume ramming action to be isentropic, they required cabin pressure of 1.01 bar, Temp of air leaving the cabin not more than 20°C find, power P, C.O.P of the system.



Sol

ramming process

Isentropic compression 1-2

$$\frac{T_2}{T_1} = \left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\boxed{T_2 = 306.8\,K}$$

Isentropic compression process 2-3

$$\frac{T_3}{T_2} = \left[\frac{P_3}{P_2}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\boxed{T_3 = 420\,K}$$

$$\eta_c = \frac{\text{Isentropic Temp raise}}{\text{Actual Temp raise}} = \frac{T_3 - T_2}{T_3' - T_2}$$

$$T_3' = 175.3\,^\circ C$$

$$\boxed{T_3' = 448.3\,K}$$

50% of enthalpy removed in the first heat exchanger

$$T_4 = 50/100 \times T_3'$$

$$= 0.5 \times 448.3$$

$$T_4 = 87.65\,^\circ C \Rightarrow 360.65\,K$$

Isentropic compression 4-5

$$\frac{T_5}{T_4} = \left|\frac{P_5}{P_4}\right|^{\frac{\gamma-1}{\gamma}}$$

$$T_5 = \underline{391\ K.}$$

$$\eta_c = \frac{T_5 - T_4}{T_5' - T_4}$$

$$T_5' = \underline{399.2K.}$$

30% of heat enthalaphy removed by second heat exchanger

$$T_6 = 0.7 \times T_5'$$

$$\boxed{\cancel{T_6 = 279.44}\ K} \quad \boxed{T_6 = 361.34\ K}$$

Isentropic expansion 6-7.

$$\frac{T_6}{T_7} = \left(\frac{P_6}{P_7}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_7 = 235.86\ K$$

$$\eta_T = \frac{\text{Actual Temp raise}}{\text{isentropic Temp raise}}$$

$$= \frac{T_6 - T_7'}{T_6 - T_7} \Rightarrow T_7' = 254.68K$$

→ Mass of air $m_a = \dfrac{\text{heat extracted per min}}{\text{heat extracted per kg}}$

$$= \frac{210 \times 10}{C_p \times [T_6 - T_7']}$$

$$m_a = 54.8 \text{ kg/min}$$

→ power $P = m_a \times C_p\,[T_3' - T_2] = W_c$

$$= 54.8 \times 1\,[448.3 - 306.8] = 7754.2 \text{ kJ/min}$$

$$P = \frac{7754.2}{60} \text{ kJ/sec}$$

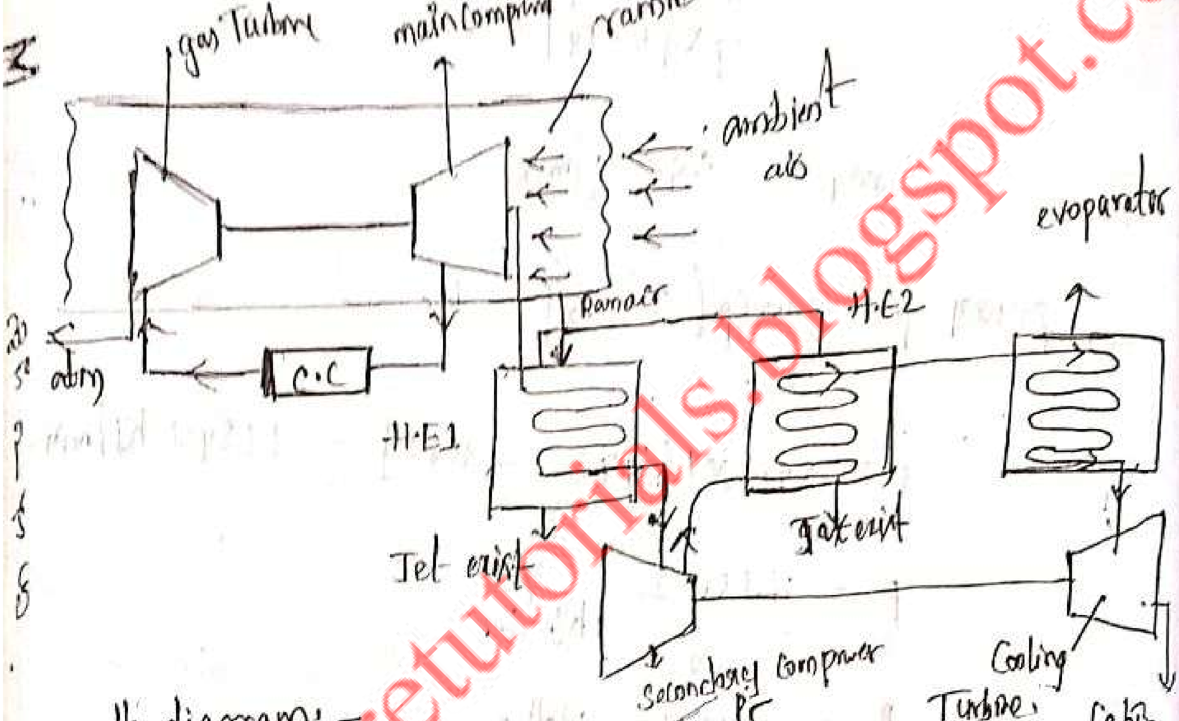
$$P = 129.23 \text{ Watts}$$

→ $C.O.P = \dfrac{N}{W_c}$

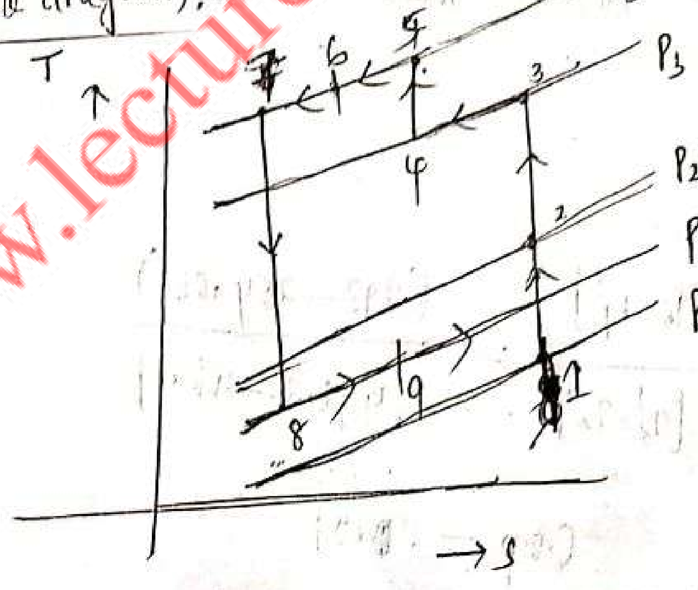
$$= \frac{\cancel{C_p}[T_6 - T_7']}{\cancel{C_p}[T_3' - T_2]} = \frac{(293 - 254.68)}{[448.3 - 306.8]}$$

$$C.O.P = 0.27$$

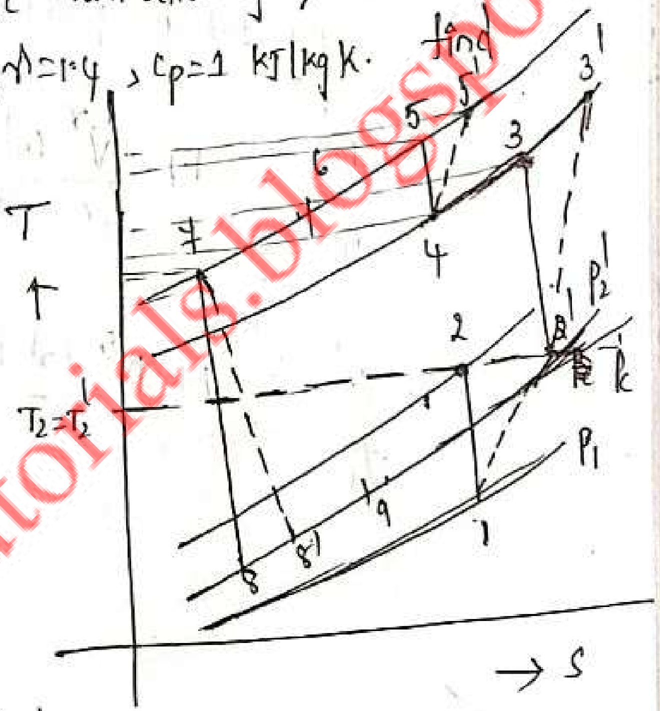
(d) ... air ... (it is similar to boot strap air cooling system additionally it provides evaporator b/w second heat exchanger and cooling turbine. The Temp of air leaving the cooling turbine is lower than the simple boot strap cooling system. Here Mass of air required for ton of refrigeration will be less.



Idle diagram:-



① A boot strap evaporative air refrigeration system is used for aeroplane to take 15 tons of refrigeration load of cabin, when it is moving with a Mach number is 1.3 $\left[M = \frac{V}{a}\right]$ the ambient conditions are $-10°C$ and 0.5 bar the pressure of air bleed from the main compressor is 4 bar (P_3) and is further compressed to 5 bar in the secondary compressor isentropic efficiency of main compressor 90%. secondary compressor 80%. isentropic efficiency of cooling turbine is 80%. the effectiveness of both heat exchanger is 0.4 The air is further cooled in the evaporator at 100°C ram efficiency is 90%. Cabin maintained at 25°C and 1 bar, $\gamma = 1.4$, $c_p = 1$ kJ/kg K. find m_a, C.O.P, power (P).



Sol: process 1-2

$$\frac{T_2}{T_1} = \left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = T_1 \left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = 263 \left[\frac{P_2}{0.5}\right]^{\frac{1.4-1}{1.4}}$$

Note – $\frac{T_2}{T_1} = 1 + \frac{V^2}{2000\, c_p T_1}$

where $T_2 = T_2'$, Then $c_p = \frac{\gamma R}{\gamma - 1}$ then

$$\frac{T_2'}{T_1} = \frac{V^2 \cdot [\gamma - 1]}{2000\, \gamma \times R T_1} \longrightarrow \text{(i)}$$

R = gas constant in J/kg K

If "R" is Joules/kg K Then Eqn (1) can be written as

$$\frac{T_2'}{T_1} = 1 + \frac{V^2 (\gamma-1)}{2\gamma R T_1} \longrightarrow (ii)$$

$$\sqrt{\gamma R T} = a$$

local sonic velocity at ambient condition Then $\gamma R T_1 = a^2$

By sub in eq (ii)

$$\frac{T_2'}{T_1} = 1 + \frac{V^2}{a^2}\frac{(\gamma-1)}{2}$$

$$\frac{T_2'}{T_1} = 1 + M^2 \frac{(\gamma-1)}{2}$$; where M - match Number

$$= \frac{\text{Aircraft velocity}}{\text{local sonic velocity}}$$

$$M = \frac{V}{a}$$

Then

$$\frac{T_2'}{T_1} = 1 + M^2 \left(\frac{\gamma-1}{2}\right)$$

$$T_2' = \left(1 + 1.3 \cdot \frac{(1.4-1)}{2}\right) 263$$

$$\boxed{T_2' = 351.89\ K}$$

$[\therefore T_2 = T_2']$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow P_2 = 1.385 \text{ bar}$$

$\eta_R = \frac{\text{Actual pressure raise}}{\text{Isentropic pressure raise}}$

$$\eta_R = \frac{P_2' - P_1}{P_2 - P_1} \Rightarrow P_2' = 1.296 \text{ bar}$$

process 2-3 $(2'-3)$

$$\frac{T_3}{T_2'} = \left[\frac{P_3}{P_2'}\right]^{\frac{\gamma-1}{\gamma}}$$

$$T_3 = 351.89\left[\frac{4}{1.296}\right]^{\frac{1.4-1}{1.4}} = 485.6\text{K}$$

Efficiency of Main Compressor

$$\eta_{c_1} = \frac{\text{Isentropic Temp raise}}{\text{Actual Temp raise}} = \frac{T_3 - T_2'}{T_3' - T_2'}$$

$$T_3' = 500.4\text{K}$$

Consider process $3'-4$ $[3-4]$

Effectiveness of 1st heat exchanger $\varepsilon_1 = \frac{T_3' - T_4}{T_3' - T_2'}$ $\quad 0.4$

$$T_4 = 441.04\text{ K}$$

Consider process 4-5

$$\frac{T_4}{T_5} = \left[\frac{P_4}{P_5}\right]^{\frac{\gamma-1}{\gamma}} \Rightarrow T_5 = 410.15\text{ K}.$$

