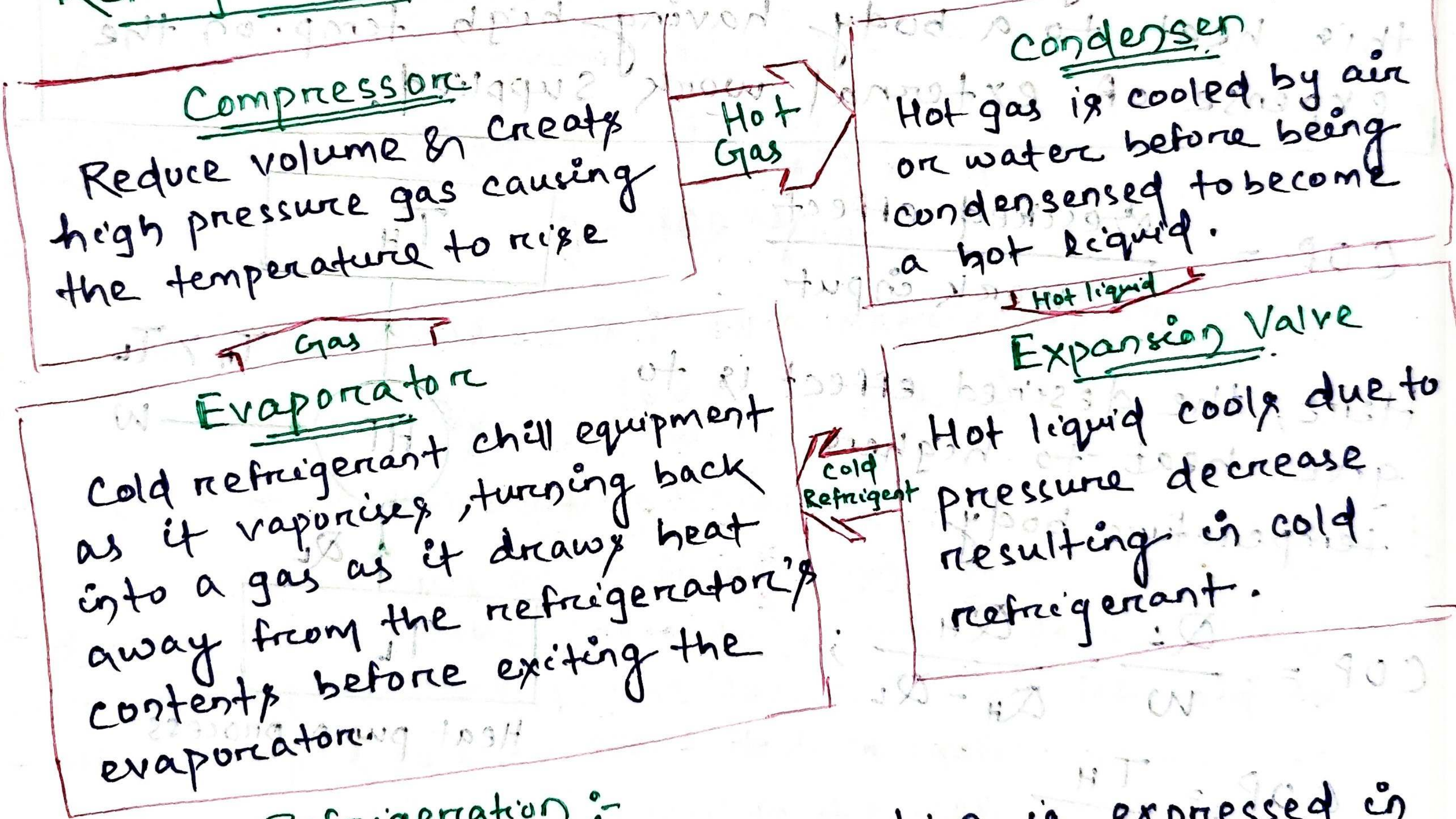
[Diploma] Refrigeration & Air Conditioning (5th sem)

Refrigeration :-

Refrigeration is the process in which heat is removed from a body enclosed space so that its temp. is reduced and then maintained at the temp. below the Surrounding temp.

Refrigeration Machine :- A refrigerating machine is a device which will either cool or maintain a body at a temp. below that of the surroundings. Heat must be made to flow from a body at low temp. to the Surrounding at high temp.

Refrigeration Cycle :-



Unit of Refrigeration :-

The practical unit of refrigeration is expressed in terms of tonne of refrigeration.

A tonne of refrigeration effect produced by the uniform melting of one tonne (1000 kg) of ice from and at 0°C in 24 hours. Since the latent heat of ice is 335 kJ/kg

There fore 1 T.R = 1000 x 335 kJ in 24 hours

$$\frac{1000 \times 335}{24 \times 60} = 232.6 \text{ kJ/min}$$

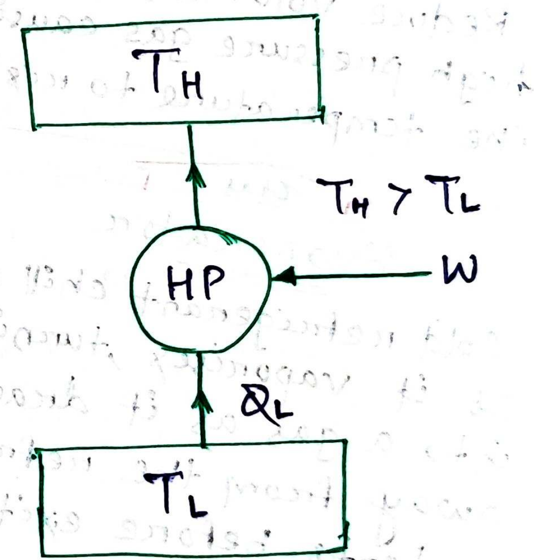
In actual, one tonne of refrigeration is taken as equivalent to 210 kJ/min or 3.5 kW (i.e 3.5 kJ/s)

COP :- Coefficient of performace :- The COP of a heat pump refrigerator or air conditioning System is a ratio of useful heating or cooling provided to work required.

→ Higher COPs equate to higher efficency, lower energy (power) consmption & thus lower operating costs.

Heat Pump :- Heat pump is used to remove heat from a body at lower temperature & trasfer this heat to a body having high temp. on the expense of external work supplied.

$$COP = \frac{\text{Desired effect}}{\text{work input}}$$



Heat pump process

Here, the desired effect is to give heat to higher temperature body.

$$COP = \frac{Q_1}{W} = \frac{Q_H}{Q_H - Q_L};$$

$$\therefore COP = \frac{T_H}{T_H - T_L}$$

$$(COP)_{pump} = \frac{1}{1 - \frac{T_L}{T_H}}$$

where T_H = high temperature

T_L = lower temperature

Q = Amount of heat extracted in the refrigerator / the amount of refrigeration produced or the capacity of refrigerator

W = Amount of work done.

Note: 1 for per unit mass, C.O.P. = q/w

Note: 2 The coefficient of performance is the reciprocal of the efficiency (i.e $1/\eta$) of a heat engine. It is thus obvious, that the value of C.O.P is always greater than unity.

Note: 3 The ratio of the actual C.O.P to the theoretical C.O.P is known as relative coefficient of performance.

Mathematically,

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

Q.1 Find the C.O.P of a refrigeration system if the work input is 80 KJ/kg and refrigeration effect produced is 160 KJ/kg of refrigerant flowing.

Soln: Data given $w = 80$ KJ/kg

$q = 160$ KJ/kg

We know that C.O.P of a refrigeration system

$q/w = 160/80 = 2$ (Ans)

Open Air Refrigeration Cycle :-

In an open air refrigeration cycle, the air is directly led to the space to be cooled (Refrigerator), allowed to circulate through the cooler & then returned to the compressor to start another cycle.

→ Since the air is supplied to the refrigerator at atmospheric pressure, therefore, volume of air handled by the compressor & expander is large. That's way the compressor & expander should be large.

→ Another disadvantage of open air refrigerator is that the moisture is regularly carried away by the air circulated through the cooled space.

→ This leads to the formation of frost at the end of the expansion process and clog the line. So in a open air refrigeration system a drier should be used.

Closed or Dense Air Refrigeration Cycle :-

→ In a closed or dense air refrigeration cycle the air is passed through the pipes & component parts of the system at all time.

