

Ammonia Absorption System

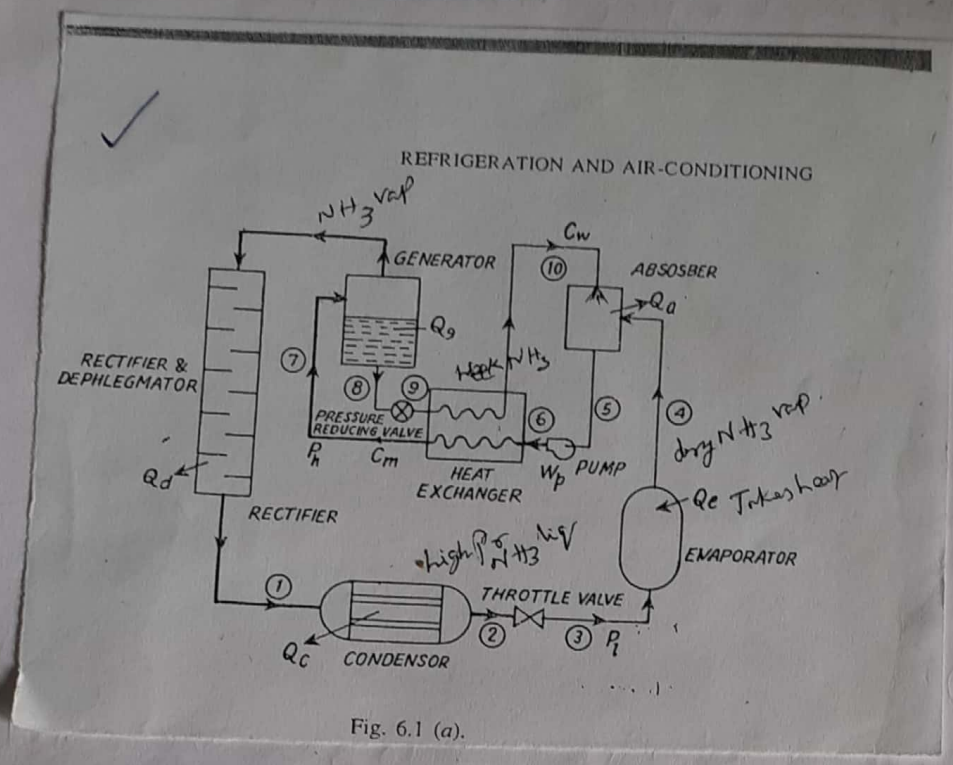


Fig. 6.1 (a).

Simple Ammonia Absorption system diagram is shown. Here NH_3 is refrigerant and water is absorbent.

Strong solution of NH_3 is heated in the generator. Refrigerant vapour is driven out and sent to condenser. Rectifier & dephlegmator are used to remove moisture or water particles. In the condenser, heat is rejected and the refrigerant is condensed to high pressure liquid NH_3 . It is passed through a throttle valve & then to evaporator where it absorbs heat of products & comes out as dry NH_3 & goes to absorber.

Weak soln of NH_3 left in generator is throttled to low pressure and sent to absorber. Dry NH_3 vapour mixes with weak NH_3 soln in absorber to become strong NH_3 solution.

The strong solution is pumped back to Generator. This completes the cycle. Heat exchanging is done between weak NH_3 soln & strong NH_3 soln for thermodynamic advantage.

Practical NH_3 Absorption System

The basic components are

- 1) Generator 2) Analyser 3) Rectifier
- 4) Condenser 5) Receiver 6) Heat Exchanger (HE_1) or dry Sub cooler 7) Expansion valve 8) Evaporator 9) water jacketed absorber 10) Pumps 1, 2 11) HE_2 (Aqueous NH_3 Heat Exchanger) 12) ER_2 13) Cooling water pad 14) Heating coil.

Analyser & Rectifier — To remove moisture.

~~Heat~~ HE_1 — Receiver outlet & evaporator outlet are Heat Exchanged.

HE_2 — weak soln & strong NH_3 soln are Heat Exchanged.

Cooling water, ~~is used~~ & pump are used to cool Condenser & absorber jacket.

$$\text{e. o. p} = \frac{\text{Heat absorbed}}{\text{work}}$$

$$= \frac{Q_a}{Q_s + w_1 + w_2}$$

Q_a = amount of Heat absorbed

Q_s = Heat supplied in Gen.

Properties of Ideal Refrigerant

- 1) It should have vap. pr. characteristics that will permit boiling at 2 to 10°C & Condensation at 40°C or above.
- 2) High critical temp
- 3) large latent heat of vaporization
- 4) low sp. heat.