Effeciency of second compressor

$$\eta_{c_2} = \frac{\text{Isentropic Temp raise}}{\text{Actual Temp raise}}$$

$$\eta_{c_2} = \frac{T_5 - T_4}{T_5' - T_4} \Rightarrow T_5' = 477.4\,K$$

process 5-6 [5'-6] :-

Effectiveness of second heat exchanger $\varepsilon_2 = \frac{T_5' - T_6}{T_5' - T_4}$

$$T_6 = 462.85\,K$$

process 7-8

$$\frac{T_7}{T_8} = \left[\frac{P_7}{P_8}\right]^{\frac{\gamma-1}{\gamma}}$$

$P_7 = 5,\ P_8 = 1$

$T_7 = 100°C$

$$T_8 = \frac{373}{\left[\frac{5}{1}\right]^{\frac{1.4-1}{1.4}}} = 235.5\,K$$

η of cooling Turbine $\eta_T = \frac{\text{Actual Temp raise}}{\text{Isentropic Temp raise}}$

$$\eta_T = \frac{T_7 - T_8'}{T_7 - T_8}$$

$$T_8' = -10°C = 263°K$$

→ Mass Flow rate $m_a = \frac{\text{heat extracted per min}}{\text{heat extracted per kg}}$ (or)

$$m_a = \frac{\text{heat extracted per min}}{\text{refrigeration effect per kg}}$$

$$m_a = \frac{210 \times 15}{1 \times [T_9 - T_8']} = \frac{210 \times 15}{1 \times [298 - 263]}$$

$$m_a = 90\ \text{kg/min}$$

→ power $p = W_c = \dot{m}_a \times c_p \times [T_3' - T_2'] / 60$

$$= \frac{1 \times 90 \times [500.4 - 351.89]}{60}$$

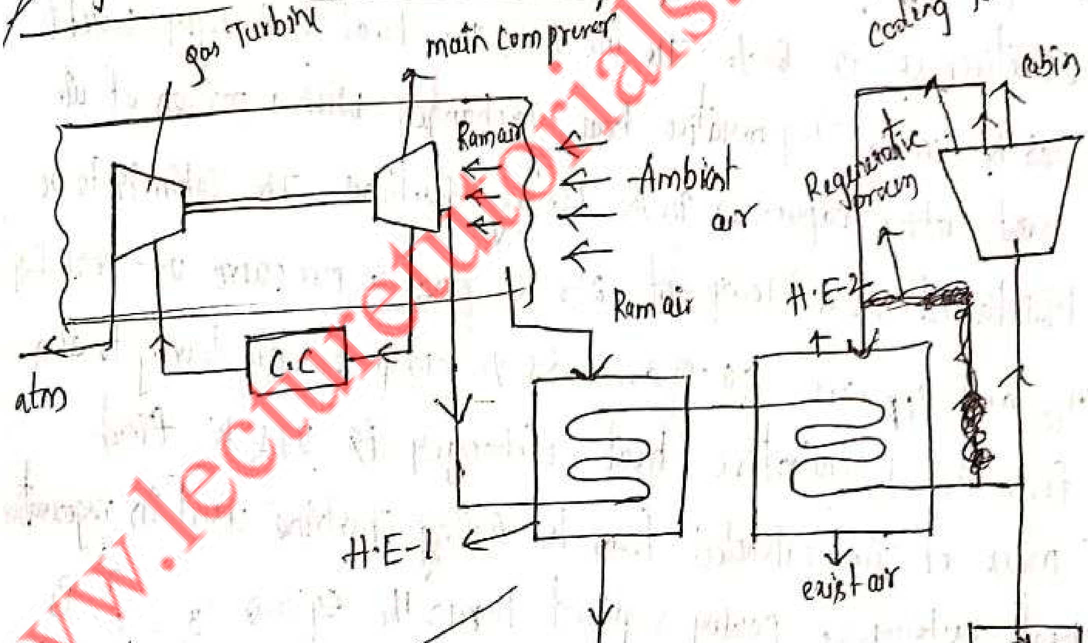
$$P = \underline{222.76 \text{ KW}}.$$

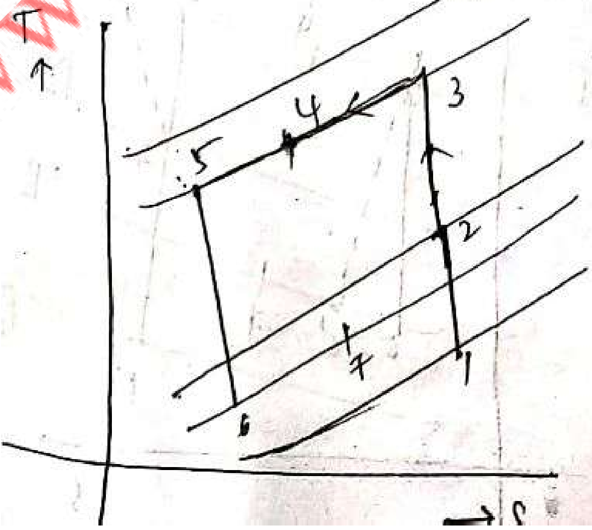
→ $C.O.P = \frac{N}{W_c} = \frac{c_p(T_4 - T_8')}{c_p \times (T_3' - T_2')}$

$$\boxed{C.O.P = 0.23}$$

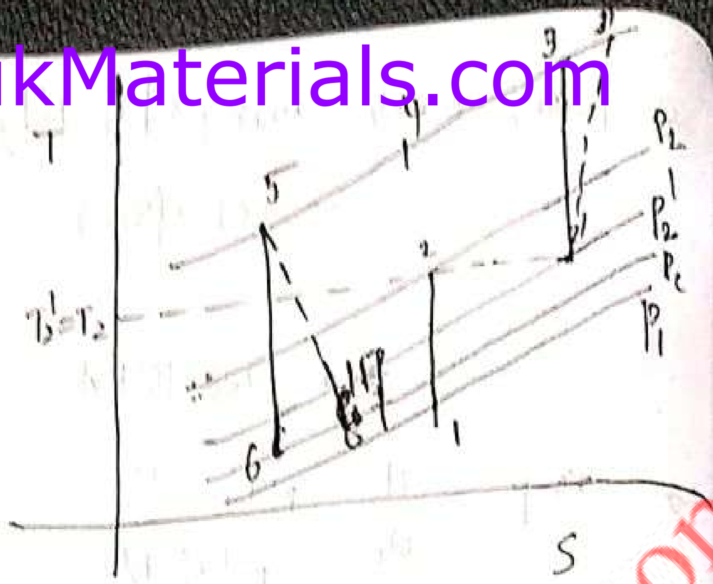
In refrigeration c.o.p is always less Than 1

Regenerative Air cooling System :-





(Ide vs Actual)



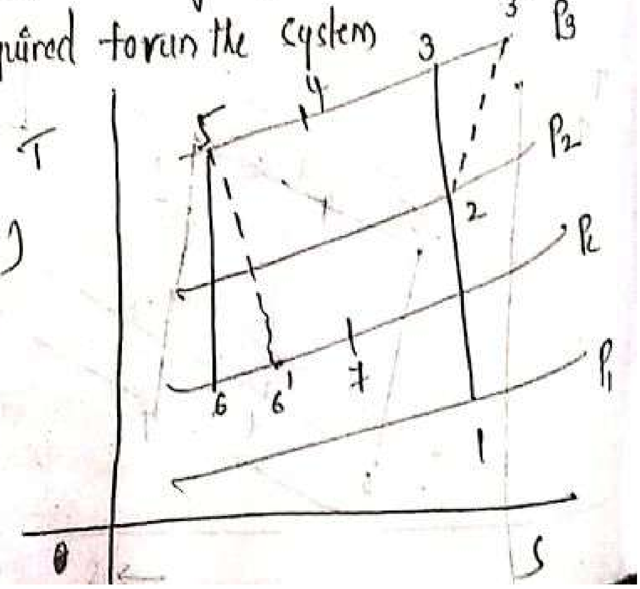
3) Q. A Regenerative cooling system is used for an aeroplain to take 15 tons of refregeration load $Cp[T_7 - T_6]$ The ambient pressure and Temp are 0.85 bar to 83 K is rammed isentropically to a pressure of 1.275 bar the air bled from Main compressor at 4.78 bar is cooled by ram air in the heat exchanger whose effectiveness is 60%. The air from the heat exchanger cooled to 335 K in the regenerative heat exchanger with a portion of air bled after expansion in the cooling Turbine The cabin is to be Maintained at a Temp of 298 K and a pressure of 1.06 bar η_c and η_T are 90% and 85%. Temp of air leaving to atm from the regenerative heat exchanger is 375 K find Mass of air extracted from the cooling Turbine used in regenerative heat exchanger, power required to run the system

Sol → Consider process 1-2

(Ram compressor process)

$$\frac{T_2}{T_1} = \left[\frac{P_2}{P_1}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\boxed{T_2 = 317.8\ K}$$



Compression process 2-3

$$\frac{T_3}{T_2} = \left[\frac{P_3}{P_2}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\boxed{T_3 = 463.67\ K}$$

$$\eta_c = \frac{\text{Isentropic Temp raise}}{\text{Actual Temp raise}} = \frac{T_3 - T_2}{T_3' - T_2}$$

$$\boxed{T_3' = 479.9\ K}$$

Cooling of air in the heat exchanger 3-4

$$\varepsilon_{pe} = \frac{T_3' - T_4}{T_3' - T_2}$$

$$\boxed{T_4 = 382.64\ K}$$

Consider isentropic expansion process 5-6

$$T_5 / T_6 = \left(\frac{P_5}{P_6}\right)^{\frac{\gamma-1}{\gamma}}$$

Given $T_5 = 335\ K$.

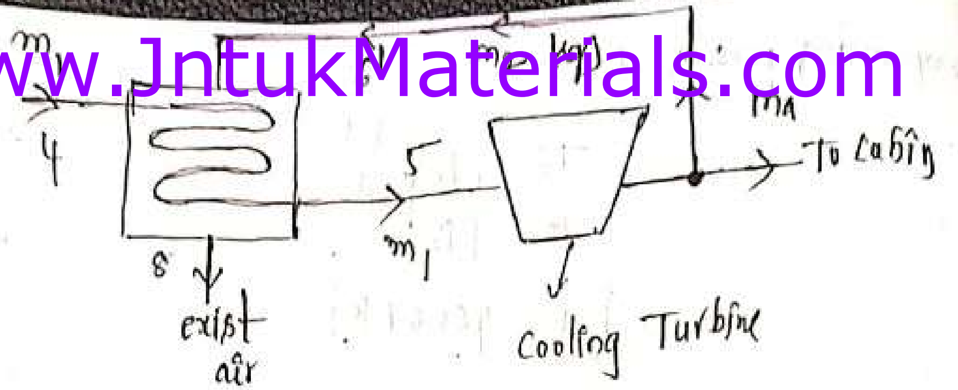
$$\boxed{T_6 = 217.8\ K}$$

$$\eta_T = \frac{\text{Actual raise in Temp}}{\text{Isentropic Temp raise}} = \frac{T_5 - T_6'}{T_5 - T_6}$$

$$\boxed{T_6' = 235.38\ K}$$

(i) Mass of air extracted from cooling Turbine for regenerative heat exchanger

$$m_a = \frac{\text{heat extracted per minitue}}{\text{heat extracted per kg}}$$



$$m_a = \frac{15 \times 210}{C_p(T_7 - T_6')}$$

$$\boxed{m_a = 50.03 \ kg/min}$$

Then $\rightarrow$ $m_a = m_1 - m_2 \longrightarrow$ (ii)

$\cancel{m_1 (T_4 - T_5)} = m_2 [T_8 - T_6']$

$$m_a = m_1 [T_4 - T_5] - m_2 [T_8 - T_6'] \longrightarrow (i)$$

$$m_a = 47.64 \ m_1 - m_2 \ 102$$

$$\boxed{m_1 = 93.95 \ kg/min} ; \boxed{m_2 = 43.15}$$

46.3

power required to run the system, Then $P = \frac{m_a \ C_p (T_3' - T_2)}{60}$

$$\Rightarrow \frac{m_1 \times C_p [T_3' - T_2]}{60}$$

$$\boxed{P = 206.13 \ W}$$

C.O.P of system $= \frac{N}{W}$

$210\ kJ/min = 3.5\ kW$

$C_p \cdot (T_3' - T_2)$

$$C.O.P = \frac{3.5 \times 15}{C_p [T_3' - T_2]}$$

$$\boxed{C.O.P = 0.32}$$

$$C.O.P = \frac{3.5 \times 15}{P}$$

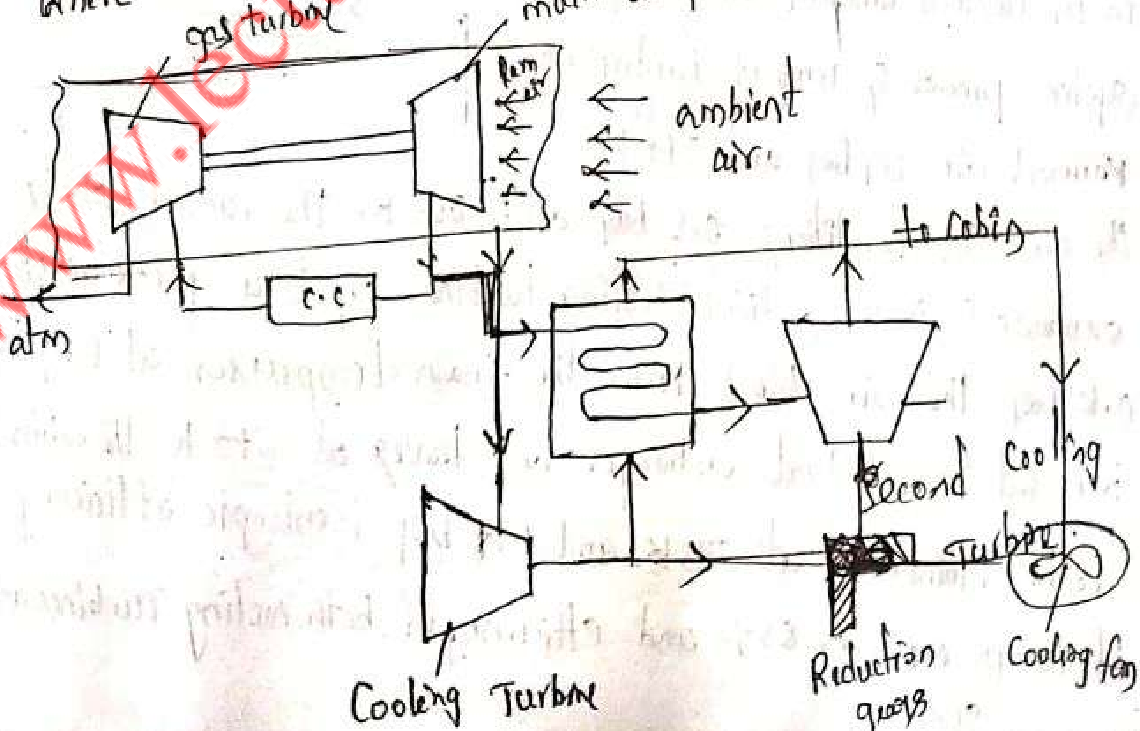
$$C.O.P = \frac{3.5 \times 15}{206.13}$$