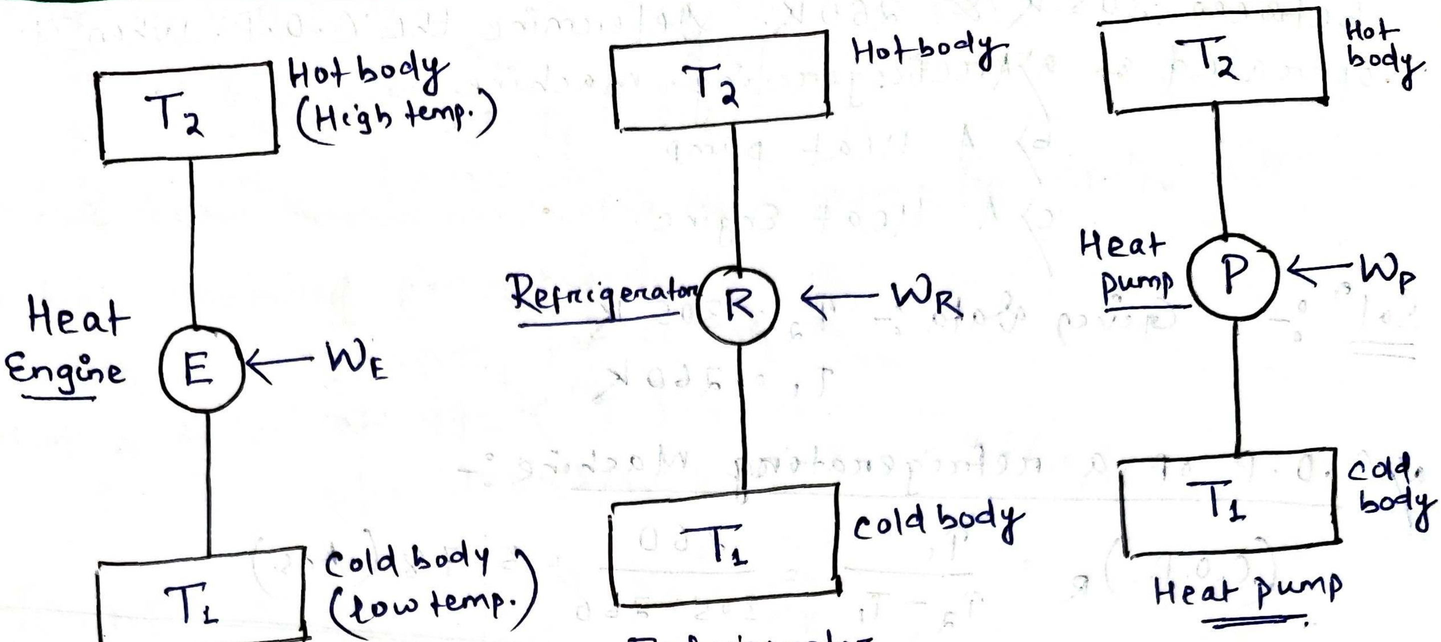
→ The air, in this system, is used for absorbing heat from the other fluid (say brine) & this cooled brine is circulated in to the space to be cooled. In the closed system the air does not come in contact directly with the space to be cooled.

→ Here it can work at a suction pressure higher than that of atmospheric pressure so the volume of air handle by compressor & expander are smaller as compared to an open air refrigeration cycle system

→ The operating pressure ratio can be reduced, which ~~resulting~~ results in higher co-efficient of performance.

Open System	Closed System
* Cold air at the exit of the turbine flows in to a room or cabin & cold HX doesn't exist.	* The same gas (air) flows through the cycle
* Will take fresh air for next cycle	* low side pressure can be above atmospheric.
* In such case, the low side pressure will be atmospheric.	* These systems are known as dense air systems.
	* Gases other than helium can be used.

Different between a Heat Engine, Refrigerator & Heat pump.



Heat Engine   Refrigerator   Heat pump

In Heat Engine the heat supplied to the engine is converted into useful work. if Q_2 is the heat supplied to the engine & Q_1 is the heat rejected from the engine the the work done by the Engine is $\boxed{W_E = Q_2 - Q_1}$

$$\eta_E \text{ or } (C.O.P.)_E = \frac{\text{work done}}{\text{Heat Supplied}} = \frac{W_E}{Q_2} = \frac{Q_2 - Q_1}{Q_2}$$

A refrigerator is a reversed heat engine which either cool or maintain the temperature of a body (T_1) lower than the atmosphere temp. (T_a). This is done by extracting the heat (Q_1) from a cold body & delivering into a hot body (Q_2). So work (W_R) is required to be done on the system. Thermodynamics 1st law. (Energy can be transferred from place to place or changed between different forms.)

$$W_R = Q_2 - Q_1$$

$$(C.O.P.)_R = \frac{Q_1}{W_R} = \frac{Q_1}{Q_2 - Q_1}$$

Heat pump similar to refrigerator. so

$$W_P = Q_2 - Q_1$$

$$(C.O.P.)_P \text{ or } E.P.R. = \frac{Q_2}{W_P} = \frac{Q_2}{Q_2 - Q_1}$$

$$= \frac{Q_1}{Q_2 - Q_1} + 1 = (C.O.P.)_R + 1$$

Q.1. A machine working on a Carnot cycle operates between 305 K & 260 K. Determine the C.O.P. when it is operated as a) A refrigerating machine
b) A Heat pump
c) A Heat Engine.

Sol^n :- Given data :- $T_2 = 305\,K$
$T_1 = 260\,K$

a) **C.O.P of a refrigerating Machine :-**

$$(C.O.P.)_R = \frac{T_1}{T_2 - T_1} = \frac{260}{305-260} = 5.78 \text{ (Ans.)}$$

b) **C.O.P. of a heat pump :-**

$$(C.O.P.)_P = \frac{T_2}{T_2 - T_1} = \frac{305}{305-260} = 6.78 \text{ (Ans.)}$$

$$(C.O.P.)_P = (C.O.P.)_R + 1 = 5.78 + 1 = 6.78 \text{ (Ans)}$$

c) **C.O.P. of Heat Engine**

$$(C.O.P.)_E = \frac{T_2 - T_1}{T_2} = \frac{305-260}{305} = 0.147 \text{ (Ans)}$$

$$(C.O.P)_E = \frac{1}{(C.O.P)_P} = 1/6.78 = 0.147 \text{ (Ans)}$$

Q.2. A Carnot refrigeration cycle absorbs heat at 270 K & rejects it at 300 K.

a) Calculate the coefficient of peformance of this refrigeration cycle?

b) if the cycle is absorbing 1130 KJ/min at 270 K, how many KJ of work is required per second?

c) if the carnot heat pump operates between the same temp. as the above refrigeration cycle, what is the coefficient of performace?

d) How many KJ/min will the Heat pump deliver at 300K if it absorbs 1130 KJ/min at 270 K.

Sol^n :- Given data :- $T_1 = 270\,K$
$T_2 = 300\,K$

a) We know that co-efficient of performance of Carnot refrigeration cycle,

$$(C.O.P.)_R = \frac{T_1}{T_2 - T_1} = \frac{270}{300 - 270} = 9 \text{ Ans.}$$

~~We know that C.O.P. of a heat pump $(C.O.P.)_P = (C.O.P.)_R + 1$~~

b) Work required per second

W_R = work required per second

Heat absorbed at 270 K (T_1)

$$Q_1 = 1130 \text{ KJ/min} = 18.83 \text{ KJ/sec.}$$

$$(C.O.P.)_R = \frac{Q_1}{W_R} \Rightarrow 9 = \frac{18.83}{W_R}$$

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

c) Co-efficient of performance of Carnot heat pump.

We know that coefficient of performance of Carnot heat pump.

$$(C.O.P.)_P = \frac{T_2}{T_2 - T_1} = \frac{300}{300 - 270} = 10 \text{ (Ans)}$$

d) Heat delivered by heat pump at 300K.

Let Q_2 = Heat delivered by heat pump at 300 K

Heat absorbed at 270 K (T_1)

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

We know that $(C.O.P.)_P = \frac{Q_2}{Q_2 - Q_1} \Rightarrow 10 = \frac{Q_2}{Q_2 - 1130}$

