RAC

CHAPTER-1 [Basic Concepts]

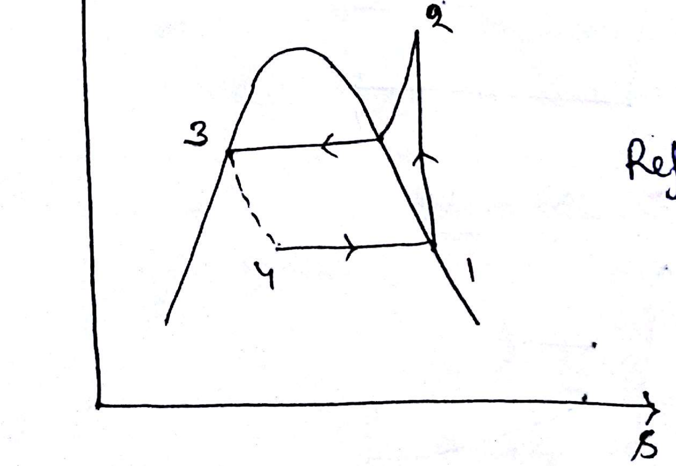
- $(COP)_{HP} = \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}$
- $(COP)_R = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L}$
- $(COP)_{HP} = (COP)_R + 1 = \frac{1}{\eta_E}$ [∴ when working b/w same tempʳ limits]
- Unit of Refrigeration

1TR = 3.5 KW = 210 $\frac{KJ}{min}$ = 50 $\frac{Kcal}{min}$ = 12000 BTU

1TR = amount of Heat needed to extract from 1000 Kg of water at 0°c to convert it into 1000 kg of ice at 0°c in a day (24 hrs)

- Dryness fraction = $x = \frac{m_v}{m_v + m_l}$

CHAPTER-2 [VCRS]



$(COP) = \frac{RE}{W_{in}} = \frac{h_1 - h_4}{h_2 - h_1}$

Refrigeration effect = RE = $h_1 - h_4$ KJ/Kg

Refrigeration Capacity = RC = $\dot{m}(h_1 - h_4)$ KW

$W_{in} = h_2 - h_1$ KJ/Kg

$P_{in} = \dot{m}(h_2 - h_1)$ KW

- Volumetric efficiency (η_v)

$$\eta_v = \frac{\dot{m}\, v_{entry}}{\frac{\pi}{4} d^2 l \cdot \frac{N}{60} \cdot K}$$

N = rpm
K = no. of cylinder
v_{entry} = Specific volume at entry of comp.

$$\eta_v = 1 + C - C\left(\frac{P_H}{P_L}\right)^{\frac{1}{n}}$$

$C = \frac{V_c}{V_s} = \frac{\text{clearance vol.}}{\text{Swept. vol.}}$

n = polytropic index.

- Disadvantage of wet compression
  1) RE ↓
  2) Refrigerant may wash away the lubricant
  3) wear & tear
  4) damage to compressor valves & Body.

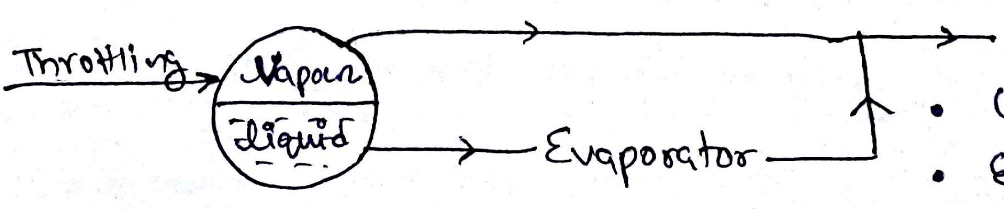
- $P_E \downarrow$ or $P_C \uparrow \Rightarrow RE \downarrow \Rightarrow W_{in} \uparrow \Rightarrow COP \downarrow \Rightarrow \frac{P_H}{P_L} \uparrow$
  $\Rightarrow \eta_v \downarrow \Rightarrow \dot{m} \downarrow$

- W_{in} to compressor is function of inlet tempr to the compressor.

- Superheating in evaporator
  RE ↑ , W_{in} ↑
  ⇒ COP may increase or decrease ; R-12 COP ↑
  NH_3 COP ↓

- Subcooling in condenser
  RE ↑ , W_{in} = Const. , COP ↑

- Use of flash chamber



→ Compressor
- COP ⇒ no change
- Evaporator size ↓

- Use of heat exchanger implies both subcooling & superheating [Enthalpy of subcooling = Enthalpy of superheating]
- Cascade Refrigeration System

$$(COP) = \frac{(COP)_1 \cdot (COP)_2}{(COP)_1 + 1 + (COP)_2}$$

- For two engines in series.

$$\eta = \eta_1 + \eta_2 - \eta_1 \eta_2$$

for same W.D. $T_2 = \frac{T_1 + T_3}{2}$

for same η $T_2 = \sqrt{T_1 T_3}$

CHAPTER - 3 [Refrigerants]

- Primary Refrigrants ⇒ R-11, R-12, R-22, R-134(a), NH_3

  Secondary ⇒ H_2O, Brine

- Saturated hydrocarbon

  $C_m H_n F_p Cl_q$ R - (m-1)(n+1) p

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

eg:-

R-11 ⇒ $CFCl_3$

R-12 ⇒ CF_2Cl_2

R-22 ⇒ CHF_2Cl_1 Cl ↓ dec.

R-134 ⇒ $C_2H_2F_4Cl_0$

⇓

Known as ecofriendly bcz of abscence of clorine.