$$\boxed{C.O.P = 0.25}$$

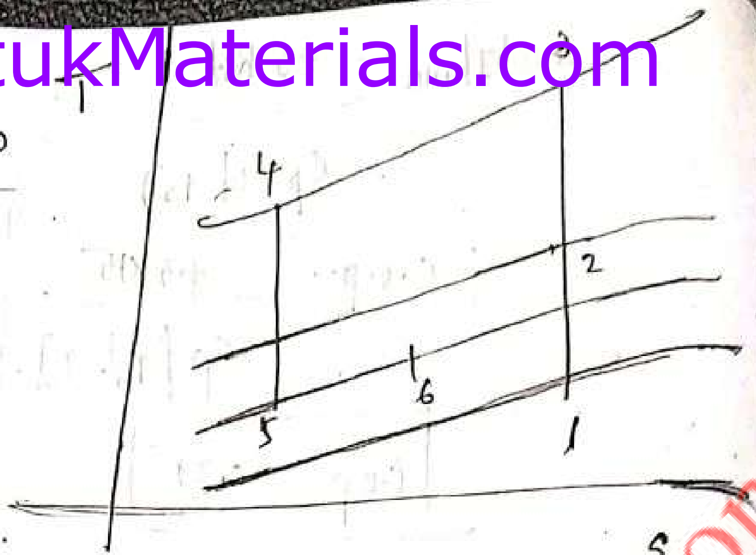
Reduced Ambient air cooling system :-

It is used for high speed applications. Where the ram air Temp is too high to act as a heat exchanger coolant. It consists two cooling turbine and 1 heat exchanger

At first air is Taken from the main compressor and is cooled in the heat exchanger, cooled air from the first cooling turbine is used as coolant for heat exchanger the air from the heat exchanger is expanded in the second cooling Turbine from the where air is supplied to cabin.



Idle T-s diagram



1-2 → isentropic raming of air

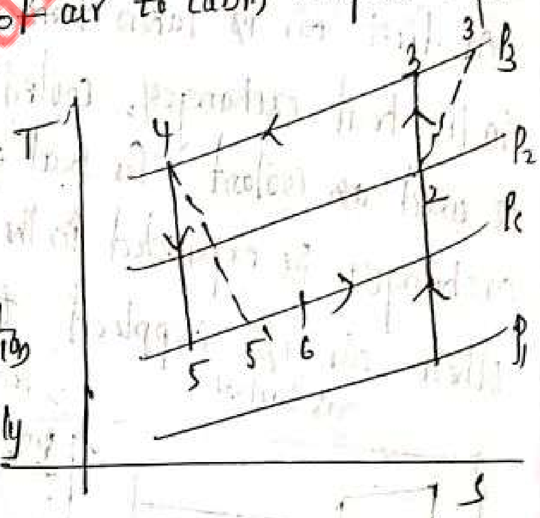
2-3 → Compression of air in the main Compressor

3-4 → Cooling of compressed air in the heat exchanger from 1st cooling Turbine

4-5 → Isentropic expansion of air in the 2nd cooling Turbine

6 → is the cabin condition,

5'-6 → represents the heating of air to cabin Temp at const. pressure.



① ~~In the~~ Idle vs Actual

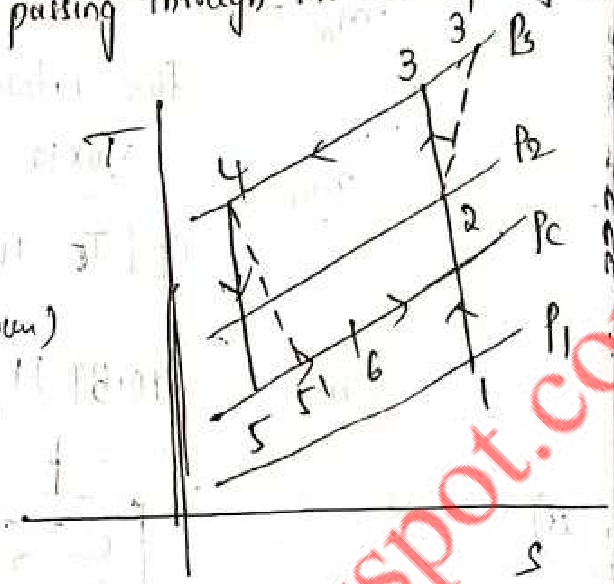
①.

In the reduced ambient air refrigeration system pressure & Temp of isentropically rammed air 1.9 bar and 370 K. the ambient conditions 0.8 bar and 283 K. the rammed air is expanded in the first cooling turbine up to a pressure of 0.8 bar the air bled from the main compressor at 5.89 bar is cooled in the heat exchanger and leaves at 373 K the cabin is to be maintained at 295 K and 1.19 bar isentropic efficiency of compressor is 85% and efficiency of both cooling Turbines are 80%.

(i) Mass flowrate of air to take load of 12 ton of refrigeration.

(ii) Mass flowrate of ram air passing through the heat exchanger if its Temp is 90 k.

(iii) c.o.p of system.



sol process 2-3 (compression process)

$$\frac{T_3}{T_2} = \left[\frac{P_3}{P_2}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\boxed{T_3 = 511.3\,K.}$$

$$\eta_c = \frac{\text{Isentropic Temp raise}}{\text{Actual Temp raise}} = \frac{T_3 - T_2}{T_3' - T_2}$$

$$T_3' = 536.2\,K.$$

Isentropic expansion (4-5) in second cooling Turbine

$$\frac{T_4}{T_5} = \left[\frac{P_4}{P_5}\right]^{\frac{\gamma-1}{\gamma}}$$

$$\frac{T_4}{T_5} = \left[\frac{5.89}{0.8}\right]^{\frac{1.4-1}{1.4}} \qquad \therefore T_4 = 373$$

$$T_5 = 230.85\,K.$$

$$\eta_T = \frac{\text{Actual Temp raise}}{\text{Isentropic Temp raise}} = \frac{T_4 - T_5'}{T_4 - T_5}$$

$$\boxed{T_5' = 259.2\,k}$$

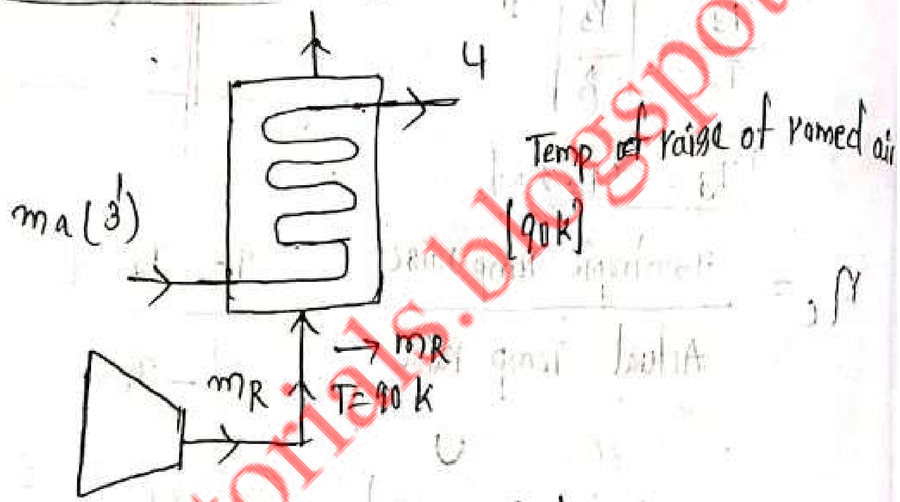
(i) Mass flow rate of air supplied to the cabin

$$m_a = \frac{\text{Heat extracted per minute}}{\text{Heat extracted per kg}}$$

$$m_a = \frac{210 \times 12}{c_p [T_6 - T_5']}$$

$$\boxed{m_a = 70.39 \text{ kg/min.}}$$

(ii)



$$m_R \cdot c_p \cdot [dT] = m_a \cdot c_p [T_3' - T_4]$$

$$m_a \cdot c_p [T_3' - T_4] \Rightarrow$$

$$m_R = \frac{70.39 \times 1 \cdot [536.2 - 373]}{1 \times 90}$$

$$\boxed{m_R = 127.64 \text{ kg/min}}$$

$$\text{c.o.p of system} = \frac{N}{W} = \frac{\text{refrigeration effect}}{\text{Work of compression per kg}}$$

$$= \frac{c_p [T_6 - T_5]}{c_p [T_3' - T_4]} = \frac{283 - 230.85}{536.2 - 370}$$

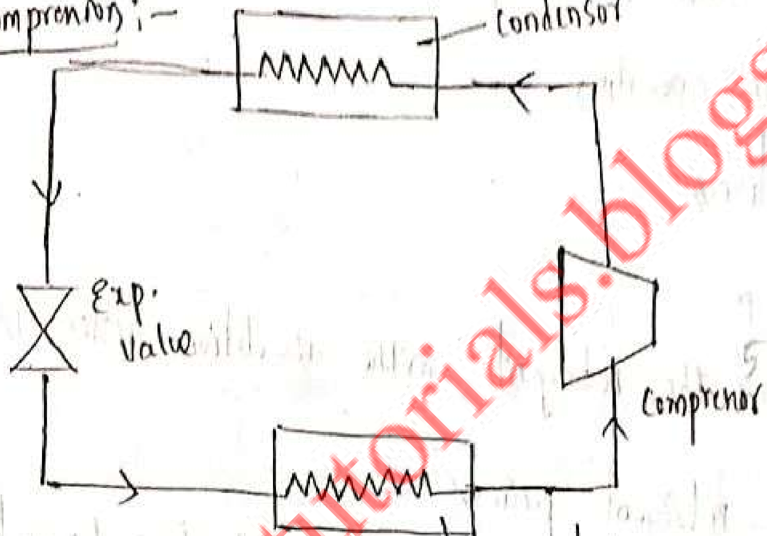
c.o.p = 0.31

"Vapour Absorbtion Refrigeration System"

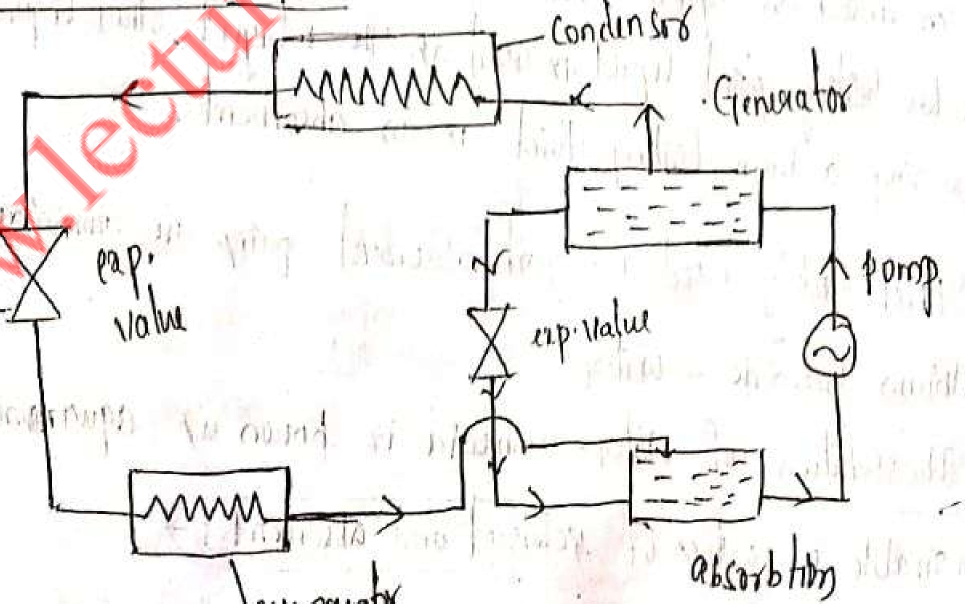
low pressure vapour from the evaporator transfer into high pressure vapour and delivered to the condensor. This task achieved by absorbtion system with the assembly of absorbtion pump and generated.

In compression system this task achieved by compressor in absorption system compressor is replaced by an absorber pump and generator.

vapour compression :-



Vapour obsorbtion system :-



Advantages :-

→ Less wear and tear because of minimum moving parts to

→ Low operating and maintaince cost

→ performance is not effected by the variation of load

→ used in where electric power is expensive, it is usually designed for steam and solar energy

→ unit capacity of refrigeration above 1000 tons for a cylinder compressor unit. [in comparison]

→ quite in operation

Limitations :-

→ Low C.O.P

→ charging of the refrigent in the absorbtion system is difficult.

Absorbent - refrigent pairs :-

In absorbtion system two fluids are used for refrigeration effect, the low boiling point liquid is used as the refrigent. other liquid possesing a high boiling point as an absorbent.