$$10 Q_2 - 11300 = Q_2$$

$$\Rightarrow Q_2 = 1256 \text{ KJ/min (Ans)}$$

Simple Vapour Compression Refrigeration System :-

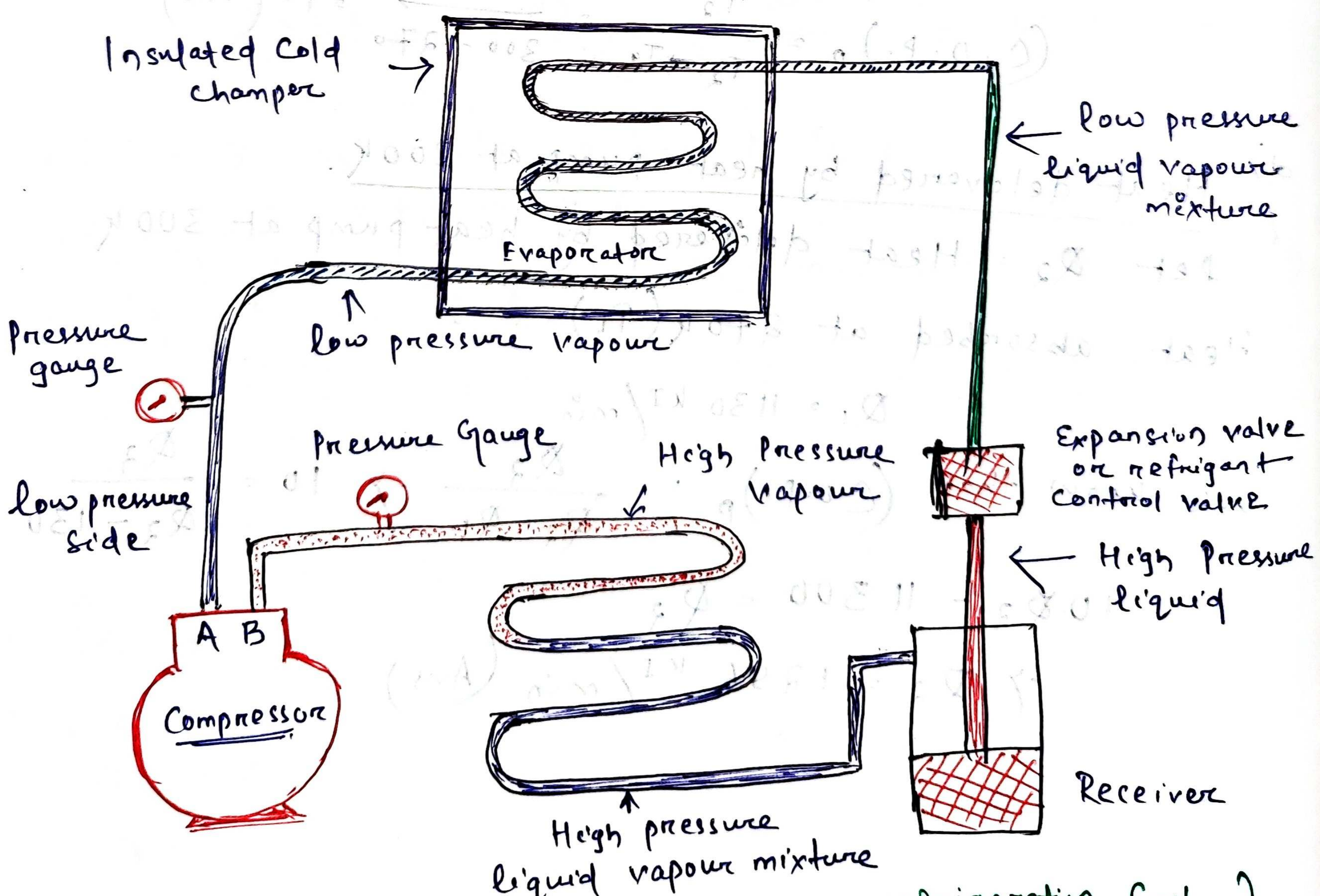
A vapour compression refrigeration system is an improved type of air refrigeration system in which a suitable working substance, termed as refrigant, is used.

→ It condenses & evaporates at temperatures & pressures close to the atmospheric conditions.

→ The refrigerator usually used for this purpose are (NH_3) ammonia, carbon dioxide (CO_2) & sulphur dioxide (SO_2). The refrigerant used does not leave the system, but is circulated throughout the system alternately condensing & evaporating.

→ In evaporating the refrigerant absorbs its latent heat from the brine (salt water) which is used for circulating it arround the cold chamber.

→ The vapour compression refrigeration system now a days used for all purpose refrigeration. generally used for all industrial purpose from a small domestic refrigerator to a big air conditioning plant.



(Simple Vapour Compression refrigeration System.)

Mechanism of simple Vapour Compression Refrigeration System:-

Compressor:- The low pressure & temp. vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve 'A'. where it is compressed to a high pressure & temp. This high pressure & temp. vapour refrigerant is discharged into the condenser through the delivery or discharge valve 'B'.

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

Receiver:- The condensed liquid refrigerant from the condenser is stored in a vessel known as receiver from where it is supplied to the evaporator through the expansion valve or refrigerant control valve.

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 & temprature to pass at a controlled rate after reducing its pressure & temp. some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporised in the evaporator at low pressure & temp.

Evaporator:- An evaporator consists of coils of pipe in which the liquid vapour refrigerant at low pressure & temp. is evaporated & changed into vapour refrigerant at low pressure & temp. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporisation from the medium which is to be cooled.

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 temp.

(iv) The COP 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.

FORMULA :-

$$C.O.P = \frac{Q}{W} = \frac{Q_H}{Q_H - Q_L}$$

$$COP = \frac{T_H}{T_H - T_L}$$

$$(COP)_P = \frac{1}{1 - \frac{T_L}{T_H}}$$

Heat Engine :-

$$(COP)_E = \frac{W_E}{Q_2} = \frac{Q_2 - Q_1}{Q_2} = \frac{T_2 - T_1}{T_2}$$

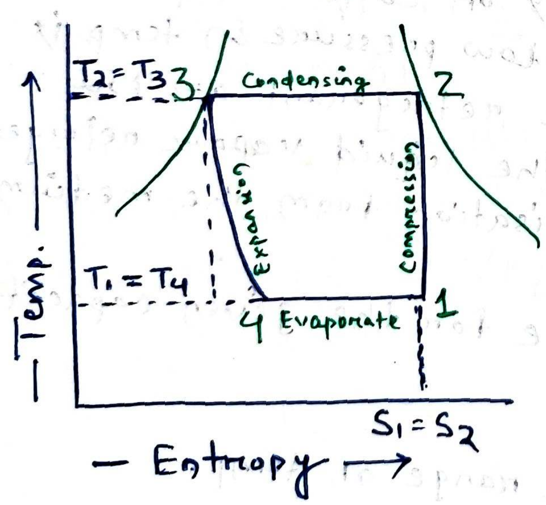
Refrigerator :-

$$(COP)_R = \frac{Q_1}{W_R} = \frac{Q_1}{Q_2 - Q_1} = \frac{T_1}{T_2 - T_1}$$

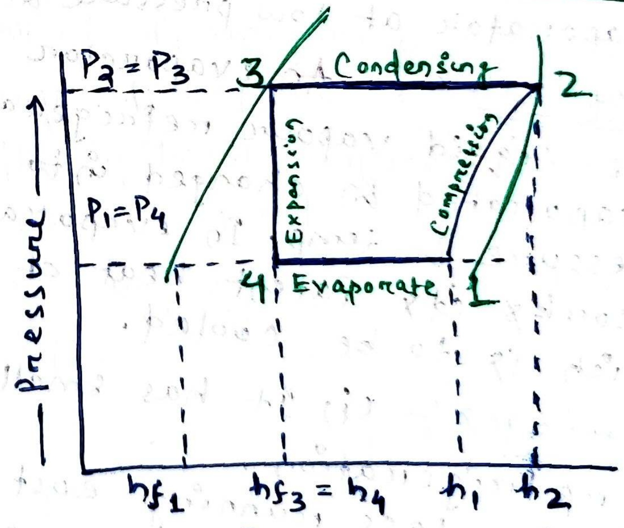
Heat pump :-

$$(COP)_P = \frac{Q_2}{W_P} = \frac{Q_2}{Q_2 - Q_1} = \frac{T_2}{T_2 - T_1}$$

Cycle with Dry Saturated Vapour after Compression



(a) T-s diagram



(b) p-h diagram

Compression Process :-

The vapour refrigerant at low pressure P1 & temp T1 is compressed isentropically to dry saturated vapour as shown by the vertical line 1-2 on T-S diagram & by the curve 1-2 on p-h diagram. The pressure & temp. rises from P1 to P2 & T1 to T2 respectively.

The work done during isentropic compression per kg of refrigerant is given by: $w = h_2 - h_1$

where h_1 = Enthalpy of vapour refrigerant at temp. T_1 that is at suction of the compressor, & h_2 = Enthalpy of the vapour refrigerant at temp. T_2, i.e. that is at discharge of the compressor.

Condensing Process :- The high pressure & temp. vapour refrigerant from the compressor is passed through the condenser where it is completely condensed at constant pressure P_2 & temp. T_2 as shown by the horizontal line 2-3 on T-S diagram & p-h diagram. The vapour refrigerant is changed into liquid refrigerant. The refrigerant while passing through the condenser, gives its latent heat to the surrounding condensing medium.

Expansion process :- The liquid refrigerant at pressure $P_3 = P_2$ & temp $T_3 = T_2$ is expanded by throttling process through the expansion valve to a low pressure $P_4 = P_1$ & temp. $T_4 = T_1$, as shown by the curve 3-4 on T-S diagram & by the vertical line 3-4 on p-h diagram. We have already discussed that some of the liquid refrigerant evaporates as it passes through the expansion valve. We also know that during the throttling process, no heat is absorbed or rejected by the liquid refrigerant.

Vapouring process :- The liquid-vapour mixture of the refrigerant at pressure $P_4 = P_1$ & temp $T_4 = T_1$ is evaporated & changed into vapour refrigerant at constant pressure & temp. as shown by the horizontal line 4-1 on T-S diagram & p-h diagram. During evaporating the liquid-vapour refrigerant absorbs its latent heat of vaporisation from the medium. (air, water or brine) which is to be cooled. The heat which is absorbed by the refrigerant is called refrigerating effect. The process of vaporisation continues up to point 1 which is starting point & thus the cycle is completed.

The refrigerating effect or the heat absorbed or extracted by the liquid - vapour refrigerant during evapouration per kg of refrigerant given by:

$$R_E = h_1 - h_4 = h_1 - h_{f3}$$

where h_{f3} is the sensible heat at temp T_3, that is enthalpy of liquid refrigerant leaving the condenser.

$$COP = \frac{\text{Refrigerant effect}}{\text{work done}} = \frac{(h_1 - h_4)}{(h_2 - h_1)}$$

Question In an ammonia vapour compression system the pressure in the evapourator is 2 bar. Ammonia at exit is 0.85 dry & at entry its dryness fraction is 0.19. during compression, the work done per kg of ammonia is 150 kJ. Calculate the COP & the volume of vapour entering the compressor per minute, if the rate of ammonia circulating is 4.5 kg/min. The latent heat & specific volume at 2 bar are 1325 kJ/kg & 0.58 m³/kg respectively.

