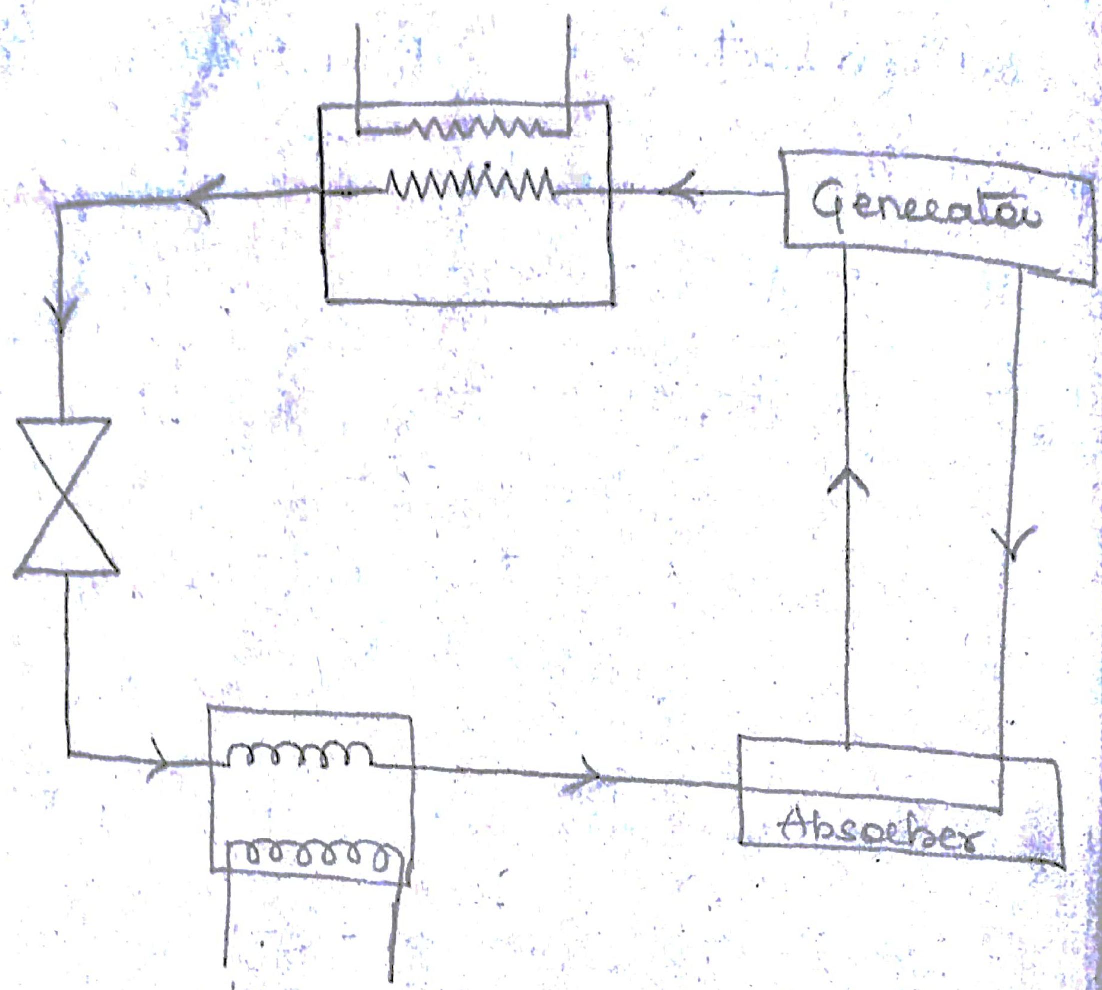
UNIT-III

Vapour absorption Refrigeration system



In VARS, Refrigerant will be phase changing takeplace due to the heat exchanging between two fluids. Heat exchanging is the process of between Generator and absorber.

1. An Ammonia based R.S operates b/w $-15°$ & $30°C$ The machine circulates 4.5 kg/min Refrigerant $\eta_{is} = 88\%$, $l/d = 1.2$ determine cop of the system & dimensions of the compressor cylinder

$$\eta_{isentropic} = \frac{A.Q}{T.Q} \qquad \frac{L}{d} = 1.2$$

$$\boxed{0.88 = \frac{4.5}{\frac{\pi}{4} \times D^2 \times L}}$$

$$0.88 \times \pi/4 \times D^2 \times L = 4.5$$

$$0.88 \times \pi/4 \times D^2 \times 1.2d = 4.5$$

$$D^3 = \frac{4.5}{0.88 \times \pi/4 \times 1.2}$$

$$D^3 = 5.45$$

$$D = 1.75 \text{ m}$$

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Assignment.

1. An ammonia based R. system works b/w $-10^\circ C$ and $30^\circ C$ determine

a) cop of the system.

b) determine the cop of the system subcooled by $10^\circ C$ before and after expansion due.

c) determine cop of the system when R is superheated by $+15^\circ C$ after compression or before compression

d) compare cop in above cases and calculate improvement in cop.

2. ~~A~~ proposal made to replace R22 refrigerant by R134A. The system is operates b/w $-15^\circ C$ to $25^\circ C$ the system will be produced 1 ton of ice / hour. ice is produced ~~from~~ begins $0^\circ C$ upto $-15^\circ C$. determine

i) mass flow rate of Refrigerant

ii) determine dimensions of the compressor cylinder when isentropic efficiency 82%.

The ratio b/w length of cylinder to bore of cylinder is 2.1

iii) determine power required to run the compressor to produce 1 ton ice / hour.

3. Determine ~~ammonia~~ amount of ice produced per hour at $-8^\circ C$ when the system is operates b/w $38^\circ C$ and $-20^\circ C$. the water is supplied into the system at the $18^\circ C$

i) The system is working based on R12 refrigerant.

ii) determine power consumed to produce ice.

explain,

4. a) classify the different types of compressor. with neat sketch.

b) classify expansion devices. explain with neat sketches.

5.

a) Explain about the working of ~~simp~~ ammonia - water based vapour absorption R-system.

b) Classify evaporators. explain with neat sketches.

