PNS School of Engineering & Technology

ANSWER OF Internal Assessment Examination-2022(5th Semester)

Subject : Th-5-Refrigeration and Air Conditioning

Branch : Mechanical Engineering

1(a) Define Tonne of Refrigeration.

One tonne of refrigeration is defined as the amount of refrigeration effect (heat transfer rate) produced during uniform melting of one ton (1000kg) of ice at 0°C to the water at the 0°C in 24 hours.

one ton of refrigeration Latent heat of ice is 335KJ/kg (heat absorbed during melting of one kg ice) 1 Ton of refrigeration,

1TR= 1000*335 in 24 hours =(1000×335)/(24×60)

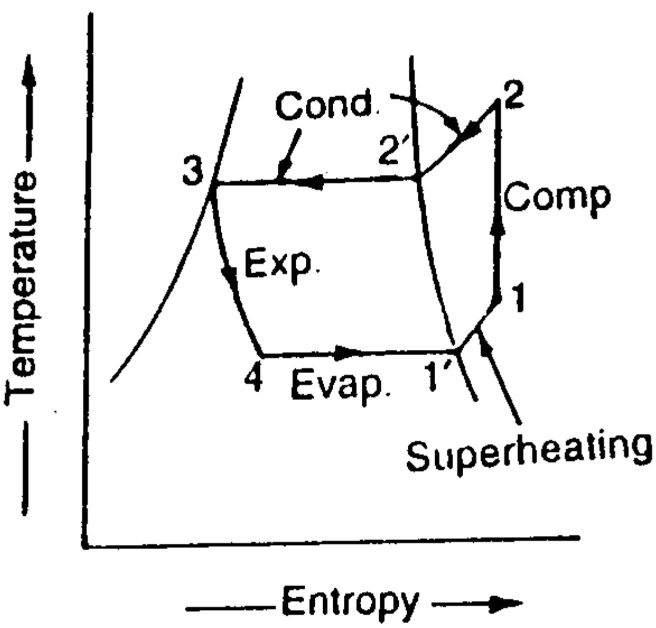
in one minute = 232.6 kJ/min

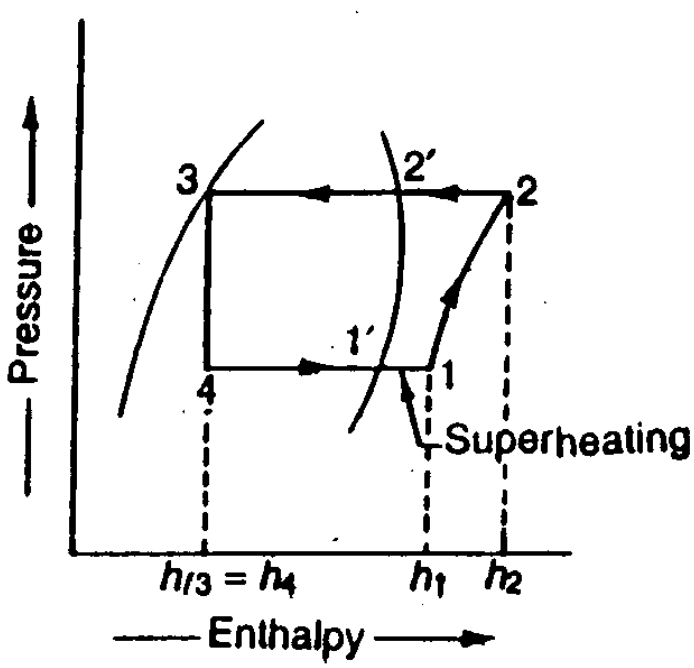
Theoretically one Ton of refrigeration taken as 232.6kJ/min, in actual practice, it is taken as 210kJ/min. 1 ton of refrigeration approximately equal to 3.5kW

(b) What is the use of absorber in vapour absorption refrigeration system ?

Absorbers are used **to absorb refrigerants**. In the absorber, there will be a weak solution of water and ammonia. When the ammonia Vapour from the evaporator reaches the absorber, the water present in the absorber will absorb it. As the water absorbs the ammonia, a strong ammonia solution and water will begin to form.

(c) Draw the P-V & T-S graph of vapour compression refrigeration system with superheated vapour before compression.





(d) What is $(COP)_R$?

It is the ratio between refrigerating effect to workdone.

Mathematically

$COP_R=$(desiredoutput)/(requiredinput)

(e) What is the function of condenser in vapour compression refrigeration system ?