Properties of Ideal Absorbent

- 1) It should have a greater affinity for refrigerant.
- 2) high boiling point
- 3) low sp. heat

Properties of Ref. Absorbent Combination

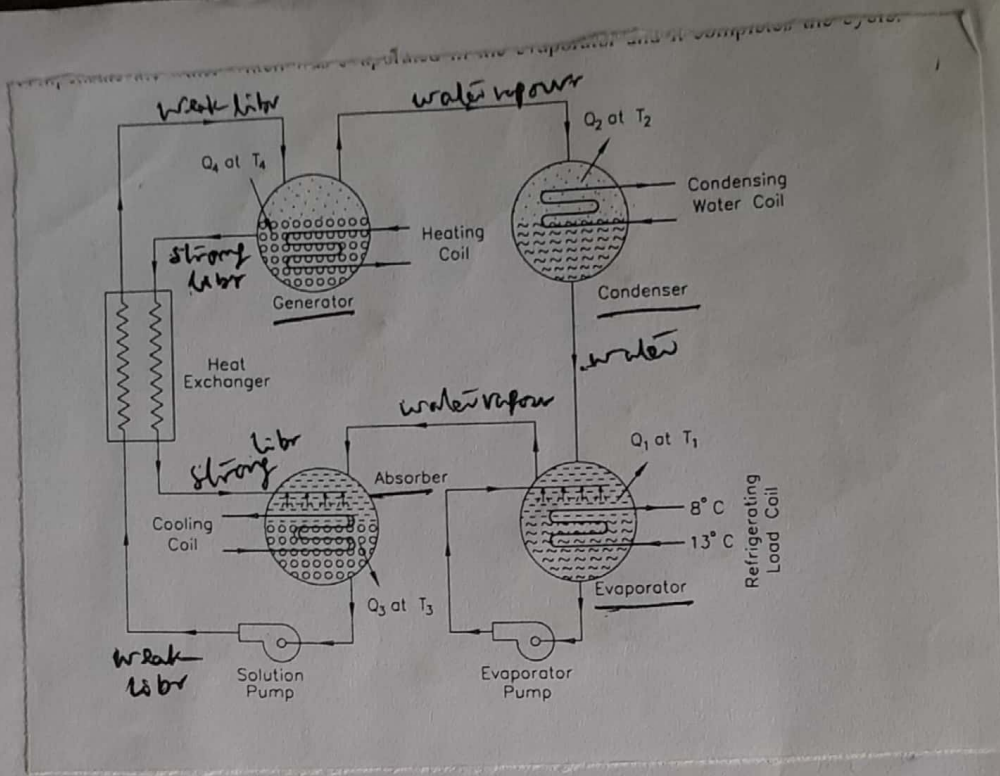
- 1) Refrigerant must be much more volatile.
- 2) Chemically stable
- 3) Both should not form ~~solid~~ solid phase
- 4) Non toxic, non inflammable, non corrosive.

Lithium Bromide Absorption System

Here water is the refrigerant and lithium Bromide salt solution is the absorbent. As the Air conditioning temps are above 0°C, this type of system is successfully used. Lithium Bromide soln has a strong affinity for water.

60% of lithium Bromide water solution at 43.5°C has a pressure of 0.625 cm of Hg which is sufficiently low to cause water to boil at 6°C. This principle is used here.

P.T.O



Around 5.5 cm Hg pressure is kept in evaporator. water will evaporate absorbing latent heat from remaining water & lowers its temp to 2°C. The cooled water in evap gets water used for A/C. water vapour from evap goes to Absorber.

In the Generator, when heating is provided, water vapour comes out from lithium bromide soln and goes to Condenser, rejects heat and condenses into water & goes to evaporator. strong lib or soln left in the Generator goes to Absorber and absorbs the water vap from evap & becomes a weak lib Br sol which is pumped back to Gen.

Heat Exchanging is done between Strong Soln & weak soln for thermodynamic advantage. The cycle repeats.

In generator NH_3 vap is formed due to heating. Separator, analyzer & rectifier help in to remove moisture particles.

Dehydrated NH_3 vap passes through condenser
 Condensed NH_3 liq pass through trap & it is evaporated in the presence of H_2 .

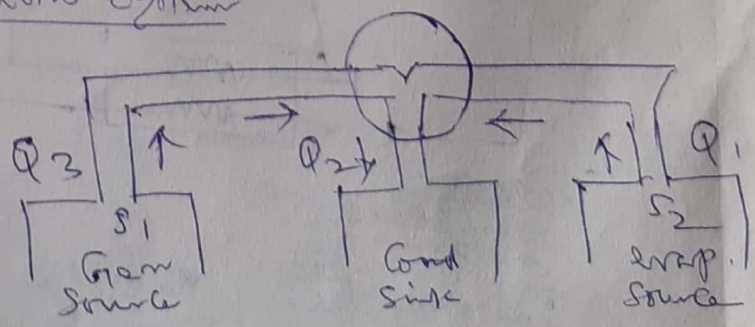
Mixture of $\text{NH}_3^{\text{vap}} \Delta \text{H}_2$ is sent to Absorber. weak Ammonia liq & also ~~also~~ come to Absorber from Separator. The weak liq absorbs NH_3 ~~and~~ in the absorber and liberates H_2 . The strong soln is sent to Generator. H_2 s are used for thermodynamic advantage

no noise in the system. no mechanical troubles. C.O.P. is very low.

