

(1) what is absorption refrigeration system and how it differs from conventional vapour compression system and explain its working?

Ans:- A simple absorption refrigeration system consists of generator, condenser, absorber and evaporator. The following schematic diagram represents the working of a simple absorption refrigeration system.

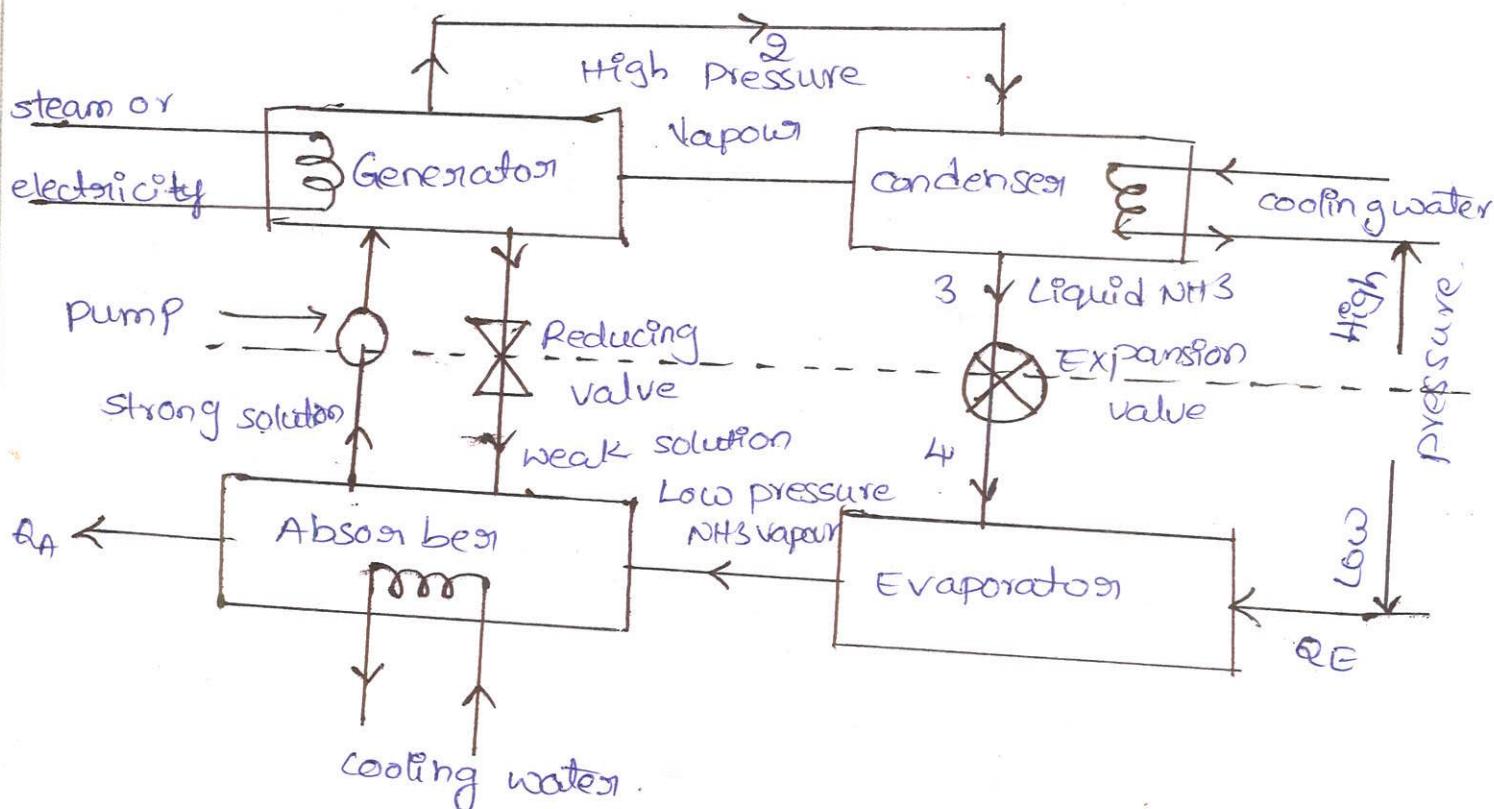


Figure: Absorption Refrigeration system.

The evaporator and absorber are located on the low pressure side while the condenser and generator are located on the high pressure side of the system as shown in figure.

