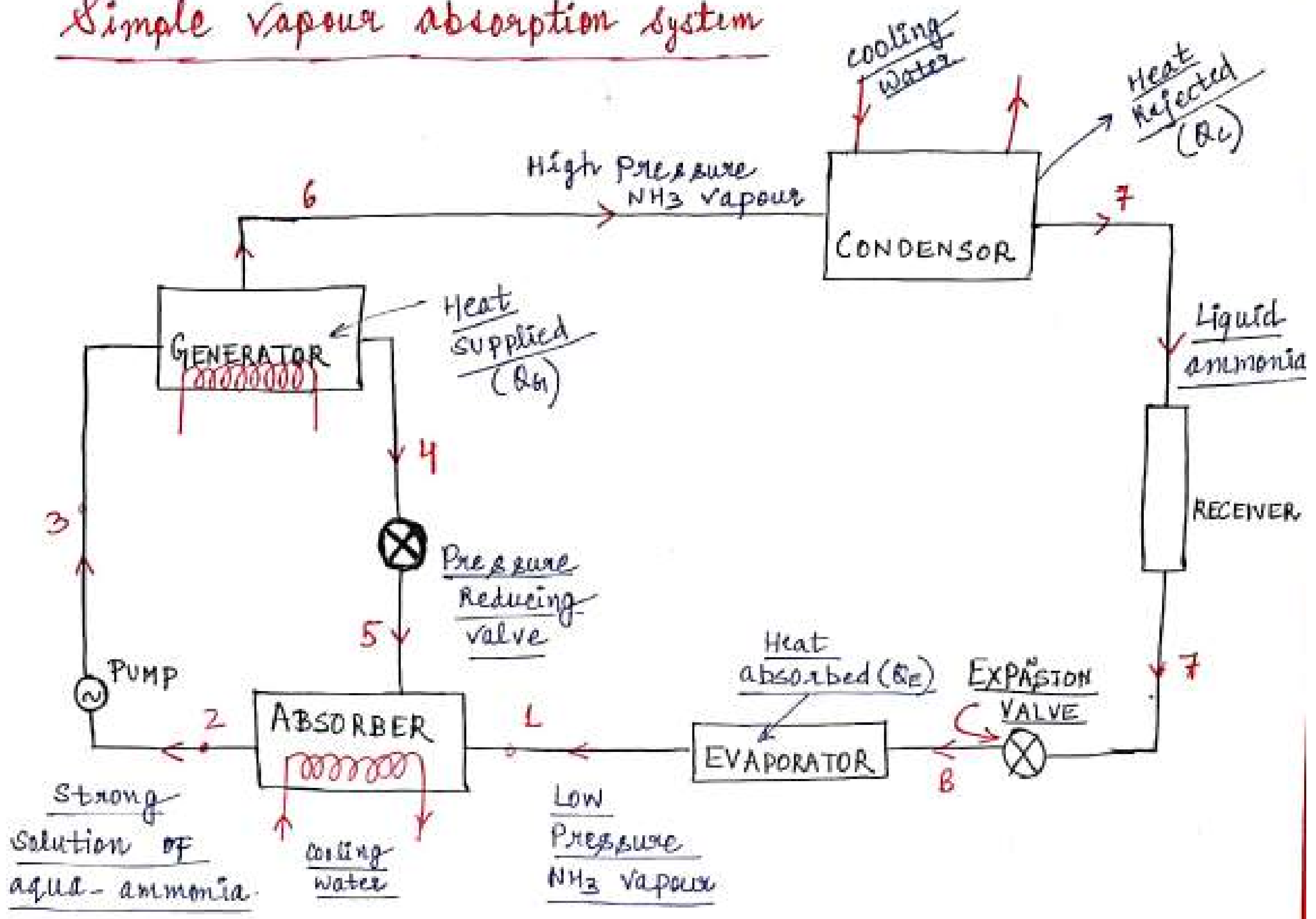
Simple vapour absorption system



→ In VARS compressor is replaced by following 4 devices.

Compressor ⟷
- → Absorber → Tank containing ~~cooling~~ water.
- → Pump
- → Generator
- → Pressure Reducing valve.

→ The low-pressure ammonia vapours from the evaporator enters the absorber where NH_3 vapours are absorbed by the water present in the absorber to form a strong solution of aqua-ammonia.

→ This strong solution of aqua-ammonia is then pumped to the generator with the help of a pump.

→ The absorption of NH_3 vapour in water lowers the Pressure in the absorber which in turn draws more ammonia vapour from the evaporator & raises the temp. of solution.

→ The solution of aqua-ammonia is cooled simultaneously to remove the heat of solution as well as to increase the absorption capacity of water.

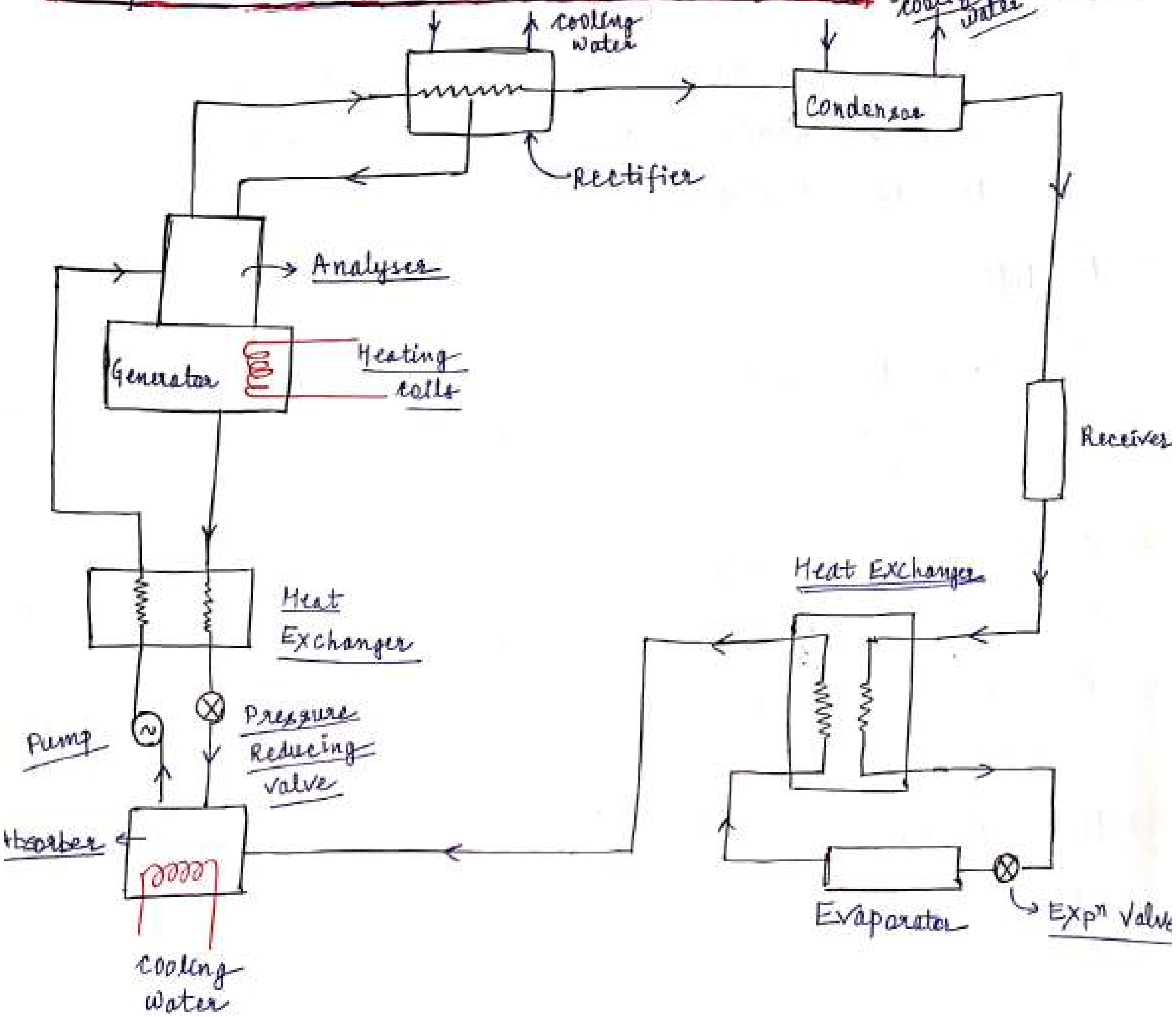
→ The strong solution is heated in the generator to liberate high pressure ammonia vapours.