Ans:- Given data

$P_1 = P_4 = 2$ bar

$x_1 = 0.85$

$x_4 = 0.19$

$W = 150$ kJ/kg

$M_a = 4.5$ kg/min

$h_{fg} = 1325$ kJ/kg

$v_g = 0.58$ m³/kg

In T-S & P-h diagram are shown in fig (a) & (b) respectively
Since the ammonia vapour at entry to the evaporator has dryness fraction (x_4) equal to 0.19, therefore enthalpy at point 4,

$$h_4 = x_4 \times h_{fg} = 0.19 \times 1325 = 251.75 \text{ kJ/kg}$$

Similarly enthalpy of ammonia vapour at exit at point 1

$$h_1 = x_1 \times h_{fg} = 0.85 \times 1325 = 1126.25 \text{ kJ/kg}$$

Heat extracted from the evaporator or RE

$$R_E = h_1 - h_4 = 1126.25 - 251.75 = 874.5 \text{ kJ/kg}$$

We know that work done during compression

$$W = 150 \text{ kJ/kg}$$

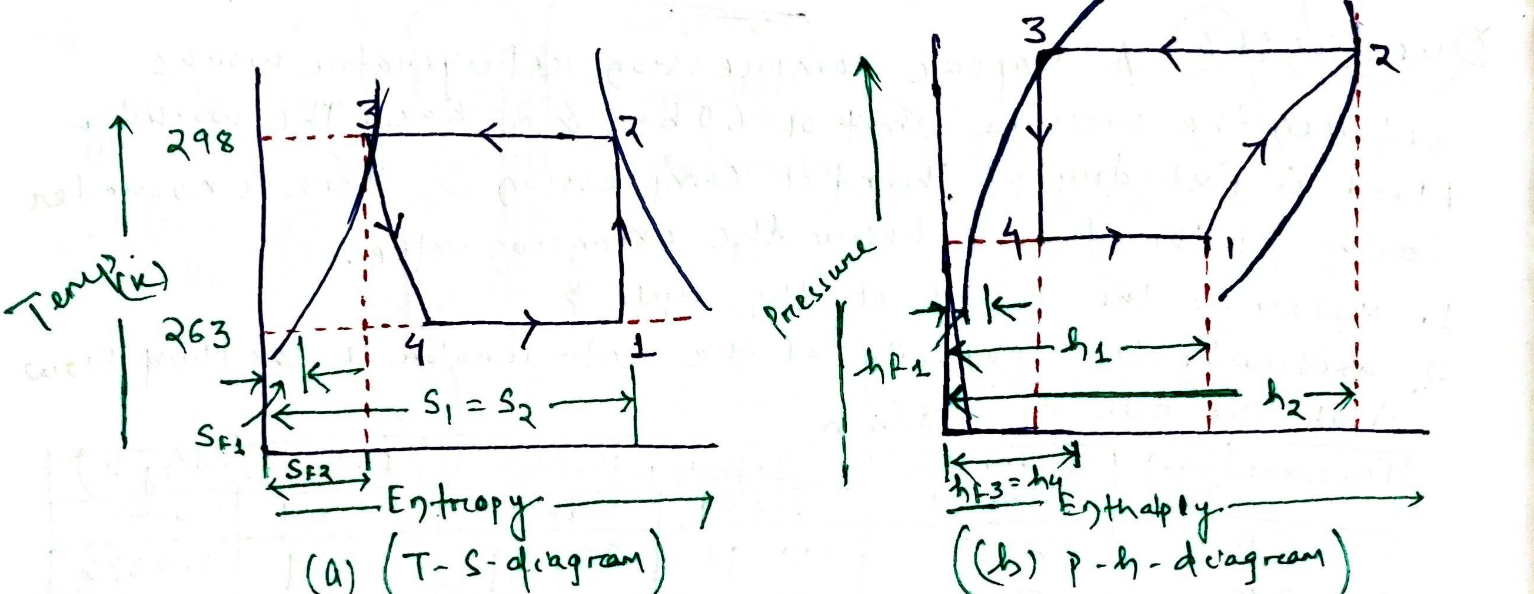
$$COP = \frac{R_E}{W} = \frac{874.5}{150} = 5.83 \text{ (Ans.)}$$

Volume of vapour entering the compressor per minute

$$M_a \times V_g = 4.5 \times 0.58$$
$$= 2.61 \text{ m}^3/\text{min (Ans)}$$

Question (2)
The temperature limits of an ammonia refrigerating system are 25°C & -10°C. If the gas is dry at the end of compression, calculate the cop of the cycle assuming no under cooling of the liquid ammonia. Use the following table for properties of ammonia:

Temp. (°C)	liquid heat kJ/kg	latent heat kJ/kg	liquid entropy kJ/kg K
25	298.9	1166.94	1.1242
-10	135.37	1297.68	0.5443



(a) (T-S-diagram) ((b) p-h-diagram)

Here in the T-S & P-h diagram shown (a) & (b) respectively

let x_1 = dryness fraction at point 1.

we know ~~enthalpy~~ entropy at point 1,

$$S_1 = S_{f1} + \frac{x_1 h_{fg1}}{T_1} = 0.5443 + \frac{x_1 \times 1297.68}{263}$$

$$= 0.5443 + 4.934 x_1 \quad \text{—— (i)}$$

Similar, entropy at point 2,

$$S_2 = S_{f2} + \frac{h_{fg2}}{T_2} = 1.1242 + \frac{1166.94}{298} = 5.04 \quad \text{—— (ii)}$$

Since the entropy at point 1 is equal to entropy at point 2 therefore equating equation (i) & (ii)

$$0.5443 + 4.934 x_1 = 5.04$$

$$x_1 = 0.91$$

we know that enthalpy at point 1

$$h_1 = h_{f1} + x_1 h_{fg1} = 135.37 + 0.91 \times 1297.68$$

$$= 1316.26 \text{ kJ/kg.}$$

enthalpy at point 2

$$h_2 = h_{f2} + h_{fg2} = 298.9 + 1166.94 = 1465.84 \text{ kJ/kg.}$$

$$\text{C.O.P.} = \frac{h_1 - h_{f3}}{h_2 - h_1} = \frac{1316.26 - 298.9}{1465.84 - 1316.26}$$

$$= 6.8 \text{ (Ans)}$$

Question :- (3) A vapour compression refrigerator works between the pressure limit of 60 bar & 25 bar. The working fluid is just dry at the end of compression & there is no under cooling of the liquid before the expansion valve.

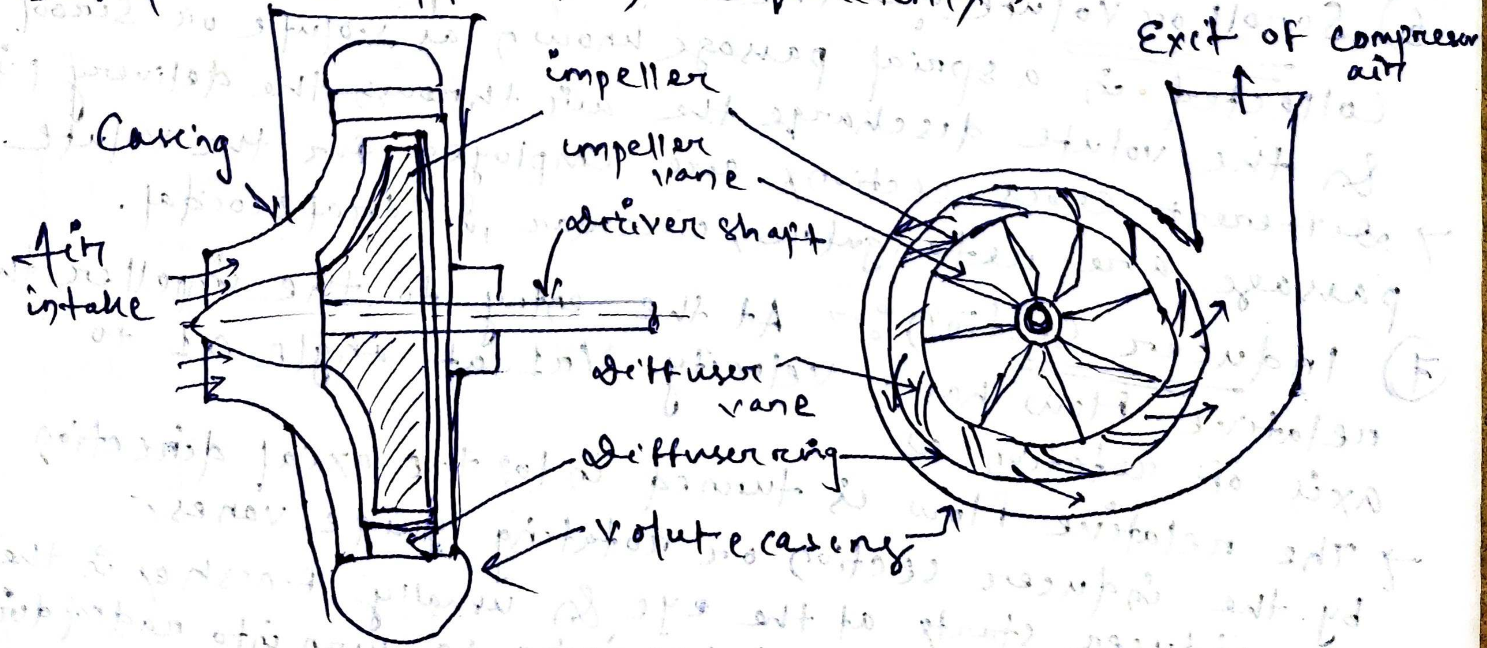
1. determine the C.O.P. of the cycle?
2. determine the capacity of the refrigerator if the fluid flow is at the rate of 5 kg/min

Pressure (bar)	Saturation temp. (K)	Enthalpy (kJ/kg)		Entropy (kJ/kg K)	
		liquid	vapour	liquid	vapour
60	295	151.96	293.29	0.554	1.0332
25	261	56.32	322.58	0.226	1.2464

Refrigeration Compressor :- In vapour compression refrigeration cycle, compressors play a vital role in pressurizing vapourized refrigerant from a low pressure & temp. to high pressure & temp. in preparation for traveling through a condenser. While compressors all serve same primary function within industrial refrigeration system, there are actually numerous types of compressors with varying methods of creating pressure.