At first the high pressure refrigerant vapour from the generator gets condensed into low pressure liquid refrigerant which gets vaporized in the evaporator into low pressure vapour refrigerant and enters into the absorber. Due to the presence of absorbent in the absorber, it changes into a strong hot solution. This strong solution of low pressure is again pumped into the generator which is at high pressure. The strong solution in the generator is helpful in separating solution and vapour.

This weak absorbent solution left in the generator is returned to the absorber and the high pressure vapour refrigerant is passed into the condenser thus completing the cycle.

(2) Derive the expression for C.O.P of absorption system.

Ans:-

Expression for C.O.P of an Absorption system:-

Consider an ideal vapour absorption refrigeration system with the following parameters. [Neglecting pump effect].

Q_G = Heat given to refrigerant in the generator.

Q_C = Heat discharged to the atmosphere (or) cooling water from the condenser and absorber.

Q_E = Heat absorbed by the refrigerant in the evaporator.

T_G = Temperature at which heat (Q_G) is given to the generator.

T_C = Temperature at which heat (Q_C) is discharged to atmosphere or cooling water from the condenser and absorber.

T_E = Temperature at which heat (Q_E) is absorbed in the evaporator.

According to first law of Thermodynamics.

$$Q_C = Q_G + Q_E \longrightarrow (1)$$

As the vapour phase absorption system can be considered as a perfectly reversible system, therefore, the initial entropy of the system is equal to entropy of the system after the change in its conditions.

$$\text{i.e., } \frac{Q_G}{T_G} + \frac{Q_E}{T_E} = \frac{Q_C}{T_C}$$

From equation (1),

$$\begin{aligned} \frac{Q_G}{T_G} + \frac{Q_E}{T_E} &= \frac{Q_G + Q_E}{T_E} \\ &= \frac{Q_G}{T_C} + \frac{Q_E}{T_C} \end{aligned}$$

(3)

Explain with the help of neat sketches the various components and their functions for a vapour absorption refrigeration system.

Ans:-

Ammonia water vapour Absorption Refrigeration system:-
NH₃-H₂O Vapour absorption refrigeration system contains ammonia as refrigerant and water as absorbent. The construction and working of ammonia-water vapour absorption refrigeration system is shown in figure.

