SWAMI VIVEKANANDA SCHOOL OF ENGINEERING & TECHNOLOGY

LECTURE NOTE

REFRIGERATION & AIR CONDITIONING

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Date: 09/08/2023

Refrigeration :-

It is the process of producing and maintaing low temperature in a storage space compare to atmospheric temperature.

Refrigeration effect (RE, Q_E) :-

It is the amount of heat which is to be removed from storage space in order to produced and maintaing low temperature.

Unit of refrigeration :-

(i) It is the amount of heat is just to be removed from 1 tonne of water at 0°C in order to convert into ice at 0°C in 24 hours.

(ii) The heat treansperate corresponding to this process is defined as "ton of refrigeration" (TR) = 1TR

Since the latent heat of ice is 335 KJ/Kg, therefore, one ton of refrigeration,

$$1TR = 907 \times 335 \text{ Kg in } 24 \text{ hr}$$

$$= \frac{907 \times 335}{24 \times 60} = 211 \text{ KJ/min}$$

Coefficient of Performance of Refrigerator ~~system~~

Coefficient of performance (C.O.P) is the ratio of heat extracted in the refrigerator to the work done on the refrigerant.

It is also known as theoritical coefficient of performance

Mathematically,

$$\boxed{\text{Theoritical C.O.P} = \frac{Q}{W}}$$

∵ Q = amount of heat extracted in refrigerator
W = work done on the refrigerant.

* The ratio of actual C.O.P to the theoritical C.O.P is known as Relative C.O.P

Mathematically,

$$\boxed{\text{Relative C.O.P} = \frac{\text{Actual C.O.P}}{\text{Theoritical C.O.P}}}$$

Ques Find the cop of refrigeration system if the work ~~done~~ input is 80 KJ/Kg and refrigeration effect produced is 160KJ/Kg of refrigerant.

Solu^n : Given :

W = 80KJ/Kg

~~q~~ Q = ·160 Kg/Kg

We know that C.o.P of refrigeration system

∴ C.O.P of refrigerant = $\frac{Q}{W}$

$= \frac{160 \text{ KJ/Kg}}{80 \text{ Kg/Kg}}$

= 2

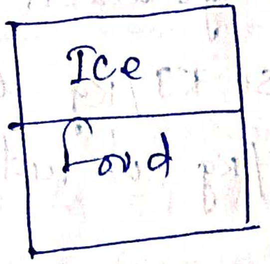
(Ans)

Date : 11/08/2023

Different type of refrigeration cycle :

1. Ideal Refrigeration cycle
2. Ice Ref. cycle
3. Dry ice Ref. cycle
4. Evaporative Ref. cycle (Indian Ref. System)
5. Expand Ref. cycle

②



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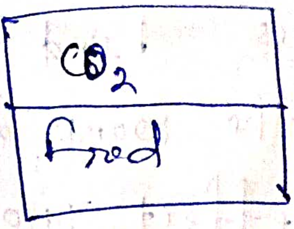

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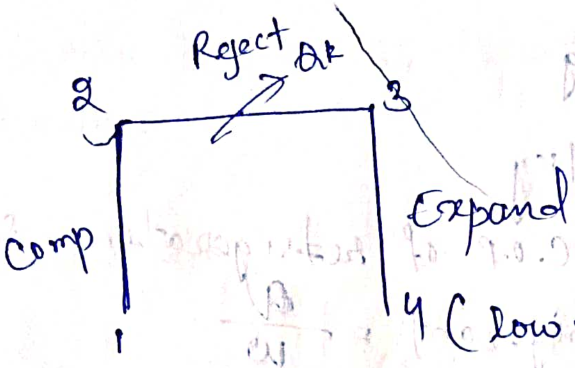
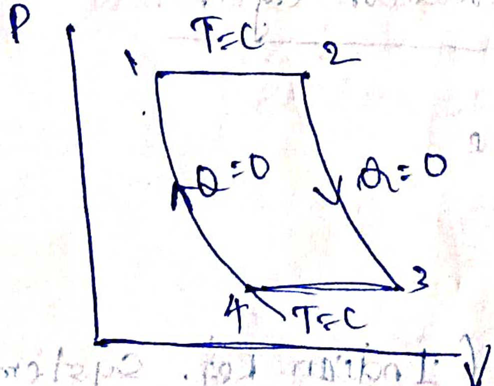
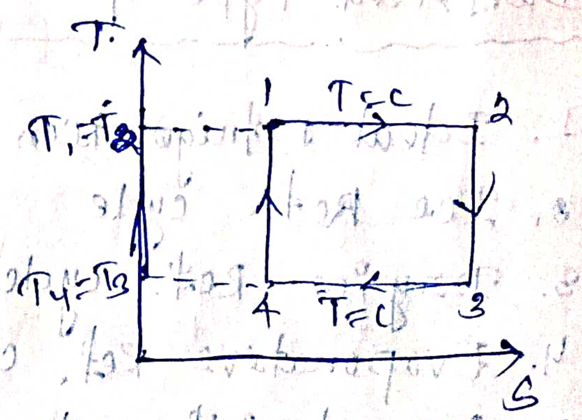


(Expand Ref. cycle)

④ Ideal Ref. Cycle :-

(Reverse carnot cycle)





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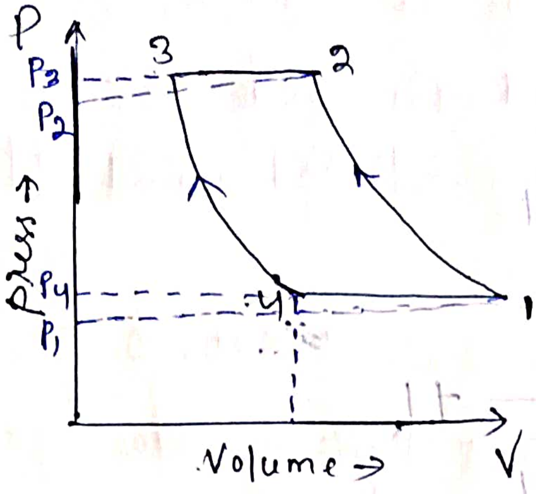
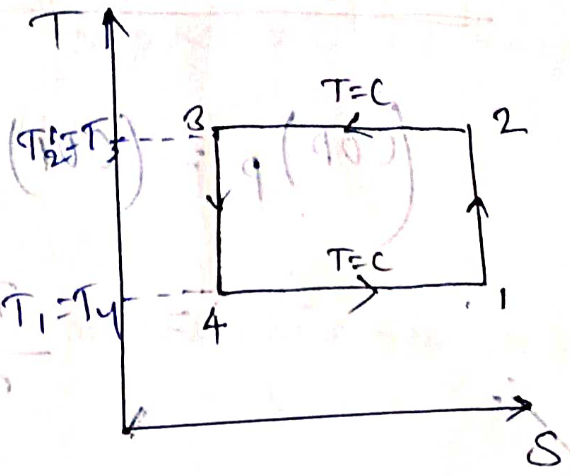




COP of reversed carnot cycle:-

$$(C.O.P)_R = \frac{\text{Heat absorbed}}{\text{work done}}$$

$$= \frac{q_A}{q_R - q_A}$$

$$= \frac{q_{4-1}}{q_{2-3} - q_{4-1}}$$

$$= \frac{T(s_2 - s_3)}{(T_2 - T_1)(s_2 - s_1)}$$

$$= \frac{T_1}{T_2 - T_1}$$

COP of Heat pump :-

$$(COP)_P = (COP)_R + 1$$

$$= \frac{T_2}{T_2 - T_1} + 1.$$

$$= \frac{T_2}{T_2 - T_1}$$

COP of effeciency of a heat engine :-

$$(COP)_E = \frac{W_R}{q_R}$$

$$= \frac{(T_2 - T_1)(s_2 - s_3)}{T_2 (S_2 - s_3)}$$

$$= \frac{(T_2 - T_1)}{T_2}$$

$$= \frac{1}{(COP)_P}$$

COP of reversed carnot cycle may be improve by

1. decreasing the higher temperature (i.e. temp of ~~ii) Inen~~ hot body T_2)

ii) Increasing the lower temperature (i.e temperature of cold body T_1)

Ques: A machine working on a carnot cycle operates between 305 K and 260 K. Determine the COP when it is operated as

(i) Refrigeration machine

(ii) Heat pump

(iii) Heat Engine

Given; T_2 = 305 K, T_1 = 260 K

(i) Refrigeration machine

$$(COP)_R = \frac{\cancel{305}\ 260}{305 - 260} = \frac{\overset{52}{\cancel{260}}}{\underset{9}{\cancel{45}}}$$

= 5.78

(ii) $(COP)_P = \frac{T_2}{T_2 - T_1}$

$= \frac{305}{305 - 260}$

$= \frac{\cancel{305}^{61}}{\cancel{45}_{9}} = 6.78$

(iii) $(COP)_E = \frac{1}{(COP)_P} = \frac{1}{6.78} =$

$= \frac{1}{\frac{678}{100}}$

$= 1 \times \frac{100}{678}$

$= 0.147$

Ques A carnot refrigeration cycle absorbs heat at 270K rejects it at ~~270~~ 300K

(i) Calculate the coefficien of performance of refregeration cycle

(ii) If the cycle is absorbing 1130 KJ/min at 270 K how many KJ of work is required per second

(iii) If the carnot heat pump operates between operates between the same temperature as the above refrigeration cycle, what is the cop

(iv) How many KJ per min will the heat pump deliver at 300K if heat absorbs 1130 KJ per minute at 270K

Solution :

Given ; $T_1 = 270K$, $T_2 = 300K$

(i) C.O.P of refrigeration cycle

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

$$= \frac{270K}{(300 - 270)K}$$

$$= \frac{270}{30} = 9$$ (Ans)

(ii) If cycle is absorbing 1130 KJ/min at 270K

$$Q_1 = 1130 \text{ KJ/min}$$

$$= \frac{1130 \text{ KJ}}{60} =$$

$$= 18.83 \text{ KJ/sec}$$

We know that,

$$\left(C.O.P\right)_R = \frac{Q_1}{W_1}$$

$$\Rightarrow 9 = \frac{18.\cancel{8}83}{W_1}$$

$$\Rightarrow W_1 = \frac{18.83}{9}$$

$$= 2.1 \text{ KJ/sec}$$ (Ans)

(iii) C.O.P of heat pump

$$\left(C.O.P\right)_P = \frac{T_2}{T_2 - T_1}$$

$$= \frac{300}{300 - 270}$$

$$= \frac{300}{30}$$

$$= 10$$ (Ans)

4(iv) We know that COP of heat pump

$$\left(C.O.P\right)_p = \frac{Q_2}{Q_2 - Q_1}$$

$$\Rightarrow 10 = \frac{Q_2}{Q_2 - 1130}$$

$$\Rightarrow 10 = \frac{Q_2}{Q_2 - 1130} \quad \cancel{\frac{Q_2}{1130}}$$

$$\Rightarrow 10Q_2 - 11300 = Q_2$$

$$\Rightarrow 10Q_2 = Q_2 + 11300$$

$$\Rightarrow 10Q_2 - Q_2 = 1130$$

$$\Rightarrow 9Q_2 = 11300$$

$$\Rightarrow Q_2 = \frac{11300}{9} = 12556 \text{ KJ/min}$$

(Ans)

Ques A cold storage is to be maintained at -5°C while the surrounding are at 85°C. The heat rejects from the surroundings in to the cold storage is estimated to be 29 KW. The actual cop of refrigeration plant is 1/3 o an ideal plant working between the same temp erature. find the power required to ~~dreipe~~ dr the plant

Solution :

Given ; $T_1 = -5°C = -5 + 273K = 268K$

$T_2 = 35°C = 35 + 273K = 308K$

$Q_1 = 29 KW$

~~We Know that~~

~~$(C.O.P)_R = \frac{1}{3}$~~

~~We Know that~~

~~$(C.O.P)_R = \frac{Q_1}{W_R}$~~

~~$\Rightarrow \quad =$~~

We Know that COP of refrigeration

~~$(C.O.P)_R = \frac{Q_1}{W_R}$~~

~~$\Rightarrow \frac{T_1}{T_2 - T_1} = \frac{29}{W_R}$~~

Ques: A cold storage is to be maintained at -5°C while the surrounding are at 35°C. The heat leakage from the surrounding in to the cold storage is estimated to be 29 KW. The actu COP of refrigeration plant is 1/3 of ~~and~~ idea plant working between the same temperatur find the power required to drive the plant.