Various types of Compressor :- Centrifugal, Rotary vane, Rotary screw, Rotary Scroll, Reciprocating

① Centrifugal :- Centrifugal compressor also known as turbo or radial compressor, pressurize a refrigerant by forcing the refrigerant through a rotating impeller. The impeller spins the refrigerant at an increasing speed, generating kinetic energy. The generated kinetic energy is then used to pressurize the refrigerant by passing it through a diffuser, which slows the vapour's radial movement of the refrigerant converts the kinetic energy to potential energy in the form of pressure. Centrifugal compressor have the largest capacity & are well suited for compressing large volumes of refrigerant. Additionally centrifugal compressors can be set up in either single two-stage, or multistage configurations to further compress the refrigerant to a higher pressure & temp. based on the application requirements.



① Inlet casing with accelerating nozzle :-

→ The function of the inlet casing is to accelerate the fluid from its initial condition to the entry of inlet guide vanes & to provide uniform velocity at the eye.

→ The inlet flange is axisymmetric & the inlet duct takes the form of a simple converging nozzle.

→ The outlet of the inlet casing is known as the impeller eye.

② Inlet guide vanes (IGV) :- The ~~function of~~ inlet guide vanes should be chosen so as to obtain a minimum relative mach number at the eyetip.

→ The inlet guide vanes function is to direct the flows in the desired direction at the entry of the impeller.

③ Impeller :- The function of the impeller is to increase the energy level of fluid by whirling it outwards by increasing the angular momentum of the fluid.

→ Both static pressure & velocity of fluid are increased in the impeller.

④ Impeller vane :- The function of Impeller vane to help to transfer the energy from the impeller to the fluid.

⑤ Diffuser :- A diffuser consisting of a number of fixed diverging passages in which the air is decelerated with a consequent rise in static pressure.

⑥ Scroll or volute :- The air leaving the diffuser is collected in a sprial passage known as volute or scrool & the volute discharge the air through the delivery pipe

→ different cross-sections are employed for the volute passage are retangular, circular, & trapezoidal.

⑦ Inducer section :- At the entry to the impeller the relative flow has a velocity V_{r1} at angle α_1 to axis of rotation as.

→ The relative flow is turned into the axial direction by the inducer section or rotating guide vanes.

→ The inducer starts at the eye & usually finishes in the region where the flow is beginning to turn into radial direction

Advantages & disadvantages of Centrifugal compressors Over Reciprocating Compressors :-

Advantages :- (i) Since the centrifugal compressors have no valves, piston, cylinders, connecting rod etc. therefore the working life of compressors is more as compared to reciprocating compressors.

(ii) These compressors operate with little or no vibration as there no unbalanced masses.

(iii) The operation of centrifugal compressors is quite & calm.

(iv) The centrifugal compressor run at high speed (3000 rpm & above.) therefore these can be directly connected to electric motor or steam turbine.

(v) Because of the high speed, these compressors can handle large volume of vapour refrigerant as compared to reciprocating compressors.

(vi) The centrifugal compressor are especially adapted for systems ranging from 50 to 5000 tonnes. They are also used for temp. range between −90°C & +10°C

(vii) The efficiency of these compressors is considerably high.

(viii) The large size centrifugal compressor require less floor as compared to reciprocating compressor.

Disadvantages :-

(i) The main disadvantage in centrifugal compressors is surging. it occurs when the refrigeration load decrease to below 35 percent of rated capacity & causes severe stress conditions in the compressor.

(ii) The increase in pressure per stage is less as compared to reciprocating compressors.

(iii) The centrifugal compressor are not pratical below 50 tonnes capacity load.

(iv) The refrigerants used with these compressors should have high specific volume.

Reciprocating Compressor :-

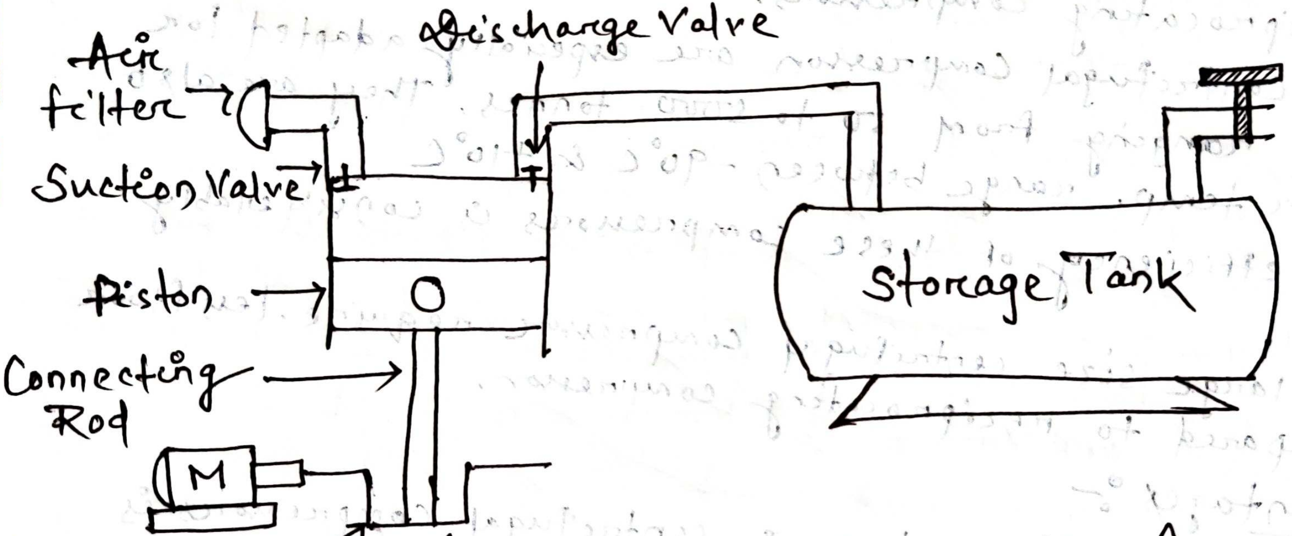
The reciprocating compressor is a positive displacement air compressor where the air is sucked in a chamber & it is compressed with a reciprocating piston.

A reciprocating air compressor is a positive displacement compressor as air is first sucked in a chamber & compressed by decreasing the area of the chamber & the area is decreased by a piston.

Working Principle :-

→ In the reciprocating air compressor, the piston moves to BDC and air is sucked into a cylinder from the atmosphere & moves it to the TDC.

→ The compression of air starts and increasing & pressure is also increased. After reaching the limit of the pressure the discharge valve is open and the compressed air is flowing through to the storage tank.



(Main Parts of Reciprocating Compressor)

Piston :- It has reciprocating motion in the cylinder and it compresses the air.

Cylinder :- The air is compressed in the cylinder.

Connecting Rod :- This connecting Rod is connects the piston with crankshaft.

Crankshaft :- This is connected to the shaft of the electric motor and transfer rotary motion of the piston.

Suction Valve :- Air is sucked through a suction valve when the piston moves to BDC

Discharge Valve :- Compressed air is discharged through the discharge valve of the storage tank.

WORKING:- when the power in on, the electric motors starts rotating and rotates the crankshaft which attached to it and the piston starts moving the to and fro motion inside a cylinder.

→ The piston is moved downward the air from the atmosphere enters into the cylinder chamber.

→ After reaching to BDC the piston starts moving upward & the compression of air starts and its pressure tends to increase.

→ After reaching the set pressure the discharge valve is open & through it, the compressed air is transfer to a storage tank where it can be used.

Different Types Reciprocating Compressor:-

(I) Single Acting
(II) Double Acting
(III) Single stage Air Compressor
(IV) Double stage Air Compressor.

Applications:- (I) Reciprocating compressor used to produce high pressure gas output (II) Reciprocating compressor is mainly used in the refrigeration cycle (III) It is widely used in oil refineries, gas pipelines, natural gas processing plants, chemical plants, etc. It is also used in blowing of plastic bottle.

Advantages:- (I) Used to produce high-pressure gas.
(II) It can compress gases & refrigerant of a wide range of molecular density.
(III) High efficiency & flexibility
(IV) Cheap and rugged design.