This type of Refrigerator is known as three fluid absorption system. The inert gas (H_2) is confined to low side of system only (evap & Absorber). By its presence uniform pressure is maintained throughout the system, and at the same time permitting the refrigerant to evaporate at low temp corresponding to its partial press.

C.O.P. of Absorption system

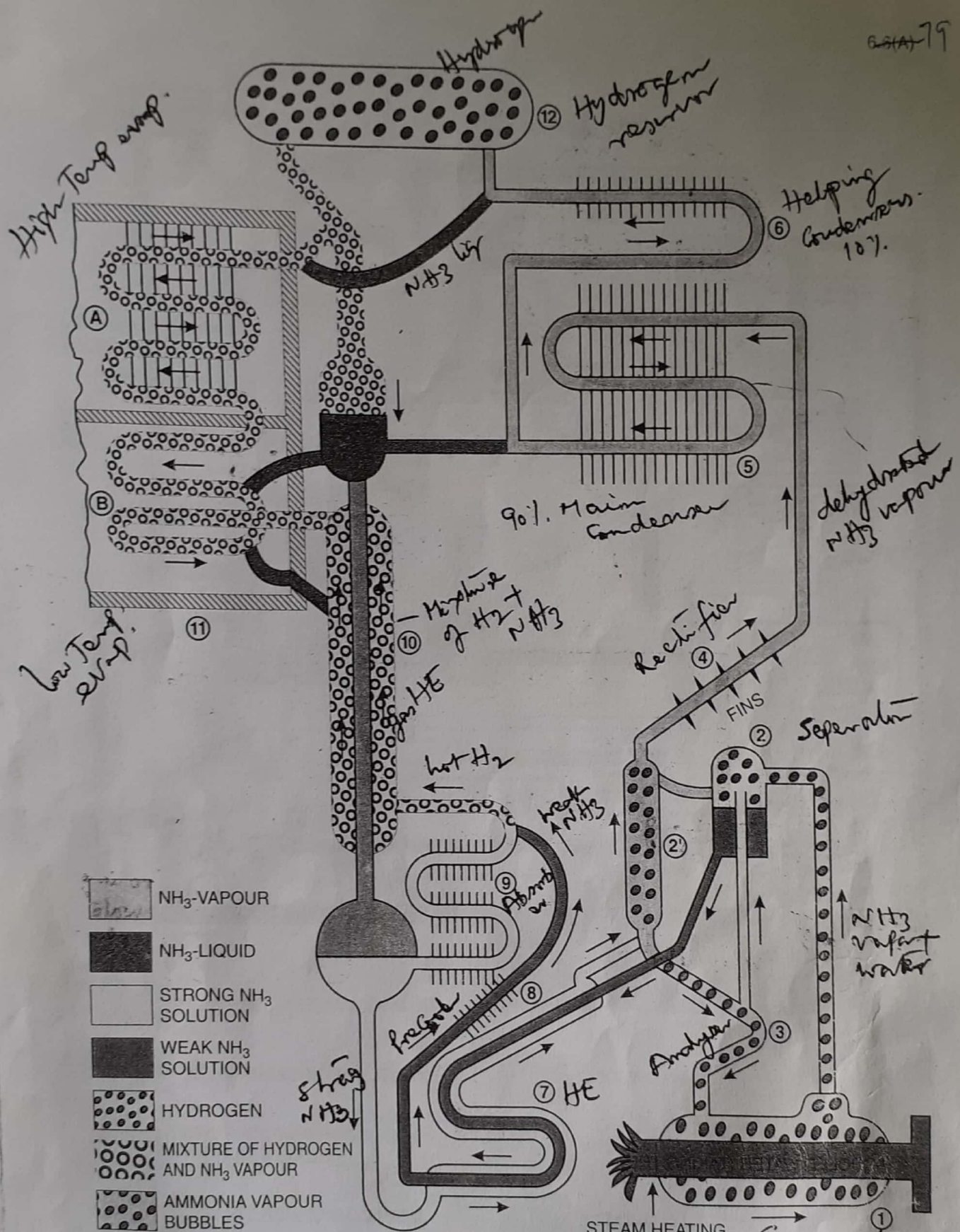
- $Q_3 =$ heat given at Gen at T_3
- $Q_1 =$ Heat absorbed at evap at T_1
- $Q_2 =$ Heat discharged in Cond & absorber at T_2