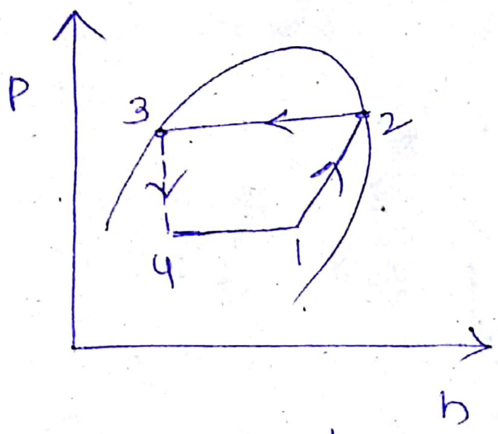
COP of VARS

It is the ratio b/w R.E produced by the system to the Heat supplied to the system (or) Heat generated by the system.

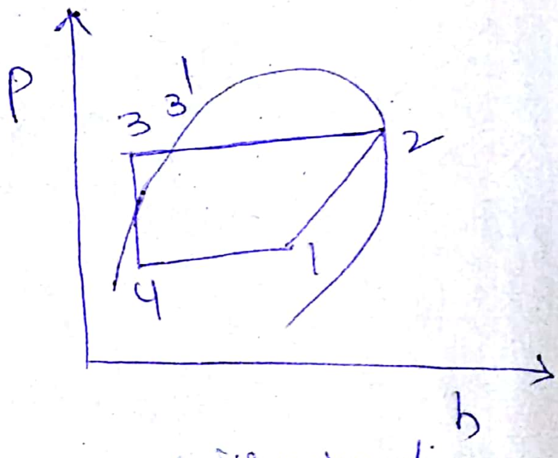
$$\boxed{COP_{VARS} = \frac{RE}{Q_g / Q_{ey}}}$$

$$= \frac{m_r \, C_{p_R} (dT)_R}{M_g \cdot C_p \cdot dT}.$$

Case (i)



No subcooling



with subcooling

1. $COP = \dfrac{h_1 - h_4}{h_2 - h_1}$

R- capacity $= \dot{m}(h_1 - h_4)$

$S_2 = S_1$

$S_2 = 0.1763 + x_1(0.7582)$

$\boxed{x_1 = +0.093}$

$h_1 = h_{f1} + x_1 h_{fg1}$

$= 44.94 + 0.93\,(207.03) = 237.479\ \text{kJ/kg}$

$$COP = \frac{237.47 - 97.03}{263.13 - 237.47} = 5.475$$

$R.\text{capacity} = \dot{m}(h_1 - h_4)$

$= 1.5\,(237.13 - 97.03)$

$= 210.15\ \text{kJ/min}.$

Case – 2

$h_3 = h_3' - C_{pl}(T_3' - T_3) \qquad C_{pl} = 1.325$

$h_3' = 97.03$

$T_3 = 39$

$T_3' = 39 - 10 = 29$

$h_3 = 97.03 - 1.325\,(29) = 58.605\ \text{kJ/kg}$

$$COP = \frac{237.4779 - 58.605}{263.13 - 237.47} = 6.97$$

$\boxed{COP = 6.97}$

$RC = (237.4779 - 58.605) \times 1.5$

$= 268.309\ \text{kJ/min}$

Q. Cooling effect = 8TR

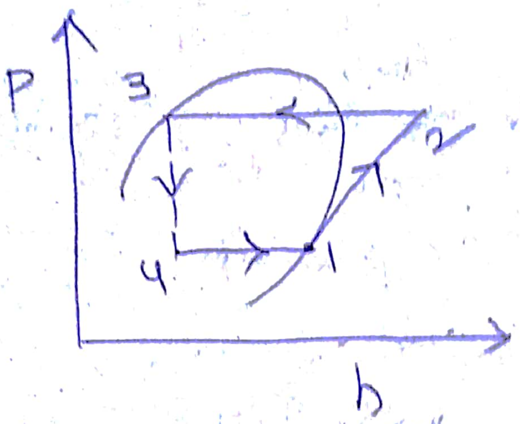
evaporative temp = 0°C

condensed temp = 30°C

$\frac{d}{l} = 0.9$, $d = 0.9l$

$N = 300$ rpm

$\eta_v = 85\%$



h_1 at 0°C = 251.97 kJ/kg

$h_4 = h_3$ at 30°C = 84.38 kJ/kg

$\dot{m}(h_1 - h_4) = 8 \times 211$

$\dot{m}(167.59) = 8 \times 211$

$\boxed{\dot{m} = 10.072}$

$\dot{m} = \frac{V_a}{v}$

v at 0°C = 0.0471

$10.072 \times 0.0471 = V_a$

$\boxed{V_a = 0.47 \text{ kg/m}^3}$

$\eta_v = \frac{V_a}{V_s}$

$l = 0.142$ m

$d = 0.12$ m.

$0.85 = \frac{0.47}{\frac{\pi}{4} \times D^2 \times L \times N}$

$0.85 = \frac{0.47}{\pi/4 (0.9l^2) \times l \times 300}$

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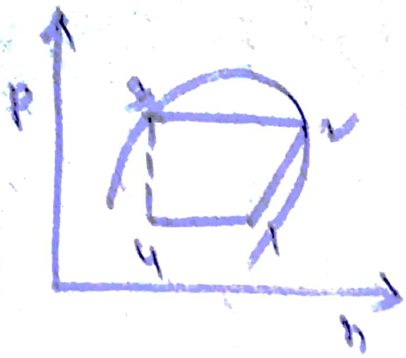
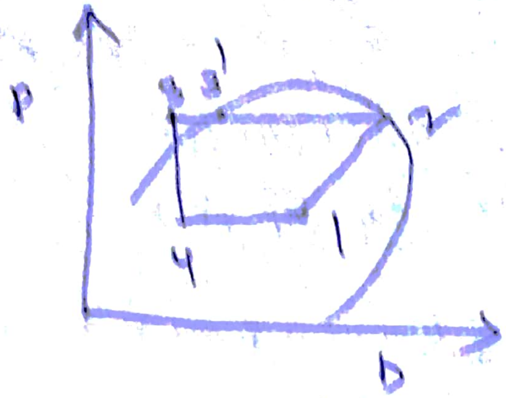
$P_1 = 8\,bar$