Solution: Given; $T_1 = -5°C = -5 + 273K = 268\,K$

$T_2 = 35°C = 35 + 273K = 308K$

$Q_1 = 29\,KW$

The actual COP of refrigeration plant is 1/3 of an ideal plant

$$\therefore (COP)_{Act} = \frac{1}{3}(COP)_{Ideal} \quad --- ①$$

We know that,

$$(C.O.P)_{Ideal} = \frac{T_1}{T_2 - T_1}$$

$$= \frac{268}{308 - 268}$$

$$= \frac{268}{40}$$

$$= 6.7$$ (Ans)

Putting the value of $(COP)_I$ in equⁿ ① we get

$$(COP)_A = \frac{6.7}{3}$$

$$= 2.233 \quad (Ans)$$

$$\therefore (COP)_A = \frac{Q_1}{W_R}$$

$$\Rightarrow 2.233 = \frac{29 \text{ KW}}{W_R}$$

$$\Rightarrow W_K = \frac{29 \text{ KW}}{2.233}$$

$$= 12.98 \text{ KW} \quad (Ans)$$

Dt : 19/08/2023

Ques: A refrigeration system of operates on the reverse carnot cycle. The higher temperature of the refrigerant in the system is 35°C and the lower temperature is -15°c. The capacity is to be 12 tonnes determine

(i) COP

(ii) Heat rejected from the system per hour.

(iii) Power required

Solution Given;

$T_H = T_2 = 35°C = 35 + 273 = 308K$

$T_L = T_1 = -15°C = -15 + 273 = 258$

$Q_1 = 12TR = 12 \times 210 = 2520$ KJ/

(i) COP ~~of~~ of refrigeration system

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

$$= \frac{258\,K}{(308 - 258)\,K}$$

$$= \frac{258}{50} = 5.16 \quad (Ans)$$

(iii) Power required

We know that,

$$(COP)_R = \frac{Q_1'}{W_R}$$

$$\Rightarrow 5.16 = \frac{2520}{W_R}$$

$$\Rightarrow W_R = \frac{2520 \text{ KJ/min}}{5.16}$$

$= 488.3$ KJ/min (Ans)

$= \cancel{8.}\ 8.13$ KJ/sec

(iii) Heat rejected from the system per hour

We know that

$$Q_2 = Q_1 + W_R$$

$= 2520 + 488.3$ KJ/min

$= 3008.3$ KJ/min

~~$= \frac{3008.3}{60}$ KJ/hr~~

~~$= 180498$~~

$= 3008.3 \times 60$ KJ/hr

$= 180498$ KJ/hr (Ans)

Ques: The capacity of a refrigerator is 200 TR when working between -6°C and 25°C. Determine the mass of ice produced per day from water at 25°C. Also find the power required to drive the unit. Assume that the cycle operates on reversed carnot cycle and latent heat of ice 335 KJ/Kg.

Solution: Given

The capacity of refrigerator = 200TR = 200 X 210 K

= 42000 KJ/m

$T_L = T_1 = -6°C = -6+273K = 267K$

$T_H = T_2 = 25°C = 25+273K = 308 K$

Latent heat of ice = 335 KJ/Kg

heat removed from 1kg of water at 25°C to 0°C

= mass X specific heat X rising temperature + late
h

$= 1000 \times 4.187 (25-0) + 335$

$= \boxed{439.5 \text{ KJ/Kg}}$

Mass of ice produced per minute

$$= \frac{\text{Heat extraction capacity}}{\text{Heat removed}}$$

$$= \frac{42000 \text{ KJ/min}}{439.5 \text{ KJ/Kg}}$$

= 95.56 Kg/min

∴ Mass of ice produced per day

$= 95.52 \, Kg/min$

$= 95.52 \times 24 \times 60 \, Kg$

$= 137\,48.8 \, Kg$ (Ans)

We know that the formula of $(COP)_R$ is

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

$$= \frac{267 \, K}{(308 - 267) K}$$

$$= 8.6$$

~~Al~~ Another formula of $(COP)_R$ is

$$(COP)_R = \frac{Q}{W_R}$$

$$\Rightarrow 8.6 = \frac{42000}{W_R}$$

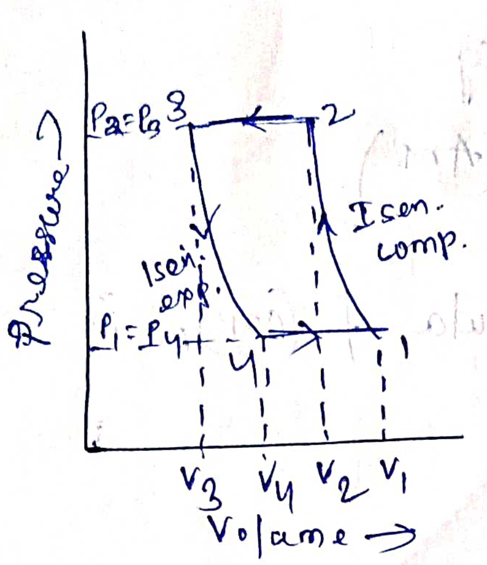
$$\Rightarrow W_R = \frac{42000 \, KJ/min}{8.6}$$

$$= 4883.72 \, KJ/min$$

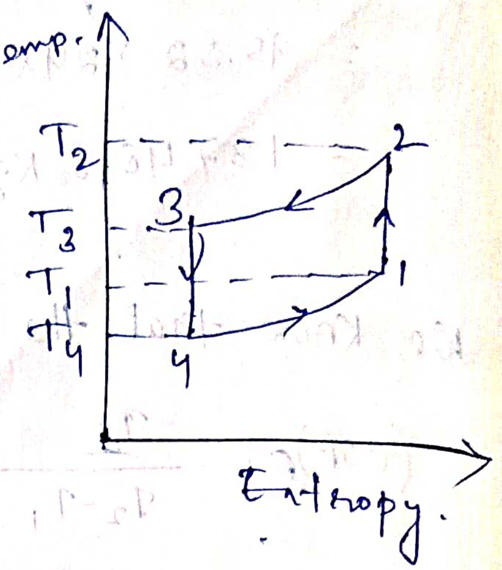
∴ Work done ~~per~~ required to drive the unit

$$= \frac{4883.72}{60} \Rightarrow 81.4 \, KJ/sec = 81.4 \, KW$$

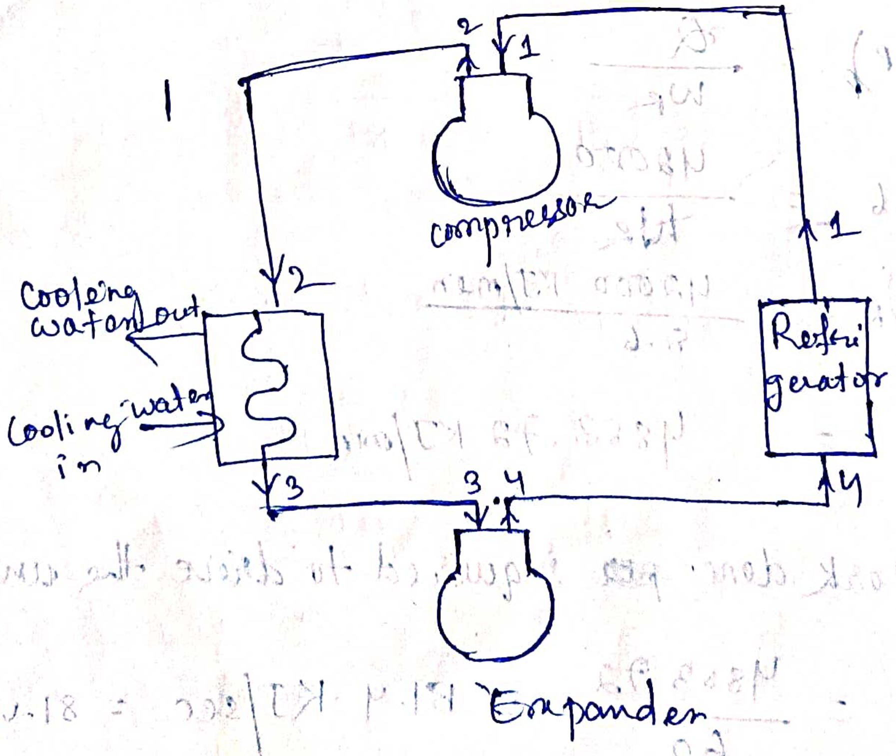
Bell - coleman refrigeration cycle :



a) P-v diagram

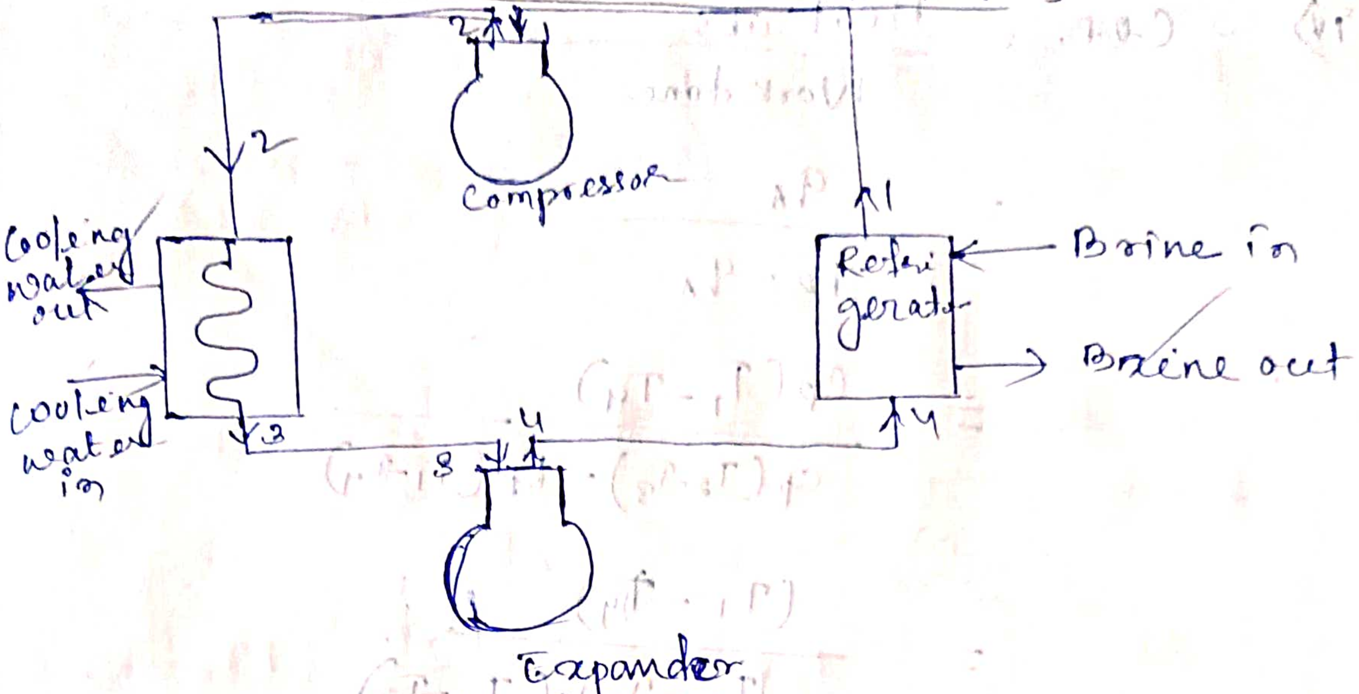


b) T-s diagram



OPEN CYCLE AIR BELL COLEMAN Ref.

