KULKARNI ACADEMY
Mechanical Engineering
Toppers Handwritten Notes
Refrigeration Air Condition
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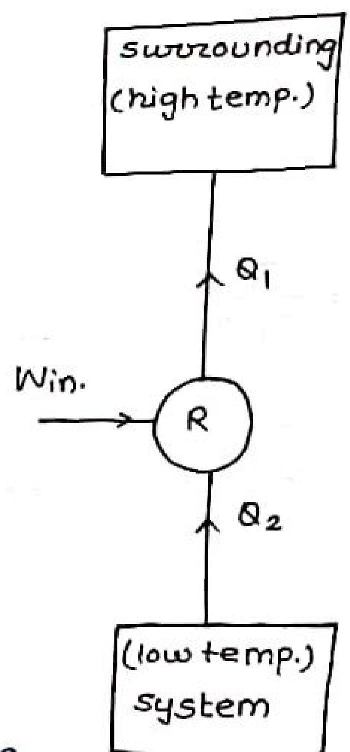
Refrigeration & air conditioning.

Refrigeration:
It is the process of maintaining lower temperatures compare to surroundings, in order to maintain lower temp. continuously the system should operate on a cycle.

Refrigerants:
These are the substances which are used for producing lower temperatures.

Examples: CO_2, air, water, R-11, R-22, R-134 etc.

Refrigeration Effect (RE): The amount of heat that is to be removed from the storage space in order to maintain lower temp. is known as refrigeration Effect.



$$c.o.p. = \frac{Q_2}{W_{in}}$$

Refrigeration effect (RE) = Q_2

$$c.o.p_R = \frac{RE}{W_{in}}$$

Significance of cop:
cop represents the running cost of the system. Greater the cop lessar is the running cost therefore systems with higher cop are desired.

Note: cop can be greater than 1, equal to one or less than one.

Window air conditioner $\simeq$ 3

Domestic Refrigerator, cop $\simeq$ 1

Vapour absorption system, cop is generally < 1.

1 British tonne = 2220 lbs = 1000 kg

Unit of Refrigeration : [TR]

1 Ton of refrigeration means the amount of heat that is to be removed from 1 American tonne (2000 lbs = 907 kg) of water at 0°c is order to convert it into ice at 0°c in 1 day (24 hours).

Therefore ton of refrigeration represents heat transfer rate but not mass.

$$1\ TR = \frac{907 \times 334}{24 \times 3600}$$

$$\boxed{1\ TR = 3.5\ KJ/sec.}$$

$$\boxed{1\ TR = 210\ KJ/min}$$

1 kcal = 4.18 KJ

$$\boxed{1\ TR = 50\ K\text{-}cal/min.}$$

Ideal Refrigeration cycle :

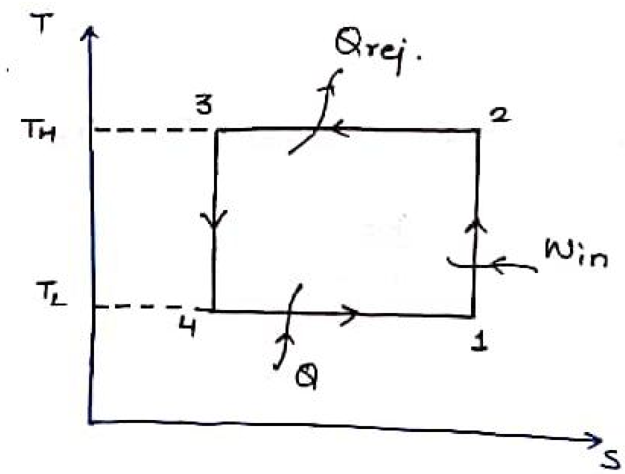
Reverse carnot cycle is an ideal ref. cycle.

$$c.o.p_{rev} = \frac{T_L}{T_H - T_L}$$

$$cop_{max} = \frac{T_L}{T_H - T_L}$$

↓

ideal cop.



Refrigeration capacity (R.C) :

$$\boxed{RC = \dot{m} \times RE}$$

$$\downarrow$$

$$kg/s \times \frac{KJ}{kg} \Rightarrow \frac{KJ}{Sec} = kW$$

Generally RE is expressed in KJ/kg and RC is expressed in KJ/sec.