$P_2 = 15\,bar$

$\dot{m}_r = 1.5\,kg/min$



nosubcooling



subcooling

$$cop = \frac{h_1 - h_4}{h_2 - h_1}$$

$$R.E = \dot{m}_r (h_1 - h_4)$$

$x_2 = 1$

$S_1 = S_2$

$$\boxed{S_{f_1} + x_1 S_{fg_1} = S_{f_2} + x_2 S_{fg_2}}$$

R. Capacity = 1.5 (

$h_3 = h_3' - cp_l(T_3 - T_3')$

$= 97.33 - 1.32(39 - 10) =$

$$\frac{h_1 - h_3' =}{h_2 - h_1}$$

2.

C.F = 8TR

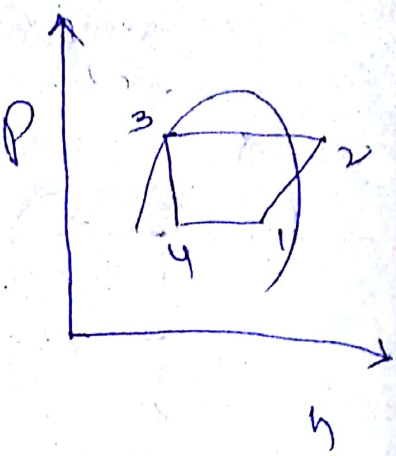
evaporative = 0°C

Condenser temp = 30°C

$\frac{d}{l} = 0.9$, $d = 0.9l$

N = 300 rpm

$\eta_v = 0.85$



$R.E = \dot{m}(h_1 - h_4)$

$8 \times 210 = \dot{m}(167 - 59)$

$\dot{m} = 10.072$

$\dot{m} = \frac{V_a}{v}$ v at 0°C = 0.0471