Neglecting pump work & losses, cycle considered as reversible

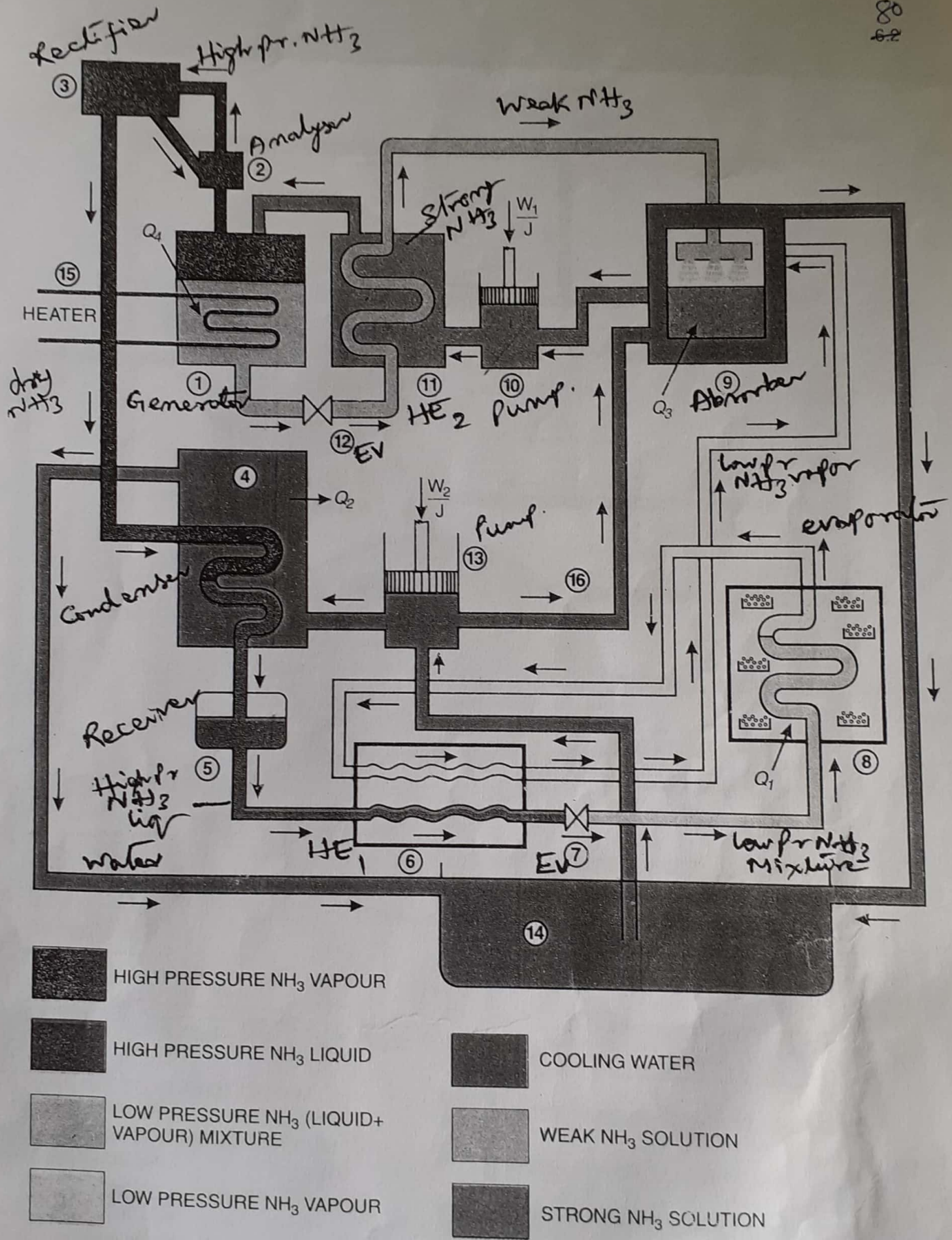
Initial entropy = Final entropy

$$\frac{Q_3}{T_3} + \frac{Q_1}{T_1} = \frac{Q_2}{T_2}, \quad \text{C.O.P.} = \frac{Q_1}{Q_3} = \frac{T_1}{T_2 - T_1} \cdot \frac{T_3 - T_2}{T_3}$$