→ Subsequently these vapours are condensed in the condensor followed by expansion in expansion valve.

→ Finally the low pressure NH_3 vapours are made to enter in the evaporator where it gains heat from the surroundings to produce refrigeration effect.

→ Thus the cycle is repeated.

Improved Vapour Absorption System



1) Analyser

→ The analyser contains a series of trays mounted above the generator.

→ The strong solution from the absorber and the aqua from the rectifier are introduced at the top of analyser and flows downward over the trays and into the generator.

→ Thus considerable liquid surface is exposed to vapour rising from the generator.

→ The vapour is cooled & most of the water vapour condenses & mainly ammonia vapour (99%) leaves the top of analyser.

2) Rectifier.

→ In case the water vapours are not completely removed in the analyser, a closed type vapour cooler called rectifier is used.

→ It is generally water cooled & may be of double-pipe, shell & coil or shell & tube type.

→ It's function is to further cool NH_3 vapours leaving the analyser so that remaining water vapours are condensed.

3) Heat Exchangers

Three heat exchangers are provided :-

H.E. I —
- → B/W Pump & generator.
- → used to cool the weak hot solution returning from the generator to the absorber.
- → heat Removed from the weak solⁿ raises the temp. of strong solⁿ coming in the way.

H.E – II
- → Provided b/w condenser & Evaporator
- → called Liquid sub-cooler.

$$COP = \frac{\text{Heat absorbed in Evaporator}}{\text{Work done by pump + Heat supplied in Generator}}$$

Properties of Ideal Refrigerant-Absorbent combination

- → The affinity of refrigerant towards absorber should be high at low temperatures.
- → The combination should possess high degree of negative deviation from Roult's Law.
- → Mixture should have low specific heat & low viscosity.
- → Mixture should have low freezing point.
- → Mixture should be non-corrosive.
- → Large difference in normal boiling points of the Refrigerant and the absorbent.

Comparison b/w VCRS & VARS

VCRS	VARS
→ For the same capacity VCRS has more wear & tear, noise due to moving parts of compressor.	→ In VARS, the only moving part is pump. Thus, VARS operation is relatively quiet with little wear.
→ VCRS system uses mechanical energy to change the state of refrigerant from evaporator.	→ VARS uses heat energy (Low grade Energy)
→ COP is higher (3 to 5)	→ COP is low (0.3 to 0.5).
→ Heat Rejection takes place in:- condenser	→ Heat Rejection takes place in:- i) condenser ii) Absorber.
→ Chances of Leakage of Refrigerant	→ Very Low chance of Leakage.
→ Performance of VCRS at partial loads is poor.	→ Load variations does not affect Performance of VARS.
→ More space Requirement than VARS	→ Lesser Space Requirement.

COP of an Ideal VARS

By I Law of Thermodynamics :-

Heat Rejected = Heat Supplied [For Refrigerant]

$$Q_C = Q_G + Q_E \quad \text{— (1)}$$

$Q_C \rightarrow$ heat rejected by Ref. in condenser.

$Q_G \rightarrow$ heat supplied in Generator

$Q_E \rightarrow$ heat absorbed in Evaporator.

Considering VARS as reversible system.

$$\Rightarrow \quad ds = \frac{dQ}{T} = 0$$

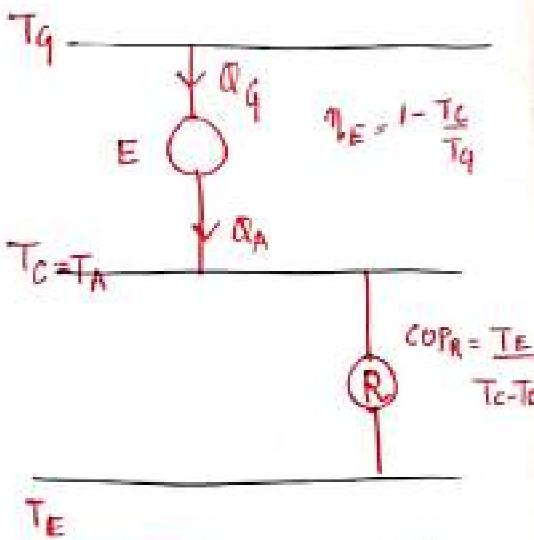
$$\Rightarrow \quad \frac{Q_G}{T_G} + \frac{Q_E}{T_E} = \frac{Q_C}{T_C}$$

$$\Rightarrow \quad \frac{Q_G}{T_G} + \frac{Q_E}{T_E} = \frac{Q_G + Q_E}{T_C}$$

$$Q_G\left[\frac{1}{T_G} - \frac{1}{T_C}\right] = Q_E\left[\frac{1}{T_C} - \frac{1}{T_E}\right]$$

$$\Rightarrow \quad Q_G\left[\frac{T_C - T_G}{T_C \cdot T_G}\right] = Q_E\left[\frac{T_E - T_C}{T_C \cdot T_E}\right]$$

$$\Rightarrow \quad Q_G = Q_E\left(\frac{T_C - T_E}{T_E}\right)\left(\frac{T_G}{T_G - T_C}\right)$$