$10.072 \times 0.0471 = V_a$

$V_a = 0.47 \ kg/m^3$

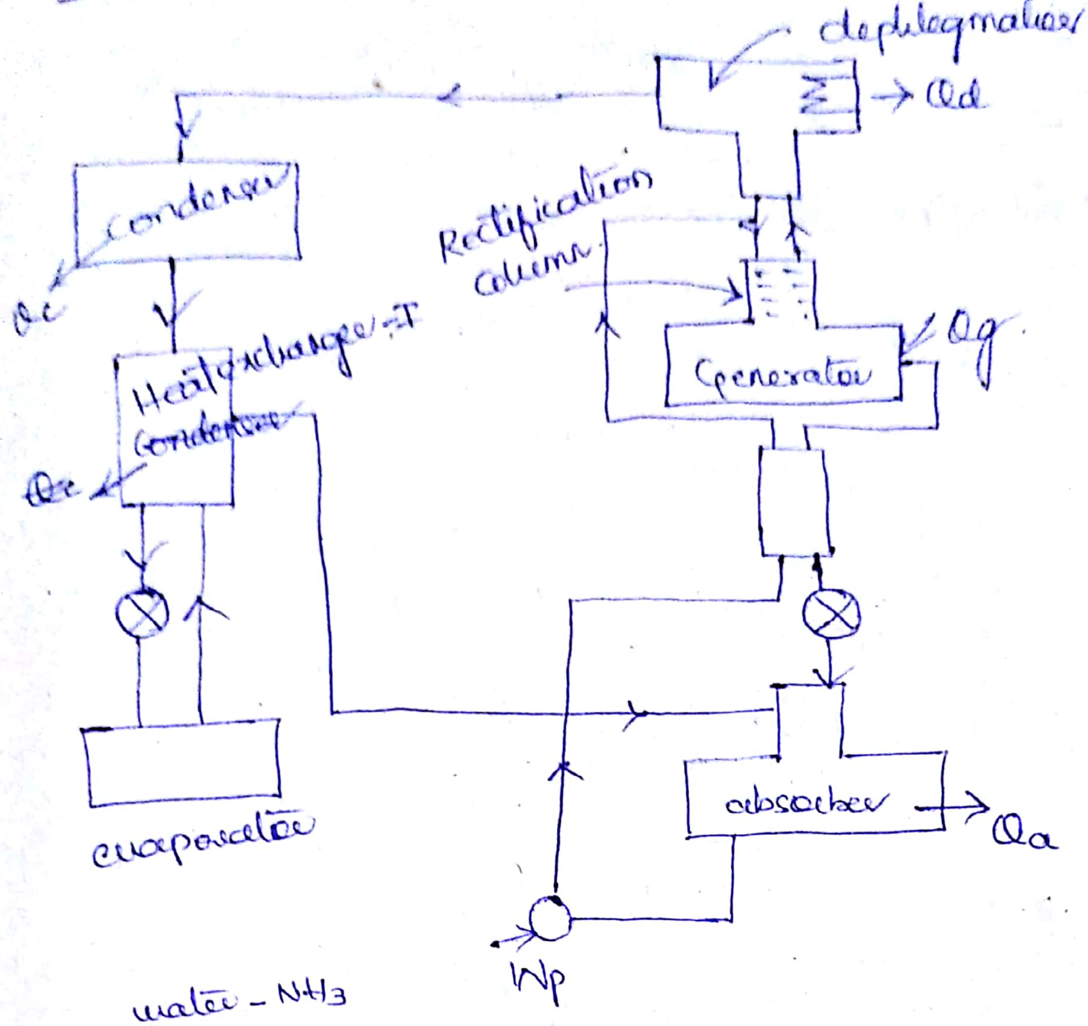
$$\boxed{\eta_v = \frac{V_a}{V_s}}$$

$$0.85 = \frac{0.47}{\frac{\pi}{4} \times (0.9 l)^2 \times l \times 300}$$

$l = 0.142m$

$d = 0.12m$

Ammonia Water Based Refrigeration System



water - NH_3

In VARS ammonia is Refrigerant and water is absorbent

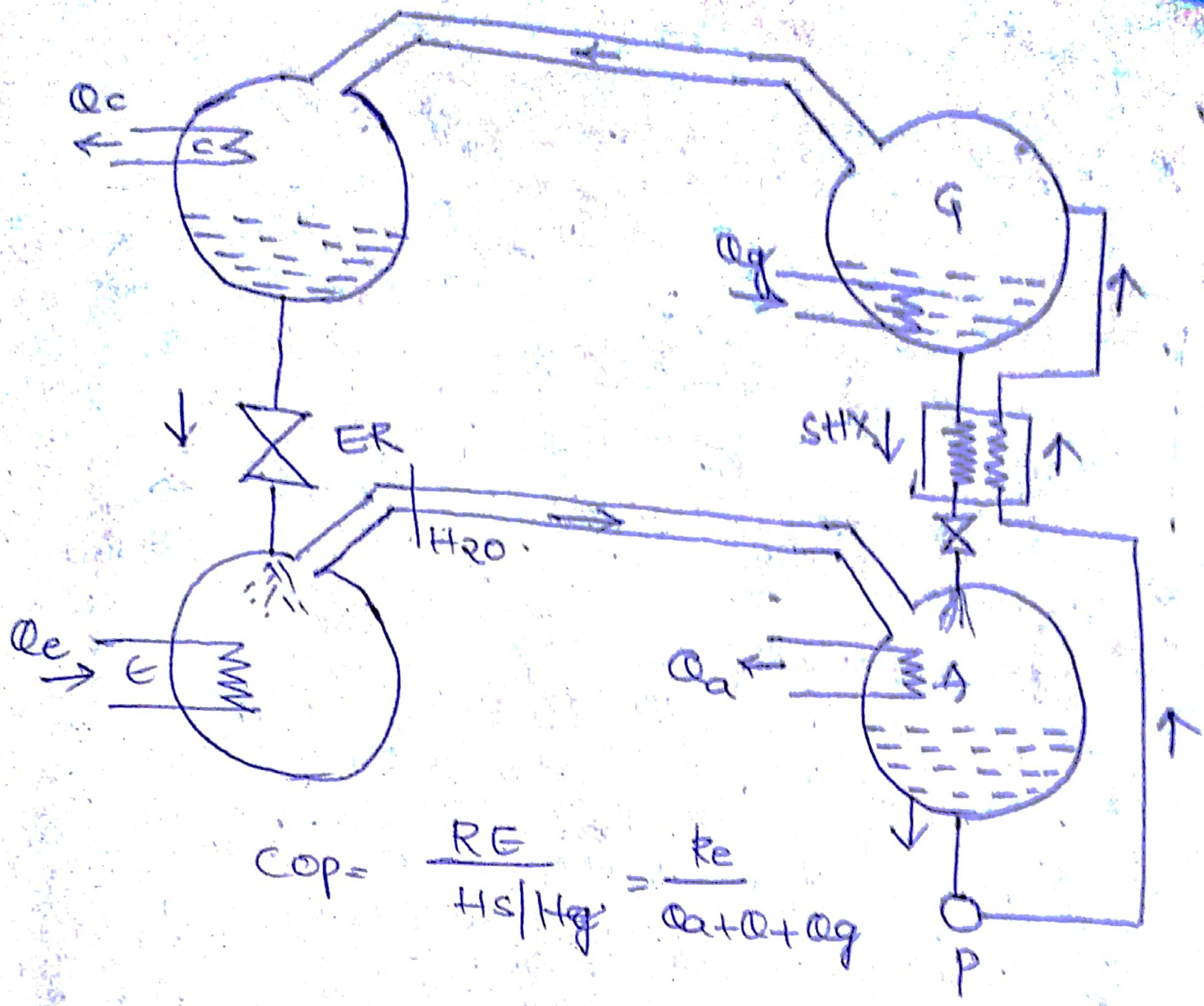
COP of Ammonia - water VARS

$$COP_{VARS} = \frac{Q_{Rejected}}{Q_{supplied}}$$

amount of heat extracted in ammonia is gives the Refrigeration effect.

amount of heat required to raise the temperature of water. is gives the heat supplied.

$H_2O - LiBr$.