CLOSED CYCLE AIR BEER-COLEMAN REF :-



Date: 23/08/2023

(i) The heat rejected by the air during constant pressure, per kg of air

$$\boxed{Q_R = Q_{2-3} = C_p(T_2 - T_3)}$$

ii) The heat abs. by air / heat extracted from ref / the refrigerating effect produced during constant pressure expansion per kg of air is

$$\boxed{q_A = q_{4-1} = C_p(T_1 - T_4)}$$

iii) The workdone during the cycle per kg of air

$$= \text{Heat rejected} - \text{Heat absorbed}$$

$$= q_R - q_A = \boxed{C_p(T_2 - T_3) - C_p(T_1 - T_4)}$$

iv) $$\text{C.O.P.} = \frac{\text{Heat abs}}{\text{Work done}}$$

$$= \frac{q_A}{q_R - q_A}$$

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

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

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

We know that, for isentropic comp. process 1-

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

Similarly, for isentropic expansion process 3-4

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{- - - -} \quad \text{(iii)}$$

Since $P_2 = P_3$ and $P_1 = P_4$ therefore equ^n (ii) and (iii)

$$\frac{T_2}{T_4} = \frac{T_3}{T_4} \quad \text{or} \quad \frac{T_2}{T_3} = \frac{T_1}{T_4} \quad \text{- - - -} \quad \text{(iv)}$$

Now substituting the value in equ^n ①

$$C.O.P = \frac{T_4\left(\frac{T_1}{T_4}-1\right)}{T_3\left(\frac{T_2}{T_3}-1\right) - T_4\left(\frac{T_1}{T_4}-1\right)}$$

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

$$\boxed{= \frac{T_4}{T_3 - T_4}}$$

$$= \frac{T_4}{T_4\left(\frac{T_3}{T_4}-1\right)}$$

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

$$\boxed{= \frac{1}{\left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}} = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1}} \leftarrow \text{--} ⑤$$

P_3/P_4 = | P_2/P_1 = r_p = compression ratio or expansion ratio.

✱ Some times compression and expansion process take place according to the law of PV = constant.

i) We know that work done by compressor during the process 1-2 per kg of air,

$$W_C = \frac{n}{n-1}\left(P_2V_2 - T_1V_1\right) = \frac{n}{n-1}\left(RT_2 - RT_1\right)$$

$$\left(\because PV = RT\right)$$

ii) Work done by the expander during the process 3-4 per kg of air

$$W_E = \frac{n}{n-1}\left(P_3V_3 = P_4V_4\right) = \frac{n}{n-1}\left(RT_3 - RT_4\right)$$

$$= \frac{n}{n-1} \times R\left(T_3 - T_4\right)$$

iii) Net workdone during complete cycle per kg of air

$$W = W_C - W_E = \frac{n}{n-1}\left(RT_2 - RT_1\right) - \frac{n}{n-1}\left(RT_3 - RT\right.$$

iv) $$C.O.P = \frac{\text{Heat absorbed}}{\text{work done}}$$

(v)

$$= \frac{C_p\left(T_1 - T_4\right)}{\frac{n}{n-1} \times R\left[\left(T_2 - T_1\right) - \left(T_3 - T_4\right)\right]}$$

We know that
$R = C_p - C_v$
$= C_v(\gamma - 1)$

* Substituting
1 The value of R in equation (vi)

$$C.O.P = \frac{C_p(T_1 - T_4)}{\frac{n}{n-1} \times R\left[(T_2 - T_1) - (T_3 - T_4)\right]}$$

$$= \frac{C_p(T_1 - T_4)}{\frac{n}{n-1} \times (\gamma - 1) C_v \left[(T_2 - T_1) - (T_3 - T_4)\right]}$$

$$= \frac{\gamma(T_1 - T_4)}{\frac{n}{n-1} \times (\gamma - 1) \left[(T_2 - T_1) - (T_2 - T_4)\right]}$$

$$= \frac{(T_1 - T_4)}{\frac{n}{n-1} \times \left(\frac{\gamma - 1}{\gamma}\right) \left[(T_2 - T_1) - (T_3 - T_4)\right]} \quad \text{.... (vii)}$$

$$\boxed{C.O.P = \left(\frac{n-1}{n}\right) \times \left(\frac{\gamma}{\gamma - 1}\right) \times \frac{T_4}{T_3 - T_4}}$$

Note:

(1) In this case the value of T_2 and T_4 are to be obtained from the following relations

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} \quad \text{or} \quad \frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{n-1}{n}}$$

2. for Isentropic compression or expansion $n = \gamma$ therefore, the equation (vii) may be written a

$$CO.P = \frac{T_1 - T_4}{\left[(T_2 - T_3) - (T_1 - T_4)\right]}$$

Date: 24/08/2023

Ques: In a refrigeration plant working on Bell-coleman cycle, air is compressed to 5 b from 1 bar. Its initial temperature is 10°c after compression the air is cooled upto 20°c in a cooler before reexpanding that to a pressure of one bar. determine the theoritical cop of the plant and Net refrigeration ef

Take $C_p = 1.005$ KJ/KgK, $C_v = 0.718$ KJ/Kg K

Sol^n: Given; $P_1 = P_4 = 1$ bar,

$P_2 = P_3 = 5$ bar

$T_1 = 10°C = 10 + 273K = 283K$

$T_3 = 20°C = 20 + 273 = 293 K$

$C_p = 1.005$ KJ/Kg K

$Cv = 0.718 \ KJ/Kg \ K$

We know that $\gamma = \frac{Cp}{Cv} = \frac{1.005}{0.718} = 1.4$

(i) The theoritical COP of the plant

$$COP = \frac{T_4}{T_3 - T_4}$$

We know that, for isentropic process

$$\left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = \frac{T_3}{T_4}$$

$$\Rightarrow \left(\frac{5}{1}\right)^{0.286} = \frac{293}{T_4}$$

$$\Rightarrow T_4 = \frac{293}{(5)^{0.286}} = 185 K$$

$$\therefore COP = \frac{T_4}{T_3 - T_4} = \frac{185}{293 - 185} = 1.713 \text{ Ans}$$

ii) Net refregeration effect

$$q_A = q_{4-1} = Cp(T_1 - T_4)$$

$$= 1.005(283 - 185)$$

$$= 98.5 \ KJ/kg \ (\text{Ans})$$

Ques A refrigerator working on Bell - coleman cy
oporates between pressure limit of 1.05 bar
and 8.5 bar. Air is drawn from the cold chamber
at 10°c compressed and then it is coold to 30°c bef
entering the expansion cylinder. The expansion &
compression follows the law of $pv^{1.3}$ = constant.
Determined the theoritical COP of the system.

Solu Given data

$P_1 = P_4 = 1.05$ bar

$P_2 = P_3 = 8.5$ bar

$T_1 = 10°C = 10 + 273\,K = 283\,K$

$T_3 = 30°C = 30 + 273\,K = 303\,K$

$pv^{1.3} = C$

$n = 1.3$

Let, T_2 and T_4 = Temp. at the end of compr
and expansion respectively.

Since, the compression & expansion follows th
law $pv^{1.3} = c$, therefore

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{8.5}{1.05}\right)^{\frac{1.3-1}{1.3}} = 1.62$$

$$\therefore T_2 = T_1 \times 1.62 = 283 \times 1.62 = 458.5K$$

Similarly,

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{n-1}{n}} = \left(\frac{8.5}{1.05}\right)^{\frac{1.3-1}{1.3}} = 1.62$$

$$\therefore T_4 = T_3/1.62 = \frac{303}{1.62} = 187 K$$

we know that theoretical coefficient of performance

$$C.O.P = \frac{(T_1 - T_4)}{\frac{n}{n-1} \times \frac{(\gamma-1)}{\gamma} \times \left[(T_2-T_3)-(T_1-T_4)\right]}$$

$$= \frac{(283-187)}{\frac{1.3}{1.3-1} \times \frac{1.4-1}{1.4}\left[(458.5-303)-(283-187)\right]}$$

...(taking $\gamma = 1.4$)

$$= \frac{96}{1.24 \times 59.5} = 1.3 \quad \underline{Ans}$$

Ques The atmospheric air at pressure 1 bar and temp -5°C is drawn in the cylinder of the compressor of Bell-Coleman cycle. It is compressed isentropically to a pressure of 5 bar. In the cooler, the compressed air is cooled to 15°C, pressure remaining the same. It is then expanded to a pressure of 1 bar in an expansion cylinder, from where it is passed to the cold chamber find ① The work done per kg of air, (ii) COP of the Plant

For air assume law for expansion $pv^{1.2} = C$ & for comp^n $pv^{1.4} = C$ and $Cp = 1 Kg/KgK$

Solu

Soluⁿ Given data;

$P_1 = P_4 = 1$ bar

$P_2 = P_3 = 5$ bar

$T_1 = -5°C = -5 + 273 = 268\,K$

$T_3 = 15°C = 15 + 273 = 288\,K$

$n = 1.2, \quad \gamma = 1.4$

$C_p = 1\,KJ/Kg\,K$

Let, T_2 and T_4 = Temperature at the end of Compression & expansion

Since, the compression follow the law $pV^{1.4} = c$ therefore,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{5}{1}\right)^{\frac{1.4-1}{1.4}} = (5)^{0.286} = 1.585$$

$$\therefore T_2 = T_1 \times 1.585 = 424.8\,K$$

Similarly, the expansion follows the law $PV^{1.2} = C$ therefore,

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{n-1}{n}}$$

$$\Rightarrow \frac{288}{T_4} = \left(\frac{5}{1}\right)^{\frac{1.2-1}{1.2}}$$

$$T_4 = \frac{288}{(5)^{0.386}} = 220K$$

1. Work done per kg of air

We know that the work done by compressor 1-2

$$W_c = \frac{\gamma}{\gamma-1} \times R(T_2 - T_1)$$

$$= \frac{1.4}{1.4-1} \times 0.287(424.8 - 268) \cdots (\text{Takin } R = 0.287)$$

$$= 159 \text{ KJ/Kg}$$

and work done by expander during the process 3-4 per kg of air

$$W_E = \frac{n}{n-1} \times R(T_3 - T_4)$$

$$= \frac{1.2}{1.2-1} \times 0.287 \times (288 - 220)$$

$$= 118.3 \text{ KJ/Kg}$$ ~~Ans~~

~~Took~~

∴ Net work done by the system per kg of air

$$W = W_C - W_E$$

$$= 159 - 118.3 = 40.7 \text{ KJ/Kg}$$ **Ans**

2. COP of the plant

$$C.O.P = \frac{C_P(T_1 - T_4)}{W} = \frac{48}{40.7}$$

$$= 1.18$$ **Ans**

Ques: Refrigerator using carnot cycle require 1.25 KW per tonne of refrigeration to maintain a temperature of -30°. find (i) cop of carnot refrigerator, (ii) temperature at which heat is rejected (iii) Heat rejected per tonne of refrigeration.

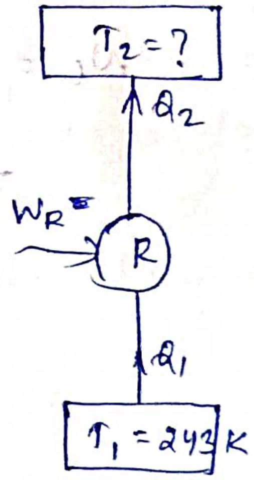
Solun Given data:

$W_R = 1.25\ KW = 1.25\ KJ/sec = \cancel{25}\ 1.25 \times 60 = 75\ KJ/m$

$T_1 = -30°C = -30+273 = 243\ K$

we know that heat extracted from the cold body

$Q_1 = 210\ KJ/\cancel{kg}\ min$



(i) COP of carnot refrigerator

we know that

$$(C.O.P)_R = \frac{Q_1}{W_R}$$

$$= \frac{210}{75} = 2.8 \quad \text{Ans}$$

(ii) Temperature at which heat is rejected

we know that,

$$(C.O.P)_R = \frac{T_1}{T_2 - T_1}$$

$$\Rightarrow 2.8 = \frac{243}{T_2 - 243}$$

$$\Rightarrow T_2 - 243 = \frac{243}{2.8}$$

$$\Rightarrow T_2 = \frac{243}{2.8} + 243$$

$$= 329.7K = 56.7 K \quad \underline{\text{Ans}}$$

(iii) Heat rejected per tonne of refrigeration

$$Q_2 = W_R + Q_1$$

$$= 75 + 210 = 285 \text{ KJ/min} \quad \underline{\text{Ans}}$$

Ques A refrigeration system working on Bell coleman recieves air from cold chamber at -5°c and compress it from 1 bar to 4.5 bar. The compressed air is then cooled to a temperature of 37°c before it is expanded in the expander. Calculate cop of the system when expansion and compression are

(i) Isentropic

(ii) follow the law $PV^{1.25} = C$

Solⁿ Given data;

$T_1 = -5°c = -5 + 273K = 268 K$

$T_3 = 37°c = 37 + 273 = 310 K$

$P_1 = P_4 = 1$ bar

$P_2 = P_3 = 4.5$ bar

Let, T_2 and T_4 = Temperature at end of compression & expansion respectively.