It condenses the superheated vapour to liquid state.

It also act as subcooler.

(f) A refrigerator works between temperature limits of 38^0C & -5^0C. Calculate $(COP)_R$.

Given

T1=38 ^{0}c=38+273 k=311k

T2=-5^{0}c=-5+273 k=268 k

Cop =268/(311-268)=6.23

(g) What is sub-cooler in refrigerator ?

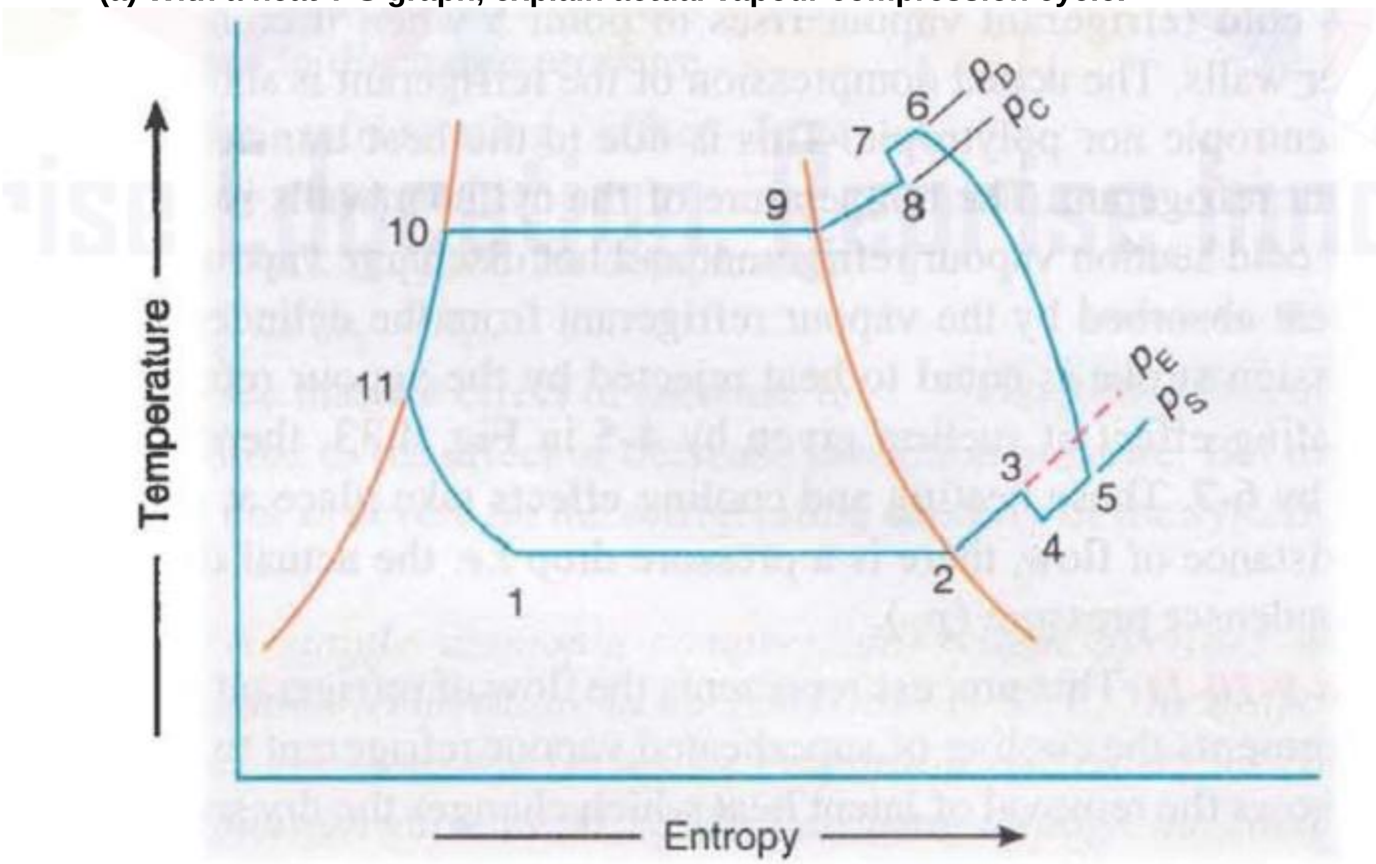
subcooling is used to bring the refrigerant from the condenser completely liquid **form.**

So the temperature of refrigerant goes below the saturated temperature.

This increases cop of the system.