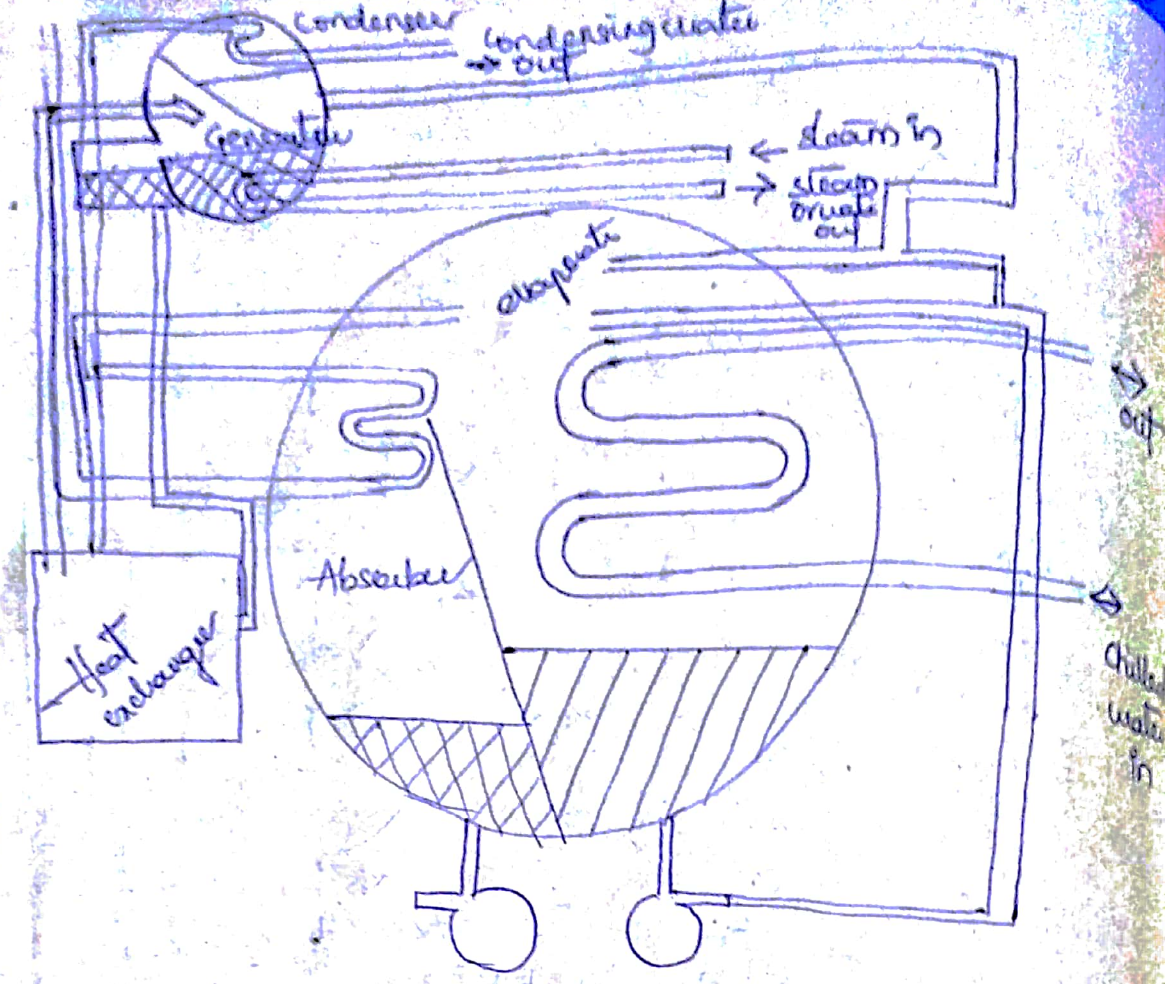
$$COP = \frac{RE}{Hs/Hg} = \frac{Re}{Q_a + Q + Q_g}$$

In this water - lithium bromide system water is Refrigerant and lithium bromide is absorbent.

Types of water - lithium bromide system

1. Twin drum type (double drum)
2. Single drum type

Twin drum Type :-



Analysis of vapour Absorption Refrigeration system

Consider a simple VARS which having evaporator temperature Te. and Generated Temperature Tg. and absorber temperature Ta.

Amount of heat energy available in the corresponding sections

At absorber,

Qa

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A/c to First law of thermodynamics

$$\boxed{Q_e + Q_g = Q_a}$$

A/c to IInd law of thermodynamics

total entropy = entropy of the system + entropy of the surrounding.

$$S_{total} = S_{system} + S_{universe}$$

total entropy of the system is always greater than zero.

where entropy of the system is zero

$$S_{total} = S_{sur} \geq 0.$$

A/c to clausius inequality entropy of the system is amount of heat to the temperature

$$S = \frac{Q}{T}$$

absorber,

$$S_a = \frac{Q_a}{T_a}$$

$$S_e + S_g = S_a$$

$$S_e + S_g - S_a = 0.$$

evaporator,

$$S_e = \frac{Q_e}{T_e}$$

generator

$$S_g = \frac{Q_g}{T_g}$$

$$S_e + S_g - S_a = 0 = S_{univ}$$

$$S_e + S_g - S_a \geq 0$$

$$\frac{Q_e}{T_e} + \frac{Q_g}{T_g} = \frac{Q_a}{T_a}$$

$$\frac{Q_e}{T_e} + \frac{Q_g}{T_g} = \frac{Q_e + Q_g}{T_a}$$

$$\frac{Q_e}{T_e} - \frac{Q_e}{T_a} = \frac{Q_g}{T_a} - \frac{Q_g}{T_g}$$

$$Q_e\left[\frac{T_a - T_e}{\cancel{T_a}\cdot T_e}\right] = Q_g\left[\frac{T_g - T_a}{T_g \cdot \cancel{T_a}}\right]$$

$$\boxed{\frac{Q_e}{Q_g} = \left[\frac{T_g - T_a}{T_a}\right] \times \left[\frac{T_e}{T_a - T_e}\right]}$$

where, $\frac{Q_e}{Q_g}$ is COP of the system

$$\frac{T_g - T_a}{T_a} = \eta_{carnot}$$

$$\frac{T_e}{T_a - T_e} = COP_{carnot}$$

$$\boxed{COP = \eta_{carnot} \times COP_{carnot}}$$

1. The operating temparature of single stage VARS are generator 90°C, condenser & absorber 40°C, evaporator 0°C find the ideal cop of the system.

$$Cop = \left[\frac{Tg - Ta}{Tg}\right] \times \left[\frac{Te}{Ta - Te}\right]$$

$$= \left[\frac{90-40}{90}\right] \times \left[\frac{0}{40-0}\right]$$

$$= 0.94$$

2. determine the cop of the VARS refrigerator capacity 100kW & heat input the system is 160kW

$$Cop = \frac{R.E}{Qs} = \frac{100}{160} = 0.625$$

3. determine the temp of the evaporator when cop of the system is 2.2 generator temparature 120°C & condenser temparature 35°C & absorber temp 20°C

$$Cop = \left[\frac{Tg - Ta}{Tg}\right] \times \left[\frac{Te}{Ta - Te}\right]$$

$$2.2 = \left[\frac{393-293}{393}\right] \times \left[\frac{Te}{293-Te}\right]$$

$$2.2 = 0.254 \times \frac{Te}{293-Te}$$

$$Te = -10°C$$

Air conditioning Refrigeration system

If the refrigeration process is worked on air having refrigerant is called as Air based Refrigeration system

If the air based R.S in the form of cyclic process is known as air cycle R.S

Bellcolemon cycle (Reversed Brayton cycle)