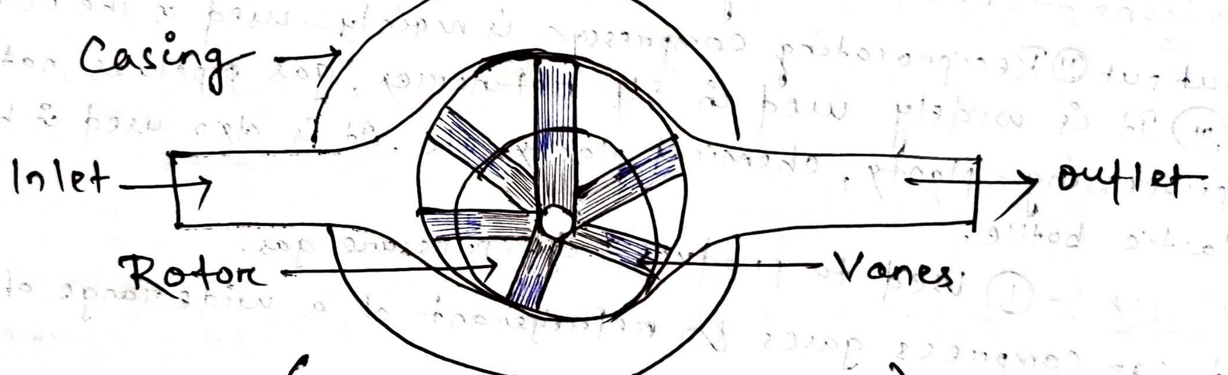
Disadvantages:- (I) High vibration & noise
(II) Piston rings & valve are extremely sensitive to the dirt present in the fluid.
(III) Pulsating of fluid flow. The operation can be made smooth by using a flywheel.
(IV) Part of the work input is lost due to frictional resistance between the piston & cylinder.
(V) The size of compressor is very large for a given capacity.
(VI) One of the drawbacks of the reciprocating compressor is that it can't self-regulate its capacity against a given output pressure. It will continue displacing the gas until told not to do.

Rotary Vane Compressor :-

A rotary vane compressor always compresses the gas to the design pressure defined by the manufacturer, regardless of the pressure in the system in which the compressor is discharging.

Working Principle :-

- This is a positive-displacement pump that consists of vanes mounted to a rotor that rotates inside a cavity
- The vane type compressor consists of a cylinder rotor with longitudinal slots in which radial sliding vanes are fitted
- The rotor is positioned eccentrically within a cylindrical housing.
- The spaces between adjacent vanes from pockets of decreasing volume from a fixed inlet port to a fixed discharge port.
- Compressor inlet and discharge valves are not employed in the design.



(Rotary Vane Compressor.)

- Rotary compressor are another type of famous compressor. it uses two Asymmetrical rotors that are also called helical screw to compress the air
- The rotors have a very special shape and they turn in opposite directions with very little clearance between them.
- The rotors are covered by cooling jackets. Two shafts on the rotors have been placed that transfer their motion with the help of timing gears that are attached at the starting point of the shafts/ compressor.
- Air sucked in at one end and get trapped between the rotors and get pushed to another side of the rotors.
- The air pushed by the rotors that are rotating in the opposite direction and compression is done when it gets trapped in clearance between the two rotors. Then it pushed towards the pressure side.

Applications :-

- Agriculture
- Body shop & Automotives
- dry cleaning
- Energy
- food & beverages
- Manufacturings
- Medical & dental

Advantages :-

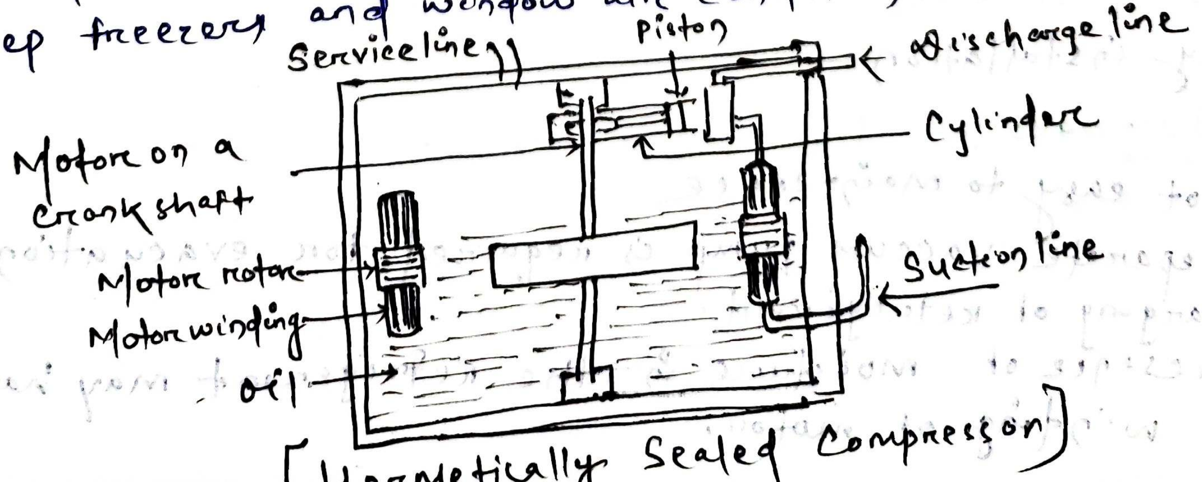
- This is oil-free air output
- This is suitable for continuous air supplied.
- This is suitable for high pressure (up to 85 bar) compression
- High power (up to 500 hp) is possible.

disadvantages :-

- The maintenance cost is high because have more moving parts.
- vibration cause when reciprocating of the cylinder.

Hermetically Sealed Compressor

Hermetically sealed compressor is mounted directly on shaft or motor. The assembly of compressor and motor is hermetically sealed in a welded steel shell. The motor is cooled by the refrigerant it self. either by vapour is cooled by the refrigerant it self, either by vapour refrigerant being drawn into the compressor from suction line or by liquid refrigerant being drawn from liquid line, starting from condenser outlet. This eliminates the needs of shaft coupling and external shaft seal, which are used in reciprocating compressor. Hermetically sealed compressor is employed in domestic refrigerators. deep freezers and window air conditioners.



[Hermetically Sealed Compressor]

Working of Hermetically Sealed Compressor :-

Compressor & motor operate on the same shaft in a common casing (i.e housing). As the motor shaft rotates, piston starts reciprocating inside the cylinder. The low temp. and low pressure vapour refrigerant from the evaporator is sucked into the compressor shell. The refrigerant sucked in the compressor shell ~~The refrigerant sucked~~ does not get admitted directly into the cylinder, but instead, it is circulated in the shell around the motor, so that, the motor can be cooled. Thus the suction vapour refrigerant is used to cool the lubricating oil as well as winding of the motor.

Then the sucked vapour refrigerant enters into the cylinder & get compressed, thereby increasing its pressure and temp. At the end of discharge stroke of the piston the high pressure refrigerant is discharged.

Applications :-

- Domestic refrigerator
- Window air conditioners
- Water cooler
- Home freezers
- Split air conditioners
- Deep freezers
- Small capacity refrigeration & air conditioning units

Advantages :-

- The leakage of refrigerant is completely prevented
- Less noisy
- Less vibration
- Compact, so require small space
- long life
- less maintenace
- Easy installation

Disadvantages :-

- Not easy to maintenace
- Separate vaccum pump is required for evacuation & charging of refrigerant.
- presence of moisture in the refrigerant may harm the winding of motor.

Heat Rejection Ratio: Heat Rejection Ratio (HRR) is the ratio of heat rejected to the heat absorbed (refrigeration capacity).