(i) COP of the system when compression and expansion are isentropic

We know that

~~$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{4.5}{1}\right)^{\frac{1.4-1}{1.4}} = (4.5)^{\frac{0.4}{1.4}} = 1.4$~~

~~$\Rightarrow T_2 = T_1 \times 1.4 = 268 \times 1.4 = 375.2\ K$~~

~~and,~~

~~$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{4.5}{1}\right)^{\frac{1.4-1}{1.4}} = 1.4$~~

~~$\Rightarrow T_4 = T_3 / 1.4 = \frac{310}{1.4} = 221.4\ K$~~

$$C.O.P_S = \frac{1}{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1}$$

$$= \frac{1}{\left(\frac{4.5}{1}\right)^{\frac{0.4}{1.4}} - 1} = 1.86 \quad \underline{\text{Ans}}$$

(ii) COP of the system when follow the law $pv^{1.25} = C$

We know that

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{4.5}{1}\right)^{\frac{1.25-1}{1.25}} = (4.5)^{\frac{0.25}{1.25}} = 1.35$$

$\Rightarrow T_2 = 1.35 \times T_1 = 1.35 \times 268 =$ R 361 and, $\frac{T_2}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{n-1}{n}} = (4.5)^{\frac{0.25}{1.25}} = 1.35$

$\Rightarrow T_4 = T_2/1.35 = \frac{310}{1.35} = 229.6\ K$

$\therefore COP = \left(\frac{n-1}{n}\right)\left(\frac{\gamma}{\gamma-1}\right) \times \frac{T_4}{T_2 - T_4}$

$= \frac{1.25-1}{1.25} \times \frac{1.4}{1.4-1} \times \frac{229.6}{310-229.6}$

$= 11.99$ Ans

Ques A dense air machine operates on reverse Brayton cycle and is required for a capacit of 10TR. The cooler pressure is 4.2 bar and refrigerator pressure is 1.4 bar. The a is cooled in the cooler at a temperature of and the temperatare of air at inlet to compressor is $-20°c$. Determine for the ideal cycle : 1. cop ; 2. mass of air circu per minute ; 3. theoretical piston displacem of compresson ; 4. theoritical ~~di~~ piston displacement of expander ; and 5. net power per ton of refrigeration

Sol^n ; Given data ;

$Q = 10TR$

$P_2 = P_3 = 4.2$ bar

$P_1 = P_4 = 1.4$ bar

$T_3 = 50°c = 50 + 273 = 323K$

$T_1 = -20 + 273 = 253 K$

Let , T_2 and T_4 = temperature at end of com expansion

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

$$\Rightarrow \frac{T_2}{253} = \left(\frac{4.2}{1.4}\right)^{\frac{1.4-1}{1.4}} = 1.369$$

$$\Rightarrow T_2 = 1.369 \times 253 = 346 \text{ K}$$

Similarly,

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \frac{323}{T_4} = \left(\frac{4.2}{1.4}\right)^{\frac{1.4-1}{1.4}} = 1.369$$

$$\Rightarrow T_4 = \frac{323}{1.369} = 236 \text{ K}$$

We know that,

① $$\text{C.O.P} = \frac{T_1 - T_4}{(T_2 - T_3) - (T_1 - T_4)}$$

$$= \frac{(253 - 236)}{(346 - 323) - (253 - 236)}$$

$$= 2.83$$ Ans

(ii) $$m_a = \frac{\text{Heat extracted /min}}{\text{Heat extracted/kg}}$$

$= \cancel{\frac{2100\ KJ/min}{17}}$

We know that,

Heat extracted / kg $= cp(T_1 - T_4)$

$= 1(253 - 236)$

$= 17\ KJ/Kg$

and $Q = 10TR = 10 \times 210 = 2100\ KJ/mi$

$\therefore\ Ma = \frac{2100\ KJ/min}{17\ KJ/Kg}$

$= 123.5\ kg/min$ Ans

(iii) Theoritical piston displacement of compressor per

$V_1 = \frac{Ma\, Ra\, T_1}{P_1}$

$= \frac{123.5 \times 0.287 \times 253}{1.4 \times 10^5\ N/m^2}$

$= 64.$[illegible] m^3 Ans

(iv) $V_4 =$ Theoritecal piston displacement of expander per min.

We know that 4-1 is constant pressure

$$\frac{V_4}{T_4} = \frac{V_1}{T_1}$$

$$\Rightarrow \frac{V_4}{236} = \frac{64}{253}$$

$$\Rightarrow V_4 = \frac{64 \times 236}{253} = 60.[illegible] \ m^3$$

(v) Net power per tonne of refrigeration.

we know that net work done on refregerating machine per min.

$= ma(\text{Heat rejected} - \text{Heat absorbed})$

$= ma \times C_p[(T_2 - T_3) - (T_1 - T_4)]$

$= 123.5 \times 1[(346 - 323) - (253 - 236)]$

$= 741 \ KJ/min$

Net power of refregeration machine $= 741/60$

$= 12.35 \ KW$

Net power per tonne of ref. $= 12.35/10 = 1.235 \ KW/TR$

Merit of Air refrigeration system :

(i) The air is available (easily) and their is no cost of refrigerant

(ii) The air is non-toxic and ~~non~~ inflammeable.

(iii) The leakage of air is small amount is tollercab

(iv) Since the main compressor is employed for the compressed air sources, therefore is no problem for space for extra compressor

(v) The air is light in weight per tonne of refrigerant.

(vi) The chilled air is directly used for cooling there by eleminating the cost of separate evaporat

(vii) Since the pressure in the whole system is quite lo therefore the piping, dusting etc are quite simle to design, fabricate and maintain.

Demerits of air refrigeration system :-

(i) It has low co-effecient of performance (C.O.P

(ii) The rate of air circulation is relatively larg

Methods of Air Ref. System:

The various methods of air refrigeration systems, used for aircrafts these days are the follows.

1. Simple air cooling System
2. Simple air evaporative cooling system
3. Boot strap air cooling system
4. Boot strap air evaporative cooling system
5. Reduced ~~air~~ ~~ed~~ ambient air cooling system
6. Regenerative air cooling system.

CH-2

SIMPLE VAPOUR COMPRESSION REFRIGERATION SYSTE

(i) A ~~vapour~~ VCRS is an improver type of air refrigeration system in which an suitable work substance termed as refrigerant is used.

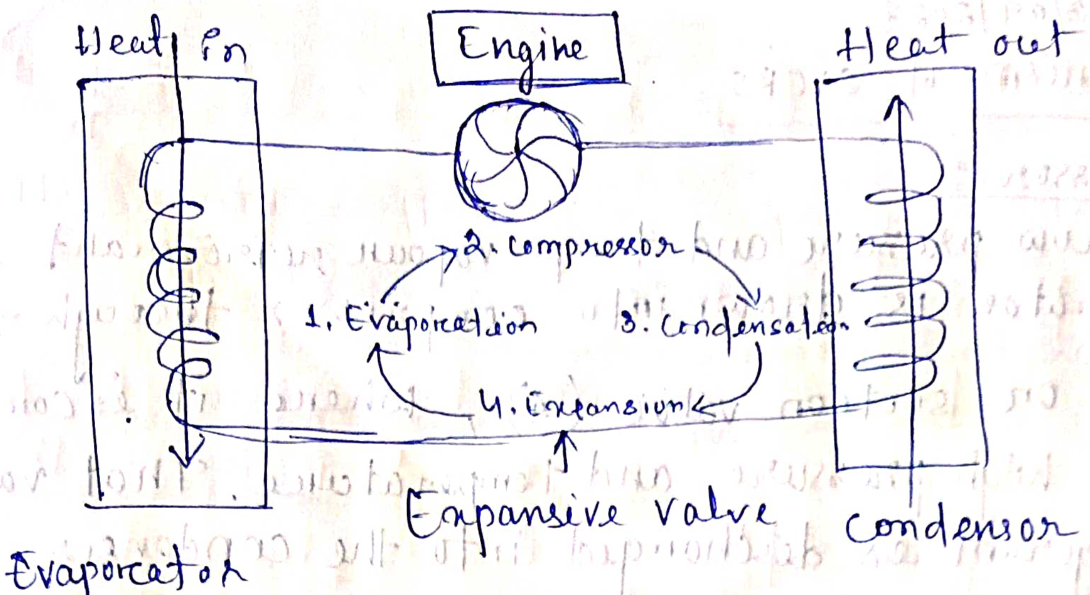
(ii) Since ~~the~~ low ~~pres va~~ pressure vapour refrig from the evaporator is changed high pressure vapour refrigerant in the compressor there force it is named as vapour compressor refrig ation system (VCRS)

(iii) The refrigerant are used in this system are ammonia (NH_3), carbon dioxide (CO_2), sulphur dioxide (SO_2).

(iv) The refrigerant used does not leave the system but it circulated through out the system alternately condensing and evaporating

(v) The vapour compression refrigeration system is now a days used for all purpose refrigeration

(vi) It is generally used for industrial purp from a small domestic refrigerator to a big air conditioning plant



(Engine - driven vapour compressor heat pump)

Advantages and Disadvantages of VCRS over air refrigeration system :

Advantages :-

(i) It has smaller size for the given capacity of refrigeration.

ii) It has less running cost.

iii) It can be employed over a large range of temperature.

iv) The C.O.P is quite high

Disadvantages :

i) The initial cost is high.

ii) The prevention of leakage of the refrigerant is the major problem in vapour compression system.

Date: 23/09/2022

Mechanism of SVCRS

1. Compressor :-

The low pressure and temp. vapour refrigerant from evaporator is drawn into compressor through the inlet or suction valve (A), where it is compressed to a high pressure and temperature. That vapour refrigerant is discharged into the condenser through the delivery or discharge valve (B)

2. Condenser :

The condenser or cooler consist of coils of pipe in which the high pressure and temp. vapour refrigerant is cooled and condensed. The refrigerant while passing through the condenser gives up its latent heat to the surrounding condensing medium which normally air or water

3. Receiver :

The condensed liquid refrigerant from the condenser is stored in a vessel known as reciever from where it is supply to evaporator through the expansion valve or refrigerant control valve

4. Expansion valve :

It is also called throttle valve or refrigerant control valve. The function of the expansion valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. some of the liquid refrigerant evaporates at it passes through the expansion valve but the greater part is vapourised in the evaporator at low pressure and temperature.

5. Evaporator

An evaporator consist of coils of pipe in which the liquid vapour refrigerant at low temp. & pressure is evaporated and change into vapour refrigerant at low temperature and low pressure. In evaporating the liquid vapour refrigerant absorbs its latent heat of vapourisation from the medium (Air, water, brine) which is to be cooled

* Breine is used as it has a very low freezing temperature

Types of vapour compression cycle :-

1. cycle with drysaturated vapour after compression
2. Cycle with wet vapour after compression
3. cycle with super heated vapour after compression
4. cycle with superheated vapour before compression
5. Cycle with under cooling or sub cooling of refrigerant.