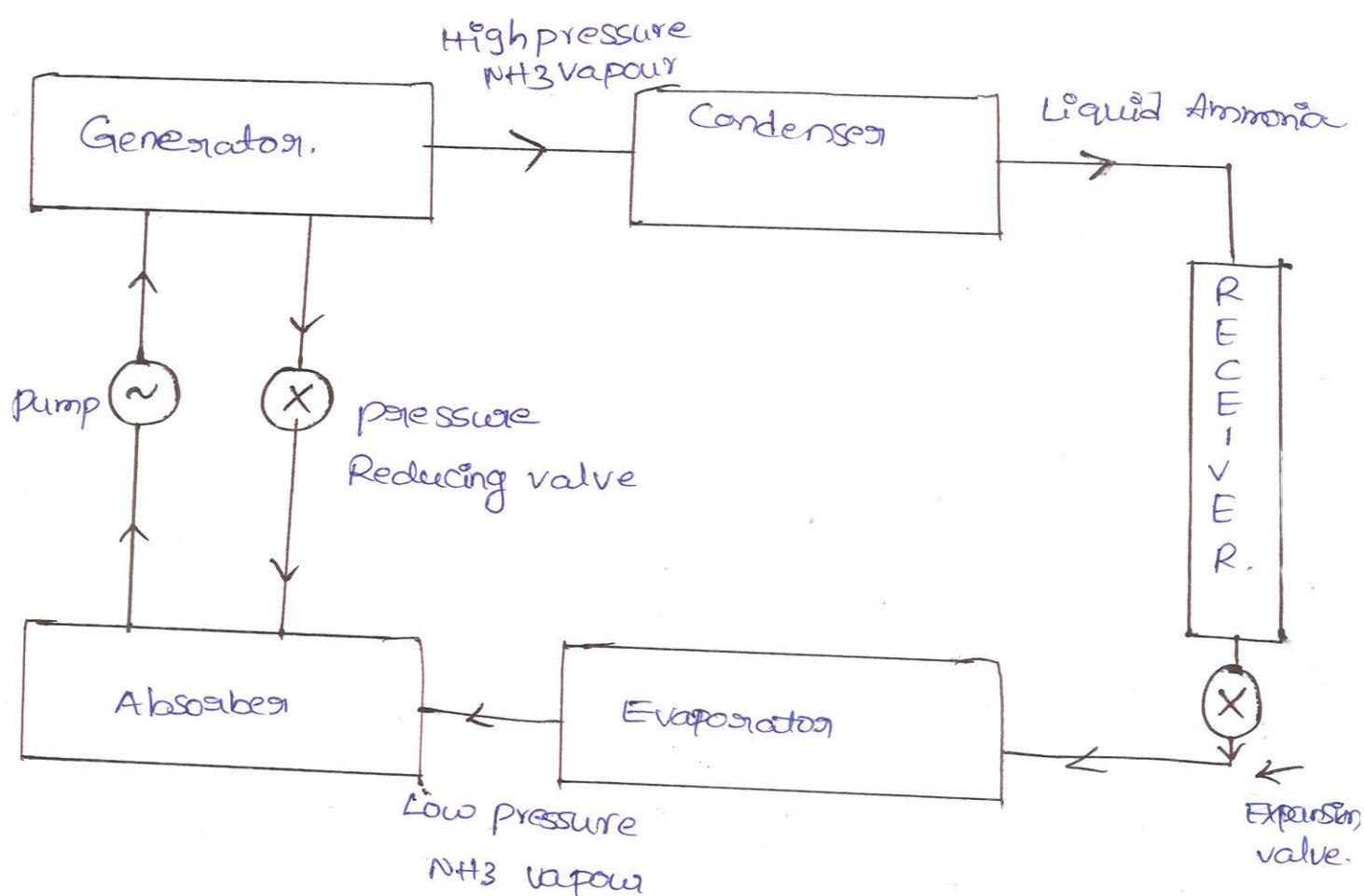


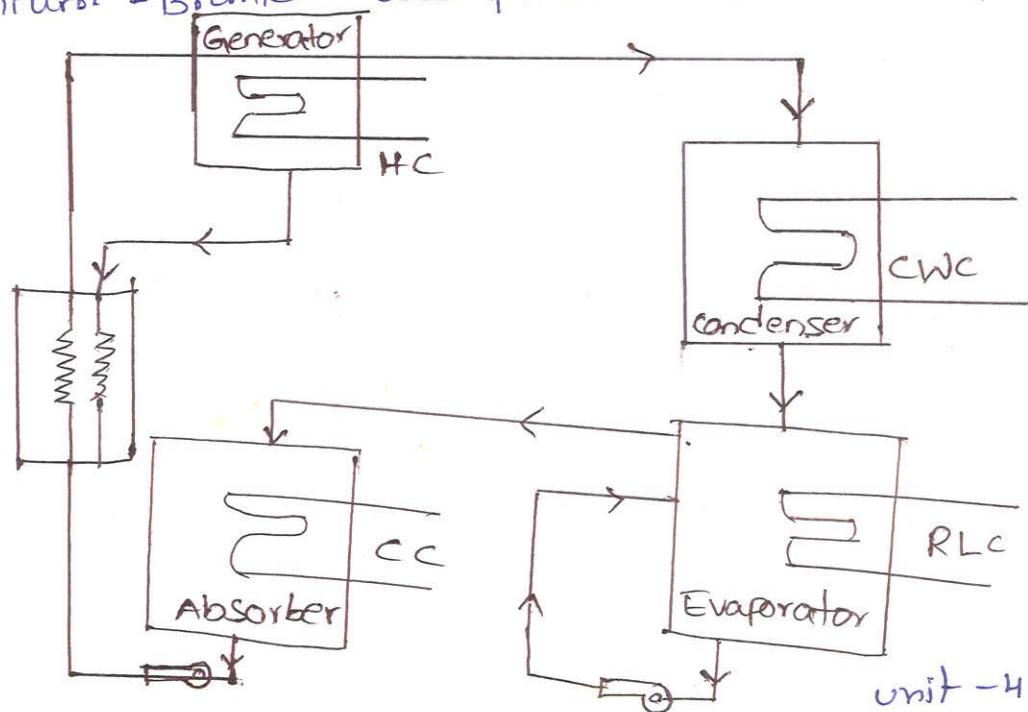
Fig:- Ammonia-water vapour Absorption refrigeration system.