1-2 :- Adiabatic compression

2-3 :- Isobaric heat rejection

3-4 :- Adiabatic expansion

4-1 :- Isobaric heat addition

$$COP = \frac{RE}{W} = \frac{Q_{1-4}}{W_C - W_T} = \frac{T_1 - T_4}{(T_2 - T_1) - (T_4 - T_3)}$$

$$T_4 - T_3 = \frac{T_1 - T_4}{(T_2 - T_1) - (T_3 - T_4)}$$

during 1-2 the process is Isentropic

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = T_1 \times (r_p)^{\frac{\gamma-1}{\gamma}}$$

3-4 the process is Isentropic

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \rightarrow T_3 = T_4\left[\frac{P_3}{P_4}\right]^{\frac{\gamma-1}{\gamma}}$$

$$T_3 = T_4 \times (r_p)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{P_2}{P_1} = \frac{P_3}{P_4} = r_p$$

$$COP = \frac{T_1 - T_4}{\left[T_1 (r_p)^{\frac{\gamma-1}{\gamma}} - T_1\right] - \left[T_4 - T_4 \times (r_p)^{\frac{\gamma-1}{\gamma}}\right]}$$

$$= \frac{T_1 - T_4}{T_1\left((r_p)^{\frac{\gamma-1}{\gamma}} - 1\right) - T_4\left[1 - r_p^{\frac{\gamma-1}{\gamma}}\right]}$$

$$= \frac{\cancel{T_1 - T_4}}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1\ \cancel{(T_1 - T_4)}}$$

$$\boxed{COP = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1}}$$

//.

Applications of Air refrigeration system

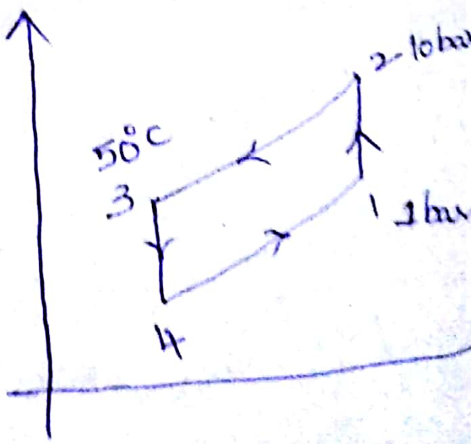
1. To maintain the temperature greater than zero & less than room temperature
2. cold storages & food processing units
3. aerofill applications
4. super markets

1. An air refrigerator working based on bell coleman cycle operates b/w 1 bar & 10 bar air is drawn from the cold chamber +10°c where air coming from the condenser is cooled to 50°c before entering the expansion device the processing of air is polytropic condition. $pv^{1.3} = c$ is followed during the expansion and condensation find the cop of the system.

$r = 1.4$. sp. of heat of air = 1 KJ/kg°c

Sol:-

$$cop = \frac{1}{(r_p)^{\frac{r-1}{r}} - 1}$$



$$\text{cop} = \frac{T_1 - T_4}{(T_2 - T_1)(T_3 - T_4)}$$

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\frac{T_1}{T_2} = \left(\frac{1}{10}\right)^{\frac{1.4-1}{1.4}}$$

$$\frac{T_1}{T_2} = 0.517$$

$$\text{Cop} = \frac{1}{\left(\frac{10}{10}\right)^{\frac{1.4-1}{1.4}} - 1.}$$

$$= 1.07$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 19.6$$

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3}\right)^{\frac{\gamma-1}{\gamma}} = 25.8$$

2. An air refrigerator working on principle of bell coleman cycle the air into the compressor is at 1 atmospheric and 10°C it is compressed to 10 atm. pressure and cooled to 40°C at same ~~temp~~ pressure. It is then expanded to 1 atmospheric and discharge to take cooling load the air circulation is 1kg/sec. The isentropic efficiency of the compressor is 80%. Isentropic η of expander = 90%. determine cop of the system and R. capacity of the system.

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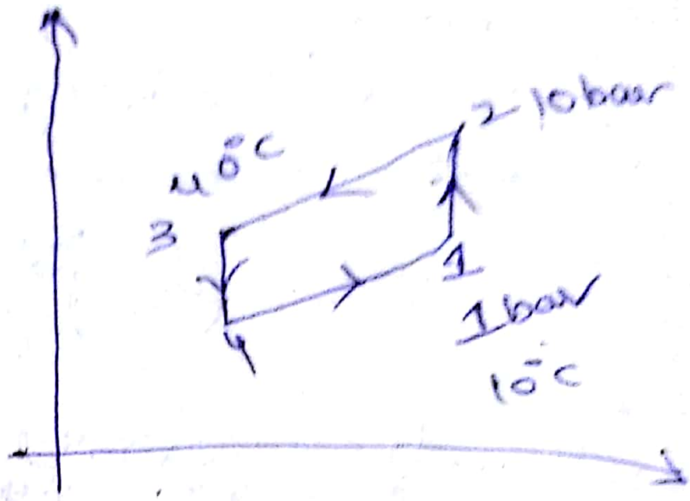
$$COP = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}} - 1}$$