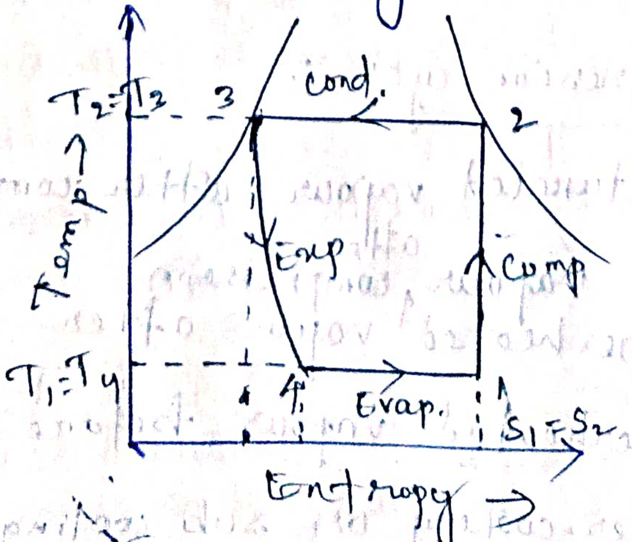
* Theoritical vapour compression cycle with dry saturat vapour after compression :

1. compression process :-

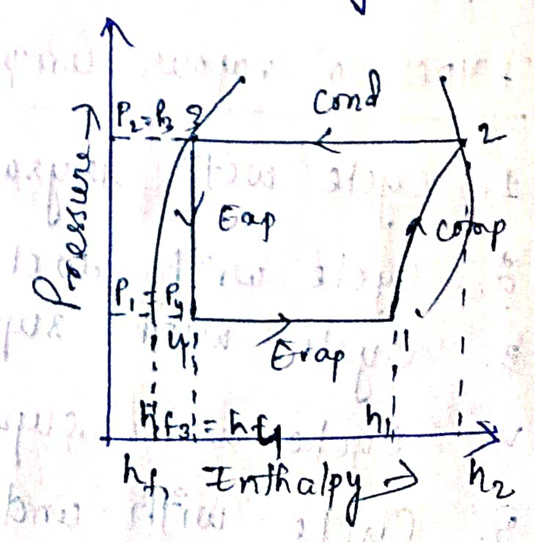
The vapour refrigerant at low pressure P_1 & temperature T_1 is compressed isentropically to dry saturated vapour as shown by vertic line 1-2 on T-s diagram and by curve 1-2 on ~~P-H~~ p-h diagram the pressure & temperature rises from P_1 to P_2 and T_1-T respectively. The work done during isentropic compression per kg of ~~are~~ refrigerant ~~is~~ is given by $W = h_2 - h_1$

h_1 = Enthalpy of vapour refrigerant at temp. T (at suction of the compressor)

h_2 = Enthalpy of the vapour refrigerant at



(T-s diagram)



(P-h diagram)

2. Condensing process:

The high pressure and temperature vapour refrigerant from the compressor is passed through the condenser, where it is completely condensed at constant pressure P_2 and temperature T_2 as shown by the ~~curve~~ horizontal line 2-3 on T-s and P-h diagram.
The vapour refrigerant change into liquid refrigerant the refrigerant passing through the condenser gives its latent heat to the surrounding condensing Medium

3. Expansion process:

The liquid refrigerant at pressure $P_3 = P_2$ ~~the~~ and temp $T_3 = T_2$ is expanded by throttling process through the expansion valve to a low pressure $P_4 = P_1$ and temperature $T_4 = T_1$ as shown by the curve 3-4 on T-s and P-h diagram.

We have already discussed that some of the liquid refrigerant as it is passes through the expansion valve but the greater portion is vapourised in the evaporator. We know that during the throttling process no heat is absorbed or rejected by the liquid refrigerant

Note: In case of expansion cylinder ~~is used if~~ is used in place of throttle or expansion valve to expand the liquid refrigerant then the ~~ss~~ refrigerant will expand isentropica as shown by the doted vertical line on T-s diagram.

→ The isentropic expansion reduces the external work being expanded in running the compressor and increases the refrigerating effect. Thus, the net result of using the expansion cylinder is to increase the C.O.P

→ Modern domestic refrigerators, capilary is used in place of expansion valve

4. Vapourising process :

→ The liquid vapour mixture at constant temperature $T_4 = T_1$ and pressure $P_4 = P_1$ is evaporated and change into the vapour refrigerent at constant pressure and temp. as shown by horizontal line 4-1 on T-s diagram and P-h diagram.

→ During evaporation the liquid vapour refriger absorbes its latent heat of vapourisation from the medium (air, water, brine) which is to b cooled.

This heat which is absorve by the refrigerant is called refrigerating effect (R_E).

We know that the refrigerating effect for heat absorbed or ~~reject~~ extracted by the liquid vapour refrigerant during evaporation per kg of refrigerant is given by

$$R_E = h_1 - h_4 = h_1 - h_{f3} \quad (\because h_4 = h_{f3})$$

where, h_{f3} = sensible heat at temp. T_3 i.e enthalpy of liquid refrigerant leaving condenser.

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

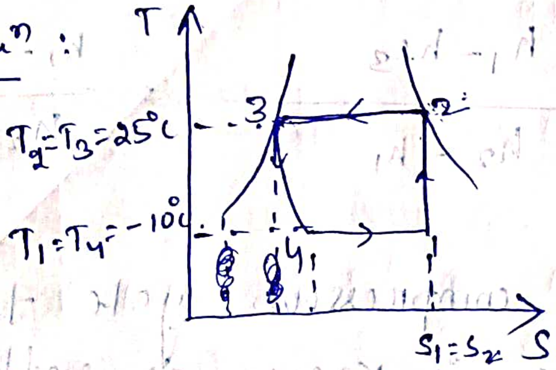
$$= \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{h_1 - h_4}{h_2 - h_1}$$

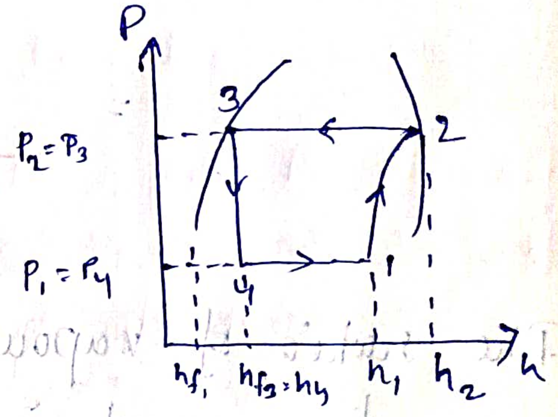
The ratio of vapour compression cycle to the C.O.P of carnot cycle is known as ~~relfi~~ refrigeration effect (η_R) or performance index (PI)

Ques The temperatur limits of an ammonia refrigera system are 25°C and -10°C. If the gas is dry at the end of compression calculate the C.O.P of the cycl assuming no under cooling of the liquid ammonia. & use the following table for the properties of ammonia.

Temp (°C)	Liquid heat	Latent heat	liquid entropy
25°C	298.9	1166.94	1.1242
-10°C	135.87	1297.68	0.5443

Solu^n :





Given data; $T_2 = T_3 = 25°C = 25+273 = 298\,K$

$T_1 = T_4 = -10°C = -10+273 = 263\,K$

$h_{f_2} = 298.9$ KJ/Kg

$h_{fg_2} = 1166.94$ KJ/Kg

$S_{f_2} : 1.1242$ KJ/Kg

$h_{f_1} = 135.87$ KJ/Kg

$h_{fg_1} = 1297.68$ KJ/Kg

$S_{f_1} = 0.5443$ KJ/Kg

Let x_1 = dryness fraction at point 1

We know that entropy at point 1

$$s_1 = s_{f_1} + \frac{x_1 h_{fg_1}}{T_1}$$

$$= 0.5443 + x_1 \times \frac{1297.68}{263}$$

$$= 0.5443 + 4.934 x_1 \quad \text{------} ①$$

Entropy at point 2

$$S_2 = S_{f_2} + \frac{h_{fg_2}}{T_2}$$

$$= 1.1242 + \frac{1166.94}{298}$$

$$= 5.04 \text{ KJ/KgK} \quad \text{------} (II)$$

We know that

$$s_1 = S_2$$

$$\Rightarrow 0.5443 + 4.934 x_1 = 5.04$$

$$\Rightarrow x_1 = \frac{5.04 - 0.5443}{4.934} = 0.911$$

Enthalpy at point 1

$h_1 = h_{f1} + x_1 h_{fg1}$

$= 135.37 + 0.91 \times 1297.68$

= ~~1316.25 KJ/Kg~~

$= 1316.25$ KJ/Kg

$h_2 = h_{f2} + h_{fg2}$

$= 298.9 + 1166.94$

$= 1465.84$ KJ/Kg

$h_3 = h_{f3} + x_3 h_{fg3}$

= ~~$h_{f3} = 298.9$ KJ/Kg $= h_{f2} = h_4$~~

$= h_{f3} = 298.9$ KJ/Kg $= h_{f2} = h_4$

$\therefore$ C.O.P = $\dfrac{\text{Refrigeration effect}}{\text{workdone}}$

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

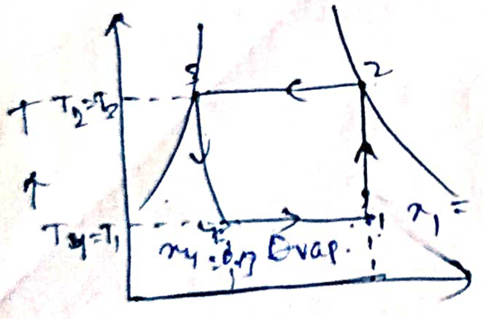
$$= \frac{1316.25 - 298.9}{1465.84 - 1316.25}$$

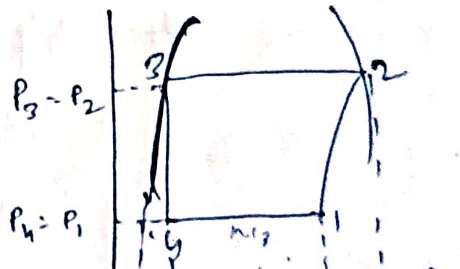
$= 6.8$ (Ans)

h_{fg} = latent heat of gas

Que In an ammonia vapour compression system the pressure in the evaporator is 2 bar. Ammonia at exit is 0.85 dry and at entry ~~[illegible]~~ its dryness fraction is 0.19. During compression the work done per Kg of ammonia is 150 KJ. Calculate the C.O.P and the volume of the vapour entering the compressor per minute If the rate of ammonia circulation is 4.5 Kg/min.