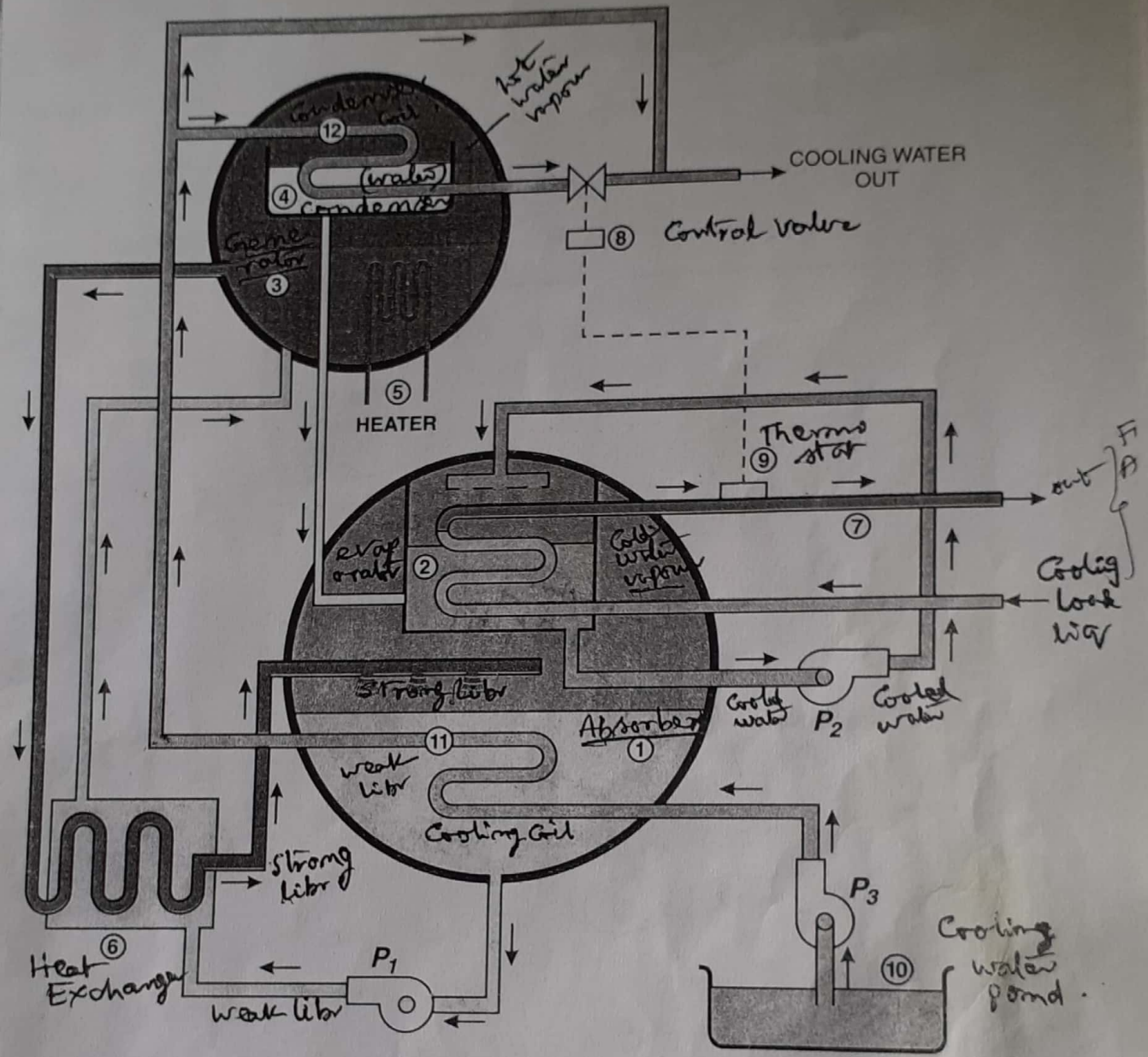











-  NH₃-VAPOUR
-  NH₃-LIQUID
-  STRONG NH₃ SOLUTION
-  WEAK NH₃ SOLUTION
-  HYDROGEN
-  MIXTURE OF HYDROGEN AND NH₃ VAPOUR
-  AMMONIA VAPOUR BUBBLES