Power Input to the compressor (P_{in}):

$$P_{in} = \dot{m} \times W_{in}$$

$\dot{m}$ = mass flow rate of refrigrant (kg/sec)

$$COP_R = \frac{RE}{W_{in}} = \frac{RE \times \dot{m}}{W_{in} \times \dot{m}} = \frac{RC}{P_{input}}$$

While calculating cop work input to the compressor is taken into account therefore cop is equal to

$$cop = \frac{RE}{W_{in\,(comp.)}}$$

Energy Efficiency Ratio (EER):

It is the ratio of RE (or Desired effect) to the work input to the Motor.

$$EER = \frac{RE}{W_{in\,(motor)}}$$

$$\eta_{comp.} = \frac{P_{comp.}}{P_{motor}} = \frac{W_{in\ comp.}}{W_{in\ motor.}}$$

if efficiency of the compressor is 100% then cop & EER are same.

Note: In refrigeration systems lower temp. are generally known as evaporators temp. and higher temp. are generally known as condensor temp.

Vapour Compression Refrigeration System:

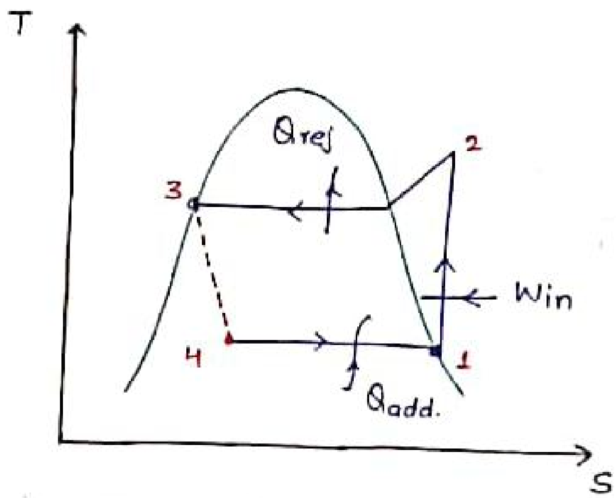
Simple / Standard / Saturated V-C cycle:-

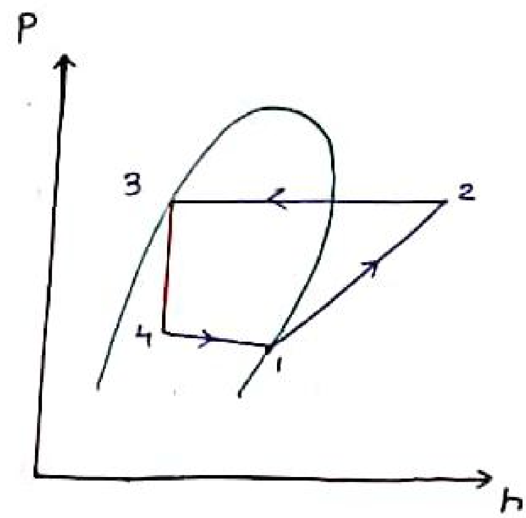
1-2:- rev. adiabatic compression

2-3- constant pressure Heat Rejection

3-4- isenthalpic expansion (throttling)

4-1- constant pressure Heat addition.





3-4 isenthalpic

$\delta Q \to 0$

$ds \geq 0$ (irrev.)

$dS_{univ} > 0$

$(ds)_{sys} + (ds)_{surr} > 0$ (0, $\delta Q = 0$)

$ds > 0$

3-4. each & every point we don't know what is happening. so ----- line.

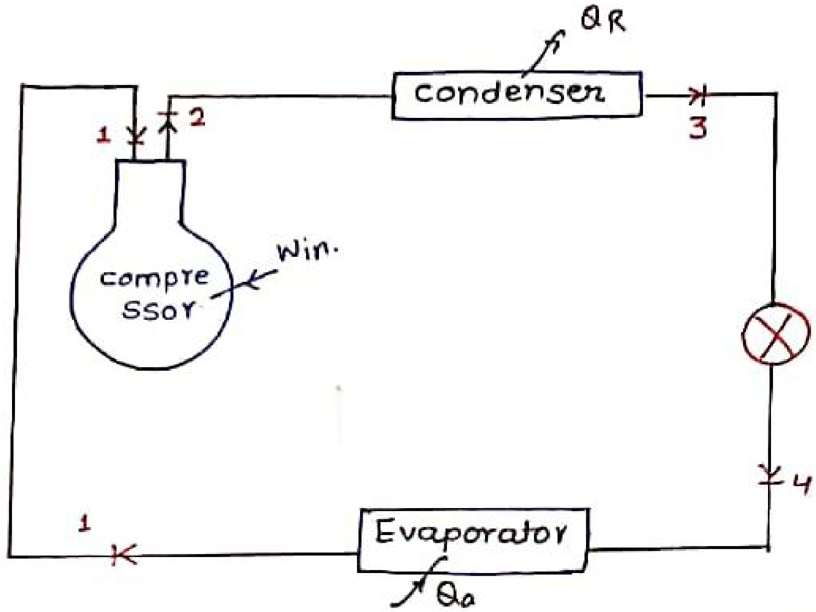
3-4. → complete line. b/c we know each & every point $h_3 = h_4$

or 3-4 may be represented by ------ (dash line) b/c throttling is an irreversible process.