$$= \frac{1}{\left(\frac{10}{1}\right)^{\frac{1.4-1}{1.4}} - 1}$$

$$= 1.07$$

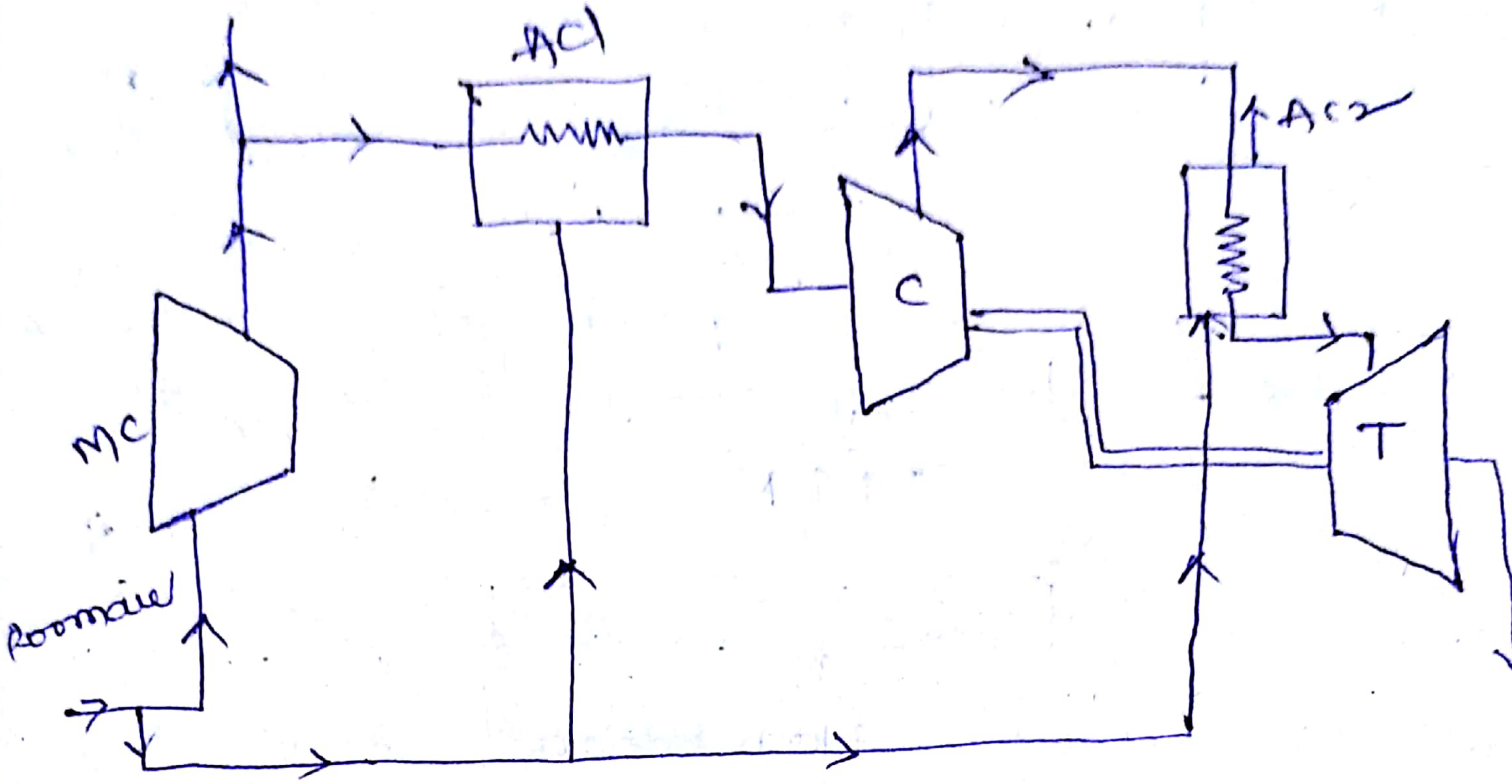


$m = 1$ kg/sec

$I\eta_c = 80\%$

$I\eta_e = 90\%$

Boot strap system :-



Ram effect :-

It is the process of Improve the pressure when lessthan atmospheric condition.

DART

Dry air Rated Temperature (DART) it is defined as a amount of moisture contained air temperature with

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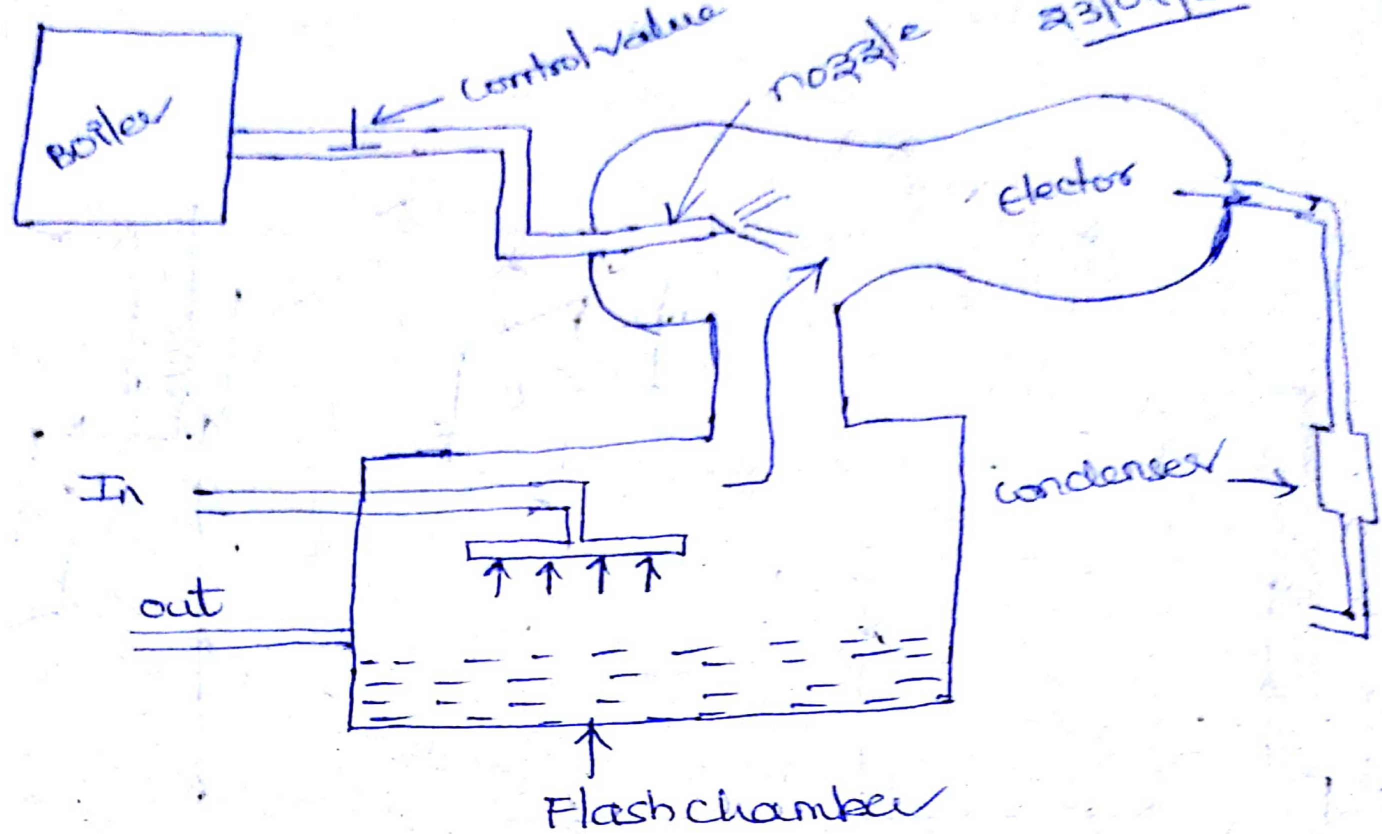


Steam Jet Refrigeration system

In this system, the temparature will be drop from less than 100°c to and less than atmospheric temparature by the principle of enthalpy droping.