Domestic Electrolux Refrigerator

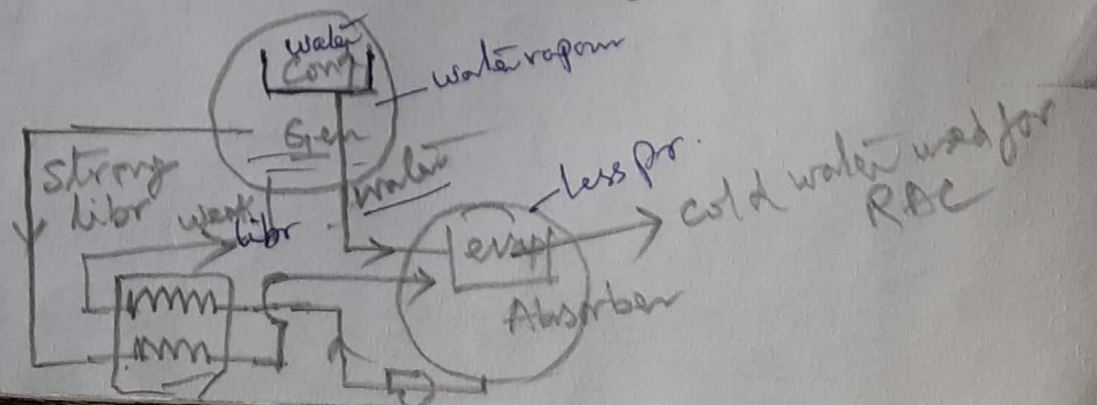


Practical Ammonia Water Absorption Refrigeration System

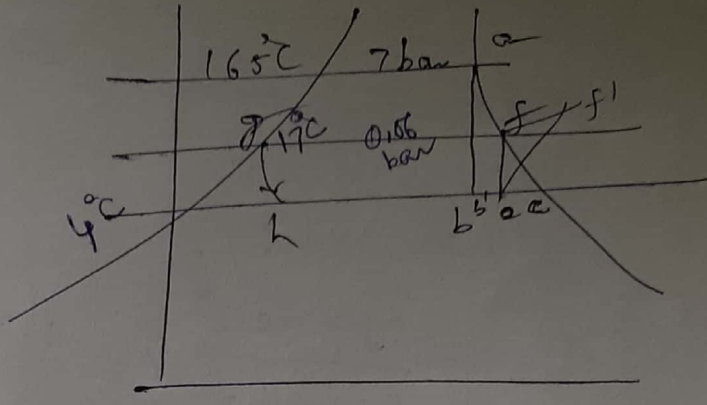


- | | |
|---|--|
|  WEAK SOLUTION OF LITHIUM BROMIDE SALT |  WATER VAPOUR AT HIGH TEMPERATURE |
|  STRONG SOLUTION OF LITHIUM BROMIDE SALT |  WATER AT HIGH TEMPERATURE |
|  CONDENSED WATER AT HIGH TEMPERATURE |  WATER AT LOW TEMPERATURE |
|  COOLED WATER (TAKING THE COOLING LOAD AT LOW TEMPERATURE) |  COOLING WATER FROM POND |
|  WATER VAPOUR AT LOW TEMPERATURE | |

Actual Lithium Bromide Salt Solution Cooling Plant



$\eta_m = 0.9$
 $\eta_e = 0.6$
 $\eta_c = 0.7$



From Tables

$7 \text{ bar } T_g = 165^\circ\text{C}$
 $h_g = 2762$
 $s_g = 6.705$

$0.06 \text{ bar } T_g = 35.2$
 $h_g = 2567.5, h_{fg} = 2416$

$s_f = 0.521, s_g = 5.33$

$4^\circ\text{C } p_s = 0.00813$
 $h_f = 16.8, h_{fg} = 2492$
 $s_f = 0.061, s_g = 9.05$

$s_a = s_b$

$6.705 = 0.061 + x \times 9.05$ ✓

$x_b = 0.74$ (Use this x)

$h_b = h_f + x \cdot h_{fg}$
 $= 16.8 + 2492 \times 0.74$ ✓
 $= 1861$ ✓

$\eta_m = \frac{h_a - h_b'}{h_a - h_b}, \quad \eta_g = \frac{2762 - h_b'}{2762 - 1861}$ ✓

$h_b' = 1951$

$\eta_e = \frac{h_a - h_d}{h_a - h_b'} = 0.6 = \frac{2762 - h_d}{2762 - 1951}$

$h_d = 2275, \quad x_d = \frac{2275 - 16.8}{2492} = 0.906$

$x_e = 0.92$ given

$h_e = 16.8 + 0.92 \times 2492 = 2309.5$

in the order to become through NH₂ solution

$$S_e = S_f$$

$$S_f = 8.33 = 0.061 + 0.9 \left(\frac{9.05}{9} \right)$$

$$n_f = 1$$

$$h_f = 2567.5$$

$$\eta_c = \frac{h_f - h_e}{h_f' - h_e}, \quad 0.7 = \frac{2567.5 - 2309.5}{h_f' - 2309.5}$$

$$h_f' = 2677.4$$

$$m_s = \frac{h_f - h_e}{\eta_m \eta_e \cdot \eta_c (h_e - h_b) - (h_f - h_e)}$$

$$= \frac{2567.5 - 2309.5}{0.9 \times 0.6 \times 0.7 (2762 - 1861) - (2567.5 - 2309.5)}$$

$$= 3.12 \text{ kg/kg of vap}$$

Flash

$$h_c + m_s \cdot h_d = (1 + m_s) h_e$$

$$h_c + 3.12(2295)$$

$$= (1 + m_s) 2309.5$$

$$h_c = 2417$$

$$h_c = h_f + u \cdot (h_{fg})$$

$$2417 = 16.8 + u \cdot 2492$$

$$u = 0.963$$

$$RE = h_c - \text{Makeup water at } 17^\circ C$$

$$= 2417 - 4.2 \times 17 = 2345.4$$

c = water vapor in chamber
 d = before this step
 e = after this step

Non Conventional Refrigeration System

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Thermoelectric System:

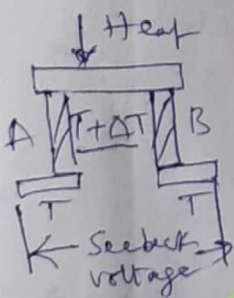
In 1821 Seebeck (German) observed that if a closed circuit was made of 2 dissimilar metals, an electric current flowed in the circuit when the two junctions were maintained at different temps.