2. Answer the following questions (any Two) [5 x 2]

(a) With a neat T-S graph, explain actual vapour compression cycle.



1. The vapour refrigerant leaving the evaporator is in superheated state.
2. The compression of refrigerant is neither isentropic nor polytropic.
3. The liquid refrigerant before entering the expansion valve is sub-cooled in the condenser.
4. The pressure drops in the evaporator and condenser.

The actual vapour compression cycle on *T-s* diagram is shown in Fig. 4.33. The various processes are discussed below :

(a) Process 1-2-3. This process shows the flow of refrigerant in the evaporator. The point 1 represents the entry of refrigerant into the evaporator and the point 3 represents the exit of refrigerant from evaporator in a superheated state. The point 3 also represents the entry of refrigerant into the compressor in a superheated condition. The superheating of vapour refrigerant from point 2 to point 3 may be due to :

(*i*) automatic control of expansion valve so that the refrigerant leaves the evaporator as the superheated vapour.

(*ii*) picking up of larger amount of heat from the evaporator through pipes located within the cooled space.

(*iii*) picking up of heat from the suction pipe, *i.e.* the pipe connecting the evaporator delivery and the compressor suction valve.

In the first and second case of superheating the vapour refrigerant, the refrigerating effect as well as the compressor work is increased. The coefficient of performance, as compared to saturation cycle at the same suction pressure may be greater, less or unchanged.

The superheating also causes increase in the required displacement of compressor and load on the compressor and condenser. This is indicated by 2-3 on *T-s* diagram as shown in Fig. 4.33.

(b) Process 3-4-5-6-7-8. This process represents the flow of refrigerant through the compressor. When the refrigerant enters the compressor through the suction valve at point 3, the pressure falls to point 4 due to frictional resistance to flow. Thus the actual suction pressure (p_S) is lower than the evaporator pressure (p_E). During suction and prior to compression, the temperature of the cold refrigerant vapour rises to point 5 when it comes in contact with the compressor cylinder walls. The actual compression of the refrigerant is shown by 5-6 in Fig. 4.33, which is neither isentropic nor polytropic. This is due to the heat transfer between the cylinder walls and the vapour refrigerant. The temperature of the cylinder walls is some-what in between the temperatures of cold suction vapour refrigerant and hot discharge vapour refrigerant. It may be assumed that the heat absorbed by the vapour refrigerant from the cylinder walls during the first part of the compression stroke is equal to heat rejected by the vapour refrigerant to the cylinder walls. Like the heating effect at suction given by 4-5 in Fig. 4.33, there is a cooling effect at discharge as given by 6-7. These heating and cooling effects take place at constant pressure. Due to the frictional resistance of flow, there is a pressure drop *i.e.* the actual discharge pressure (p_D) is more than the condenser pressure (p_C).

(*c*) *Process 8-9-10-11.* This process represents the flow of refrigerant through the condenser. The process 8-9 represents the cooling of superheated vapour refrigerant to the dry saturated state. The process 9-10 shows the removal of latent heat which changes the dry saturated refrigerant into liquid refrigerant. The process 10-11 represents the sub-cooling of liquid refrigerant in the condenser before passing through the expansion valve. This is desirable as it increases the refrigerating effect per kg of the refrigerant flow. It also reduces the volume of the refrigerant partially evaporated from the liquid refrigerant while passing through the expansion valve. The increase in refrigerating effect can be obtained by large quantities of circulating cooling water which should be at a temperature much lower than the condensing temperatures.

(*d*) *Process 11-1.* This process represents the expansion of subcooled liquid refrigerant by throttling from the condenser pressure to the evaporator pressure.

(b) What are the advantages of vapour absorption system over vapour compression system ?

Following are the advantages of vapour absorption system over vapour compression system :

1. In the vapour absorption system, the only moving part of the entire system is a pump which has a small motor. Thus, the operation of this system is essentially quiet and is subjected to little wear.

The vapour compression system of the same capacity has more wear, tear and noise due to moving parts of the compressor.

2. The vapour absorption system uses heat energy to change the condition of the refrigerant from the evaporator. The vapour compression system uses mechanical energy to change the condition of the refrigerant from the evaporator.

3. The vapour absorption systems are usually designed to use steam, either at high pressure or low pressure. The exhaust steam from furnaces and solar energy may also be used. Thus this system can be used where the electric power is difficult to obtain or is very expensive.