V-C cycle is an irreversible cycle because This cycle consist of throttling which is an irrev. process.

which device is help in flow ref.

Q=0 in throttling then why temp. drop.

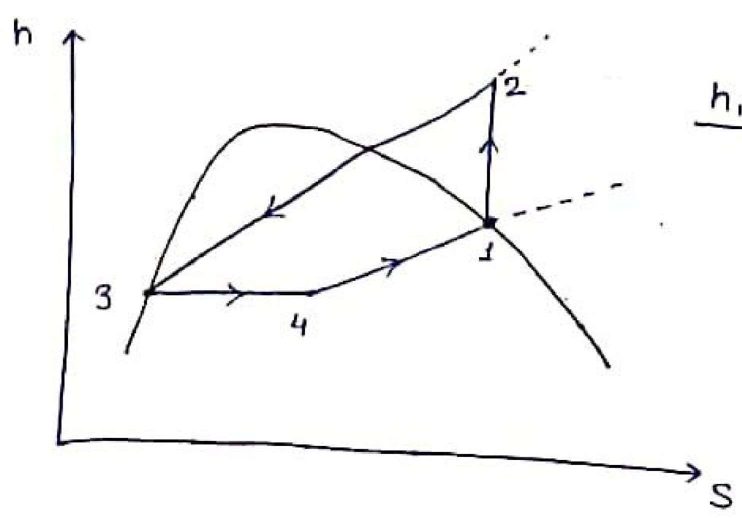


The basic components of v-c cycle are compressor, condenser, expansion valve, Evaporator.

The flow of refrigerant

compressor
↓
condenser
↓
Expansion valve
↓
Evaporator.

~~Analysis~~ Plot v-c cycle on h-s diagram.



$h_1 > h_3$.

Analysis of the cycle:

Assumptions:

1] Each device is treated as a steady flow device.

2] K.E & P.E. changes are Neglected.

3] Compression is assumed to be rev. adiabatic.

(1-2) Rev. adiabatic device (compressor)

From SFEE

$$h_1 + \cancel{\frac{c_1^2}{2}} + \cancel{gz_1} + \cancel{q} = h_2 + \cancel{\frac{c_2^2}{2}} + \cancel{gz_2} + W$$

$$h_1 = h_2 + W$$

$$\Rightarrow \quad W = h_1 - h_2 \quad \Rightarrow \quad W = -(h_2 - h_1)$$

$$\boxed{W_{comp.} = h_2 - h_1} = W_{input}$$

2-3. constant pressure heat rejection (condenser)

$$h_2 + \cancel{\frac{c_2^2}{2}} + \cancel{gz_2} + q = h_3 + \cancel{\frac{c_3^2}{2}} + \cancel{gz_3} + \cancel{W}$$

$$\Rightarrow \quad h_2 + q = h_3$$

$$q = h_3 - h_2 \quad \Rightarrow \quad -(h_2 - h_3)$$

$$\boxed{q_{rej.} = h_2 - h_3}$$

3-4. Isenthalpic expansion (throttling)

$$h_3 + \cancel{\frac{c_3^2}{2}} + \cancel{gz_3} + \cancel{q} = h_4 + \cancel{\frac{c_4^2}{2}} + \cancel{gz_4} + \cancel{W}$$

$$\boxed{h_3 = h_4}$$

4-1. constant pressure heat ~~Rejection~~ Absorption (Evaporator)

$$h_4 + \cancel{\frac{c_4^2}{2}} + \cancel{gz_4} + q = h_1 + \cancel{\frac{c_1^2}{2}} + \cancel{gz_1} + \cancel{W}$$

$$\boxed{q_a = h_1 - h_4} = \text{(Refrigeration effect)}$$

$$COP = \frac{R.E \rightarrow (Q_{ab}\text{. from starage in evaporator})}{W_{in} \rightarrow W_{comp}\text{. 'or Net work}}$$

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

$$h_4 = h_3$$

$$\boxed{COP = \frac{h_1 - h_3}{h_2 - h_1}}$$

⇒ In v-c cycle work transfer occurs only in one device that is compressor where as in all other devices work transfer is zero.