Most widely used refrigent-absorbent pairs are ammonia-water, lithium bromide - water

The solution of water-ammonia is known as aquammonia

desirable properties of refrigent and absorbent :-

Refrigent -

low boiling point

from and at 0°c or below and condensate at 40°c or above

→ High critical pressure and Temp.

→ Low specific heat

→ Low molecular weight

→ Chemical and Thermal stability

→ High enthalpy of vapourization

Absorbent –

→ High boiling point

→ low viscosity

→ low specific heat

→ low molecular weight

→ Chemical and Thermal stability

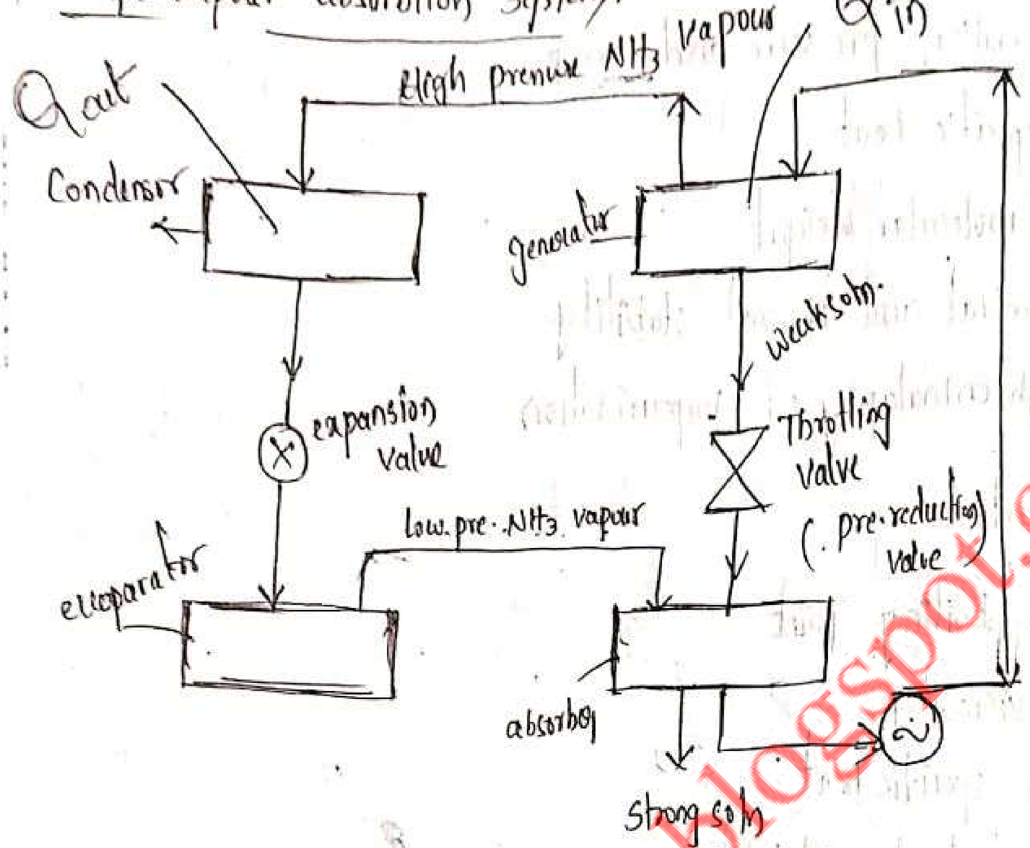
→ Ammonia-water pair widely used in domestic refrigerator and in industrial units because

1) Ammonia is high ~~solu~~ soluble with water, 1 cum (cubic meter) absorbs 800 cum of ammonia

2) The weight of the solution decreases, as more ammonia is added.

The only disadvantage is, it generates more heat in the absorber which requires to provide cooling and also special materials are used to prevent corrosion

Simple vapour absorption system



low pressure ammonia vapour from evoparator Enter into the absorber and gets dissolved in the water which reduce the pressure further, draws ~~the~~ More ammonia from the evoparator.

Heat from the strong solution [rich NH_3], in absorber ~~heat~~ is removed by water as cooling media.

The pumps draws the strong solution from the absorber and sends into the generator. Heat energy supplied to the generator where ammonia gets evoparated due to low boiling point. The ammonia vapour enters into the Condensor where it is Condensed into liquid.

The weak solution [solution with small amount of NH_3], from the generator returns back to the absorber via pressure reducing valve.

High pressure liquid ammonia is passed through an expansion value to reduce the pressure. at low pressure liquid ammonia enter the evoparator where it absorb its latent heat thust produces refrigerating effect.

C.O.P of The Idle absorbtion cycle:-

$$C.O.P = \frac{\text{Net refrigerating effect}}{\text{Total energy supplied}} \text{ (or) } \frac{\text{heat absorbed in the evoparator}}{\text{heat supplied in the generator}}$$

Q_e = heat absorbed by refrigent in the evoparator at Temp. T_e

Q_c = heat rejected from the refrigerent in the condensor at Temp T_c

Q_g = heat supplied to the refrigerent in the generator at Temp T_g

by neglecting losses and pump work.

the Energy eqn. can be written as $\boxed{Q_c = Q_g + Q_e} \longrightarrow (i)$.

$$\frac{Q_g}{T_g} + \frac{Q_e}{T_e} = \frac{Q_c}{T_c} \longrightarrow (ii).$$

For reversible cycle by combining (i) & (ii)

$$\frac{Q_g}{T_g} + \frac{Q_e}{T_e} = \frac{Q_g}{T_c} + \frac{Q_e}{T_c}$$

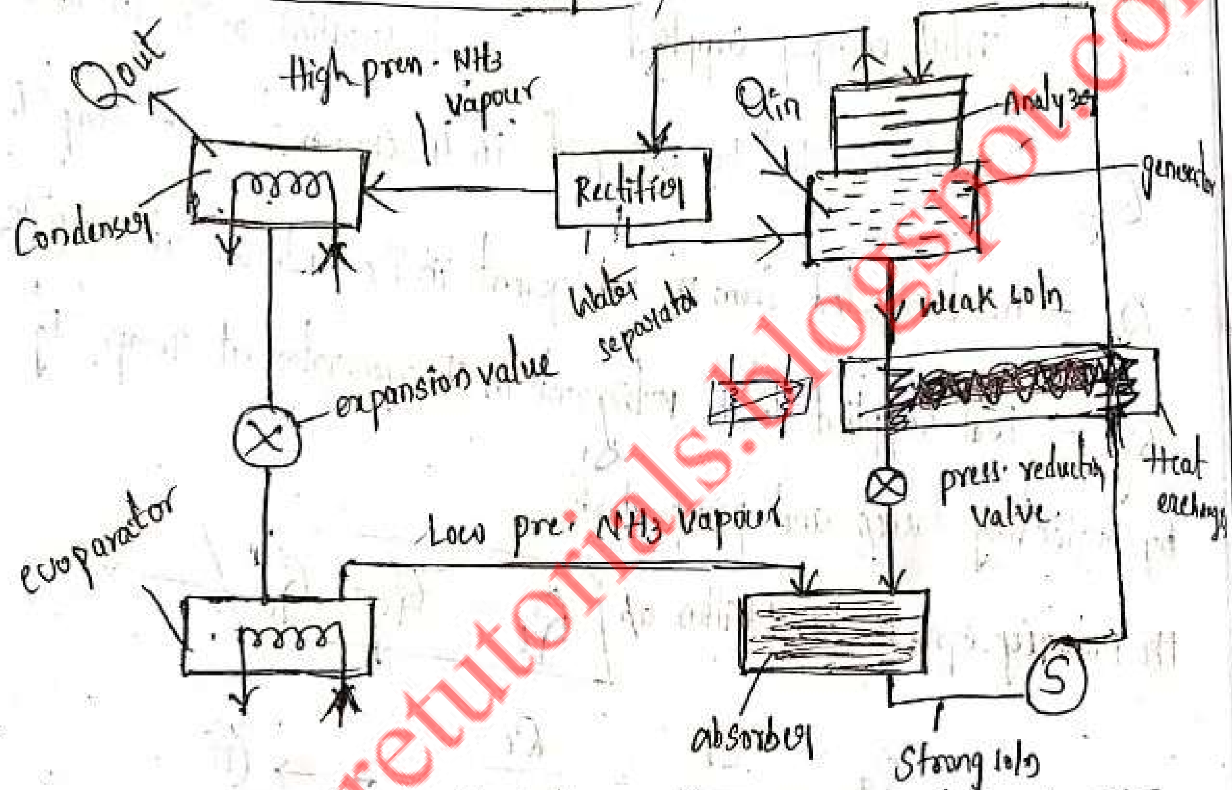
$$\frac{Q_e}{T_e} - \frac{Q_e}{T_c} = \frac{Q_g}{T_c} - \frac{Q_g}{T_g}$$

$$Q_e\left[\frac{T_c - T_e}{T_c \cdot T_e}\right] = Q_g\left[\frac{T_g - T_c}{T_g T_c}\right]$$

$$\frac{Q_e}{Q_g} = \left[\frac{T_C \cdot T_E}{T_C \cdot T_E}\right]\left[\frac{T_g - T_C}{T_g - T_C}\right]$$

$$\boxed{\frac{Q_e}{Q_g} = \frac{T_g}{T_e}\left[\frac{T_c - T_e}{T_g - T_c}\right]}$$ for Maxi. COP

Actual vapour absorbtion system:-



→ Analyser :- it consists of no. of Trays mounted above the generator strong soln from the absorber are introduce over the trace into the generator. in generator heat is added to the system by external force. vapour raising from the generator is cooled by strong solution in analyzer and Most of water vapour condenses, Then only ammonia vapour leaves the Top of analyser [The analyser remove the unwanted water particles associated with ammonia vapour going to the condensor

→ Rectifier — It is a closed type cooler located b/w analyser and cooler its main purpose is to cool the vapour leaving the analyser, so that remaining water vapour is condensed leaving only dry ammonia vapour to flow into the condensor rectifier is generally water cooled with double pipe designed, very effective for cooling commonly shell and coil type or shell and tube type rectifiers are used. the cooled water then sends into the generator

Comparision b/w compression and absorbtion system

→ vapour absorbtion systems are less perfect thermodynamically than vapour compression system. but they are reliable in service and are cheaper to manufacture. They are widely used for domestic refrigerators

Absorbtion	Compression
→ only pump is moving part operation is ~~not~~ quite little wear	→ Moving parts are more luxury noisey and wear and tear also more.
→ Heat energy supplied	→ Mechanical energy is supplied
→ cop is low	→ cop is High
→ Not effected by variation of load	→ performance is ~~more~~ poor at partial loads
→ less leakage	→ More leakage
→ charging of refrigerent is difficult	→ charging of refrigerent is simple

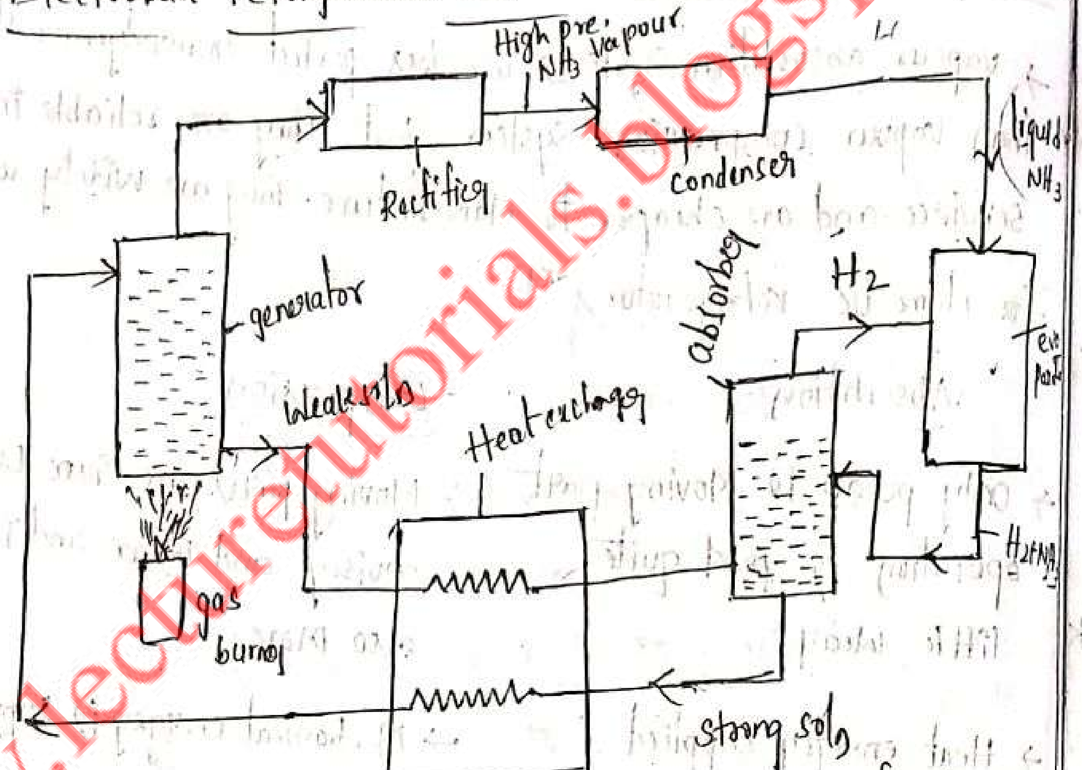
→ simple design → complicated design

→ Smaller condenser → larger condensor

→ over 1000 tons of capacity → with single compressor is not possible.