$$\eta_{VARS} = \eta_E \times (COP)_R$$

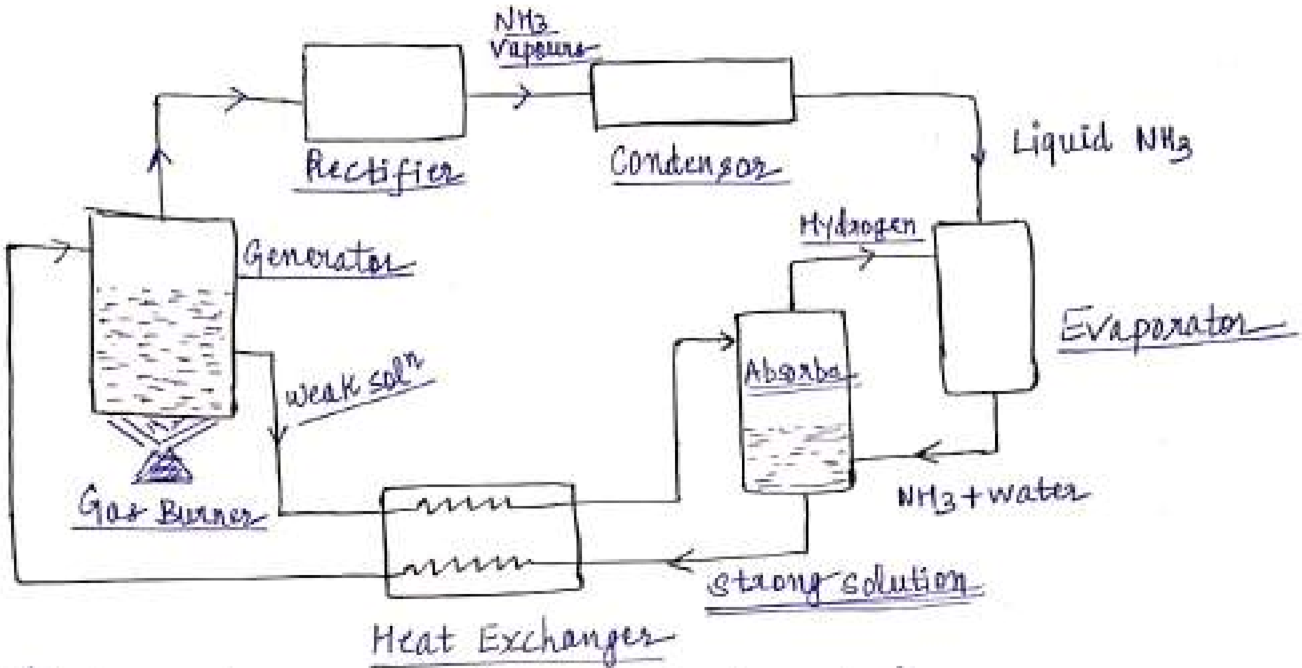
$$\underline{\text{Max}} \quad COP = \frac{Q_E}{Q_G} = \frac{Q_E}{Q_E\left(\frac{T_C - T_E}{T_E}\right)\left(\frac{T_G}{T_G - T_C}\right)}$$

$$\Rightarrow \quad \boxed{(COP)_{max} = \underbrace{\left(\frac{T_E}{T_C - T_E}\right)}_{I}\underbrace{\left(\frac{T_G - T_C}{T_G}\right)}_{II}}$$

I $\rightarrow$ COP of Carnot Ref. working b/w T_E & T_C.

II $\rightarrow$ η of Carnot Engine working b/w T_G & T_C.

Domestic Electrolux Refrigerator



→ It is also called 'Three-fluid system'.

→ The main purpose of this system is to eliminate the pump so that in the absence of moving parts, machine becomes noiseless.

→ The three fluids that are used are:-

NH_3 → used as a refrigerant.

H_2O → used as an absorber.

H_2 gas → used to increase the evaporation rate in Evaporator.
→ used in Low pressure side of the system.

Working

→ The strong NH_3 sol^n from the absorber through the heat Exchanger is heated in the generator by supplying heat.

→ The ammonia vapours are lifted off the generator.

→ These vapours are then passed through the rectifier where any water vapour impurities are separated.

→ The ~~wat~~ NH_3 vapours are then condensed in the condensor.

→ The liquid refrigerant leaving the condensor flows under gravity to the evaporator where it is mixed with H_2 gas.

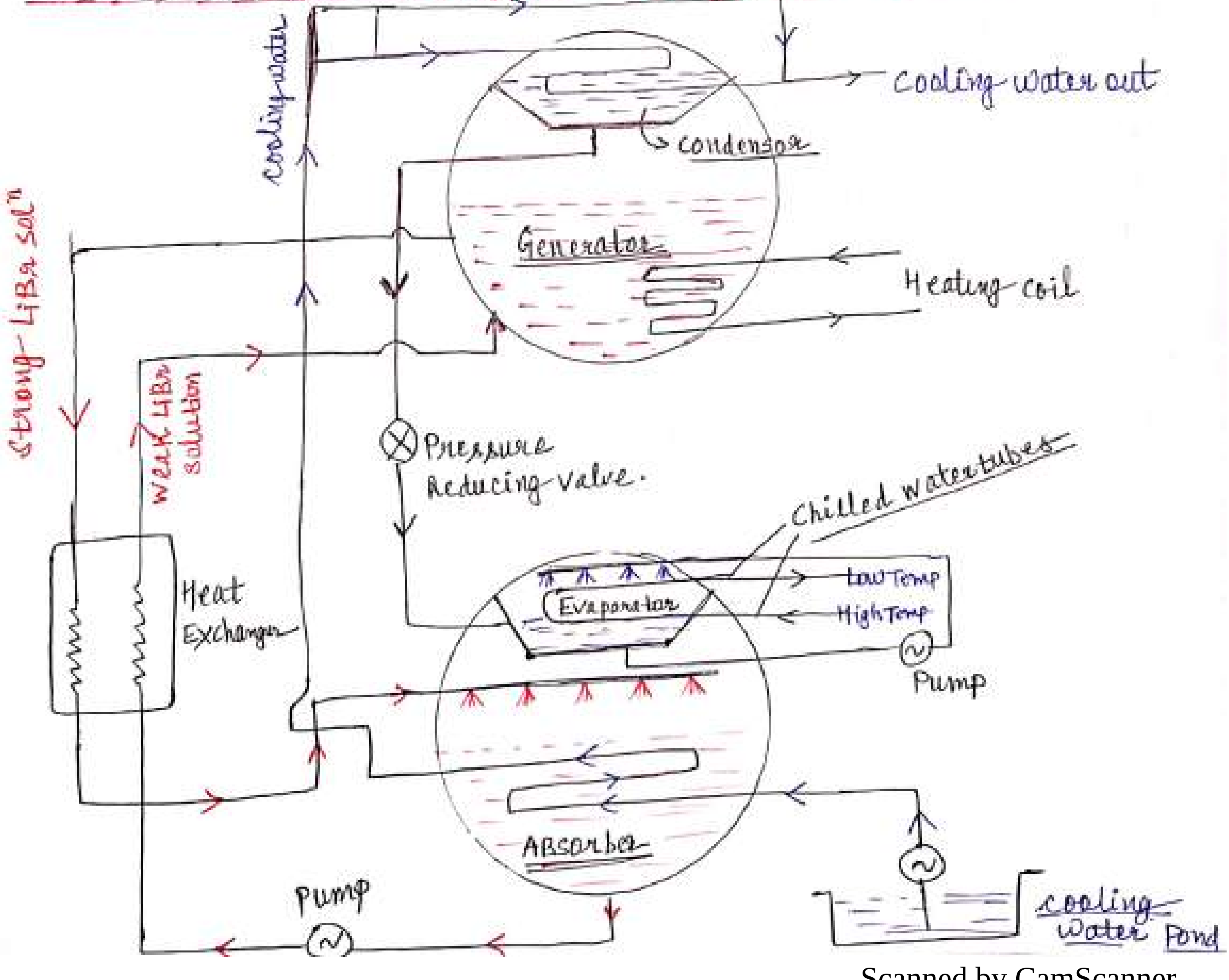
→ The hydrogen gas which is being fed to the evaporator permits the liquid NH_3 to evaporate at low pressure & Temp.

→ During the process of evaporation, the ammonia absorbs latent heat from the refrigerated space & thus produces cooling effect.

→ The mixture of NH_3 & H_2 is passed to the absorber where NH_3 is absorbed in water while the hydrogen rises to the top and flows back to the evaporator. Thus the cycle is completed.

$$COP = \frac{\text{Heat absorbed in Evaporator}}{\text{Heat supplied in generator}}$$

Lithium Bromide Absorption Refrigeration System



→ The water in the evaporator tubes be[illegible] up the heat or rejecting the heat to the Refrigerant water sprayed above the evaporator tubes.