4. The vapour absorption systems can operate at reduced evaporator pressure and temperature by increasing the steam pressure to the generator, with little decrease in capacity. But the capacity of vapour compression system drops rapidly with lowered evaporator pressure.

5. The load variations do not affect the performance of a vapour absorption system. The load variations are met by controlling the quantity of aqua circulated and the quantity of steam supplied to the generator.

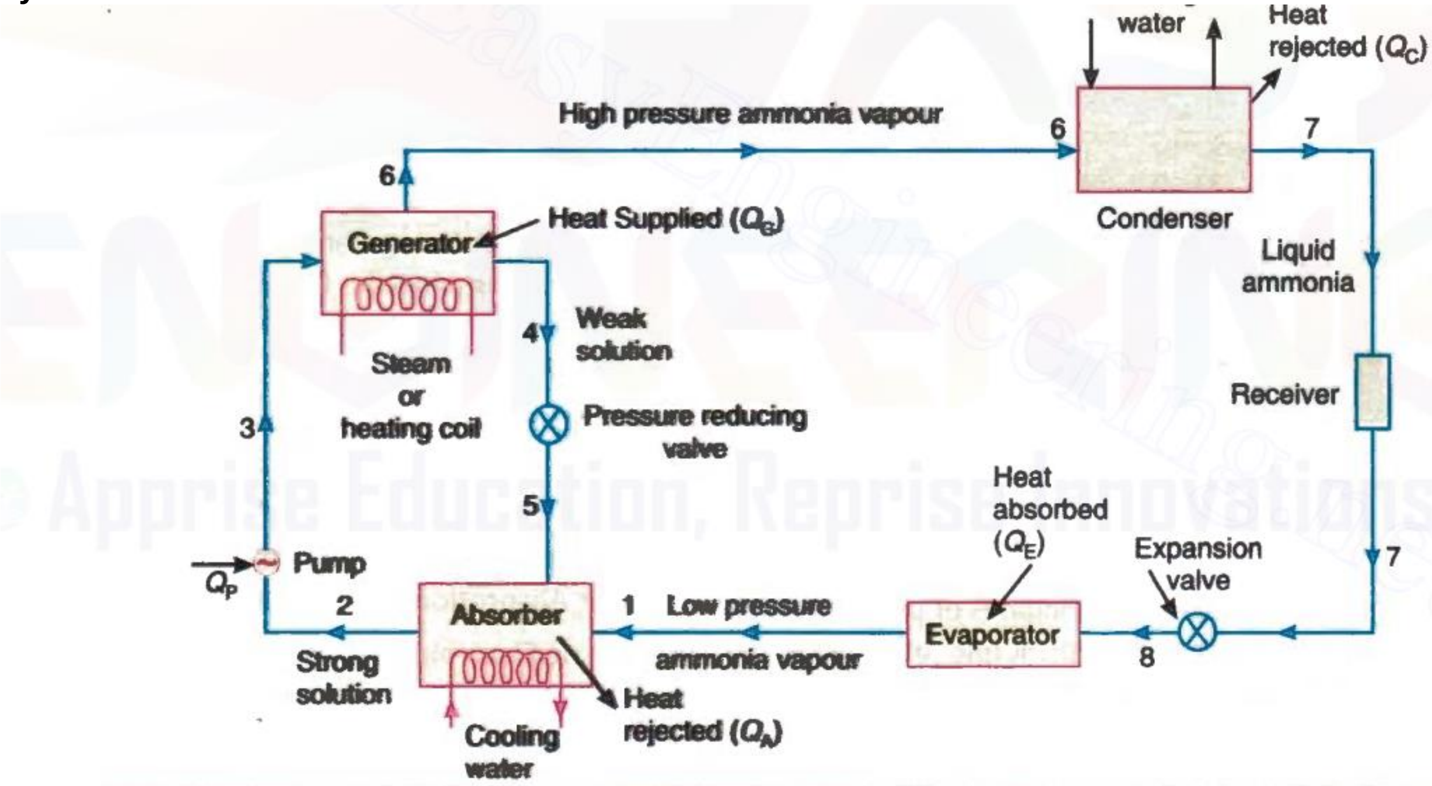
The performance of a vapour compression system at partial loads is poor.

6. In the vapour absorption system, the liquid refrigerant leaving the evaporator has no bad effect on the system except that of reducing the refrigerating effect. In the vapour compression system, it is essential to superheat the vapour refrigerant leaving the evaporator so that no liquid may enter the compressor.

7. The vapour absorption systems can be built in capacities well above 1000 tonnes of refrigeration each, which is the largest size for single compressor units.