This system mainly consists of generator, pump, pressure reducing valve, absorber, evaporator, expansion valve, receiver and condenser. In its working, the low temperature pressure ammonia vapour from the evaporator enters into the absorber and gets absorbed with cold water used as absorbent. Since, water has the ability to absorb very large quantities of ammonia vapour. Thus, the solution formed is known as aqua-ammonia. The absorption of ammonia vapour in water lowers the pressure in the absorber.

Therefore, it draws more ammonia vapour from the evaporators increasing the temperature of the solution. The strong solution thus formed in the absorber is then pumped to the generator with the help of aqua pump, increasing the pressure. This strong solution in the generator gets heated up with some external source, thus evaporating ammonia vapour at high pressure and leaving the weak ammonia solution in the generator. This weak NH₃ solution flows back through pressure reducing valve into the absorber at low pressure. The high pressure ammonia vapour from the generator gets condensed in the condenser and becomes high pressure liquid ammonia. This liquid ammonia enters into the receiver and then through the expansion valve it enters again into the evaporator, thus completing the cycle.

(4) Draw a neat compact diagram of Lithium Bromide water absorption refrigeration system and explain its working.

Ans:- Lithium-Bromide Absorption Refrigeration System:-
The following schematic diagram represents the working of a Lithium-Bromide absorption refrigeration system.



H.C = Heating coil

C.C = cooling coil

C.W.C = condensing water coil

R.L.C = Refrigerating load coil.

E.P = Evaporator pump

S.P = solution pump.

The main components of Li-Br absorption refrigeration system are absorber, evaporator, condenser, generator, heating coil, heat exchanger, condensing water coil. Refrigerating load coil, solution pump and evaporator pump.

Li-Br salt solution is used as a refrigerant whereas in this system, water is used as an absorbent.

Li-Br salt solution as an absorbent.

The water present in the evaporator gets evaporated absorbing its latent heat from the remaining water and the remaining cooled water in the evaporator is used for taking cooling loads. The water vapour formed is absorbed by the strong LiBr salt sprayed in the absorber.

Therefore, the solution becomes weak and is further pumped to the generator as shown in the figure. This weak solution again becomes strong with the help of steam present in the generator. This strong solution is

again passed into the absorber through heat exchanger.

The water vapour formed in the generator is condensed in the condenser by the condensing water coil. Hence, the condensate from the condenser is again supplied to the evaporator to compensate the vapour formed in the evaporator and it completes the cycle.

(5) what are the characteristics of ideal absorbent and refrigerant mixture in vapour absorption refrigeration?

Ans: The characteristics of ideal absorbent and refrigerant mixture in vapour absorption refrigeration are,

1. Both refrigerant and absorbent should have low specific heats.
2. Both should have low viscosities to minimize pump work.
3. Both should be non-toxic and non-inflammable.
4. They should not cause corrosion.
5. The refrigerant should be more volatile than the absorbent.
6. The boiling point of the refrigerant must be lower than the absorbent.
7. At the operating conditions, the refrigerant and absorbent must be chemically stable.
8. To reduce the refrigerant flow rate, the latent heat of vaporization of the refrigerant should be high.
9. Both refrigerant and absorbent should not form a solid phase.
10. The operating pressures should be low, since to reduce the size of shells and connecting pipes.
11. The affinity of the absorbent should be strong for the refrigerant.

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(6) A refrigerator using Ammonia works between the temperatures -10°C and 25°C . The gas is dry at the end of compression and there is no under cooling of liquid. Using the tables, calculate the theoretical C.O.P. of the cycle.

Ans:-

Given that,

Working substance of refrigerator = Ammonia (NH_3)