→ The refrigerant water after accepting heat becomes vapour which get absorbed by the strong Lithium Bromide solution sprayed in the absorber.

→ After absorbing water vapour the LiBr solution becomes weak.

→ This weak LiBr solution is pumped by the pump to generator before passing through a heat exchanger.

→ The accumulated solution is heated in the generator by heating coils such that a portion of water is vapourized and the solution becomes more strong.

→ These Refrigerant vapours (water vapours) formed in the generator is condensed in condenser by the cooling water flowing through the condenser water tubes.

→ This cooling water for condensing is pumped from cooling water pond.

→ This cooling water first enters the absorber where it takes away the heat of condensation & dilution.

→ The condensate from condenser is supplied to the evaporator through a pressure reducing valve. This pressure reducing valve reduces the pressure of condensate from condenser pressure to evaporator pressure.

→ The Ref water is pumped & sprayed over evaporator tubes. This completes the cycle.

Q) In an absorption type refrigerator, the heat is supplied to NH_3 generator by condensing steam at 2 bar & 90% dry. The temperature in the Refrigerator is to be maintained at −5°C. Find the max. COP possible.

If the refrigeration load is 20 tonnes & actual COP is 70% of maximum COP. Find the mass of steam required per hour. Take Temp. of atmosphere as 30°C.

Soln

Given:- Evaporator Temp $(T_E) = -5°C = 268\,K$, $Q = 20\,TR$

$= 20 \times 3.5$

$Q = 70\,kW$

For steam used in Generator.

$P = 2$ bar

dryness fraction $= 0.9$

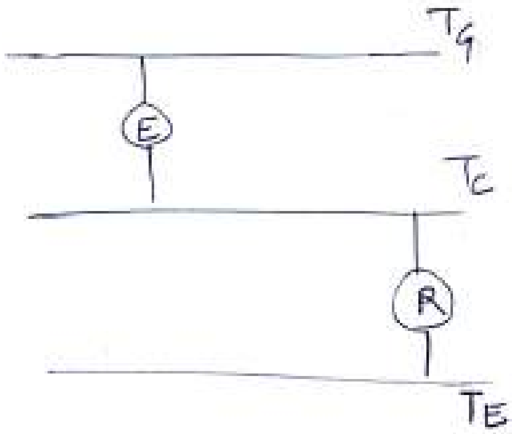
Saturation Temp corresponding to P=2bar [From steam table]

$T_G = 120.2°C = 120.2 + 273 = 393.2\,K$

$T_G = 393.2\,K$

Condensor Temp $(T_C) = 30°C$

Max. COP :-



$$(COP)_{max} = \eta_E \times (COP)_R$$

$$= \left(1 - \frac{T_C}{T_G}\right)\left(\frac{T_E}{T_C - T_E}\right)$$

$$= \left(\frac{T_G - T_C}{T_G}\right)\left(\frac{T_E}{T_C - T_E}\right)$$

$$(COP)_{max} = \left(\frac{393.2 - 303}{393.2}\right)\left(\frac{268}{303 - 268}\right)$$

$$(COP)_{max} = 1.7565$$

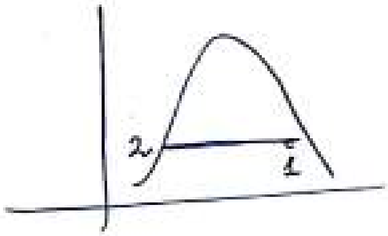
Actual COP $= 0.7 \times (COP)_{max}$

$$(COP)_{max} = 1.23$$

$\frac{R.C}{Q_G} = COP \Rightarrow 1.23 = \frac{(20 \times 3.5)}{Q_G}$

$\Rightarrow \boxed{Q_G = 56.91\ KW}$

since heat is supplied by condensation of steam



$\Rightarrow h_{12} = x h_{fg}$

$= 0.9 \times 2201.6$

$h_{12} = 1981.44\ KJ/kg$

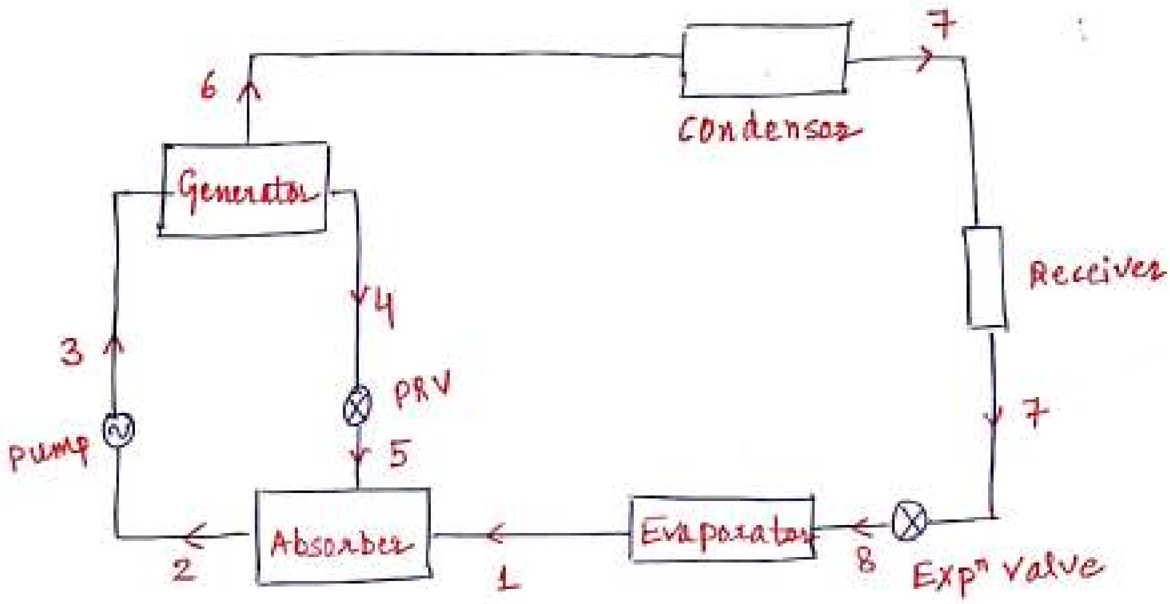
mass of steam Required/s $= \frac{Q_G}{h_{12}} = \frac{56.91}{1981.44} = 0.02872\ kg/s$

$= 103.4\ kg/hr$

Q) In an aqua-ammonia absorption refrigeration system of 10TR capacity, the vapours leaving the generator are 100% Pure NH_3 saturated at 40°C. The evaporator, absorber, condenser & generator temperatures are −20°C, 30°C, 40°C, & 70°C, respectively. At absorber exit (strong solution), the concentration of NH_3 in solution is $x = 0.38$ and enthalpy $h = 22\ KJ/kg$. At generator exit (weak soln) $x = 0.1$ & $h = 695\ KJ/kg$.

1) Determine mass flow rate of NH_3 in Evaporator
2) Carry out overall mass ~~concent~~ conservation & mass conservation of NH_3 in absorber to determine mass flow rates of weak & strong soln.
3) Determine heat Rejection in absorber & condenser.
4) Heat added in generator
5) COP.

given :- R.C = 10 TR,



given: $T_6 = 40°C = 313\,K$, $T_E = -20°C = 253\,K$, $T_A = 30°C = 303\,K$

$T_c = 40°C = 313\,K$ & $T_G = 70°C = 343\,K$

$x_2 = x_3 = 0.38$, $h_2 = h_3 = 22\,KJ/kg$

$x_4 = 0.1$ & $h_6 = 695\,KJ/kg$.