→ liquid refrigerant leading the evaporator not affect the system → liquid refrigerant leading the evoparator may damage the compressor.

Electrolux refrigerator (or) 3-fluid refrigerator



→ It is domestic type refrigerator is also called as 3 fluid absorbtion system the main purpose of the system is to eliminate the pump to avoid the moving parts

It is toxic, due to absence of moving parts there is a little leakage in the system the hydrogen is the light gas used to increase the rate of evoparation of liquid ammonia passing through the evoparator The hydrogen is non corrosive and insoluble in water hydrogen is used in the low pressure side of the system. Water is used as solvent, it absorbs ammonia readily

Hydrogen gas fed into the evaporator which permits liquid ammonia to evaporate at low pressure and Temperature. According Dalton's principle. During the process of evaporation the ammonia absorbs latent heat from the refrigerated space and that produces cooling effect.

The Mixture of ammonia vapour and hydrogen passed to absorber where ammonia is absorbed in water while light weight of hydrogen gas raises to the top and flows back to the evaporator.

$$cop = \frac{\text{Heat absorbed in the evaporator}}{\text{Heat supplied in the generator}}$$

→ cop is low only for domestic purpose not for industrial purpose

dalton's law $pV = P_A + P_B$

P_b - Barometric pressure

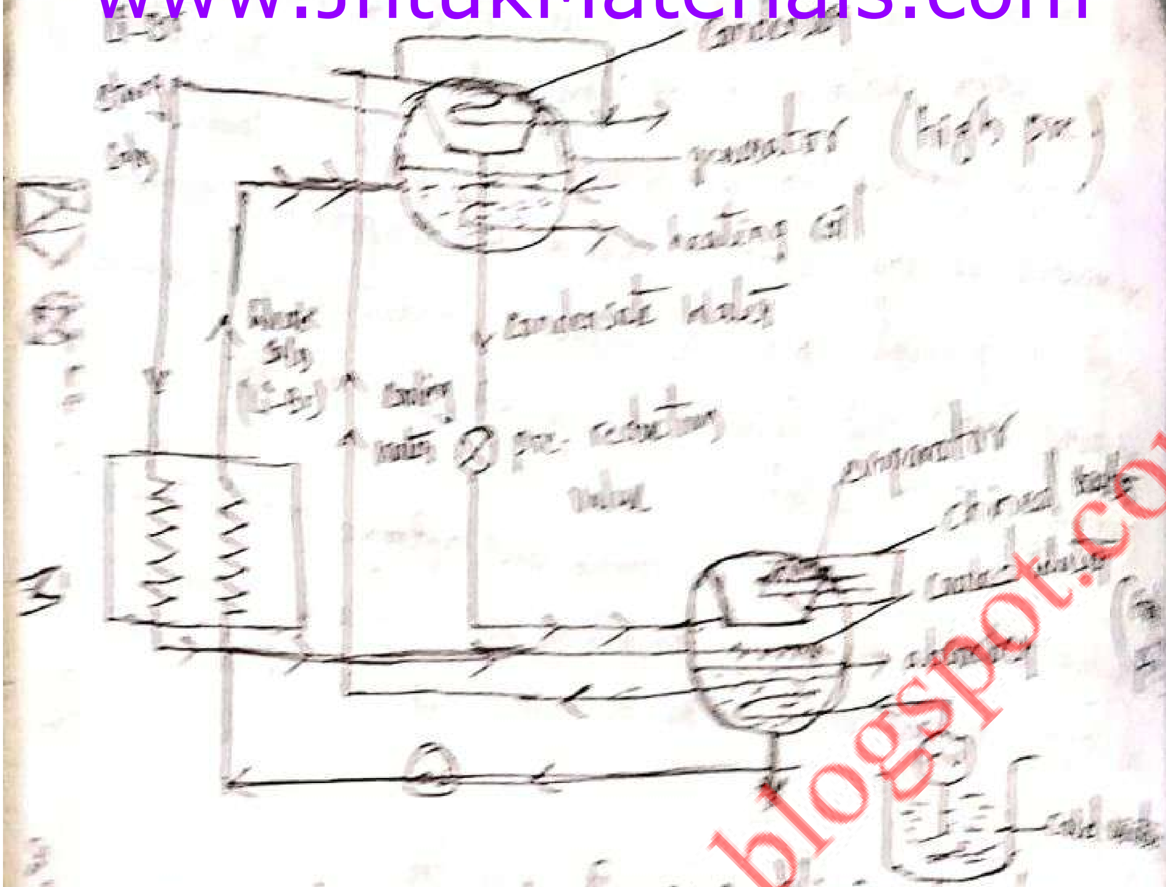
P_a = partial pre. of dry air

P_b - partial " of water vapour

Lithium Bromide absorbtion refrigeration system :-

→ Li-Br absorbtion system uses a solution of lithium bromide in water ~~water~~ is used as a refrigerent, Li-Br which is a highly hydroscopic salt as an absorbent.

→ Li-Br solution has a strong affinity for water vapour because of its very low ~~very~~ vapour pressure. Li-Br solution has corrosive inhebitor is added to avoid the corrosion problem



→ These system is popular for air conditioning for low refrigeration temp not below than 1°C

→ pr. inside the evaporator is maintain at very low for refrigerant water evaporating. The water vapour absorbed by strong Li-Br solution which is sprayed in the absorber.

→ In absorbing the water vapour Li-Br solution maintaining very low pressure in the evaporator, and the soln becomes weak.

→ This weak soln pumped to the generator where it is heated by using steam or hot water in the heating coil

→ A portion of water is evaporated by the heat and soln now becomes more strong. This strong soln is passed to heat exchanger and then sprayed in the absorber

→ The weak soln of Li-Br from the absorber to the generator is also passed to the heat exchanger

→ These weak solution gets heat from the strong solution of H.E, Thus reducing the quantity of steam required to heat the weak solution in the generator.

→ Thus refrigerant water vapour formed in the generator due to heating of soln. are passed to the condenser where they are cooled ~~passed~~ and condensed by the cooling water following through the condensed water tubes.

→ The cooling water for condensing is pumped from the tower or cooling pump these cooling water first enter the absorber where it takes away the heat of condensation and dilution.

→ the condensate from the condenser is supplied to the evaporator to compensate the water vapour formed in the evaporater.

→ The pre. reduction value reduces the pre. of condensate to the evaporate evaporator pre. the cooled water from the evaporator is pumped and sprayed in the evaparater inorder to cool the water for air conditioning flowing through the chilled tubes this complete the cycle.

① Following Li-Br + H_2O absorption generator Temp = 80°c, condenser Temp = absorber Temp = 30°c, evaporator Temp = 10°c, Condensate Temp = 25°c, steam enter The generator at 120°c (Dry saturated, x = 1) steam] and leaves at 100°c as Condensate.

Concentration of liquid leaving the generator is 0.65 and its enthalpy is -75 kJ/kg concentration of liquid leaving the absorber is 0.51 and its enthalpy is -170 kJ/kg enthalpy of vapour leaving the generator is 2620 kJ/kg flow rate Through evaporator is 0.4 kg/sec. determine

(a) pre. in generator in generator, Condensor, evaporator, absorber

(b) Tonnage in mm of Hg

(c) Heat rejected to Condenser & absorber

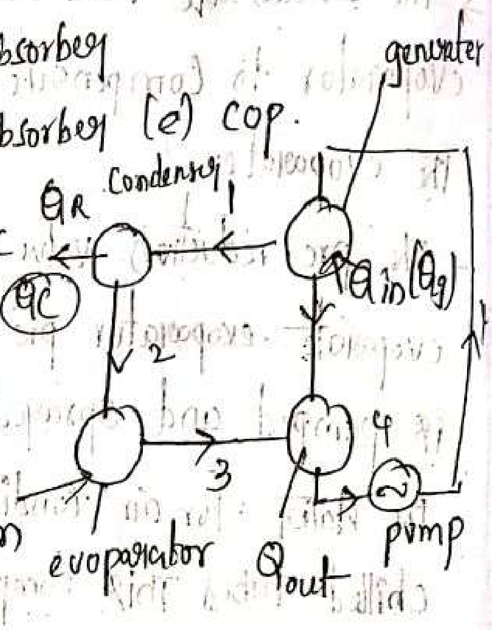
(d) rate of Mass leaving the absorber (e) cop.

Given → $T_g = 80°c$, $T_c = T_A = 30°c$

$T_E = 10°c$

Condensate Temp = 25°c

$m_1 = m_2 = m_3 = 0.4$ kg/sec



(a) P_g at 80°c ⇒ 0.4736 bar

$$= \frac{0.4736}{1.013 \times 760} = 355.3 \text{ mm of Hg}$$

P_c at 30°c ⇒ 0.04242 bar

$$= \frac{0.04242}{1.013 \times 760} = 31.82 \text{ mm of Hg}$$

P_E at T_c = 0.1227 bar

$$= \frac{0.1227}{1.013 \times 760} = 9.3 \text{ mm of Hg}$$

P_a at 30°C = 31.82 mm of Hg

(b) cooling capacity (or) Tonnage

at 10°C, $h_3 = 2519.9$ KJ/kg

at 25°C (condensate) $h_{f_2} = 104.8$ KJ/Kg

$m_1 = m_2 = 0.4$ Kg/sec.

cooling capacity $= m \cdot \Delta h = m(h_3 - h_{f_2})$

$$= 0.4 [2519.9 - 104.8]$$

$$= 966.04 \text{ KJ/sec}$$

$$= \frac{966.04}{3.5} = 276.01 \text{ Tonnes}$$

(c) Heat rejected from Condenser and absorber

Heat rejected from Condenser $\quad Q_c = m_2 \times (h_1 - h_{f_2})$

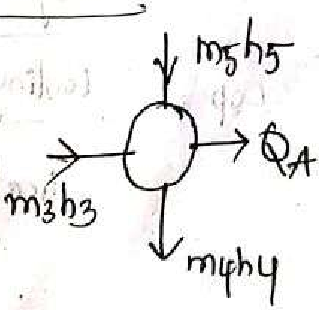
$T_g = 88°C$, $h_1 = 2643.8$

$T_c = 25°C$ $\quad h_{f_2} = 104.8$

$$Q_c = 0.4 [2643.8 - 104.8]$$

$$Q_c = 1006.08 \text{ KJ/sec}$$

Absorber analysis



$$m_3h_3 + m_5h_5 = Q_A + m_4h_4$$

$$m_3 + m_5 = m_4 \rightarrow (i)$$

Balance of Li-Br soln in absorber

$$x_4 m_4 = x_5 m_5$$

Then $m_4 = \dfrac{x_5 m_5}{x_4}$

$$m_4 = \frac{0.65\, m_5}{0.51} = 1.27\, m_5$$

Sub This eqn (P)

$$0.4 + m_5 = 1.29\, m_5$$

$$0.4 + m_5 - 1.29\, m_5 = 0$$

$$m_5 [1 - 1.29] + 0.4 = 0$$

$$\underline{m_5 = 1.48 \text{ kg/sec}}$$

$$m_3 + m_5 = m_4$$

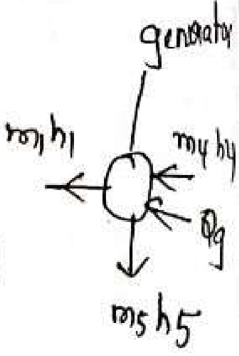
$$0.4 + 1.48 = m_4$$

$$\boxed{m_4 = 1.88 \text{ kg/sec}}$$

$$0.4 [2519.9] + 1.48 [-75] = Q_A + (1.18)[-170]$$

$$\underline{Q_A = 1214.78 \text{ kJ/sec}}$$

(e) COP Consider energy balance for generator



$$m_1 h_1 + m_5 h_5 = m_4 h_4 + Q_g$$

$$0.4 [2643.8] + 1.48 [-75] - 1.88 [-170] = Q_g$$

$$\underline{Q_g = 1254.4 \text{ kJ/sec}}$$

$$COP = \frac{\text{Cooling capacity}}{\text{heat supplied}} = \frac{966.04}{1254.4}$$

$$COP = 0.77$$

Steam Jet Refrigeration System:-

In this system water is used as refrigerant freezing point of the water is 0°c system to be maintained at 5°c. The main application of the system is for water coolers and air conditioning systems

advantages :-

→ Flexible

→ can be adjusted easily for load variations

→ No moving parts except pump

→ cause of this free from vibrations

→ Reliable and life is long

water as a refrigerent, so safe and economical

Low maintain cost

Disadvantages :-

→ Not suitable for below 4°c

→ Generation of high pressure steam is costly

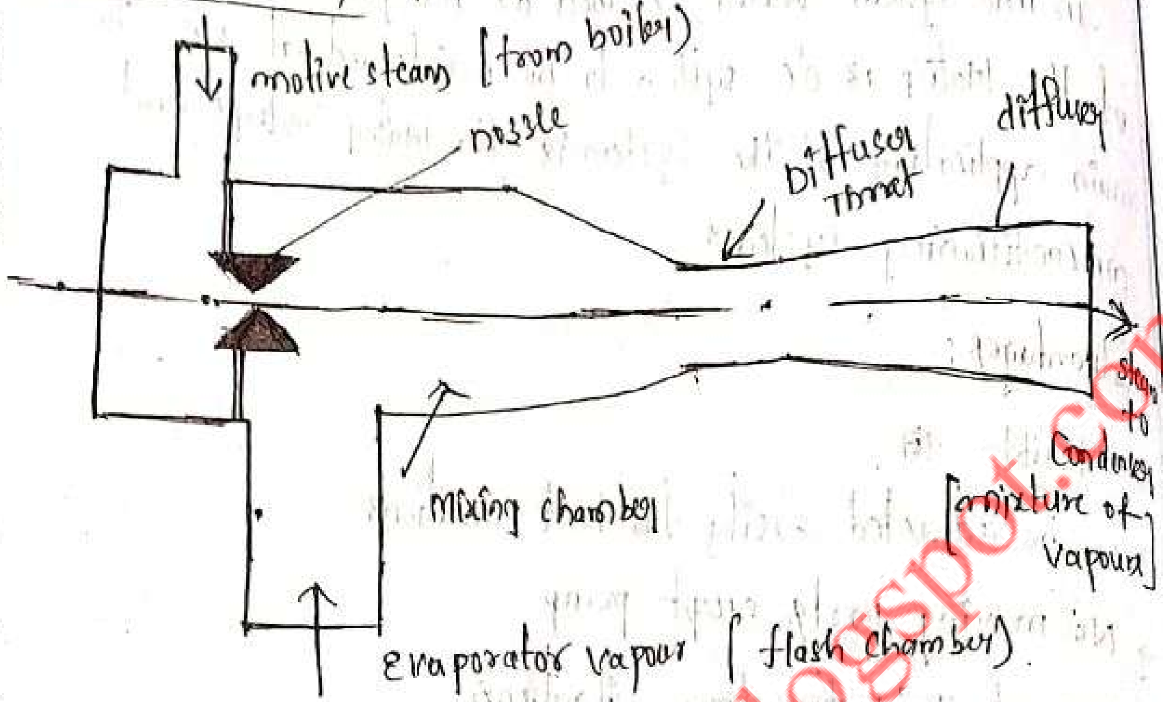
→ large volume of vapour is required to produced chilled water by direct evaporation