Low temperature = -10°C = $263\text{ K} = T_1 = T_4$

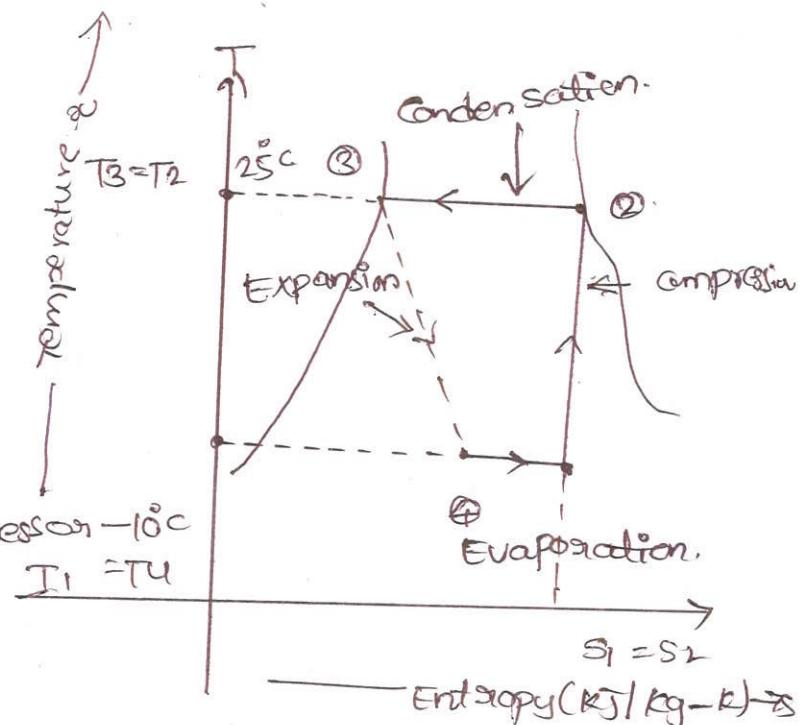
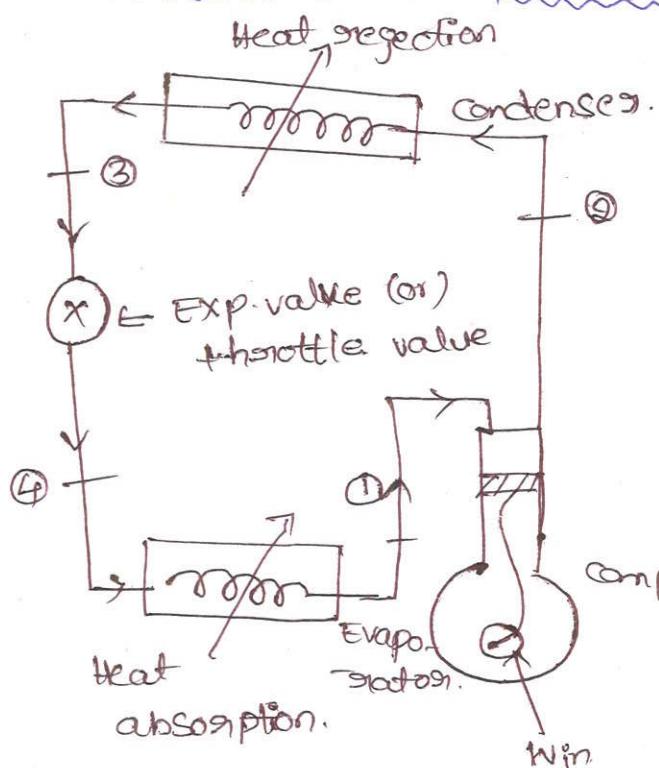
High temperature = 25°C = $298\text{ K} = T_2 = T_3$

Condition of ammonia gas at the end of compression process is dry.
i.e., $x_2 = 1$

No under cooling takes place at the end of condensation (i.e., before throttling process)

Let C.O.P. = Theoretical coefficient of the performance of the cycle.

Representation of cycle:-



Simple vapor compression refrigeration system.

use the following table properties of saturated Ammonia (NH_3).

Temperature (°C)	Liquid heat (kJ/kg) (h_f)	Latent heat (kJ/kg) (h_{fg})	Liquid entropy (kJ/kg-K) (s_f)
-10°C	135.37	1297.68	0.5443
25°C	298.9	1166.94	1.1242

At -10°C (263K) ($T_1 = T_4$)

$$\therefore h_{f1} = 135.37 \text{ kJ/kg}$$

$$h_{fg1} = 1297.68 \text{ kJ/kg}$$

$$s_{f1} = 0.5443 \text{ kJ/kg-K}$$

At 25°C (298K) : ($T_2 = T_3$)

$$s_{f2} = 1.1242 \text{ kJ/kg-K}$$

$$h_{f2} = 298.9 \text{ kJ/kg}$$

$$h_{fg2} = 1166.94 \text{ kJ/kg}$$

At point (3)

$$h_{f3} = 298.9 \text{ kJ/kg}$$

Let x_1 = Dryness fraction (i.e., quality) of ammonia gas.
we know that, process (1) to (2) is isentropic compression (i.e., $s_1 = s_2$)