$h_6 = 1473\,KJ/kg$. [as NH_3 vapours are saturated at 40°C]
↳ enthalpy of saturated NH_3 vapour

$h_7 = 372\,KJ/kg$
↳ enthalpy of saturated liq. NH_3 at 40°C

$h_7 = h_8 = 372\,KJ/kg$.

$h_1 = 1420\,KJ/kg$
↳ enthalpy of saturated vapour NH_3 at -20°C.

1) $\dot{m}_{NH_3}$ in evaporator

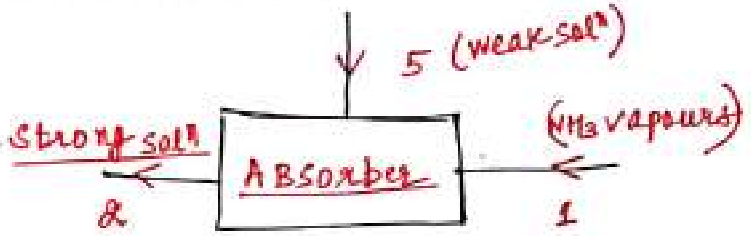
$R.C = \dot{m} \times R.E$

$(10 \times 3.5) = \dot{m} \times (h_1 - h_8)$

$35 = \dot{m} \times (1420 - 372)$

$\Rightarrow \dot{m} = 0.03339\,kg/s$ or $\boxed{\dot{m}_{NH_3} = 2.004\,kg/min}$

2)



Notes by Vaibhav Sir

Conservation of mass in the absorber <u>For the solution</u>

$\Rightarrow \quad m_1 + m_5 = m_2$

$\Rightarrow \quad \dot{m}_1 + \dot{m}_5 = \dot{m}_2$

<u>Conservation OF mass For NH_3</u> in the absorber

$$\dot{m}_1 \times x_1 + \dot{m}_5 \times x_5 = \dot{m}_2 \times x_2$$

$x_1 = 1$] pure NH_3 vapours.

$$\dot{m}_1 x_1 + \dot{m}_5 x_5 = (\dot{m}_1 + \dot{m}_5) x_2$$

$$\dot{m}_1 + \dot{m}_5 \times 0.1 = (\dot{m}_1 + \dot{m}_5) 0.38$$

$$\dot{m}_1 (1 - 0.38) = \dot{m}_5 (0.38 - 0.1)$$

$$\Rightarrow \quad \dot{m}_5 = 0.0339 \times 2.21428$$

$$\dot{m}_5 = 0.0739 \text{ Kg/s} \quad \text{or} \quad \boxed{\dot{m}_5 = 4.4361 \text{ Kg/min}}$$

↳ mass Flow Rate of weak solution.

$$\dot{m}_2 = \dot{m}_1 + \dot{m}_5$$

$$\boxed{\dot{m}_2 = 6.4361 \text{ Kg/min}}$$

↳ mass flow Rate of ~~weak~~ strong soln in absorber.

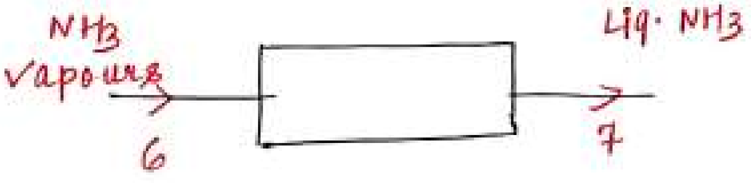
3) <u>For absorber</u>

Heat absorbed $= Q_A = \dot{m}_1 h_1 + \dot{m}_5 h_5 - \dot{m}_2 h_2$

$$\Rightarrow \quad Q_A = (2 \times 1420) + (4.4361 \times 695) - (6.4361 \times 22)$$

$$\Rightarrow \quad \boxed{Q_A = 5781.5 \text{ KJ/min}}$$

For condensor



Heat Rejected in the condensor

$Q_c = \dot{m}_2(h_6 - h_7)$

$= 2 \times (1473 - 372)$

$\boxed{Q_c = 2202 \text{ KJ/min}}$

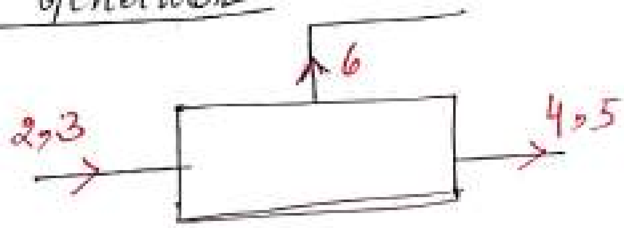
$\dot{m}_6 = \dot{m}_3 - \dot{m}_4$

or

$\dot{m}_2 - \dot{m}_5$

$\Rightarrow \boxed{\dot{m}_6 = 2 \text{ kg/min}}$

4) For Generator



Heat added = ~~$\dot{m}_2 h_2 + x$~~

$\dot{m}_6 h_6 + \dot{m}_4 h_4 - \dot{m}_2 h_3$

$= (2 \times 1473) + (4.4361 \times 695) - (6.4361 \times 22)$

$= 5887.5 \text{ KJ/min}$ or 981.25 KJ/s

5) COP

$COP = \frac{Q_E}{Q_G} = \frac{10 \times 3.5}{981.25} = 0.356$

Thermoelectric Refrigeration System

Basic principles Involved :-

1) Seebeck Effect

→ When the two junctions of a pair of dissimilar metals are maintained at different temperatures, there is a generation of Emf (Electromotive force).

→ After a series of tests it was found that :-

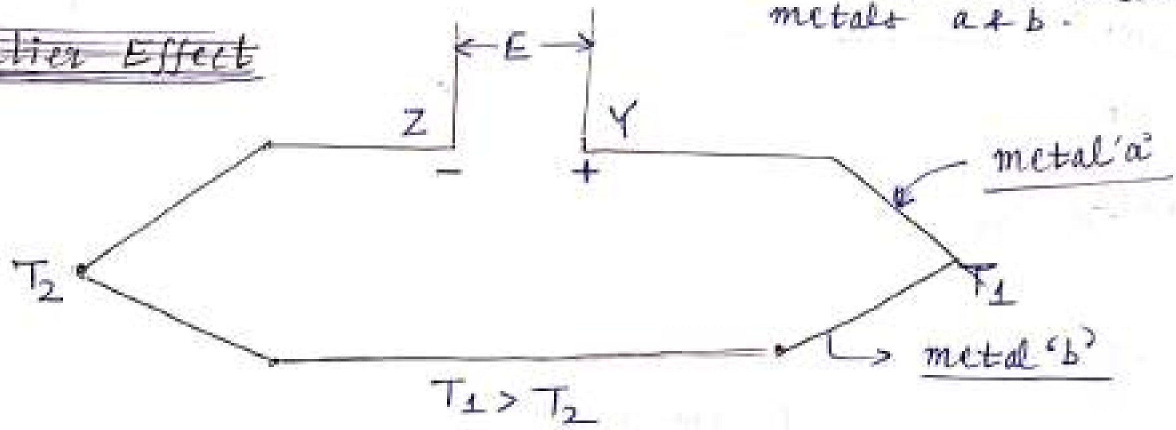
$$\Delta E \propto \Delta T$$

Where,
ΔE → Emf output.
ΔT → Temp. difference.

$$\Delta E = \alpha_{ab} \, \Delta T \Rightarrow \alpha_{ab} = \Delta E / \Delta T.$$

α_{ab} → Seebeck coefficient. For a pair of different metals a & b.