Refrigerants :-

It is the fluid to produce cooling effect by exchanging process.

properties of Refrigerants :-

To select the refrigerant following properties are considered.

1. Thermodynamic properties

2. physical properties

3. chemical properties.

Thermodynamic properties

(A) suction pressure of the compressor

i) when suction pressure will be too high the workdone on the system will be less than cop will be too high

ii) discharge pressure

a) If the pressure exit from the compressor is less than the condensation process is requiring less energy, during the condensation only. The temperature will be drop, less than atmospheric condition

iii) pressure ratio

→ It should be the small for higher volumetric efficiency, to get the higher cooling effect

iv) Latent heat of vapourisation

→ It should be the large to get the high cop. for small capacity.

v) Isentropic index of compression

→ It should be the small or equal during the process

vi) Thermal conductivity

→ If the Thermal conductivity of refrigerant is high, high heat transfer coefficient will be occur.

vii) viscosity

viscosity of Refrigerant should be less

<u>physical properties</u>:

Toxicity.

1. The selected refrigerant should be nontoxic, It won't be effects on any living organisms.

2. Ozone depletion potential.

→ Ozone depletion should be either less or zero.

3. Global Warming

→ Refrigerant should have less Global warming potential that reduces the environmental impacts.

4. Total Equivalent Warming Index.

→ The factor TEWI should be less.

5. Flammability.

→ The refrigerant should have low flamability.

6. Chemical stability

→ The refrigerant should be chemically stable as long as they are inside the refrigeration system

7. compatability

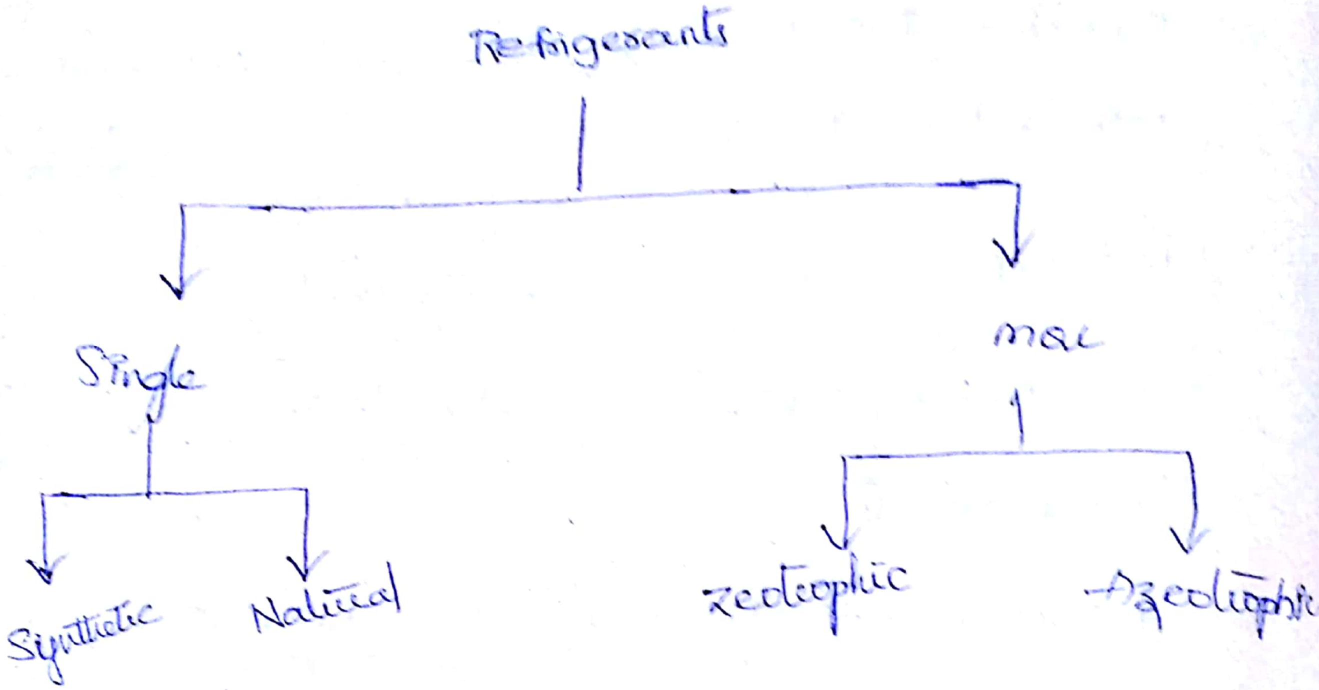
→ The refrigerant should be convenience with System material condition.

8. Easy of leak detection

The leakage of refrigerant should be easily detection required.

Refrigerants classification

Generally Refrigerants are classified. Single component or more than one component.



Zeotropics :-

It is the combination of more two refrigerants

Azeotropic :-

It is the combination of 2 substances

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Designation of Refrigerant

Generally refrigerants are designated by

R_{xyz}.

where

x is the no. of carbon atoms

y is the no. of hydrogen atoms

z is the no. of ~~F~~ chlorine atoms.

Chemical Indication of Refrigerants

C_nH_{n+2}

$C_nH_{n+2}F_n$.

n is the no. of carbon, hydrogen, fluorine, chlorine as per the chemical balance.

Representation of methane

CH_3Cl.