$$s_{f1} + x_1 \frac{h_{fg1}}{T_1} = s_{f2} + x_2 \frac{h_{fg2}}{T_2}$$

$$0.5443 + x_1 \times \frac{1297.68}{263} = 1.1242 + \frac{1 \times 1166.94}{298}$$

$$\Rightarrow 0.5443 + 4.934x_1 = 1.1242 + 3.916$$

$$\therefore x_1 = 0.9112$$

specific enthalpy at point (1) (h_1) (before compression)

$$\therefore h_1 = h_{f1} + x_1 \cdot h_{fg1} = 135.37 + 0.9112 \times 1297.68$$

$$[\because h_1 = h_{f1}]$$

$$\therefore h_1 = 1371.82 \text{ kJ/kg}$$

∴ specific enthalpy at point (2) [after compression]

$$h_2 = h_{f2} + \alpha_2 \cdot h_{g2}$$

$$= 298.9 + 1 \times 1166.94 \quad [\because h_2 = h_{f2}]$$

$$= 1465.84 \text{ kJ/kg.}$$

∴ theoretical C.O.P of the vapour compression refrigeration system

$$= \frac{h_1 - h_{f3} (\text{or}) h_4}{h_2 - h_1}$$

Process (3) to (4) is constant enthalpy process

$$(h_4 = h_{f4} = 298.9 \text{ kJ/kg})$$

$$= \frac{1317.82 - 298.9}{1465.84 - 1317.82}$$

$$\therefore \text{COP}_{\text{theoretical}} = 6.884.$$

(7)

Explain the electrolux refrigeration system. How the system is operated to obtain different pressures in the cycle without a pump?

(OR)

Draw a neat diagram of three fluid system of refrigerator and explain its working.

(OR).

With the help of a neat diagram, explain the functioning of electrolux refrigerator.

Ans:- Electrolux Refrigeration System:-

The electrolux type of refrigerator used in absorption refrigeration system is also called a three-fluid absorption system. Since, it uses three fluids namely ammonia (NH_3), hydrogen (H_2) and water (H_2O). The main purpose of this system is to eliminate the pump.

so that in the absence of parts, the machine becomes noiseless. The construction and working principle of a simple electro lux refrigeration system is shown in the figure.