The latent heat and the specific volume at 2 bar are 1325 KJ/Kg and 0.58 m^3/Kg respectively





Sol^n Given data;

$P_4 = P_1 = 2$ bar

$x_1 = 0.85$, $x_4 = 0.19$

$W = 150$ KJ/kg

$h_{fg} = 1325$ KJ/Kg

$v = 0.58$ m^3/Kg

$m_a = 4.5$ Kg/min

① C.O.P $= \frac{h_1 - h_4}{W}$

Let, Enthalpy at point 1

$h_1 = x_1 \times h_{fg} = 0.85 \times 1325 = 1126.25$ KJ/Kg

Enthalpy at point 4

$h_4 = x_4 \times h_{fg} = 251.75$ KJ/Kg

$\therefore$ RE $= h_1 - h_4 = 1126.25 - 251.75 = 874.5$ KJ/Kg

$$\therefore \quad C.O.P = \frac{h_1 - h_4}{W} = \frac{1126.25 - 251.75}{150}$$

$= 5.83$ (Ans)

② Volume of the vapour

= Ma × specific volume

$= 4.5\ \cancel{Kg}/min \times 0.58\ m^3/\cancel{Kg}$

$= 2.61\ m^3/min$ (Ans)

Theoritecal cycle with wet vapour compressi

Q. find the theoritecal COP for a CO_2 machine working between the temp. range of 25°C and -5°C. The dryness fraction ~~during~~ of CO_2 gas during the suction stroke is 0.6. following properties of CO_2 are given

$h_{f_3} = h_{f_2} = 164.77$ KJ/Kg

$h_{f_1} = h_{f_4} = 72.57$ KJ/Kg

$s_{f_2} = 0.5978$ KJ/KgK

$s_{f_1} = 0.2862$ KJ/Kg K

$h_2' = 282.23$ KJ/Kg

$h_1' = 321.33$ KJ/Kg

$s_2' = 0.9918$ KJ/KgK

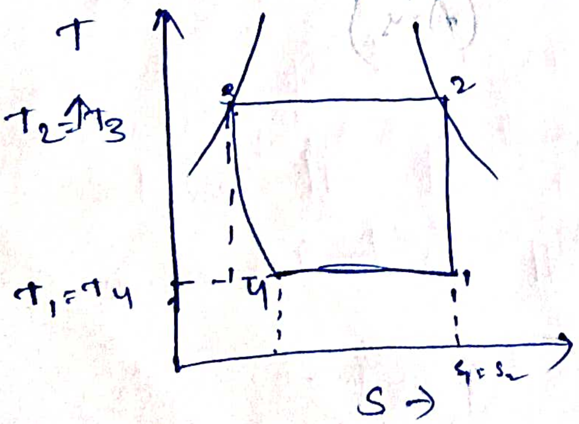
$s_1' = 1.2146$ KJ/KgK

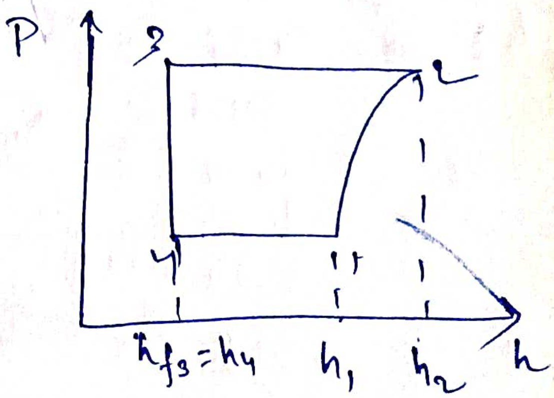
$h_{fg_2} = 117.46$ KJ/Kg

$h_{fg_1} = 248.76$ KJ/Kg

$T_2 = 25°C = 25 + 273 = 298$ K

$T_1 = -5°C = -5 + 273 = 268$ K, $x_1 = 0.6$





$$s_2 = s_{f_2} + \frac{x_2 h_{fg_2}}{T_2}$$

$$= \overset{0.5978}{\cancel{0.2862}} + x_2 \frac{117.46}{298}$$

$$= \cancel{0.99x_2} \quad 0.5978 + 0.394 x_2$$

$$s_1 = s_{f_1} + \frac{x_1 h_{fg_1}}{T_1}$$

$$= 0.2862 + \frac{0.6 \times 248.76}{268}$$

$$= \overset{0.84}{\cancel{0.84}} \ \cancel{0.2862} +$$

We know that

$$s_1 = s_2$$

$$\Rightarrow 0.84 = \cancel{0.99x_2} \quad 0.5978 + 0.394 x_2$$

$$\boxed{\Rightarrow \cancel{x_2 = \frac{0.84}{0.99} \quad 0.84}}$$

$$\Rightarrow x_2 = \frac{0.84 - 0.5978}{0.394} = 0.62$$

$$h_1 = h_{f_1} + x_1 h_{fg_1}$$

$$= 72.57 + 0.6 \times 248.76 = 221.82 \text{ KJ/Kg}$$

$$h_2 = h_{f_2} + x_2 h_{fg_2} = 164 + 0.62 \times 117.46$$

$$= \overset{236.93}{\cancel{233.66}} \text{ KJ/Kg}$$

$$\therefore \text{Theoritical C.O.P} = \frac{h_1 - h_4}{h_2 - h_1}$$

$$= \frac{221.82 - 164.77}{236.93 - 221.82}$$

$$= 3.77 \quad \text{Ans}$$

Theoritical vapour compression cycle with wet vapour after compression:

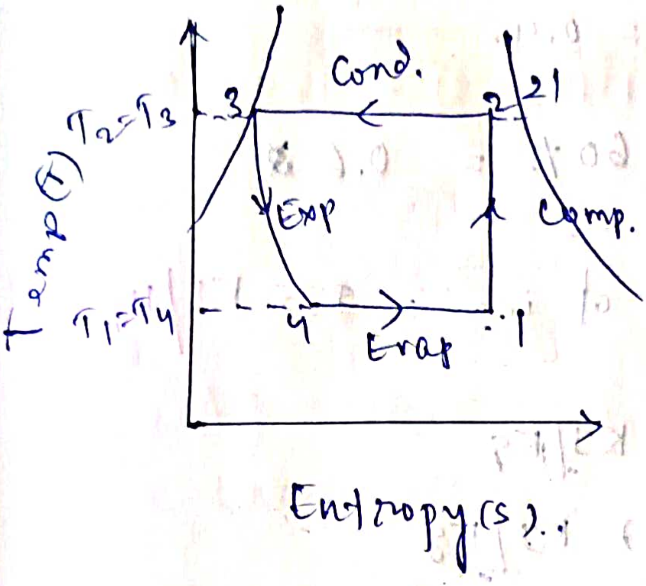
A vapour compression cycle with wet vapour comp^n is a similar kind of cycle to dry saturated vapour after compression. But in this cycle enthalpy at point '2' found out with the help of dryness fraction at this point. The dryness fraction at point 1 and 2 may be obtained by equating entropies at point 1 and 2

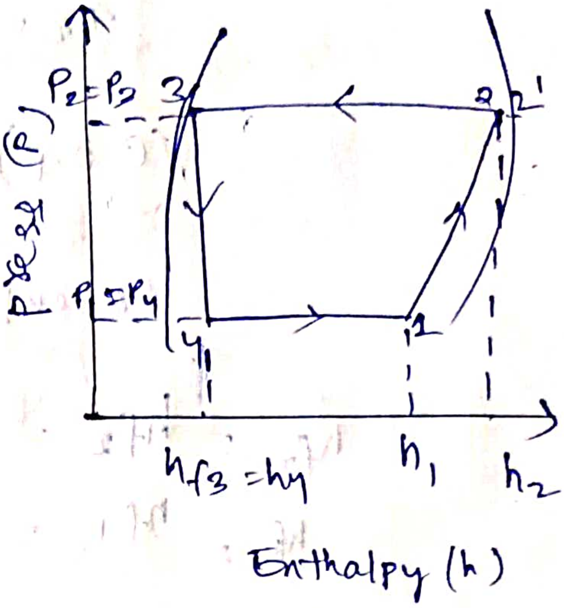
Now the theoritical C.O.P may be found out as usual from the relation

$$\text{Theoritecal C.O.P} = \frac{h_1 - h_{f_3}}{h_2 - h_1}$$

$$= \frac{\text{Reffrigeration effect}}{\text{work done}}$$

The T-s and P-h diagram of wet vapour comp^n is drawn below





Ques An ammonia refrigeration machine filled with an expansion valve, works between the temperature limits -10°c and 30°c. the vapour is 95% dry at the end of the isentropic compression & the fluid leaving the condenser is at 30°c assuming actual C.O.P as 60% of theoritical C.O.P calculate the Kgs of ice produce per KW hour at 0°c from water at 10°c. Latent heat of ice is 335 KJ/Kg

Temp (°c)	Liquid heat (h_f) KJ/Kg	Latent heat (h_{fg}) KJ/Kg	Liquid entropy (S_f)	Total Entropy of d.s.v
30	323.8	1145.80	1.2037	4.9842
-10	135.37	1297.68	0.5443	5.4770

Given data; $T_1 = T_4 = -10°C = -10+273 = 263\ K$

$T_2 = T_3 = 30°C = 30+273 = 303\ K$

$x_2 = 95\% = 0.95$

$(C.O.P)_{act} = 60\% = 0.6$

Latent heat of ice = 335 KJ/Kg

$h_{f_3} = h_{f_2} = 323.8$ KJ/Kg

$h_{f_4} = h_{f_1} = 135.87$ KJ/Kg

$h_{fg_2} = 1145.80$ KJ/Kg

$h_{fg_1} = 1279.68$ KJ/Kg

$s_{f_2} = 1.2037$ KJ/KgK

$s_{f_1} = 0.5443$ KJ/KgK

$s_2' = 4.9842$ KJ/KgK

$s_1' = 5.4770$ KJ/KgK

Let dryness fraction at point(1) x_1

$$s_1 = s_{f_1} + \frac{x_1 h_{fg_1}}{T_1}$$

$$= 0.5443 + x_1 \frac{1279.68}{263}$$

$$= 0.5443 + 4.865 x_1$$

$$s_2 = sf_2 + \frac{x_2\, hfg_2}{T_2}$$

$$= 1.2037 + \frac{0.95 \times 1145.80}{303}$$

$$= 4.796$$

we know that

$s_1 = s_2$

$\Rightarrow 0.5443 + 4.865\, x_1 = 4.796$

$$\Rightarrow x_1 = \frac{4.796 - 0.5443}{4.865}$$

$$= 0.873$$

$h_1 = hf_1 + x_1\, hfg_1$

$= 135.87 + 0.87 \times 1279.88 = 1249.919$

$h_2 = hf_2 + x_2\, hfg_2$

$= 323.8 + 0.95 \times 1145.80 = 1412.31$

Theoretical $c.o.p = \frac{h_1 - h_{f3}}{h_2 - h_1}$

$= \frac{1249.19 - 323.8}{1412.31 - 1249.19}$

$= 5.6$

Actual $c.o.p = 0.6 \times 5.6 = 3.36$ (Ans)

work to be spent corresponding to 1 Kw hr

$W = 3600$ KJ

$\therefore$ Actual heat extracted or ref. effect

Per Kw hour $= W \times (COP)_{act}$

$= 3600 \times 3.36$

$= 12096$ KJ

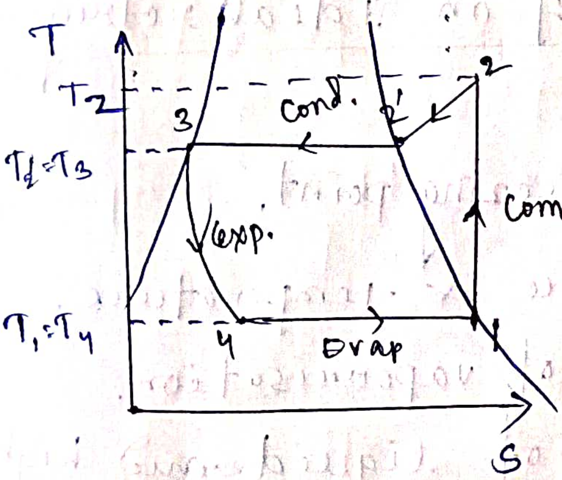
We Know that

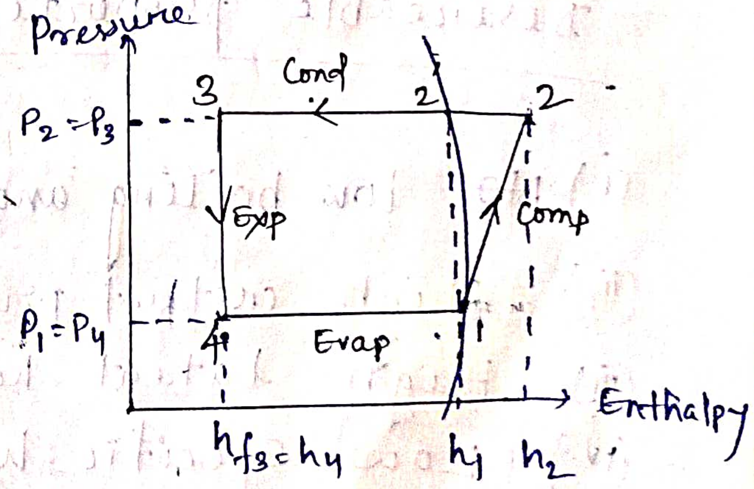
* Theoritical vapour compression cycle ~~refrigeration system~~ with superheated vapour after ~~before~~ compression

In this cycle the enthalpy at point 2 is foundout with the help of degree of super heat. The degree of super heat may be found out by equating the entropies at point 1 and 2. Now the C.O.P may be found out as usual from the relation

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

$$= \frac{h_1 - h_{f3}}{h_2 - h_1}$$





A little consideration will show that the super heating increases the refrigerating effect and the amount of work done in the compressor. since the increase in refrigeration effect is less as compare to increase in work done, therefore the net effect of super heating is to have low C.O.P

In this cycle the cooling of superheated vapour ~~to~~ will take place in two stages.