In 1834, Peltier discovered that when D.C. is passed through a junction of 2 dissimilar metals, the junction became either hot or cold.

1838, Lemé has proved both these effects & their importance.

After the development of Semiconductors (they can produce wide temp differences) in 1930, Seebeck & Peltier effect got importance.

In 1851, Thomson pointed out that heat absorbed or evolved in a single conductor depends on the temp gradient along it & the current flowing. This effect is in addition to joules I^2R heating.



Seebeck: - For small T. Diff between 2 junctions of A & B, open ckt. voltage developed.

$$\Delta V = \alpha_{ab} \Delta T$$

ΔV = open ckt voltage developed

α_{ab} = Seebeck coeff for materials A, B

ΔT = Temp diff between junctions of A & B

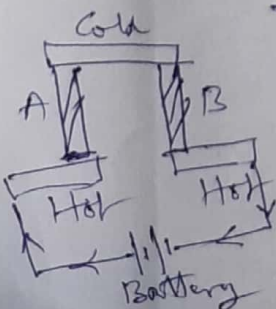
Peltier: - Same ckt, battery introduced to provide D.C. current I .

$$Q_p = \pi_{ab} I$$

Q_p = Heat evolved or absorbed in unit time (watts)

π_{ab} = Peltier coeff

I = D.C. in amperes.



Thomson effect: In addition to current flow, Temp gradient exists.

This depends on the properties of a single material.

$$\frac{dT}{dx} = \text{Temp gradient}$$

$$\frac{dQ_T}{dx} = \pi \cdot I \cdot \left(\frac{dT}{dx} \right)$$

Thomson heat

Current

Temp gradient

π = Thomson Co-efficient

Joule's effect is irreversible dissipation due to electrical resistance ($I^2 R$ loss)

Seebeck, Peltier, Thomson effects are reversible in nature.

Kelvin's relationship

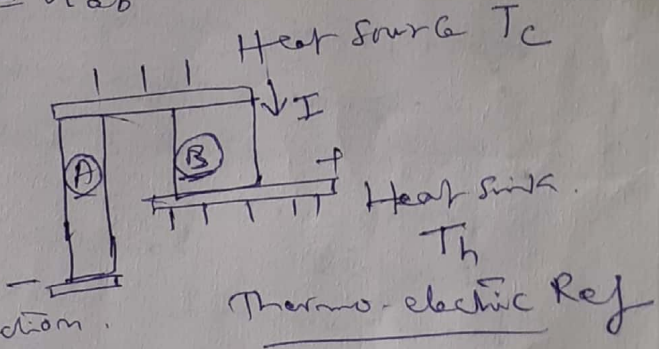
Seebeck Coeff

$$\text{Peltier Coeff} \leftarrow \pi_{ab} = \alpha_{ab} \cdot T$$

Thermoelectric Refgn.

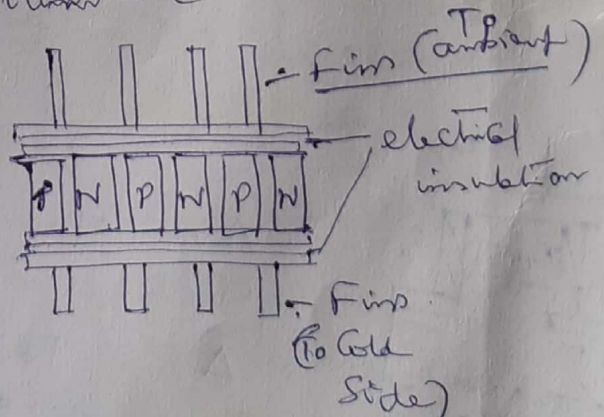
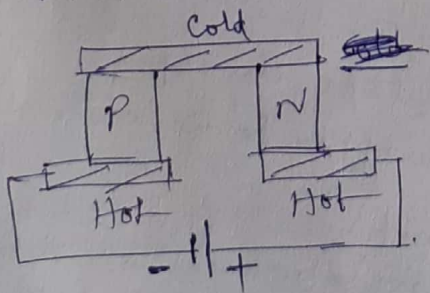
Assumptions

- Heat absorption & heat rejection occur only at Junction.
- Thomson Coefficient is negligible.