→ cop is low in b/w 0.4 to 0.6

Applications :-

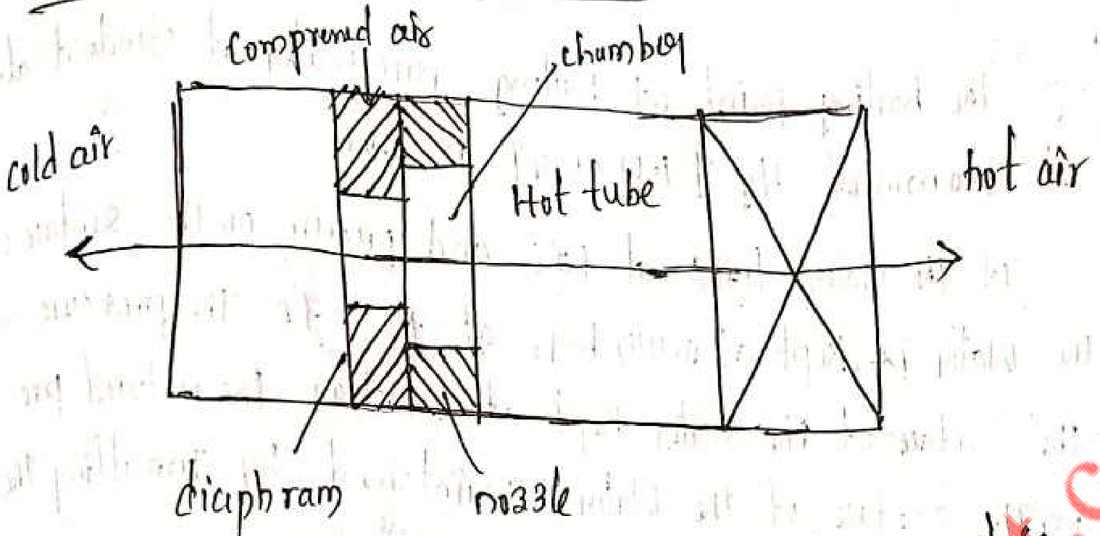
widely used in industrial plants where high pressure steam and large cooling water for condensers are available Generally in coolers, A.C [air conditioners], food processing plant in paper only ...

Steam ejector :-



It is also called steam jet compressor high pressure steam from boiler expands to convergent - divergent nozzle to low pressure and attains high velocity in the range of 1350 m/sec the high velocity steam entrained with water vapour from flash chamber and both are mixed in mixing chamber at constant pressure after mixing, the steam attains supersonic velocity and then it is diffused in the duty at the throat of the diffuser super sonic steam gets normal stock, which results in the raise of pressure and the flow is subsonic flow. Then it flows through the diffuser where the velocity is reduced inorder to produce High pressure. the steam finally use the ejector slightly above the condenser pressure.

Vortex-Tube refrigeration System

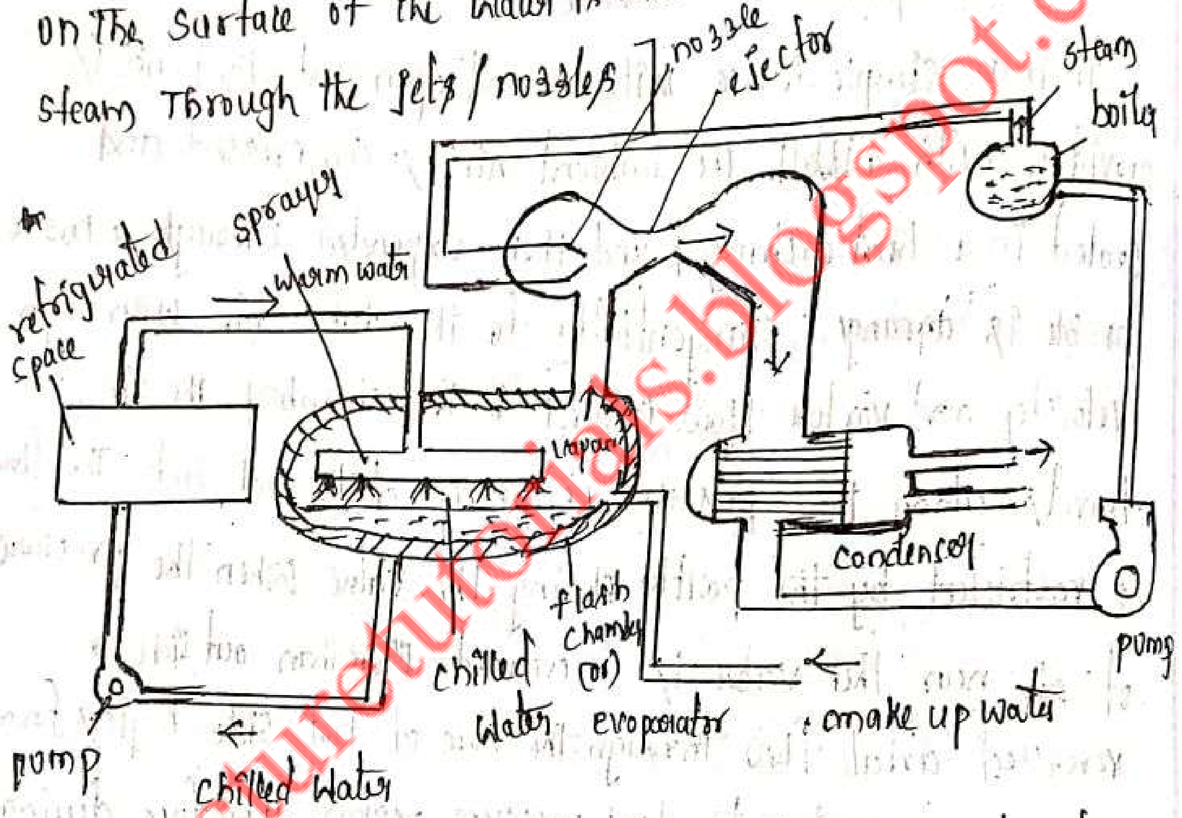


It is a simple device with one end open and other end is provided with a wall the ambient air is compressed and cooled in a heat exchanger and then expanded through a nozzle, nozzle is arranged Tangentially to the tube air with high velocity and vortex flow created in the chamber The air travels along the ~~pressure~~ periphery of the hot side the flow is restricted by the partly closing the valve when the pressure of air near the valve is increased more than out side. a reversed axial flow Through the core of hot side begins from High pressure region to Low pressure region Therefore during this process energy Transfer from reversed stream to forward stream Takes place. The air stream ~~pour~~ to the core gets cooled while the air stream in forward direction gets heated the cold stream flow through the ~~dia from the whole~~ diaphram Into the cold side, while hot steam is escaped Through the opening of the valve

"Working of steam jet refrigerator system:-

→ The boiling point of cooling pure water at standard atm of 760 mm of Hg [1.013 bar] is 100°c

If the water boils at 12°c and pressure on the surface of the water is kept at 0.014 bar, at 7°c the pressure on the surface of the water kept at 0.01 bar the reduced pre. on the surface of the water is maintained by throatling the steam through the jets / nozzles



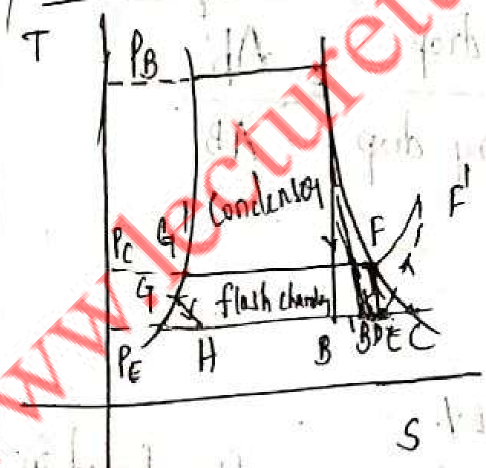
→ The main components are flash chamber, steam nozzle, steam - ejector, and condenser

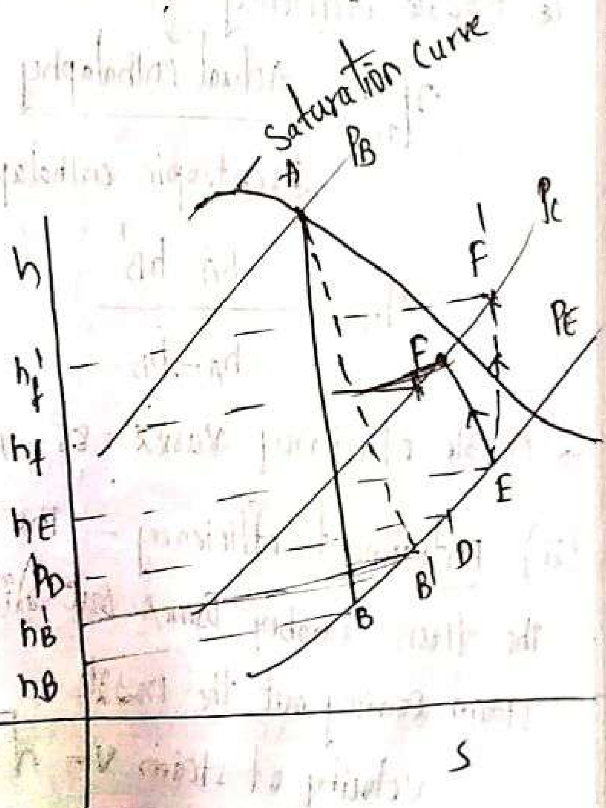
→ Flash chamber is a large vessel and is heavily insulated to avoid the rising Temp of water due to high ambient Temp. it is fitted with perforated pipes for spraying water the warm water coming out of the refrigerated steam is sprayed into the flash chamber, sum of which is converted into vapours after absorbing the latent heat from cooling the rest of water

The high pressure steam from the boiler passed through the steam nozzles, increases its velocity. The high velocity steam in the ejector would entrained the water vapours from the flash chamber which would result further formation of vapours. The mixture of steam and water vapour passes through the venturi tube of ejector and gets compressed. The Temp and pressure of the mixture raises, Then fed into the water cooled condenser where it gets condensed. The condensate is again fed to the boiler as feed water.

A constant water level is maintained in flash chamber, if any loss of water due to evoparation is made up from makeup water line.

Analysis of steam Jet refrigerator:-





A - represents Initial condition of motive steam before passing through nozzle

B - final condition of steam is isentropic expansion.

C - Intial condition of water vapour in the flat chamber,

E = condition of mixture of high velocity steam from nozzle and entrained [seaws]. water vapour before compression

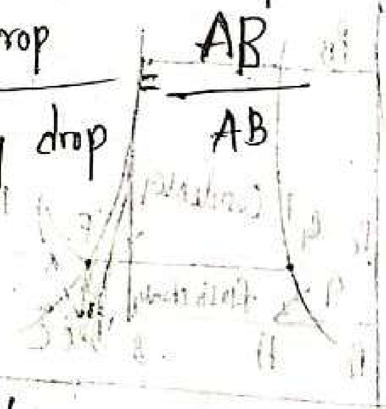
3. Assume Isentropic compression, final condition of mixture discharged to Condenser by point f.

→ Condition of motive steam before mixing water vapour at 'D'

→ The makeup water is supplied at point 'G' The temp at G slightly lower than Condenser Temp. and is throatled to point 'H' in the flash chamber

(i) nozzle efficiency

$$\eta_n = \frac{\text{Actual enthalaphy drop}}{\text{Isentropic enthalaphy drop}} = \frac{AB'}{AB}$$



$$\eta_n = \frac{h_A - h_B'}{h_A - h_B}$$

→ nozzle efficiency varies 85-90%.