Reason for using throttling instead of isentropic expansion in vc cycle:

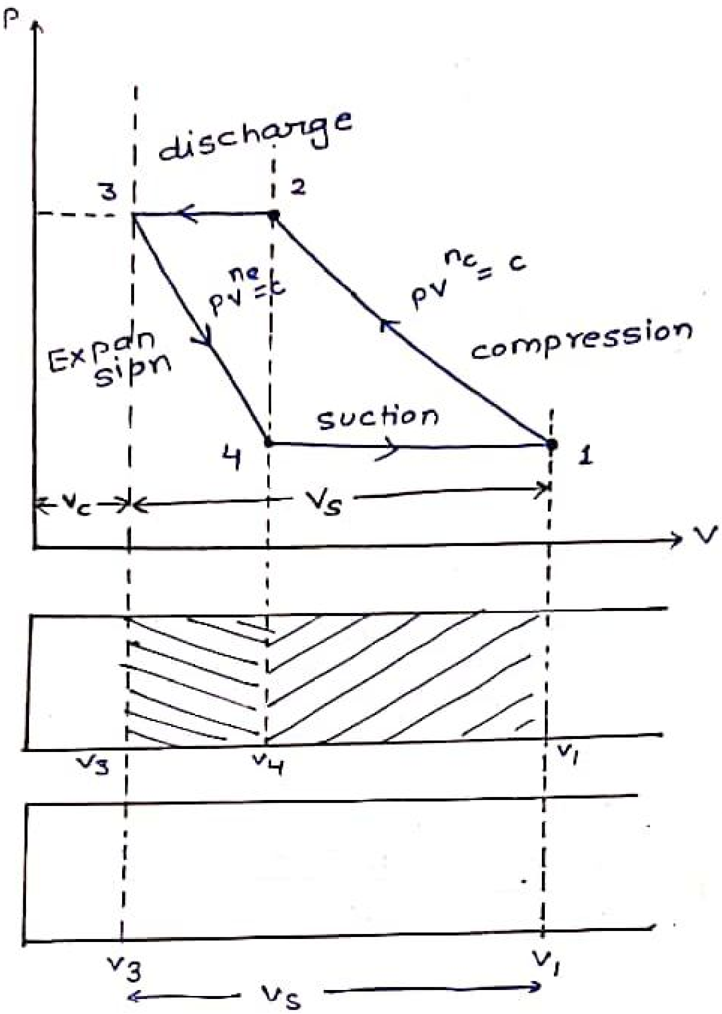
If isentropic expander is used instead of throttling there is some work output during expansion. It is the liquid refrigerant that expands as the specific volume of liquid is very small and hence expansion work is small. Therefore cost of the expander does not justify it's ~~uses~~ usages. therefore throttling is used in v-c cycle, instead of isentropic expansion.

* **Volumetric efficiency of a reciprocating compressor:**

$$\eta_{vol} = \frac{V_{act}}{V_s} = \frac{V_1 - V_4}{V_1 - V_3}$$

clearance ratio or clearance factor (c)

$$C = \frac{V_c}{V_s} = \frac{V_3}{V_1 - V_3}$$



more compression ratio more expansion so suction vol. $(V_1 - V_4)$ is less.

$$\eta_{vol} = \frac{V_1 - V_4}{V_1 - V_3} = \frac{V_1 - V_3 + V_3 - V_4}{V_1 - V_3}$$

$$= 1 - \frac{(V_4 - V_3)}{V_1 - V_3}$$

$$\Rightarrow 1 - \frac{V_3}{V_1 - V_3}\left[\frac{V_4}{V_3} - 1\right]$$

$$\Rightarrow 1 - C\left[\frac{V_4}{V_3} - 1\right] \Rightarrow 1 + C - C\left(V_4/V_3\right)$$

$$\frac{V_4}{V_3} = \left(\frac{P_3}{P_4}\right)^{1/ne} = \left(\frac{P_2}{P_1}\right)^{1/ne}$$

ne = index of expansion.

$$\boxed{\eta_{vol.} = 1 + C - C\left(P_2/P_1\right)^{1/ne}}$$

Note:- if Nothing is mention then the index of compression and expansion are taken to be same.