8. The space requirements and automatic control requirements favour the absorption system more and more as the desired evaporator temperature drops.

(c) With a neat schematic diagram, explain simple vapour absorption refrigeration system.



In this system, 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 vapour in water lowers the pressure in the absorber which in turn draws more ammonia vapour from the evaporator and thus raises the temperature 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 at higher temperature water absorbs less ammonia vapour. The strong solution thus formed in the absorber is pumped to the generator by the liquid pump. The pump increases the pressure of the solution up to 10 bar.

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 generator. This weak ammonia solution flows back to the absorber at low pressure after passing through the pressure reducing valve. The high pressure ammonia vapour from the generator is condensed in the condenser to a high pressure liquid ammonia. This liquid ammonia is passed to the expansion valve through the receiver and then to the evaporator. This completes the simple vapour absorption cycle.

(d) A refrigerator working on Bell-coleman cycle operates between pressurance limits of 1.05 bar & 8.5 bar. Air is drawn from cold chamber at 10⁰C compressed & it is cooled at 30⁰C before entering the expansion cylinder. The exparsion & compression follows the Law Pv$^{1.3}$ = Constant. Calculate COP of the system.

Given : $p_1 = p_4 = 1.05$ bar ; $p_2 = p_3 = 8.5$ bar ; $T_1 = 10°C = 10 + 273 = 283$ K ;

$T_3 = 30°C = 30 + 273 = 303$ K ; $n = 1.3$

Let T_2 and T_4 = Temperature of air at the end of compression and expansion respectively.

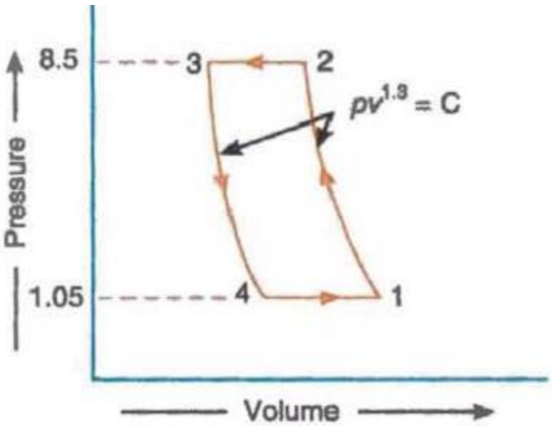
Since the compression and expansion follows the law $pv^{1.3} = C$, therefore

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \left(\frac{8.5}{1.05}\right)^{\frac{1.3-1}{1.3}} = (8.1)^{0.231} = 1.62$$

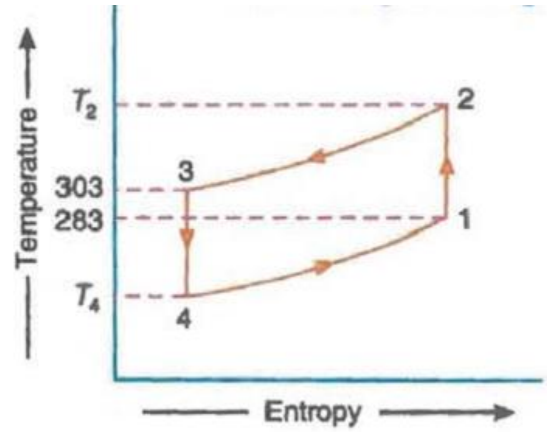
$$\therefore \quad T_2 = T_1 \times 1.62 = 283 \times 1.62 = 458.5 \text{ K}$$

Similarly $$\frac{T_3}{T_4} = \left(\frac{p_3}{p_4}\right)^{\frac{n-1}{n}} = \left(\frac{8.5}{1.05}\right)^{\frac{1.3-1}{1.3}} = 1.62$$

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



(*a*) *p-v* diagram.



(*b*) *T-s* diagram.

The theoretical C.O.P. of the plant may also be obtained as follows:

We know that compression or expansion ratio,

$$r_p = \frac{p_2}{p_1} = \frac{p_3}{p_4} = \frac{5}{1} = 5 \quad \text{and} \quad \text{C.O.P.} = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1} = \frac{1}{(5)^{\frac{1.4-1}{1.4}} - 1} = \frac{1}{1.584 - 1} = 1.712 \ \textbf{Ans.}$$

We know that theoretical coefficient of performance,

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

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

$$= \frac{96}{1.24 \times 59.5} = 1.3 \ \textbf{Ans.}$$