$$HRR = Q_c / Q_e = \frac{Q_e + W_c}{Q_e} = 1 + \frac{1}{COP}$$

Cooling Tower:-

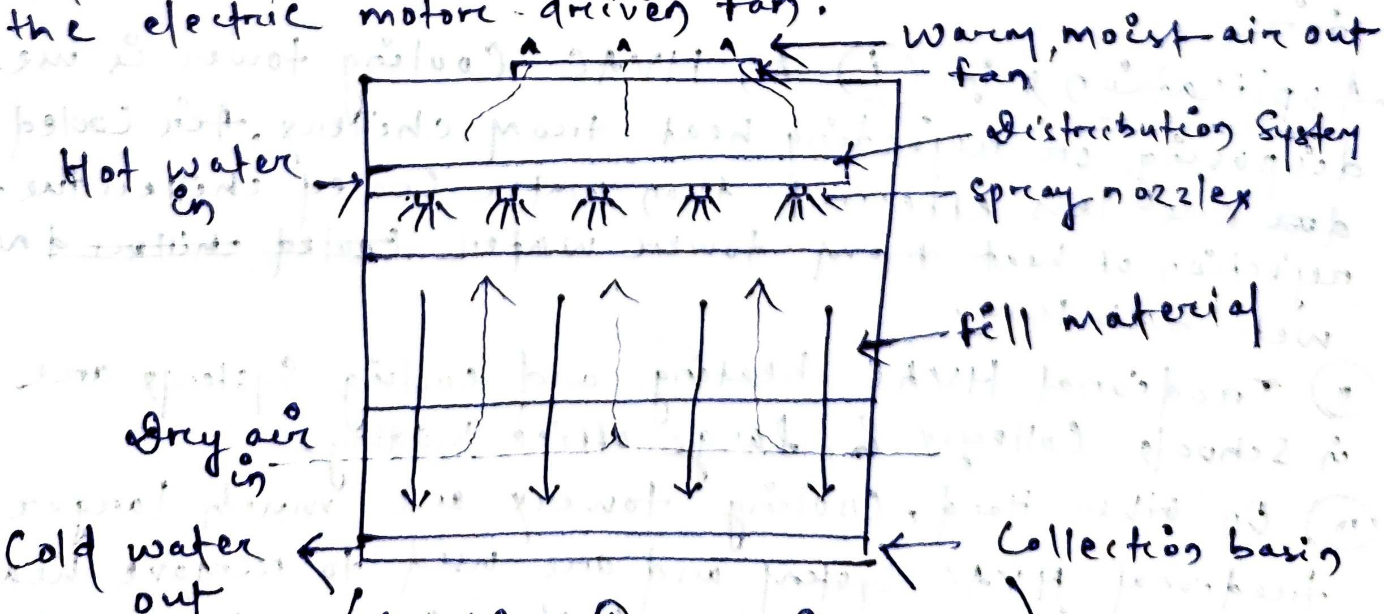
(i) A cooling Tower is a specialized heat exchanger in which air & water are brought into direct contact with each other in order to reduce the water's temp.

(ii) As this occurs, a small volume of water is evaporated, reducing the temp. of the water being circulated through the tower.

(iii) Water, which has been heated by an industrial process or in an air-conditioning condenser is pumped of the cooling tower through pipes

(iv) The water spray through nozzles onto banks of material called "fill", which shows the flow of water throught the cooling tower & exposes as much water surface area as possible for maximum air-water contact.

(v) As the water flows through the cooling tower, it is exposed to air, which is being pulled through the ~~water~~ tower by the electric motor-driven fan.



(Cooling Tower Diagram with parts)

Types of Cooling tower :-

(i) Crossflow Cooling tower (ii) Counterflow Cooling tower.
(iii) forced draft & Induced draft (iv) draft Cooling tower.
(v) Natural draft & fan Assisted Natural
(vi) factory Assembled Cooling tower. (FAP) factory Assembled Product.
(vii) field Elected Tower (FEP)

Working Principle :-

(i) There are many different types of cooling towers but the Cooling tower working principle stay pretty much the same. Most cooling towers work based on the principle of "evaporative Cooling".

(ii) Evaporative Cooling is the process where warm water from an industrial process is pumped up to the top of the Cooling tower where the water distribution system.

(iii) The water then gets distributed by Cooling tower nozzles to the wet deck. At the same time, air is being drawn through the air inlet louvers forcing water to evaporate

(iv) Evaporation cause the heat to be removed from the make-up water. The hot air naturally rises out of the tower.

Applications :-

(i) An HVAC Cooling tower is used for disposing or rejecting heat from chillers. Air Cooled chillers ~~are~~ are less efficient than water cooled chillers due to rejection of heat from tower water ~~cooled chillers~~ near wet-bulb temp.

(ii) Tradional HVAC heating and cooling systems are used in schools, Colleges & large office building.

(iii) On other Hand, Cooling towers are much larger than tradional HVAC system and are used to remove heat from cooling tower water system in petroleum refineries plants, natural gas processing plants. petrochemical plants and other industrial processes and facilities.

Advantages of Cooling tower

- The performance is good.
- Highly reliable.
- It requires less maintenance.
- It can be operated for a long time.
- Life of cooling tower very long.

Disadvantages :-

- Scale and corrosion forms on the body of cooling towers
- Initial cost is very high.

Spray Pond Cooling System :-

- The spray pond cooling is the one of the simplest method of cooling the condenser water. In spray pond warm water is broken up into a spray by means of nozzles.
- The hot water coming out of condenser is sprayed through the nozzles to expose maximum surface area of water to air for effective cooling.

Advantages :-

- pumping cost is low
- Head required is less
- lesser wastage of water
- Low drift losses
- least choking
- Easy to maintain
- High durability & long life

Disadvantages :-

- Large area is required. Approximately 25-50 times the area of cooling tower.
- Spray losses due to evaporating and windage losses
- There is no control over the temp of cooled water.
- Cooling effect reduces with reduced wind velocity
- when load on the plant increases it does not respond to change.

Principle of working, construction & operation of an Evaporators :-

- The function of evaporator is to absorb heat from surrounding location or medium which is to be cooled by means of refrigerant.
- The refrigerant either boils as it flows through a pipe, tube or other type of space so that liquid is continuously wetting all the inside surface or it boils in a shell around submerged tubes through which the fluid to be cooling is flowing.
- various methods are used for evaporators depending upon the refrigerant to be used and evaporator application, but iron, steel and copper predominate.
- Refrigerant evapourators should be of extended surface or finned tube type whatever pratical. in order to keep the ~~between~~ average surface temperature down, a good bond between the fin and tube is essential. Integral fins formed out of the tube it self are best in this respect and give the best heat transfer rate.

Types of Evaporator :-

(I) Bare tube evaporator
(II) plate evaporator.
(III) finned tube evaporator.
(IV) Shell tube evaporator.
(V) Tube in tube evaporator.

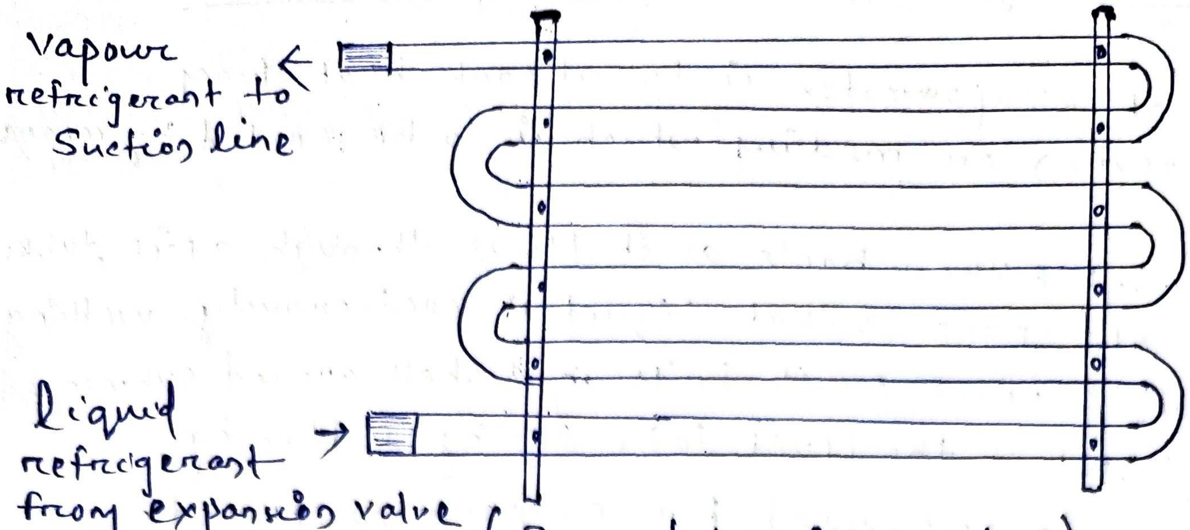
Bare tube Evaporator :-

(I) The bare tube evaporator are made up of copper tubing or steel pipes.

(II) The copper tubing is used for small evaporators where the refrigerant other than ammonia is used while the steel pipes are used with the large evaporators that uses ammonia as refrigerants.

(III) The evaporator comprises of several turns of tubing and are usually used for liquid chilling.

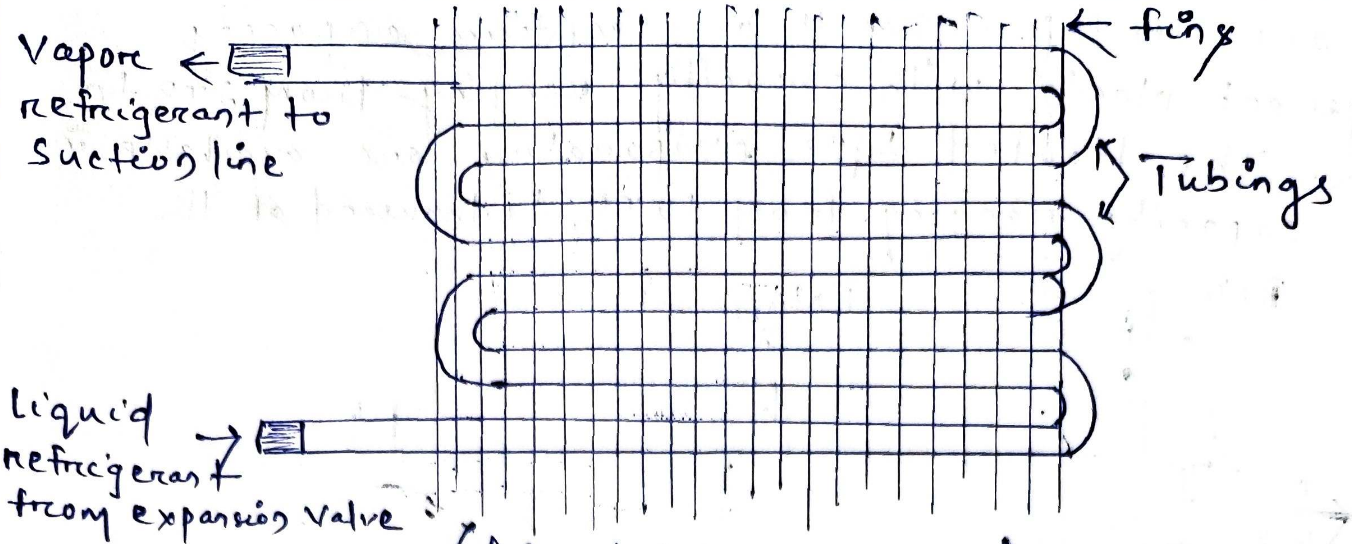
(IV) In blast cooling and freezing operations, atmospheric air flows over bare tube evaporator and the chilled air leaving it used for cooling purpose.