→ Firstly it will be condensed to dry saturated stage as constant pressure (shown by graph 2-2') and second it will be condensed at constant temp (shown by graph 2'-3). The remaining is same as discussed in wet vapour after compression

* Refrigerant :

Desireable properties of an Ideal refrigerant

(i) ~~No~~ low boiling and freezing point.
(ii) High critical pressure & temperature.
(iii) High latent heat of vapourisation.
(iv) Low specific heat of liquid and high specific heat of vapour.
(v) Low specific volume of vapour.
(vi) High thermal conductivity.
(vii) Non corrossive to metal.
(viii) Non flame-able and non-explosive.
(ix) Non toxic

(x) Low cost.

(xi) Easily and regularly available

(xii) Easy to liquify and moderate pressure & temperature

(xiii) Easy of locating legs ~~and~~ by odour or suitable indicator.

(xiv) Miscible with oil.

(xv) High COP.

(xvi) Ozone friendly

The standard compression of refrigerant, as used in the refrigeration industry is based on an evaporating temperature of -15°c and a condensing temperature of +30°c.

CLASSIFICATION OF REFRIGERANTS :

The refrigerants may be broadly classified as into the following two groups:

① Primary refrigerants and;

② Secondary refrigerants.

The ~~primary~~ refrigerants which is directly take part in the refrigeration system are called primary refrigerants. whereas the refrigerants which are first cooled by primary refrigerants and then used for cooling purpose are known as secondary refrigerants.

CH : 3

VAPOUR ABSORPTION REFRIGERATION SYSTEM

- The vapoure absorption refrigeration system is one of the oldest method of producing refrigeration effect.
- The system may be used in both domestic & larg Industriees refrigerating plant.
- The refrigerant that used in vapour absorption system is ammonia.
- The vapour absorption system uses the heat energy instead of mechanical energy as in vapour compression system in order to change conditions of the refrigerant required for the operating of the refrigeration cycle.
- In VARS, the compressor is replaced by an vapour absorber, ~~a~~ a pump, a generator & a pressure reducing valve. These components in VARS perform the same function as that of a compressor in VCS.

- The vapour refrigerant from the evaporator is drawn into an obsorber ~~which~~ where it absorbed by the weak solution of the refrigerant forming a strong refrigerant solution.

→ The strong solution is pumped to the generator whe it is heated by some external source. During the heating process the vapour refrigerant is ~~being~~ driven ~~by~~ off by the solution and enters into the condensor where it is liquified. The liquid refrigerant then flows into the evaporator and thus the cycle is completed.

SIMPLE VAPOUR ABSORPTION SYSTEM:

→ List of vapour absorption system components :-
an absorber, a pump, a generator, a pressure reducing valve, condenser, receiver, expansion valve, evaporator.

→ The low pressure ammonia vapour leaving the evaporator enters the absorber where it is absorbed by the cold water in the absorber. The water has the ability to absorb very large quantities of ammonia vapour and the solution thus, formed, is known as AQUA-AMMONIA.

→ The absorption of ammonia water lowers the pressure in the absorber which in turn draws more ammonia vapour from the evaporator and thus rises the temp of solution

→ Some form of cooling arrangement (usually water cooling) is employed in the absorber to remove the heat of solution evolved there.

→ This is necessary in order to increase the absorption capacity of water, because of higher temperature water absorber less ammonia vapour.

→ The strong solution thus formed in the absorber is pumped to the generator by the liquid pump. The pump increase the pressure of the solution up to 10 ba

→ The strong solution of ammonia in the generator is heated by some external source such as gas or steam.

→ During the heating process, the ammonia vapour is driven off the solution at high pressure leaving behind the hot weak ammonia solution in the ammonia.

→ This weak solution of ammonia flows back to the absorber at low pressure after passin through the pressure reducing valve.

→ The high pressure ammonia vapour from the generator is condensed in the condensor to a high pressure liquid ammonia.

→ This liquid ammonia is passed to the expansion valve through the reciever and then to the evaporator. This completes the simple vapour absorption cycle.

Refrigerant:

Refrigerant is a heat carrying medium whic during their cycle in the refrigeration sys absorb heat from a low temperature system and discard the heat to a higher tempera system surrounding

Properties of refrigerant :

(i) Low boiling point
(ii) High critical temperature
(iii) High latent heat of vapourisation
(iv) Low specific heat of liquid ~~and~~
(v) Low specific volume of vapour
(vi) Non corrossive to metal
(vii) Non - flameable and non explossive
(viii) Non - toxic
(ix) Low cost.
(x) Easy to liquify at moderate pressure and temperature.
~~(xi) Easy to leaks, by by~~
~~(xii) Easy of locating~~

(xi) Easy of locating ~~by~~ leaks by odoure or suitable indicator.

(xii) Mixes well with oil.

Classification of refrigerant :-

1. Primary refrigerant
2. Secondary refrigerant.

1. Primary refrigerant :-

The primary refrigerants directly take part in the refrigeration system are called primary refrigerants.

2. Secondary ref. :-

The secondary ref. are first cooled by primary refrigerant then used for cooling purposes are known as secondary refrigerants.

Primary refrigerant ~~types~~ :-

Primary refrigerants are following 4 groups

1. Halo carbon refrigerant
2. Azeotrope ref.
3. Inorganic ref.
4. Hydro carbon ref.

① Halocarbon

The American society of heating refrigeration and air-conditioning engineers (ASHRAE). Identify 42 Halocarbon compounds as refrigerants. These are all synthetically produced.

Ex -

Ref. No	Chemical Name	Chm formula
R-11	- Trichloromonofluro-Methane	CCl_3F (23.77°
R-12	- Dichloro difluoro Methene	CCl_2F_2 (-29°C
R22	- Monochloro	

Azeotrope:

The term azeotrope refers to a stable mixture of refrigerants whose vapour & liquid phases retained identical compositions over a wide range of temperature.

Ex :- R-500 → 73.8% R12 + 26.2% R152

R-502 → 48.8% R-22 + 58.2% R-

Inorganic ref.

The inoreganic refrigerants were exclussively used before the introduction of Halocarbon refrigerants

Ex :- R-717 → NH_3 → Ammonia → B.P → 33.3°C

R-729 → Air →

R-744 → CO_2 → B.P → -78.6°C

R-764 → SO_2 →

R-118 → Water (H_2O) →

Used air craft refrigeration system.

CO_2 →

SO_2 → Used in house hold and small commercial system.

H_2O) → Used for refrigerant vapour in absorption system

Hydrocarbons

It's are successfully used in industrial + commercial installations. They posses satisfactory thermodynamic properties but are highly flameable and explossive.

R-170 → Ethane → C_2H_6

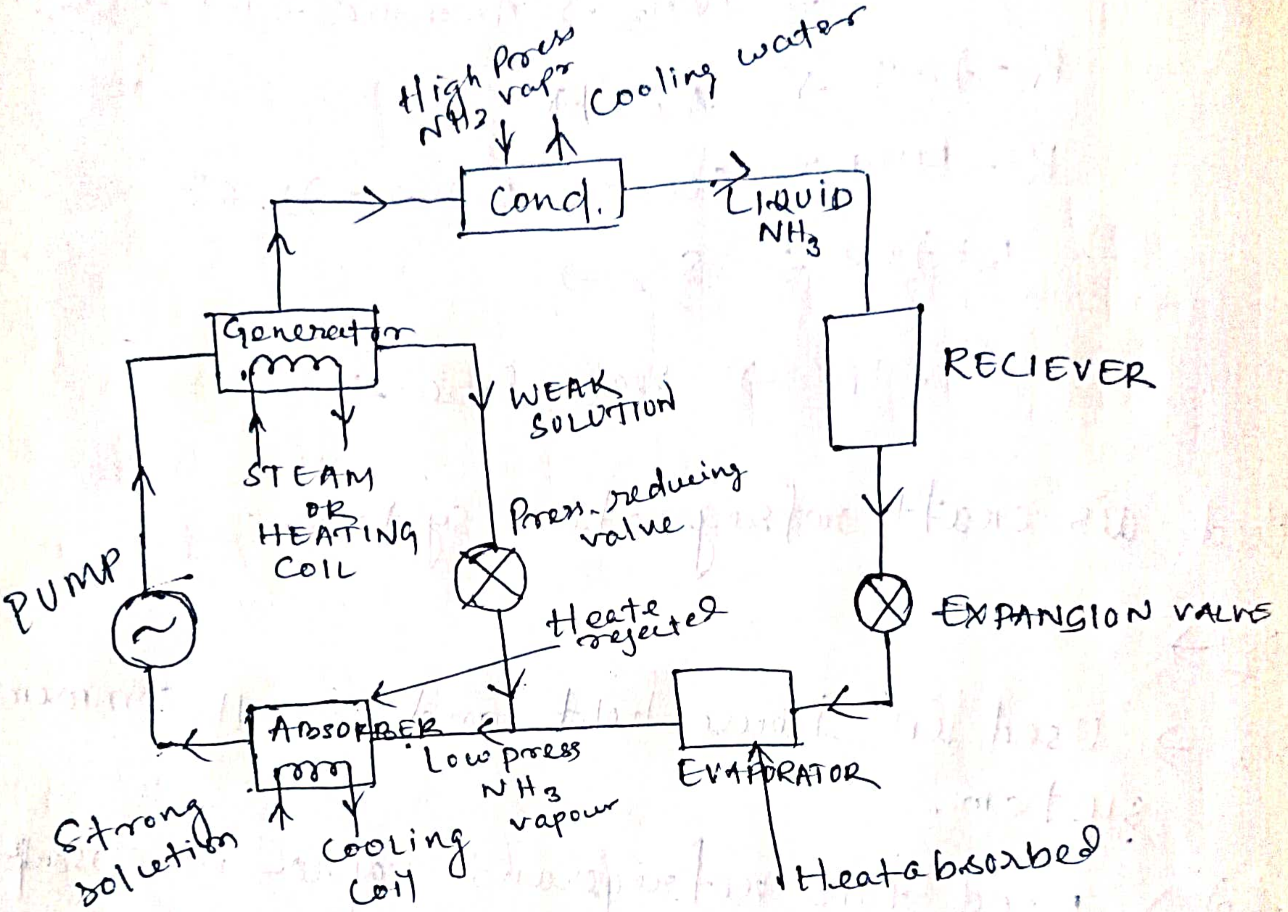
R-290 → Propane → C_3H_3

R-1150 → Ethylene → C_2H_4

R - 600 → Butane → C_4H_{10}

Date :- 25/11/2023

(CH-3) VAPOUR ABSORPTION SYSTEM



It is one of the oldest method of producing refrigeration effect. It may be used in both the domestic and large industrial refrigerating plants. NH_3 is commonly used the vapour absorption system uses heat energy, instead of mechanical energy as in vapour compression system.

In this system the vapour refrigerant from the evaporator is drawn into the absorber where it is absorb by weak solution the refrigerant forming a strong solution. This strong solution is pumped to the generator where it is heated by some external source then it is entered into the condenser where it is liquified.

(CH-5)

AIR-CONDITIONING SYSTEM

The air conditioning is a branch of engineering which deals with the study of conditioning of air i.e supplying and maintaining desireable internal atmospheric conditions for human comfort, Irrespective of external conditions

It also deals with conditioning of air for industrial purposes, food preserving, storage of food and other materials

Factor effecting ~~for~~ comfort Air-conditioning:

1. Temperature of air:

It may be noted that a human being feels comfortable when the air is at 21°C with 56% relative humidity.

2. Humidity of air:

In general for summer air conditioning, the relative humidity should be less than 60% where as for winter air conditioning it should not be 40%.

3. Purity of air:

For the comfor of a human-body proper filteration, cleaning and purification of air is essential to keep it free from dust and other impurities.