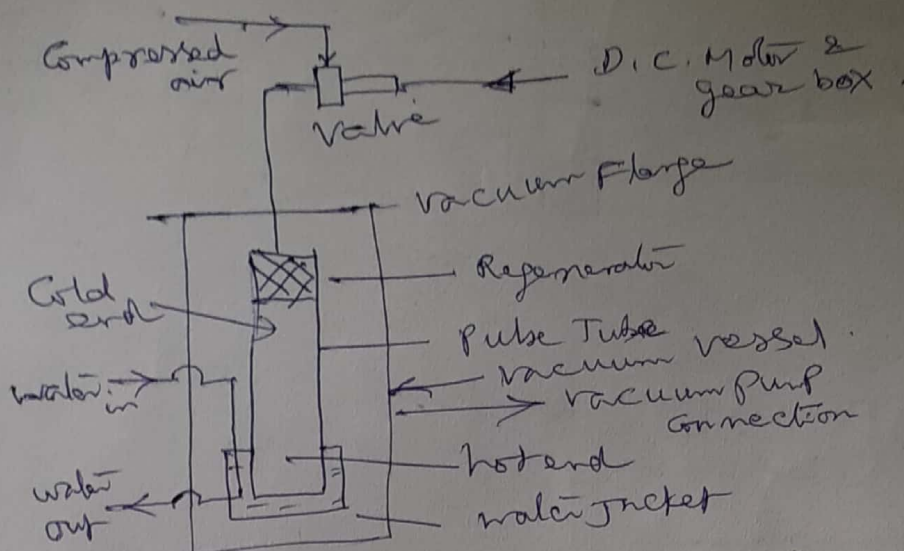
Materials Lead, Antimony, Selenium etc are used.

It has low C.O.P.



P, N \rightarrow diff types of Semiconductors.

Thermoelectric Refrigerator



It consists of a closed tube which is subjected to pressurization & depressurization alternatively. The desired pressures are obtained by valve mechanism.

operation:-

i) Pressure build up & heat rejection:-

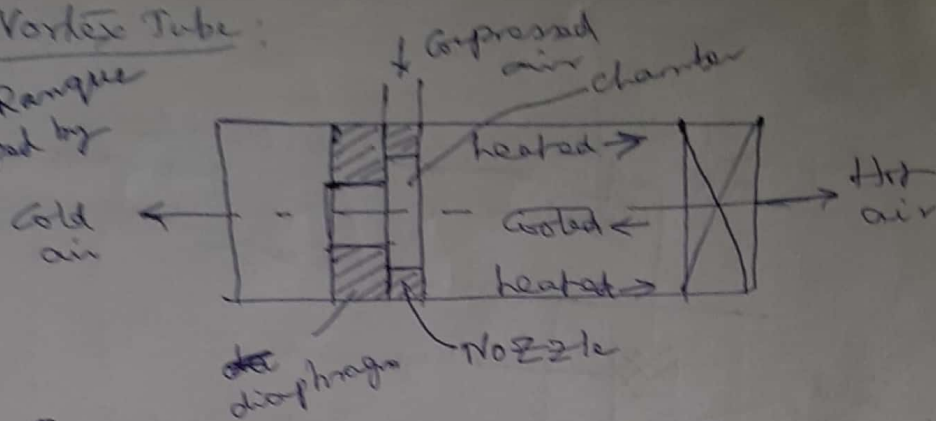
High pressure gas passes through regenerator where it is cooled slightly (because of cold end). This gas acts as gas piston & pressurises the already present gas in the tube. Tube gas temp rises and pushed towards closed end of pulse tube. Tube gas rejects heat to cooling medium (water).

ii) Press release & heat absorption:-

The gas in the pulse tube is connected to the exhaust. With the help of valve mechanism, thus releasing the gas that entered the pulse tube. This results in expansion of tube gas & decrease in temp at the cold end. ~~well exceeds~~ ~~provided~~ (ex) - helium as gas; $P_r = 25 \text{ bar}$ up to 124 K single stage & up to 79 K - two stage)

Vortex Tube:

Developed by Ranque
Further developed by
Hilsch.



It consists of

- 1) Nozzle
- 2) diaphragm
- 3) Valve
- 4) Hot air side
- 5) Cold air side.

~~Nozzle of~~

Compressed air is passed through the nozzle. Air expands and acquires high velocity due to particular shape of nozzle. A vortex flow is created in the chamber & air travels in spiral like motion ~~turning~~ along the periphery of the hot side. This flow is restricted by the valve. By partly closing the valve, pressure of air increases & a reversed axial flow through the core of the hot side starts from high pressure region to low pressure region.

Because of energy transfer of the 2 streams, air stream through the core gets cooled, air stream in forward direction gets heated. The cold stream escapes through the diaphragm hole into the cold side, while hot stream is passed through the opening of the valve. By controlling the opening of the valve, qty of cold air and its temp can be varied.