(ii) Entraiment efficiency - The water vapours flax formed in the flash chamber Comes out with low velocity Compared to steam coming out the nozzle

velocity of steam $V = \sqrt{2000 [h_A - h_B']}$

$= 44.72 \sqrt{h_A - h_B'}$

... while flowing the entrained water vapour from the flash chamber the motive steam losses sum of its kinetic energy the process of entrainment is inefficient and part of original motive force which is available for compression is reduced.

then $$\eta_E = \frac{h_A - h_D}{h_A - h_B'}$$, at a range of 65 %.

(iii) Compression efficiency –

$$\eta_C = \frac{\text{Isentropic enthalaphy Increase}}{\text{Actual enthalaphy Increase}}$$

$$\eta_c = \frac{h_F - h_E}{h_F' - h_E}$$

efficiency ranges 75 – 80 %

(iv) Mass of motive steam –

net refrigeration effect $R_e = m_v \times (h_c - h_{fg})$ kJ/min

m_s – mass of motive steam in kg/min

m_v – mass of water vapour formed in flash chamber in kg/min

m – mass of mixture for compression in kg/min

$$m = m_s + m_v$$

Q is the tonne in refrigeration Then $R_e = 210\,Q$ kJ/min

mass of water vapour $m_v = R_e / (h_c - h_{fg})$

$$= \frac{210\,Q}{(h_c - h_{fg})} \text{ kg/min}$$

1 kg of water vapour requires m_s kg of motive steam

- mass of motive steam required for Q tonne of refrigerating load

i.e mass of water vapour/min × motive steam required/kg of vap

$= m_v \times m_s$

$$\boxed{= \frac{210\,Q}{(h_g - h_{fq})} \times m_s}$$

3 → Cop of system is given by

$$\boxed{C.O.P = m_v \times (h_e - h_{fq}) / m_s (h_a - h_{fq})}$$

① A steam ejector refrigeration system is supplied with motive steam at 7 bar saturated with the water in the flash chamber at 4.5°c the make up water is supplied to the cooling system at 18°c and the condenser operate at 0.058 bar the $\eta_{nozzle} = 88\%$ $\eta_E = 65\%$, $\eta_c = 80\%$ the quality of steam and flash vapour at the begining of compression is 92%. Determine,

a) mass of the motive steam required for kg of flash vapour $\left(\frac{m_s}{m_v}\right)$

b) quality of vapour flashed from the flash chamber. (x_e)

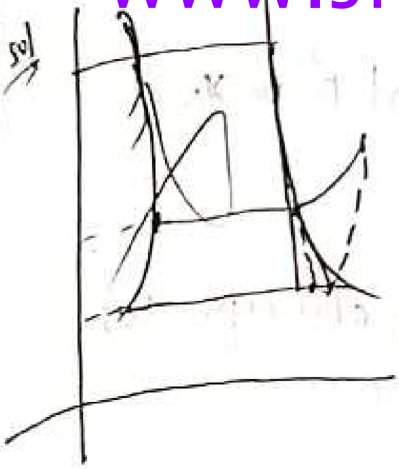
c) refrigerating effect per kg of flash vapour (R_e)

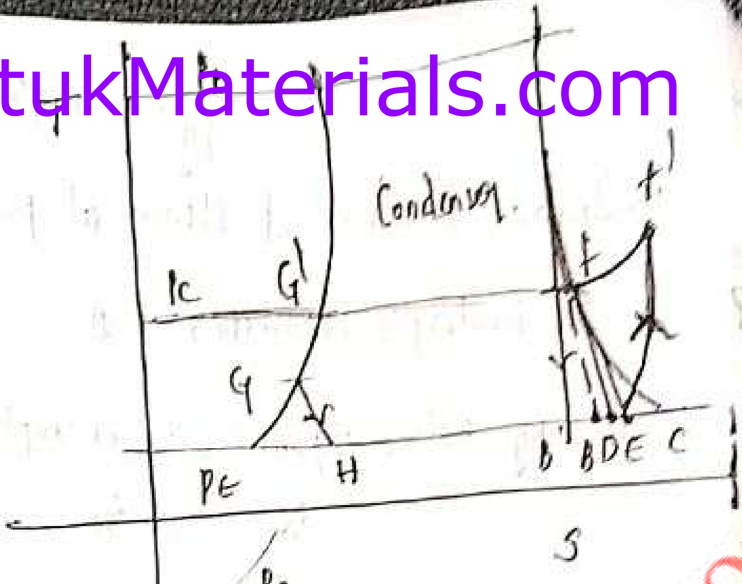
d) mass of motive steam required per hour for tonne of refrigeration

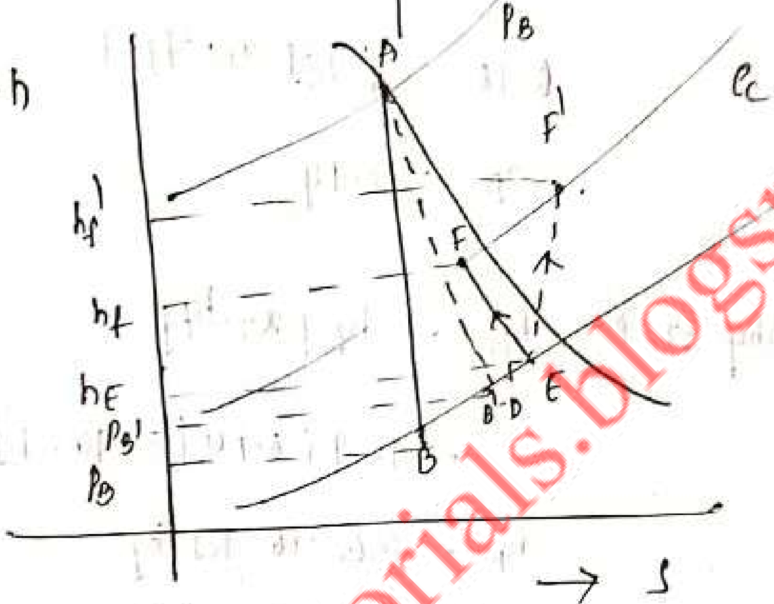
e) volume of vapour removed from the flash chamber per hour per tonne of refrigeration

f) C.O.P of the system.

Sol







given $P_B = 7$ bar

$T_W = 4.5°C$; $T_{mw} = 18°C$

$P_C = 0.058$ bar , $\eta_n = 88\% = 0.88$

$\eta_C = 80\% \Rightarrow 0.8$ $\quad \eta_E = 65\% = 0.65$

$x_C = 92\% = 0.92$

At pre-7 bar from steam table $h_A = 2762$ kJ/kg

$s_A = 6.705$ kJ/kg K

$T_A = 165°C$

At Temp $T_W = 4.5°C$, $h_f = 18.9$ kJ/kg

$h_{fg} = 2490.9$ kJ/kg

$s_f = 0.0685$ kJ/kg K

$S_{fg} = 8.9915$

The dryness fraction of steam at point B' is x_B =

for isentropic expansion A-B

→ Entrophy before expansion = entrophy after expansion

$$S_A = S_B$$

$$6.405 = [S_{fB} + x_B \cdot S_{fgB}]$$

$$x_B = 0.74$$

→ Enthaphy at B $h_B = h_f + x_B \cdot h_{fg}$

$$= 18.9 + 0.74[2490.9]$$

$$h_B = 1862.16 \text{ KJ/kg}$$

→ $$\eta_n = \frac{h_A - h_B'}{h_A - h_B}$$

$$0.88 = \frac{2762 - h_B'}{2762 - 1862.16}$$

$$h_B' = 1970.14$$

points B, B', D, E are on same pressure line, corresponds. 4.5°C then

$$h_{fB} = h_{fB'} = h_{fD} = h_{fE}$$

$$= 18.9 \text{ KJ/kg}$$

$h_{fg_B} = h_{fg_B'} = h_{fg_D} = h_{fg_E}$

$= 2490.9$ kJ/kg

enthalaphy at $B' = h_B' \Rightarrow h_{fB}' + x_B' \cdot h_{fg_B}'$

$1970.14 = 18.9 + x_B' \cdot 2490.9$

$x_B' = 0.78$ then ~~act~~

Entrainment efficiency $\eta_E = \dfrac{h_A - h_D}{h_A - h_B'}$

$0.65 = \dfrac{2762 - h_D}{2762 - 1970.14}$

$h_D = 2247.3$ kJ/kg

$h_D = h_{fD} + x_D \cdot h_{fg_D}$

$2247.3 = 18.9 + x_D \cdot 2490.9$

$\boxed{x_D = 0.894}$

Enthaphy $h_E = h_{fE} + x_E \cdot h_{fgE}$ given ($\because x_E = 0.92$)

h_E = $18.9 + 0.92 \times 2490.9$

$h_E = 2310.5$ kJ/kg

Entropy at point 'E' $S_E = S_{fE} + x_E \cdot S_{fgE}$

$S_E = 0.0685 + 0.92 \times 8.9715$

$S_E = 8.32$ kJ/kg k

$h_{fE} = h_{fB}$; $h_{fgE} = h_{fgB}$

from steam Table condenser pressure of 0.0058 bar

$$h_{f_F} = 148 \ , \ h_{fg_F} = 2417.5 \ \text{KJ/kg}$$

$$S_{f_F} = 0.512 \ \text{KJ/kg K} \ , \ S_{fg_F} = 7.831 \ \text{KJ/kg K}$$

Compression of the mixture is isentropic

Entrophy before compression (S_E) = entrophy after compression

Then

$$8.3223 = S_{fF} + x_f \cdot S_{fgF}$$

$$x_f = 0.997$$

$$H_F \Rightarrow H_F = h_{fF} + x_f \cdot h_{fgF} \Rightarrow 148 + 0.997 \times 2417.5$$

$$H_F = 2559.1$$

$$\eta_c = \frac{h_F - h_E}{h'_F - h_E}$$

$$0.8 = \frac{2559.1 - 2310.5}{h'_F - 2310.5} \Rightarrow h'_F = 2621.2 \ \text{KJ/kg}$$

ii) mass of motive steam for kg of flash chamber

$$\boxed{\frac{m_s}{m_v} = \frac{h_F - h_E}{(h_A - h_B)\eta_E \eta_c - (h_F - h_E)}}$$

$$\frac{m_s}{m_v} = 1.523 \ \text{kg/kg of flash chamber}$$

(iii) quality ...

(iv) refrigerating effect per kg of flash chamber (q_E).

$$q_E = h_C - h_{fG}$$

$h_C = 2406.8\ kJ/kg$

$$q_E = 2406.8 - 75.5$$

In $18^\circ C$ $h_{fG} = 75.5\ kJ/kgK$

$$q_E = 2331.3\ kJ/kg$$

(v) mass of motive steam required per hour per tonne of refrigeration

$$= \frac{210\ Q}{(h_C - h_{fG})\frac{m_1}{m_v}}$$

$$= \frac{210 \times 1}{[2406.8 - 75.5]1.523}$$

$$= 0.133\ kg/min/tr$$

(vi) $C.O.P = \frac{m_v [h_E - h_{fG}]}{m_s [h_A - h_{fG}']}$ from steam Table

condenser pre : 0.05 bar

Then $h_{FG}' = 148.8$

$$C.O.P = \frac{2331.3}{[2762 - 148.8]} \times \frac{1}{1.523}$$

$$C.O.P = 0.586$$

(v) volume of vapour removed from the chamber per hour for tonnes of refrigeration

v_c = volume of liquid at 'c' + x_c · [vol. of saturated vapour]

→ volume of saturated vapour at 4.5°C

$v = 152.24\ m^3/kg$

→ ~~Volume of liquid at 'c'~~ ⇒ $V_c = 1 + 0.95\,[152.2 - 1]$

$V_c = 144.66\ m^3/kg$

vol. of vapour removed from flash chamber per hour per tonne of refrigeration $= V_c \times \frac{210\,Q}{[h_c - h_{FG}]} \times 60$

$= 144.66 \times 0.133 \times 60$

$= 782\ m^3/hr/Tr$

→ Quality of vapour flashed from the flash chamber

x_c = dryness fraction of vapour from flash chamber

Enthalaphy at 'c' h_c

mass of vapour $m_v + h_c + m_s + h_D = (m_s + m_v)\,h_E$

$$h_c + \frac{m_s}{m_v} \times h_D = \left(\frac{m_s}{m_v} + 1\right) h_E$$

$$h_c = \frac{1.523\,H}{1.523 \times 2247.3} \times$$

$h_c = 2406.8\ KJ/kg$

Find x_c :-

- vol. of liquid]

$$h_c = h_{fc} + x_c \cdot h_{fgc}$$

$$2406.8 =$$

$$x_c = 0.96$$

→ die electric strength – High die electric strength for a re frigerent is desirable.