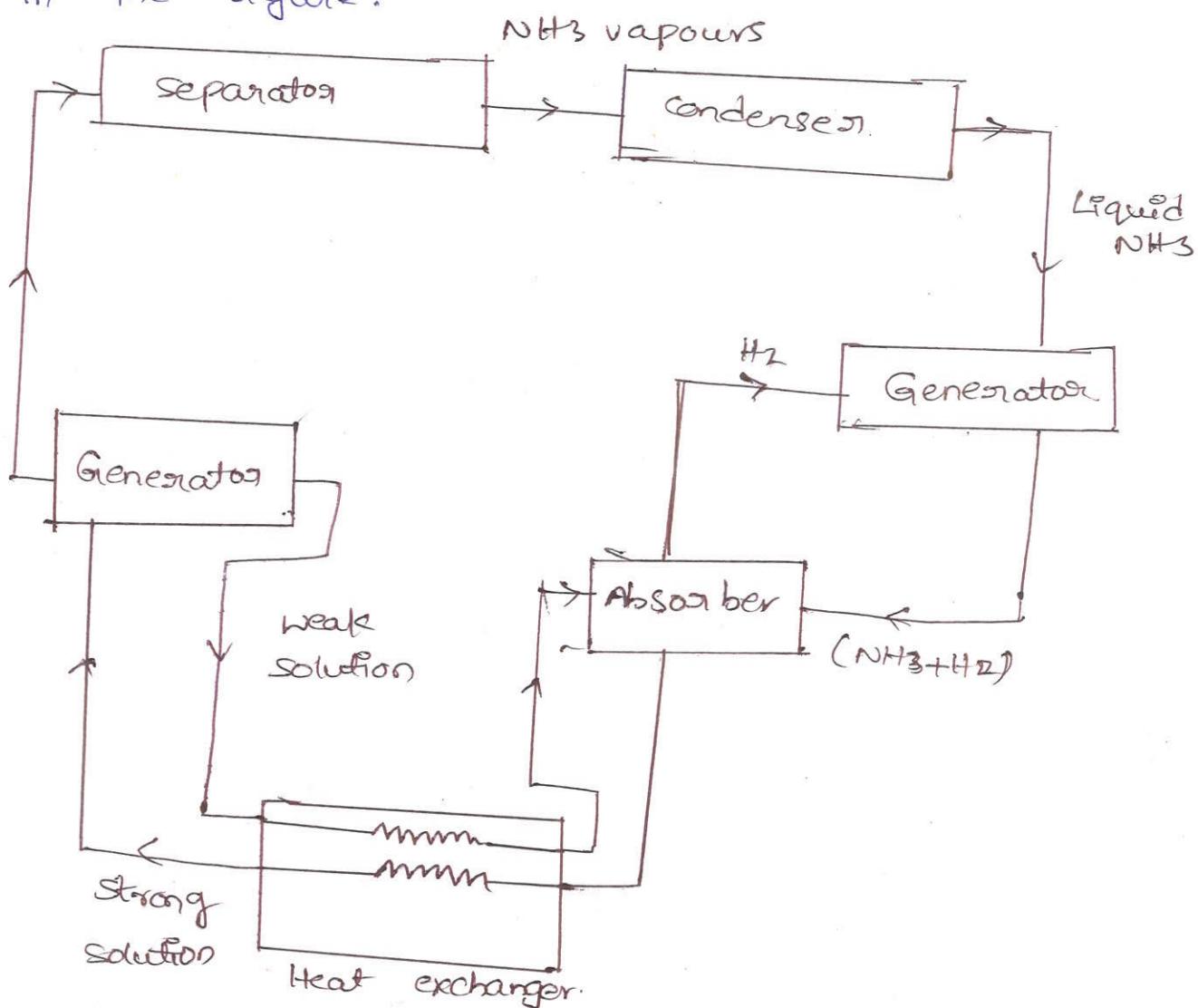


Figure: Electro lux Refrigeration System.

The main components of this system are generator, water separator, condenser, evaporator, absorber and heat exchanger. In the operation, the strong ammonia solution from the absorber through heat exchanger is heated in the generator by applying heat from an external source, releasing NH_3 vapors. These ammonia vapors with some water particles enter into the water separator where it gets separated. Then, dry NH_3 vapour again enters into the condenser and get condensed to liquid NH_3 . This liquid NH_3 vapour again enters into the condenser and get

condensed to liquid NH_3 . This liquid NH_3 under gravity is passed onto the evaporator and get mixed up with hydrogen which is present in the evaporator. Thus, evaporates liquid NH_3 at low pressure and temperature. The mixture of ammonia vapour and hydrogen is passed into the absorber where ammonia is absorbed in water while the hydrogen goes and flows back to the evaporator, as shown in the figure.

The weak solution left behind in the generator flows into the absorber through heat-exchanger and gets cooled. The heat removed by the weak solution is used to rise the temperature of strong solution passing through the heat-exchanger. The strong solution of ammonia is further passed to the generator and it completes the cycle.

(B) mention the function of each fluid in a vapour absorption system.

Ans # 1. The fluids used in three fluid vapour absorption system are ammonia as a refrigerant, water as an absorbing agent and hydrogen to increase the evaporation rate of ammonia in the evaporator.

2. The inert gas, hydrogen is restricted to the low pressure side of the system i.e., the evaporator and the absorber side, maintains the total pressure constant by allowing ammonia to evaporate at its partial pressure and at lower temperatures. It follows the Dalton's law of partial pressure.

$$(P_{\text{NH}_3} + P_{\text{H}_2} = \text{constant})$$

3. Ammonia, because of its desirable properties it is used as a refrigerant. Absence of moving parts favour the usage of ammonia as refrigerant as there are less chances of its leakage.

4. water is used as a solvent because of its ability of absorbing ammonia, forming stronger solution which is sent to the generator as it absorbs ammonia vapour, its pressure reduces which leads to the drawing of more ammonia vapour from the evaporator side.

(q) what is the effect of inert gas in three fluid refrigeration system?

Ans Domestic - Electrolux refrigerator is known as three fluids absorption refrigeration system. The three fluids used in this system are NH_3 , water and H_2 . For this working of system, a refrigerant, a solvent and an inert gas are used.

In this system, inert gas is present in the low-side of this system i.e., evaporator and absorber. Due to its presence, it maintains uniform pressure throughout the system and permits the refrigerant to evaporate at low temperature. Therefore, total pressure is equal to the sum of partial pressures of NH_3 vapour and H_2 gas which is used as inert gas.

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