(Bare tube evaporator)

finned tube evaporator:-

- The finned evaporators are tube type evaporators covered with the fins. when the fluid (air or water) to be chilled flows over the bare tube evaporator.
- Lots of cooling effect from the refrigerant goes wasted since there is less surface to transfer of heat from fluid to refrigerant
- The fin on the finned tube evaporator increases contact surface area and increases heat transfer rate Thus finned evaporator are more effective than bare tube evaporator.
- for fins to be effective, it is very important that there is good contact between coil & fins. In some cases fins are soldered directly to surface of the coil & in other cases, the fins are just slipped over the surface of tubes or coils.
- The finned evaporator are most commonly used in the air conditioners of almost all type like window, split, packaged and central air conditioning. In this system, finned evaporator is known as cooling coil.
- The hot air flows over finned evaporator for cooling. To increase effectiveness of heat transfer from evaporator, the tubing are also given internal fins.
- These fins are made by forming different internal cross section shapes at the time of manufacturing of tubing.



(finned tube evaporator)

Shell tube Evaporator :-

→ The shell and tube tyle evaporators are very efficient and require minimum floor space and head space. These are easy to maintain, Hence they are very widdy used in medium to large capacity refrigerant systems.

→ The shell-tube evaporators can be either dry type or flooded type. As the name implies, a shell & tube evaporator consists of a shell & a large number of straight tubes arranged parallel to each other.

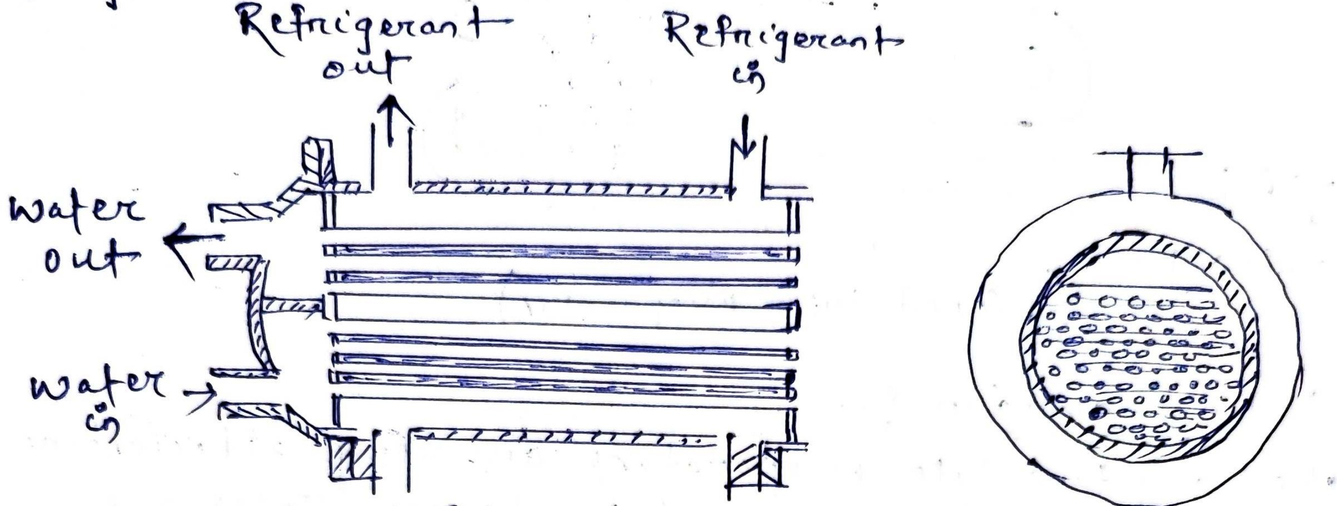
→ In dry expansion type, the refrigerant flows through the tubes while in flooded type the refrigerant is in the shell.

→ A pump circulates the chilled water or brine (one type salt water). The shell diameters range from 150 mm to 1.5 m. The number of tubes may be less than 50 to several thousands and length may be between 1.5 m to 6m.

→ Steel tubes are used with ammonia while copper tubes are used with freons. Ammonia has a very high heat transfer coefficient while freons have rather poor heat transfer coefficient, hence fins are used on the refrigerant side.

→ dry expansion type uses fins inside the tubes while flooded type uses fins outside the tube. dry expansion type require less charge of refrigerant and have positive lubricating oil return.

→ These are used for small and medium capacity refrigerant plants with capacity ranging from 2TR to 350 TR. The flooded type evaporators are available in larger capacity ranging from 10TR to thousand of TR



(Shell tube Evaporator)

5th Sem. MECH   Assignment - L [RAC]

1. a) The heat removing capacity of tonne refrigerator is equal to

(a) 21 KJ/min (b) 210 KJ/min (c) 420 KJ/min (d) 620 KJ/min

b) One tonne refrigerator machine means that

(a) one tonne is ~~equal to~~ the total mass of the machine

(b) one tonne of refrigerant is used.

(c) one tonne of water can be converted into ice

(d) one tonne of ice when melts from & at 0°C in 24 hours, the refrigeration effect produced is equivalent to 210 KJ/min.

c) The co-efficient of performance is always ______ one?

(a) equal to (b) less than (c) greater than (d) equal or less than

d) The ratio of heat extracted in the refrigerator to the workdone on the refrigerant is called

(a) coefficient of performance of Refrigeration

(b) C.O.P. of heat pump. (c) relative C.O.P. (d) refrigerating efficiency.

e) The relative coefficient of performace is equal to

(a) $\frac{\text{Theoritical COP}}{\text{Actual COP}}$ (b) $\frac{\text{Actual COP}}{\text{Theoritical COP}}$ (c) Actual COP × Theoritical COP (d)

f) In refrigerating machine, if the lower temp is fixed, then the COP of the machine can be increased by

(a) increasing the heigher temp. (c) operating the machine at a lower speed

(b) decreasing the heigher temp. (d) operating the machine at a higher speed

g) If the condenser & evapourator temp. are 312K & 273K respectively, then reversed carnot cop is

(a) 5 (b) 7 (c) 9 (d) 10

h) The C.O.P. of a reversed carnot is most strongly depend upon

(a) evaporator temp. (b) condenser temp. (c) specific heat (d) refrigerant

i) The efficiency of Carnot heat engine is 80%. The C.O.P. of a refrigerator operating on the reversed Carnot cycle is equal to.

(a) 0.25 (b) 0.40 (c) 0.60 (d) 0.80

(j) The C.O.P for a reversed Carnot refrigerator is 4. The ratio of its highest temp. to the lowest temp. will be

(a) 1 (b) 1.25 (c) 1.75 (d) 2

2) (i) How is the effectiveness of a refrigeration system measured?

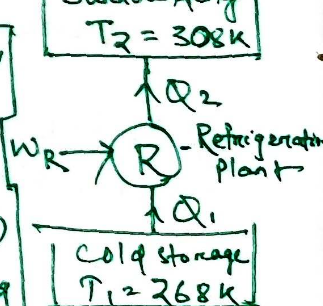
(ii) Explain is term "tonne of refrigeration"?

(iii) discuss the advantages of the dense air refrigerant system over an open air refrigeration system?

(iv) find the C.O.P. of a refrigeration system if the work input is 160 KJ/kg & refrigerating effect produced is 640 KJ/kg of refrigerant flowing?

(v) A carnot refrigerant cycle absorbs heat at 370K & rejects at 400K, How many KJ/min will the heat pump deliver at 400K if it absorbs 1450 KJ/min at 370 K.?

3) A Cold storage is to be maintained at -5°C while the surroundings are at 35°C. The heat leakage from the surroundings into the cold storage is estimated to be 29 KW. The actual C.O.P of refrigeration plant is one-third of an ideal plant working between the same temp. find the power required to drive the plant.



4) 28 tonnes of ice from and at 0°C is produced per day is an ammonia refrigerator. The temperature range is the compressor is from 25°C to -15°C. The vapour is dry & saturated at the end of compression & an expansion valve is used. There is no liquid subcooling. Assuming actual C.O.P of 62% of the theoritical, calculate the power required to drive the compressor. flowing properties of ammonia are

Temp. (°C)	Enthalpy KJ/kg		Entropy KJ/kg K	
	liquid	vapour	liquid	vapour
25°C	298.9	1465.84	1.1242	5.0391
-15	112.34	1426.54	0.4572	5.5490

-: All the Best :-