(iii) Chemical properties :-

→ non flameable and non explosive

→ non poisionus non toxine

→ shouldn't have any disagreeable odour

→ shouldn't have any corrosion action on the parts of system

→ The chemical properties relatied to safety of operations are called as safe working properties

other properties are

→ low cost & easily available

→ Easy to store and handle

→ shoudn't react with lubricating oil

Refrigerants:

In refrigeration system is a heat carrying system from a low Temp system and discards the heat so absorbed to a higher Temp system. natural ice, mixture of ice and salt

Ammonia, sulphur dioxide, methyl chloride and carbon dioxide used as refrigents in compression refrigeration machines in present days new refrigerants like hallow carbon compounds and hydro carbon compounds are used for air condition and refrigeration applications

properties of an Idle refrigerent / properties of refrigerant classified under Three catagory

i) Thermo dynamic properties
ii) physical properties
iii) chemical properties

(i)→ low boiling and freezing point
(i)→ High critical pressure and Temp
(i)→ High latent heat of vaporization
(i)→ High Thermal Conductivity
→ Non corrosive metal
→ Non toxic, non flameble, non explosive
→ low cost
→ Easily and regularly available
→ Mixes well with oil
(i)→ High cop
→ Ozone friendly

(ii) physical property

→ viscosity - low viscosity is desirable for better heat transfer and low pumping power

→ lekagetedency - should be low to prevent the laws of refrigerant

→ common refrigerant operating temp of -15°, condensing temp +30°c

(2) low specific heat of liquid ; High specific heat of vapour

(3) low specific volume of vapour

Classification Refrigerants

i) primary refrigerents (ii) secondary refrigerents → ex:- Brines, water

→ The refrigerents directly take part in the system called primary refrigerents

→ Refrigerents at first cooled by primary refrigerents and then used for cooling purpose called secondary refrigerents

(i) primary refrigerents further classification

a) Hallow Carbon (or) organic refrigerents

b) Azeotrope refrigerents

c) Inorganic refrigerents ex:- NH_3, CO_2, SO_2

d) Hydro carbon refrigerents.

(a) Hallow Carbon refrigerents :-

This group contains 1 or more of three halogents, they are chlorine, flurine, and Bromine. They are available in the Market under the trade of freon, genetron, Isotron and arcton,

These group mainly used for domestic and industrial purposes.

The common used hallow carbon refrigerents with their designation

→ freon level - Trichloro monofhloro methane - CCl_3F

[illegible] non flamable non corrosive, It is a low pressure refrigerent suitable for centrifugal compressor which is operating at low speed. freon 11 applied for 50 tons capacity air conditiong plants. its colour code is orange.

→ freon-12 - Dichloro difluro methane CCl_2F_2

It is high stable refrigerent used for domestic, commercial refrigeration and for automobile application it is non toxic, non flamable, non explosive it is colourless, odourless. its cylinder colour code is white.

→ Freon-22 - Monochloro difluro methane $CHClF_2$

It is a low Temp refrigerent used for air conditiong application with reciprocating compressor. the cylinder colour code is green. lekage of the refrigerent may be detected with halid torch.

(b) Azeotropes:-

It is a compound of two or more different substances, the substances forming can't be separated by distilation. An Azeotrope evoparates and condenses as a single substance with the properties

the Common azeotropes with their combinations

→ R-500 - 73.8% freon-12, 26.2% of freon-152 [CH_3CHF_2]

→ R-502 - 48.8% freon-22, 51.2% of freon-115 [$CClF_2CF_3$]

→ R-502 used to replace R-22 in a low Temp, high compression ratio application

It is employed in processing the frozen food and storage units for frozen foods and ice creams. It has lower compressor discharge temperature than R-22 ($CHClF_2$)

(d) Hydro Carbon Refrigerants :-

They are used in low temperature applications. Hydro carbons refrigerents are made from hydrogen & carbon. They are highly flamable and explosive, but these possess satisfactory thermodynamic properties. These refrigerents limited for chemical and Refining industries

→ hydro carbon refrigerants are methane, ethane, propane, Butane, isobutane.

(e) Inorganic compounds (or) oldest refrigerents :-

It is very used in all type of refrigerents. They possess excelent properties, but they are highly toxic & flamable. Some of inorganic components are

i) Ammonia (R717) :-

→ It is oldest and most widely used refrigerant. high toxic and flamable but it is most efficient.

→ It attacks copper and used in system fabricated steel. widely used in large commercial and industrial plants, absorbtion system cold storages and ice plants.

→ It is suitable for open type reciprocating (or) screw type compressor. It's refrigerating effect much larger than other refrigerents.

→ the lekage of the refrigerent easily detected by sulphur candle.

(ii) Carbon dioxide (CO_2) [R744]:-

→ It is colourless, odour less, heavier than the air, non toxic, non-flamable, non-explosive suitable for all working conditions. It is non corrosive. so suitable for any type of metal.

→ It has low refrigerating effect mainly for low temp. applicati of production of dry ice

→ It's boiling point is $-73.5°C$, freezing point is $-57°C$

(iii) Sulphur dioxide (SO_2) [R764]:-

→ It is colourless, non-flamable and non explosive, extremely toxic. it is non corrosive to all metals in the absense of water. but reacts with all metals in the presence of water.

→ It is used for small tonnage commercial machines, boiling point is $-10°C$. freezing point $-75.5°C$, low cop, low operating pressure used for Domestic refrigeration.

(iv) Water (H_2O) (R118):-

used of water is as ice The highly freezing Temp. of water limits its use in vapour compression system

" Impact of refrigerant on environment :-

i) ozone deflection
ii) Global Warming (or) Global house effect.

(i) ozone deflection :-

→ The ozone molecule as 3 atoms of oxygen (O_3)
→ while oxygen molecule is made up of 2-atoms (O_2)
→ An ozone layer surrounds the "earths" stratosphere and absorbs the ultra voilet rays (uv) substantially to protect the life on the earth from the high concentration of uv radiations the deflection of ozone layer causes health azards such as skin cancer, ~~severe infection~~ server infection diseases.
→ the ozone deflection pottential [ODP] is a method of the possible effect on the ozone layer by chlorine atom released from the compound.
→ ozone deflection potential of the compounds depends on their chlorine by Bromide content. and period of their stability in the atomsphere

(ii) Global Warming :-
→ Heat absorbed by the earth from the sun is reflected back to the space a film of gases like, green carbon dioxide, methane, or Nitrous oxides surrounding the earth atomsphere trapes long of the reflected heat preventing it to reach the space.

There by increasing the average Temp. of earth leaving to global warming This is known as green house effect.

→ Higher concentration of green house gases in the atmosphere will leads to harmful ecological changes due to global warming

→ Ozone depleation potential and green house potential for sustain refrigerants are (R_{11}) CCl_3F Trichloro fluro methane R_{12} CCl_2F_2 dichloro difluro methane R_{717} (NH_3)

→ C.F.C [Chloro fluro Carbon]:-

these refrigerents gradually in-feltrate the ozone which stratosphere, where they undergo a chemical change chlorine atoms detach from CFC molecules reacts with ozone molecules (O_3) and convert them into oxygen molecules (O_2) and deplete ozone layer.

→ HCFC hydro chloro fluro Carbon:-

These refrigerents have fewer chlorine atoms consequently their ozone depletion potential is must lower than those of the CFC

the following refrigerents are used as substitute

1. R_{123} for R_{11}

2. R_{134a} for R_{12}

3. R_{143a} for R_{502}

Secondary refrigerents [RIG]:-

These are first cooled by primary refrigerents and then employed for cooled purpose this is indirect cooling method. is produced by absorbtion of sensible heat water and brain are examples for secondary refrigents

→ Brine is sodium chloride (or) calcium chloride.

Qualites :-

→ Remain liquid under working temp limits

→ non-corrosive while contact with metals

→ High specific heat

→ Non change when it contact with refrigents or other gases

Advantages :-

→ In expensive and non-corrosive

→ less lekage chance

→ easy to handle and control

→ Specific volume is low, so small size pipe line

→ Different Temp are maintain by changing the quantity of flow of refrigerent.

Water :-

It is a secondary refrigerent where Temp is to be maintained above freezing point of water 0°. Water is cooled by primary refrigerent the chilled water is mainly used for air conditioning plants. chilled water circulates through ~~pipes~~ the tubes by pump.

the air forced on the chilled water tubes at screwed and ...
air is distributed in the space where cold ...

Brine :- NaCl (or) CaCl

Where water is not suitable brines are used as second refrigerants where Temp is to be maintain below freezing of water such as ice plant

NaCl are Corrosive, in-hibitors such as sodium chromate (or) dichromate is used.

→ Difficult applications brines are dairies, food process, meat packing, ice plant, chemical plants

→ Ethylene glycine poles and propalyne also used as second refrigerants

→ These are less corrosive even in presence of water

→ Ethylene glicore is more toxic than propolyne glicol, genirally preffered at low Temp

→ propolyne glycol is non-toxic and it used for food processing applications

Thermo electric refrigerators —

→ A refrigeration effect can be achieved by processing of an electric current through a closed circuit made up of two dissimilar materials and their ends are maintained at different Temp.

→ In a electric circuit made up of two dissimilar conductors a potential difference set in. i-e e.m.f is used in, if the

Junctions of 2-conductors are held at different temperatures. The magnitude is proportional to the Temp. difference of the Junction of two dissimilar conductors. This is called as 'seeback effect'

→ $dE = \alpha \cdot dT$

α – seeback coefficient

→ If a circuit composed of 2-dissimilar conductors carries a current, one of the Junction of the circuit absorbs heat and the other releases heat. The quantity of heat absorbed (or) released from the Junction is proportional to the current intensity 'I'

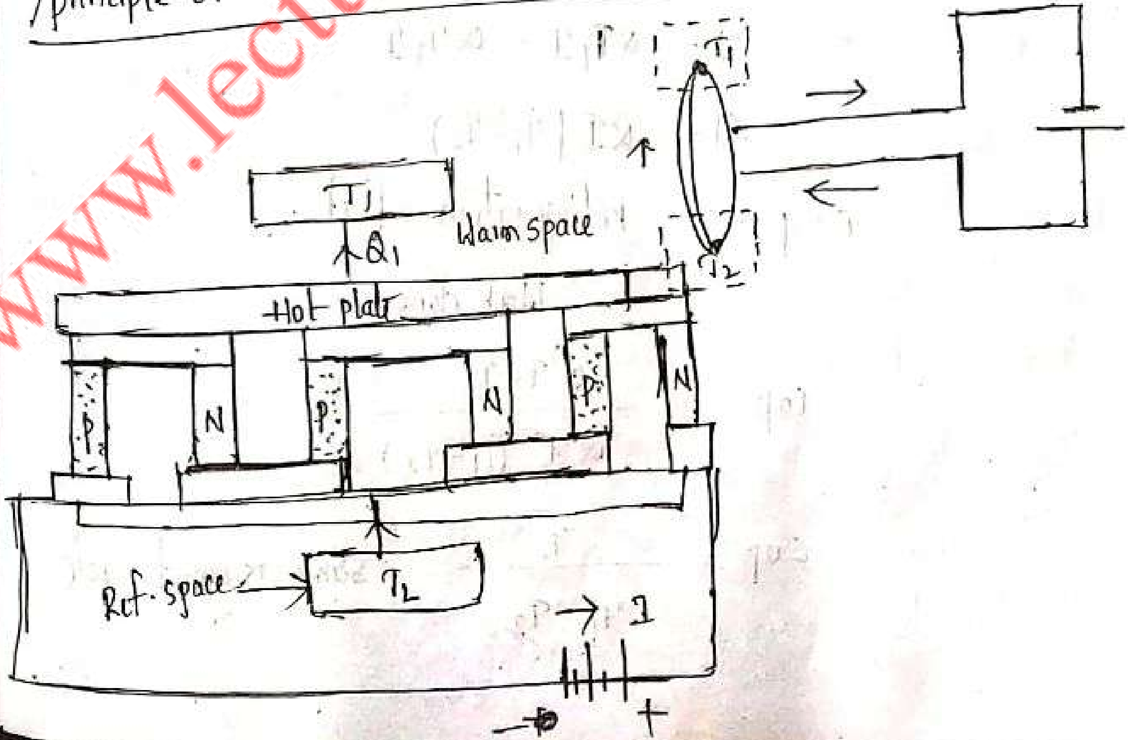
→ the peltier effect $Q_P = \pi I$, π – peltier coefficient which is related to 'α' by the eqn

$$\pi = \alpha T$$

$$Q_P = \alpha T I$$

→ In peltier effect forms the bases for the thermo electric refrigeration

principle of thermo electric refrigeration:-



→ If a current [illegible] the circuit Junction absorbs heat and other releases heat. heat absorbing Junction is place in chilled space at T_2, The Junction from which the heat is released is located in surrounding space at T_1.

→ A practical thermoelectric refrigeration system using semi conducting material is shown in fig.

Analysis of thermoelectric refrigeration system :-

→ To obtain refrigeration effect, work done by and cop of the Thermoelectric refrigerant system. are based on

→ Heat Transfer occurs only at Junctions means absorbtion & rejection

→ thermal conductivity and electrical resistence are constant over a given Temp. range

→ Irreversible losses are negligible

Heat absorbed from refrigerant space $Q_2 = \alpha T_2 I$

Heat released at high Temp : $Q_1 = \alpha T_1 I$

net Electric work $W = Q_1 - Q_2$

$$W = \alpha T_1 I - \alpha T_2 I$$

$$W = \alpha I (T_1 - T_2)$$

$$C.O.P = \frac{\text{Refrigeration effect}}{\text{Work done}}$$

$$COP = \frac{\cancel{\alpha} T_2 \cancel{I}}{\cancel{\alpha} \cancel{I} (T_1 - T_2)}$$

$$COP = \frac{T_2}{T_1 - T_2}$$ Same as Carnot cycle.

Advantages:-

→ No moving parts, No wear & Tear

→ life time is high

→ simple design easy servicing

→ maintaince easy and possible to adjust in current supply.

→ Smaller in size Compared to other Systems

→ Can be operated by heat pump (or) refrigerator by just reversing Terminals

→ cooling capacity can adjusted quickly

Disadvantages:-

→ low cop

→ suitable for small capacity units

→ power Consumption is high

→ applicable for small domestic refrigerator for low temp. chambers coolers for preservation of blood plasma and biological tissues.