~~2) Peltier Effect~~



→ The seebeck coefficient is termed positive if the emf tends to drive a current in the clockwise sense i.e 'Y' terminal becomes positive & 'Z' terminal becomes negative.

Notes by Vaibhav Sir

2) Peltier effect

→ If direct current is passed through a pair of dissimilar metals, there is heating at one junction, cooling at other depending upon material combinations. Peltier varied the current and observed the heating and cooling rate for different sets of elements. He found that :-

$$q \propto I$$

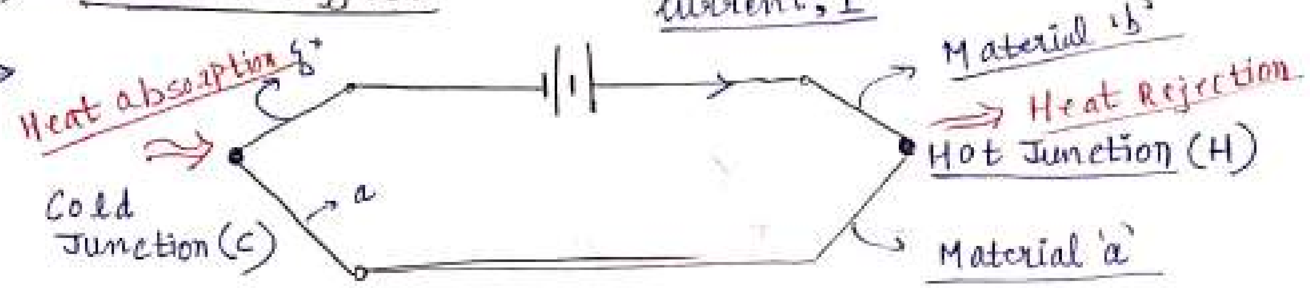
q → heating or cooling rate

$$q = \pi_{ab} \cdot I$$

↳ π_{ab}: Peltier coff. for 2 different metals.

3) ~~Joulean Effect~~

→



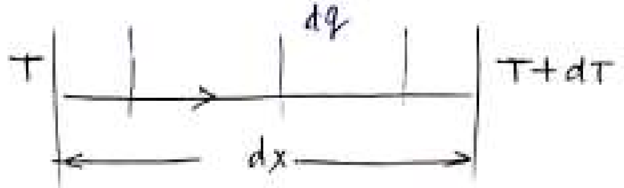
3) Thomson Effect

It is a reversible thermoelectric phenomena. When a current passes through a single conductor having a temperature gradient as exhibited in fig below :-

Heat transfer is given by :-

$$\frac{\delta q}{\delta x} = \tau I \left(dT/dx \right)$$

↳ τ: Thomson coefficient (Volt/K)



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Zemansky using I & II Laws of thermodynamics derived the relation between Seebeck & Peltier coefficients as :-

$$\pi_{ab} = \alpha_{ab} \cdot T$$

as

$$q = \pi_{ab} \cdot I$$

$$q = (\alpha_{ab} \cdot T) I$$

$$\Rightarrow \quad q = \alpha_{ab} \cdot I T$$

⇒ To get high value of cooling or heating, α_{ab} should be high, otherwise large current will be required.

→ But high current will render high heat generation due to Joulean effect.

4) Joulean effect

→ When the electric current flows through the conductor there is dissipation of electrical Energy. According to Joule it is related as :

$$q_j = I^2 R$$

This effect is called Joulean effect.

5) conduction effect

→ If the ends of any element are maintained at different Temperatures, there is heat transfer from the hot end to the cold end and is related by :-

$$q_{cond} = U(T_h - T_c)$$

$U \rightarrow$ overall conductance.

& T_h & $T_c \rightarrow$ high & Low temperatures respectively.

$$U = \frac{KA}{L}$$

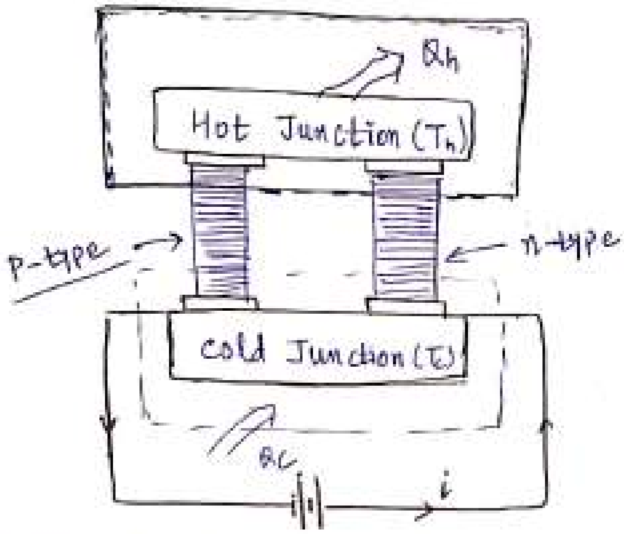
Analysis of Thermoelectric Refrigeration s/m

→ In order to analyze the system to obtain Refrigeration effect, COP etc, the following assumptions have been made:

i) Heat transfer takes place through the semi-conductors at the ends only

ii) No energy exchange b/w the elements through space separating them.

iii) Properties such as conductivity, resistance etc are invariant with temperature.



→ assume that I^2R, the Joulean heat is dissipated equally at both the junctions

$\Rightarrow Q_j = I^2R/2$ → heat dissipation at both junction

→ The conduction heat t/f is from the hot junction to cold junction and it may be expressed as

$$Q_{cond} = (T_h - T_c)\left[\frac{K_p A_p}{L_p} + \frac{K_n A_n}{L_n}\right] = U(T_h - T_c)$$

$$R = \frac{L_p \rho_p}{A_p} + \frac{L_p \rho_n}{A_n}$$

Energy balance for the control volume at the cold Junction.

$$Q_c + Q_j + Q_{cond} = \alpha_{pn} I T_c$$

Therefore, $R \cdot E = Q_c = \alpha_{pn} I T_c - \frac{I^2R}{2} - U(T_h - T_c)$

Energy balance for control volume around the hot Junction.

$$-Q_h - Q_{cond} + Q_j = -\alpha_{pn} \cdot I \cdot T_c$$

The current flows from n-type material & p-type material, hence if α_{pn} is positive the sign of thermoelectric peltier heat t/f will be negative, i.e from control volume to the surroundings.

The heat rejection to the surroundings is:-

$$Q_h = \alpha_{pn} I T_h + \frac{I^2 R}{2} - U(T_h - T_c)$$

~~Power~~ Net Energy supplied to the thermoelectric Ref. s/m is difference b/w Q_h & Q_c

$$P = Q_h - Q_c = \alpha_{pn} I (T_h - T_c) + I^2 R$$

$$COP = \frac{Q_c}{Q_h - Q_c} = \frac{\alpha_{pn} I T_c - I^2R/2 - U(T_h - T_c)}{\alpha_{pn} I (T_h - T_c) + I^2 R}$$

Figure OF Merit (z)

⇒ The Figure of merit is defined as :-

$$Z = \frac{(\alpha_{ab})^2}{UR}$$

⇒ mathematical analysis shows that Figure of merit is max. when

$$\left(\frac{A_a/L_a}{A_b/L_b}\right) = \left(\frac{\rho_a K_b}{\rho_b K_a}\right)^{1/2}$$

⇒ Higher values of 'z' denotes the high value of heating & cooling occuring at the junctions.