4. Motion of air:

The motion of air circulation is another important factor which should be controlled in order to keep constant temperature the condition space.

ates 28/

ifference between Air cooled and water cooled condenser.

Air cooled Condenser	Water cooled condenser
he construction f air cooled cond. is very simple thus he initial cost is less..	(i) The construction of water cooled condensor is complecated, thus the initial cost is high
No handling problem	(ii) Defficult to handle
Air cooled condensor donot required piping arrangement for carrying the air	(iii) water cooled condenser required piping arrangem
there is no problem in disposing of used air	(iv) There is a problem of disposing the use water unless a recirculation system is provided.
Since there is no corrosion therefore fowling effect is low	(v) since corrosion occurs insides the tube carrying the water, therefore fowling effects are high.

(vi) The air cooled condensor have low heat transfer capacity	(vi) The water cooled conde have high heat transfe capacity
(vii) The fan noise is high	(vii) There is no fan noise
(viii) These condensors have high flexibility	(viii) These condensors have low flexibility.
(ix) The distribution of air on condensing surface is non-uniform.	(ix) The distribution of water on condensing surface is uniform

Classification of compressors :-

1. According to method of compression
   - a) Reciprocating compressors
   - b) Rotary compressors
   - c) Centrifugal compressor
2. According to number of strokes :
   - a) Single acting compressors
   - b) Double acting compressors.
3. According to number of stages.
   - a) Single stage compressors
   - b) Multi stage compressors.

ii. According to drive

a) Direct drive compressors
b) Belt drive compressors.

According to location of prime mover

a) Semi hermatic compressor (Direct drive, motor and compressor in separate housings)
b) Hermetic compressors (Direct drive; motor and compressor in the same housings)

ans ⑦ Bwe Define swept volume!

-> It is also known as stroke volume or piston displacement volume.

-> It is the volume swept by the piston when it ~~mot~~ moves from top or inner dead position to bottom or outer dead possition.

$$\boxed{V_P = \frac{\pi}{4} \times D^2 \times L}$$

Psychometric terms:

1. Dry air:

-> A pure dry air is a mixture of number of gases such as nitrogen, oxygen, carbon dioxide, Hydrogen, Argon, Neon, Helium etc.

→ The pure dry air doesnot ordinarily exist because it alwaye contains some water vapour

→ The density of dry air is taken as 1.293 Kg/m³ at pressure 1.0135 bar and at temperature 0°C

2. Moist air:

→ It is a mixture of dry air and water vapour. The amount of water vapour present in the air depends upon the absolut pressure and temperature of the mixture

3. Saturated air:-

→ It is a mixture of dry air and water vapour, when the air has diffused maxim water vapour. The water vapours usual occur in the form of superheated steam.

→ when the saturated air is cooled, the wat vapour in the air starts condensing and are visible in the form of moist ~~air~~, fog of condensation on cold surfaces

4. Degree of saturation:

It is the ratio of actual mass of water vap in a unit mass of dry air to the mass of water vapour in the same mass of dry air when it is saturated at the same temperature

Date : 30/11/2022

Dry Bulb Temp

The temperature of air measured by ordinary thermometer is known as dry bulb temp. of the air

Wet bulb temperature :

The temperature of air measured by a thermometer when its bulb is covered with ~~weight~~ wet cloth is exposed to a current of air is known as wet bulb temperature.

Note: The difference between DBT & W.BT is known as wet bulb depression. Wet bulb depression will be zero when the air becomes saturated.

Dew point temperature :

It is defined as the temperature at which the moisture present in the air begins to condense when the air is cooled. The dew point temperature corresponds to the —

Saturation temperature of water vapour in the mixture of air and wet vapour

- The dry-bulb, wet bulb and dew point temperature will all be say for saturated air

Specific Humidity :

It is the mass of water vapour present in one Kg of dry air.

Absolute Humidity :

The mass of water vapour present in 1m³ of air is known as Absolute Humidity.

Degree of saturation :

It is defined as the ratio of water vapour in unit mass of dry air when it is saturated.

Relative Humidity :

It is equal to the ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour of the saturated air at the same temp

Psychometric :

The science which deals with the study of the behaviour of air and water vapour mixture is known as psycometry.

The properties of water vapour and air mixture are known as spychometric properties.

What is the function of rectifire in VARS

In case the water vapours are not completely remove in the analysies, a closed type vapour cooler called rectifiere is used. It is generally water cooled and may be of the double pipe, shell and coil, or shell and tube type. It's function is to cool further the ammonia vapours having the analyser so that the remaining water vapource are condensed thus only dry ammonia vapours flow to the condenser

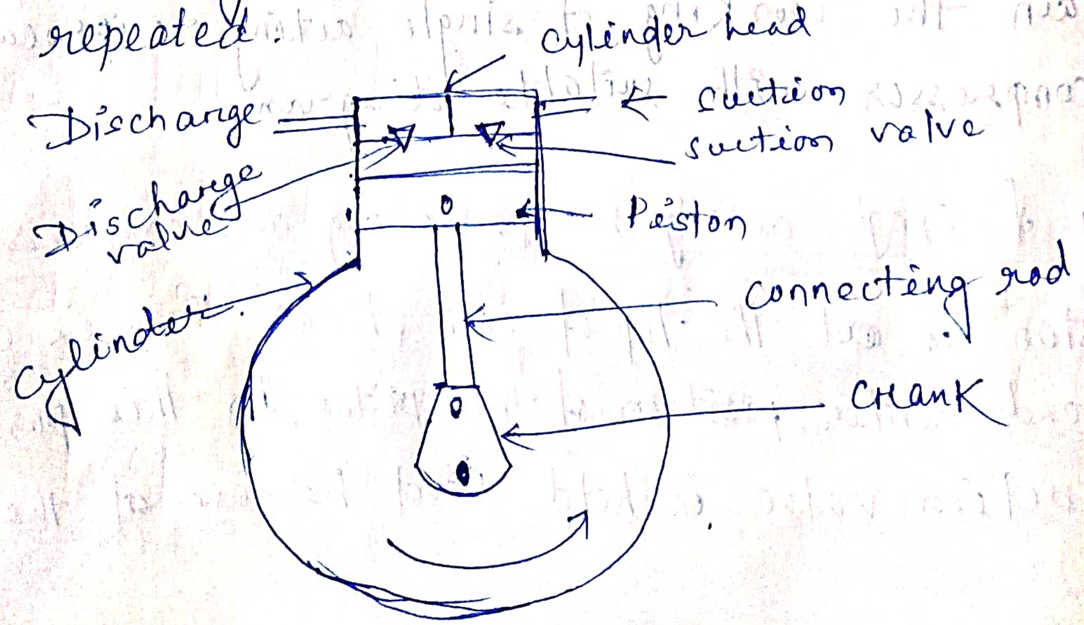
Ques Explain the working of single acting reciprocating air compressor with suitable diagram.

Working of single acting reciprocating air compressor :-

The piston is at the top of each stroke this is called Top dead center position of the piston. In this position the suction valve is held closed because of the –

Pressure in the clearance space between the top of the piston and the cylinder head. The discharge valve is also ~~held at~~ held closed because of the cylinder head pressure acting on the top of it.

→ When the piston moves down-ward, the refrigerant left in the clearance space expands. Thus the volume of the cylinder above the piston increases and the pressure inside the cylinder decreases. When the pressure becomes slightly less than the suction pressure or atmospheric pressure, the suction valve gets open and the vapour refrigerant flows in the cylinder. This flow continues until the piston reaches the bottom of the stroke. Here the suction valve closes. Now when the piston moves upward the volume of cylinder decreases and the pressure inside the cylinder increases. When the pressure inside the cylinder becomes greater than that on the top of the discharge ~~par~~ valve, the discharge valve gets upon and the vapour refrigerant is discharged in-to the condensers and the cycle is repeated.



Cold storage plant:

A cool store or cold store is a large refregerated room or building designed for storage of goods in an environment below the outer temperature.

Many food products may be stored at some temp. above the freezing point. The storage may be Short term storage or long term storage. The storages which are used for short term storage purposes are known as cold storages. The short terms storage is usually meant for written establishment where rapid turnover of the product is expected. The period for short term storage ranges from one to two days or to a week but not more than 15 days. The long term storage is usually carried out by holesallers and commercial storage ware houses. The storage period depends on the type of products stored and its condition on entering the storage. The maximum storage period for long term storage ranges from 10 days for sensitive products like ripe tomatoes and upto 6 to 8 months for more durable products such as onions. When perisable fruits are to be stored for longer period, they should be frozen and stored in frozen storages.

The conditions required for short term storages are more flexible than those required for long term storage.

→ Following points should be Kept in Mind while storing the foods in cold storages.

1. Storage temperature
2. Relative humidity and air motion
3. Mixed storage
4. Condition of products at the time of entering storage
5. Product chilling

Ques. What are the materials used for constucting duct in an air conditioning system?

1. Galvanised iron sheet metal
2. Allumenium sheet metal
3. Black steel
4. Resing bonded glass fibre
5. Cement asbestous duct for underground air distribution.
6. wooden ducts

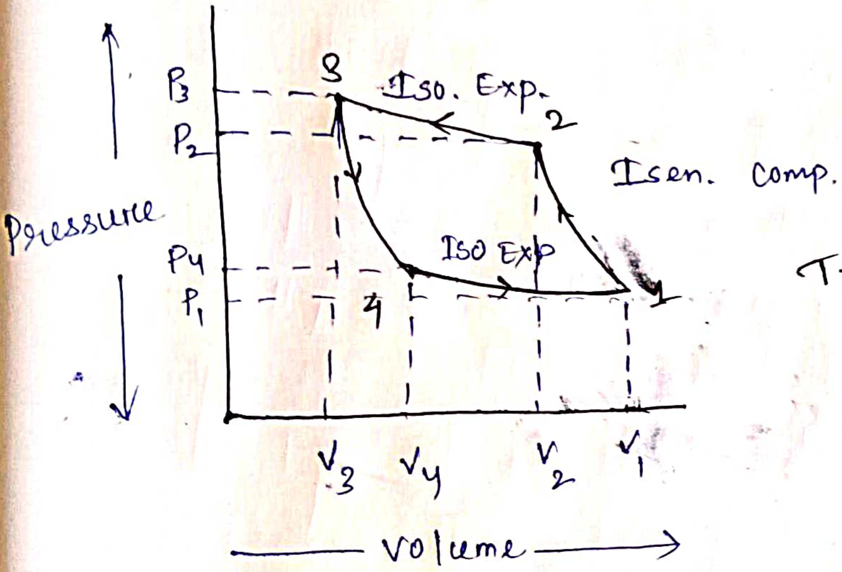
Air filter function :-

The function of air filter is to arrest the solid impurities such as soot, ash, smoke fumes & even living organisms such as virous, bacteria & fungus

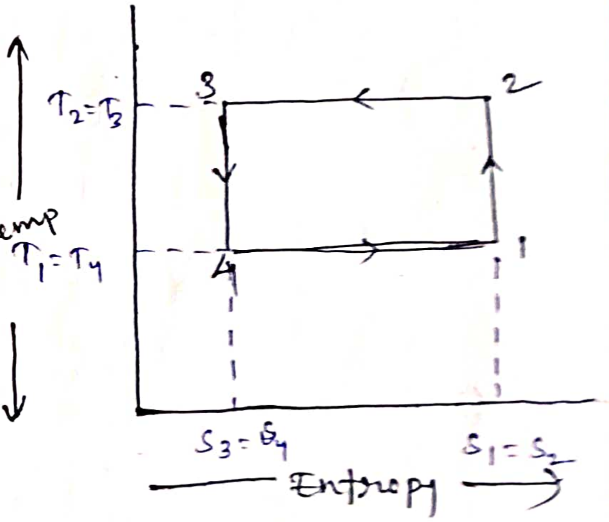
Classification of Air filter :

1. Dry air filters
2. Viscous impingement filter
3. Electrostatic filters

P-V diagram and T-S diagram of reversed carnot cycle.



(i) P-V diagram



(ii) T-s diagram.