Advantages of Thermoelectric s/m

1) There are no moving parts, hence the s/m does not have any vibration problem & does not require significant maintenance.
2) The cooling load can be easily & precisely controlled by controlling the direct current flowing through the circuit.
3) The system is very compact & works in any orientation unlike the compressor which has to be kept in vertical Position.
4) It is a very lightweight system.
5) It can be converted into a heat pump just by changing the direction of current, hence the s/m can be used for year-round air conditioning.
6) The system is very neat & clean compared to other s/m's which use refrigerant, lubricating oil & water.
7) NO problems of Leakage since refrigerant & oil not used.

Disadvantages

Due to the limitation of 'figure of merit' for the available materials, the COP is very low & running cost is high.

3.2 Typical applications for thermoelectric modules include:

- Avionics
- Black box cooling
- Calorimeters
- CCD (Charged Couple Devices)
- CID (Charge Induced Devices)
- Cold chambers
- Cold plates
- Compact heat exchangers
- Constant temperature baths
- Dehumidifiers
- Dew point hygrometers
- Electronics package cooling
- Electrophoresis cell coolers
- Environmental analyzers
- Heat density measurement
- Ice point references
- Immersion coolers
- Integrated circuit cooling
- Inertial guidance systems
- Infrared calibration sources and black body references
- Infrared detectors
- Infrared seeking missiles
- Laser collimators
- Laser diode coolers
- Long lasting cooling devices
- Low noise amplifiers
- Microprocessor cooling
- Microtome stage coolers
- NEMA enclosures
- Night vision equipment

CLASSIFICATION OF REFRIGERANTS

Primary Refrigerants

Halocarbon or Organic Refrigerants

- **R-11** (CCl_3F)
  - Stable, Non-flammable & Non-toxic
  - Used in Large centrifugal compressor systems of 200 TR & above.
  - Also used as a flushing agent for cleaning compressor
- **R-12** (CCl_2F_2)
  - Very popular Refrigerant
  - Non-Toxic, Non-corrosive & Non-Flammable.
  - Used in Refrigerator, AC's etc.
- **R-13**
- **R-14**
- **R-21**
- **R-22** ($CHClF_2$)
  - For Low evaporating Temp's -29°C to -40°C
  - Used in AC's & Refrigerators
- **R-134a** (CF_3CH_2F)
  - Replacement For R-12
  - Zero ODP (Ozone depletion Potential)

Azeotrope Refrigerants

- **R-500**
  - 78% R-12 & 26% R-152
  - Non-Flammable & Low Toxicity
  - 20% greater RC than R-12 for same size of compressor.
- **R-502**
  - 48.8% R-22 & 51.2% R-115
  - Non-Flammable & non-toxic
  - For temp's -18 to -50°C.
  - Combines good prop of R-12 & R-152.
- **R-503**
  - 40.1% R-23 + 59.9% R-13
- **R-504**
  - 48.2% R-32 & 51.8% R-115

Inorganic Refrigerants

- **R-717** (NH_3)
  - Oldest & most widely used.
  - Drawback - toxic
  - Capable of producing Large Refrigeration effect.
- **R-729** (air)
- **R-744** (CO_2)
  - Non-toxic, non-Irritating & non-Flammable.
  - Low efficiency compared to other common Refrigerants
- **R-764** (SO_2)
  - Produced by combustion of sulphur in air.
  - Toxic & injurious.
- **R-118** (water)

Hydrocarbon Refrigerants

- **R-170** (Ethane)
- **R-290** (Propane)
- **R-600** (Butane)
- **R-1150** (Ethylene)
- **R-600a** (Iso-butane)
- etc

Secondary Refrigerants

- **Brines**

Refrigerants

There are two types of Refrigerants :-

1) Primary
2) Secondary

Primary ref:- are the substances which undergoes a cyclic process and produce lower temp. There is a latent heat of transformation taken place for the refrigerant

eg R-11, R-12, R-22, R-134 (a), R-1150, NH_3, CO_2

Secondary ref:- are the substances which are first cooled by the primary ref. and then used for cooling purpose.

e.g H_2O, Brine.

Designation of Refrigerant

when the ref. is saturated hydrocarbon.

$$R-(m-1)(n+1)\,p$$

$$C_m H_n F_p Cl_q$$

$$n+p+q = 2m+2$$

where, $m \rightarrow$ no. of carbon atoms

$n \rightarrow$ no. of Hydrogen atoms

$p \rightarrow$ represents no. of Fluorine atoms

$q \rightarrow$ no. of chlorine atoms.

eg. R-11

R-011

$m-1=0 \Rightarrow \boxed{m=1}$ $n+1=1$ $\boxed{n=0}$ $\boxed{p=1}$

$n+p+q=2m+2$

$0+1+q=2+2 \Rightarrow \boxed{q=3}$

$CFCl_3$

R-12

eg. $\Rightarrow$ R-012

$m-1=0$ $\boxed{m=1}$ $n+1=1$ $\boxed{n=0}$ $\boxed{p=2}$

$n+p+q=2m+2$

$0+2+q=4 \Rightarrow \boxed{q=2}$ $\Rightarrow CF_2Cl_2$

eg. R022

$m-1=0$ $\boxed{m=1}$ $n+1=2$ $\boxed{n=1}$ $\boxed{p=2}$

$\Rightarrow CHF_2Cl$.

eg. R-134

$m-1=1$ $\boxed{m=2}$ $n+1=3$ $\boxed{n=2}$ $\boxed{p=4}$

$n+p+q=2m+2$

$2+4+q=2\times2+2$

$\boxed{q=0}$.

$C_2H_2F_4$

NOTE

R-11 $\longrightarrow CFCl_3$

R-12 $\longrightarrow CF_2Cl_2$

R-22 $\longrightarrow CHF_2Cl_1$

R-134 $\longrightarrow C_2H_2F_4Cl_0$

R-134 is known as eco-friendly refrigerant due to the absence OF chlorine element. The chlorine element which is present in the commonly used refrigerants attacks the ozone layer and depletes or minimizes its thickness. The ozone layer which is present in the stratosphere will prevent us From harmful U-V radiations emmited by sun. Therefore we have to use such a ref which has min value of Ozone depletion potential.

The other possible alternatives are Fluorocarbon, Hydrocarbon, hydro Fluoro carbon.

R-134(a) is an isomer OF R-134
same Chem formula & diff arrangement.

case II when ref is unsaturated hydrocarbon.

R-1 (m-1)(n+1) p.

$m+p+q = 2m$

$C_m H_n F_p Cl_q$.

a) C_2H_4

$C_2H_4F_0Cl_0$

R-1 (m-1)(n+1) p.

R-1 (2-1)(4+1) 0

R-1150

CASE-III when the Ref is Inorganic compound

R- (700+ Mol. wt)

a) NH_3

R-(700+17) ⇒ R-717

b) CO_2 ⇒ R-744

c) SO_2 ⇒ R-764

d) H_2O → R-718

e) Air → R-729

Selection of Refrigerants (Desirable prop. of Ref.)

1) Thermodynamic properties

1) critical temp.

The critical temp of the refrigerant should be as high as possible above the condensing temperature.

NOTE: The critical temp of CO_2 & ethylene are almost undesirable for the indian ambient summer cond's

	T_c
CO_2 →	31°C
C_2H_2 →	10.2°C

H_2O → 374°C

SO_2 → 156.5°C

NH_3 → 132.4°C

R-12 → 111.5°C

R-22 → 96.5°C

2) Specific heat

The sp. heat of vapour should be as high as possible in order to limit the degree of superheat

$R \cdot E = \Delta h$

$= (C_p \uparrow)(\Delta T \downarrow)$

The sp. heat of liquid should be as low as possible in order to limit the degree of irreversibilities (lower value of ds)

$T \cdot ds = dh - v\,dp$

$p = c$

$T \cdot ds = dh$

$T \cdot ds = c_p\,dT \Rightarrow C_p = T \cdot \frac{ds}{dT} = \frac{ds}{\left(\frac{dT}{T}\right)}$

$\boxed{c_p \propto ds}$

$ds \geq 0$

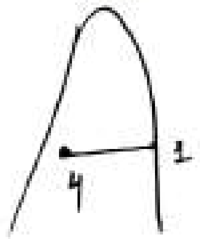
$ds = 0$ (Rev)

$ds > 0$ (Irr)

3) Enthalpy of vapourization

It should be as high as possible bcoz higher value of enthalpy of vap. requires smaller mass of refrigerant for a given capacity.

$R \cdot C = \dot{m} \downarrow \times h_{fg} \uparrow$



$h_1 - h_4 = h_{fg} = R \cdot E$

h_{fg} (KJ/kg)

$H_2O \longrightarrow 2361$

$NH_3 \longrightarrow 1369$

R-22 — 234.7

R-12 → 165.7

R-134 → 197.3

NOTE → among the commonly used ref ~~water~~ NH_3 has highest value of enthalpy of vap.

4) **conductivity**

It should be as high as possible bcoz it is directly linked with the size of evaporator and condensor.

$$Q = KA\frac{dT}{dx}$$

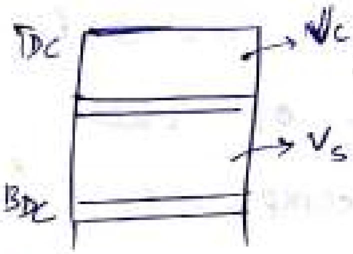
$$\Rightarrow K \propto \frac{1}{A}.$$

5) **Evaporator & cond. pressure**

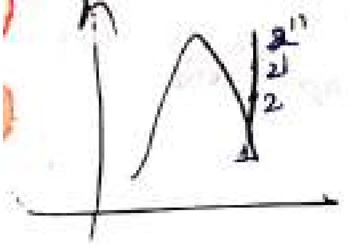
Both pressure should be positive. If the evap. pressure is lower than the atmospheric pressure then there is a possibility for the leakage of air therefore evap pressure should be kept almost equal to atmospheric pressure, whereas the cond. pressure should have some moderate values.

6) **compression ratio**

It is defined as the ratio of volume before compression to the volume after compression. Lower comp. ratio is desirable bcoz higher comp ratio results a inc. in $W_{I/P}$ to the comp & decrease in η_v.



$$r_c = \frac{V_{BC}}{V_{AF}} = \frac{V_{BDC}}{V_{TDC}} = \frac{V_s + V_c}{V_c} = 1 + \frac{V_s}{V_c}$$



$\frac{V_1}{V_2} \Rightarrow r_c$

$$\uparrow \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} \uparrow = \left(\frac{V_1}{V_2}\uparrow\right)^{n-1}$$

$W_{I/P} \uparrow$

$\eta_v \downarrow$

$$\Rightarrow \downarrow \eta_v = 1 + C - C\left[\frac{P_2}{P_1}\uparrow\right]^{1/n} \Rightarrow \eta_v \downarrow$$

7) Freezing pt.

Low Freezing point is decirable..

R-22 ⟶ −160.5°C

R-12 ⟶ −157.4°C

NH_3 ⟶ −77.3°C

R-134(a) ⟶ −101.2°C

NOTE: water is not commonly used working Fluid bcoz of the above disadvantage i.e Its F.P. It's F.P is 0°C and below 0°C it is converted into ice. and its Flow is not possible

8) compressor discharge temp.

among the most commonly used working Fluids ammonia has the highest comp. discharge temp. Therefore ammonia comp are generally water cooled. Rise in temp causing heating to the cy. valves in the compressor body. The cy. have to be cooled in order to avoid loss of strength of the compressor material. R-12 & R-22 comp. are generally air cooled.

R-11 → 52
R-12 → 48
R-22 → 71
R-~~717~~ → 120

9) COP,

COP represents the running cost of the equipment. Higher the value of COP lower will be the running cost of the equipment.

NOTE
⇒ Almost all of the refrigerant are having similar values of COP when operating b/w same temp. limits

⇒ Even though the LH of vapourization for ammonia has highest value but it does not help in any ways to improve its COP because of its higher work I/P.

	COP
R-12 →	4.04
NH_3 →	4.06
R-22 →	4.12

⇒ Rec. comp. → are used to handle high pressure and low volume of working fluid.
eg NH_3 & CO_2

Centrifugal or rotary comp:- are used to handle low pressure and high volume of working fluid. eg R-11, & R-113

CHEMICAL PROPERTIES

1) **Toxicity** ⇒ The ref should non-Toxic.

NOTE: NH_3 is TOXIC IN NATURE

2) **Flammablity**

→ Ref. should be non-Flammable,

NOTE: NH_3 is Flammable in nature

3) **Action with oil**

R + Fully miscible with oil → R-11, R-12] ⇒ Desired

R + immiscible with oil → NH_3, CO_2] ⇒ Desired

R + Partially miscible with oil → R-22] ⇒ undesirable

→ The ref which are Fully miscible with oil & immiscible with oil does not create any Problem but the ref. which are partially miscible with oil like R-22 creates problem. That's why mostly choking problem are observed in R-22 therefore synthetic oil is used in place of mineral oil

NOTE:

→ Oil separator is installed b/w compressor & condensor

→ oil sep. is not reqd to be installed when Ref. & oil are immiscible at condensor pressure and temperature.

→ Sensing Bulb.

→ It is placed at the exit of evaporator.

1) Acting with material of construction

⇒ NH_3 attacks copper hence either wrought iron or steel is used as a material of construction on the other hand. Freon or halocarbon ref. attacks aluminium & generally preferred with copper as the material of construction

PHYSICAL PROPERTIES

1) Cost :- It should be low.

2) Viscosity :- It should be low for the easy flow of refrigerants.

3) Leak Detection :- First of all the ref. should not leak out from the system at any cost and if at all it leaks then it's detection should be as fastest as possible by the easiest method. For eg

DETECTED BY

1) FREON LEAKS ⟶ i) Halide Torch Method → In the presence of FREON Leaks the colour of light change from Blue to Bluish green.
(ii) Soap Bubble method →

2) NH_3 LEAKS are detected by sulphur candle test. In the presence of NH_3 leaks white fumes of ammonium sulphite is formed.

5) SO_2 leaks → are detected by **NH₃ swab Test**

Refrigerants & their App's

Ref	APPLICATION
1) R-11	→ large centralized a/c units
2) R-12	→ ~~Window AC~~, domestic Ref; water coolers
3) R-22	→ Window a/c
4) NH_3	→ Cold storage plants / icing plants
5) Air	→ Aircraft ref. systems Gas liquefaction
6) Brine	→ milk chilling plants
7) CO_2	→ Direct contact Freezing of Foods.

AZEOTROPES :- are the mixture of ref. behaves as a pure substance.

eg R-500.