- Chlorine ⇒ attacks ozone layer present in stratosphere.

  ⇒ Ozone protects from UV radiations

- Unsaturated hydrocarbon

R - 1 (m-1)(n+1) p $C_m H_n F_p Cl_q$

& $n+p+q = 2m$

eg:- $C_2H_4 \Rightarrow$ R-1150

- when refrigrant is inorganic compound

R - (700 + mol. wt.)

eg:- $NH_3 \Rightarrow$ R-717

$CO_2 \Rightarrow$ R-744

$SO_2 \Rightarrow$ R-764

$H_2O \Rightarrow$ R-718

Air $\Rightarrow$ R-729

- Selection of refrigerant

Required Thermodynamic Properties

- → Critical temp^r ↑
- → Specific heat
  - → vapour ↑
  - → liquid ↓
- → Enthalpy of vaporisation ↑
- → Conductivity ↑
- → $P_E \Rightarrow$ almost equal to 1 Atm
- → $P_c \Rightarrow$ moderate
- → Comp. ratio ↓
- → freezing Point ↓
- → Comp. discharge temp ↓
- → COP $\propto \frac{1}{\text{running cost}}$

Required Chemical Properties

- Toxicity should be low (or zero)
- Ref. should be non-flamable
- Partially miscible Refri. are harmful eg → R-22

	attack	Favourable
NH_3	Cu	wrought iron
Freon or Halo carbon	Al	Cu

Required Physical properties

- Cost ↓
- Viscosity ↓
- leak Detection should be easy.

- Critical tempr of CO_2 & ethylene are almost unfavorable for Indian climate

$CO_2 \longrightarrow 31^\circ C$

Ethylene $\longrightarrow 10.2^\circ C$

- NH_3 has highest value of enthalpy of vapourisation among commonly used refrigerants.
- Almost all refrigerant are having similar value of COP when operating b/w same tempr limit.
- NH_3 is both toxic & flammable.
- Oil seperator is installed b/w comp. & condenser
- Oil seperator is not required to be installed if refrignant & oil are immiscible at P_c & T_c.
- Sensing bulb is installed at exit of evaporator
- Leak detection

1) Freon or Halocarbon a) Halide torch test

light changes from blue → bluish green

b) Soap bubble test.

2) Amonia leaks ⇒ Sulphur stick method

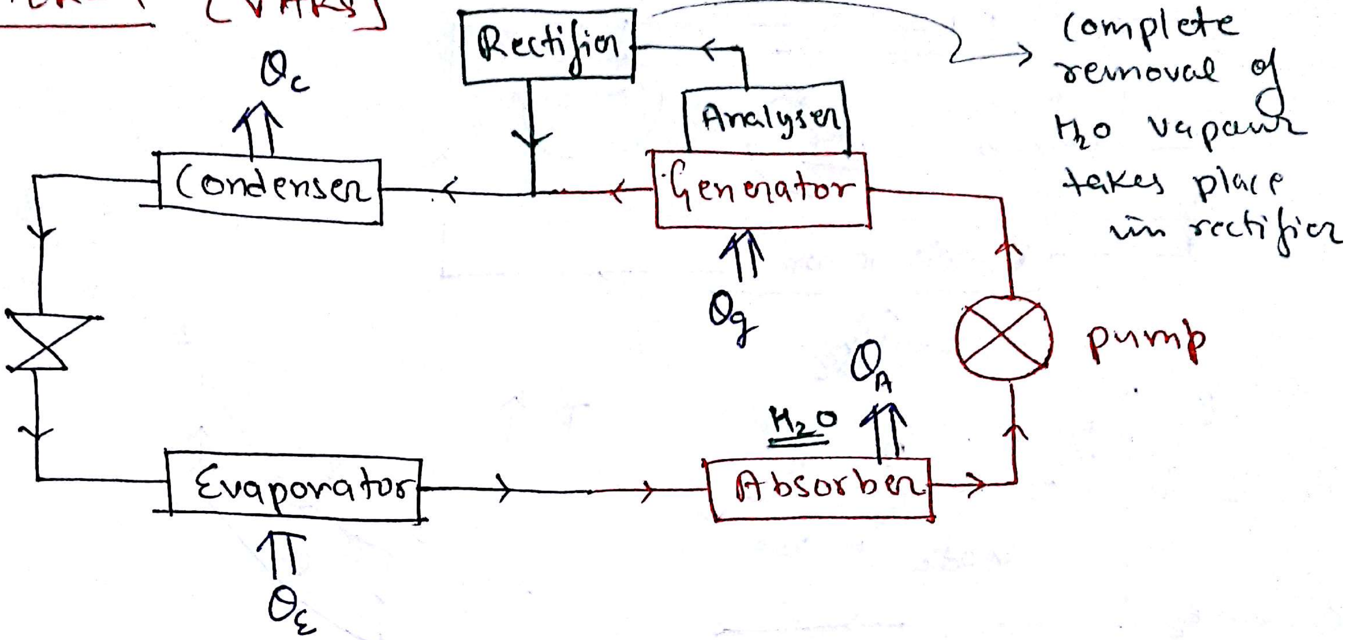
3) SO_2 leaks ⇒ Amonia swab test.

- Refrigrant & their Applications

R-11	Large centralised Air conditioning plants
R-12	Domestic refrigerator, water cooler
R-22	Window AC
NH_3	Cold storage plant
Brine	milk chilling plant
CO_2	Direct contact freezing of food
Air	Gas liquification, Aircraft ref. system

- Azeotrops: mixture of refrigerants which behaves like pure substance. Their designation started with R-500.

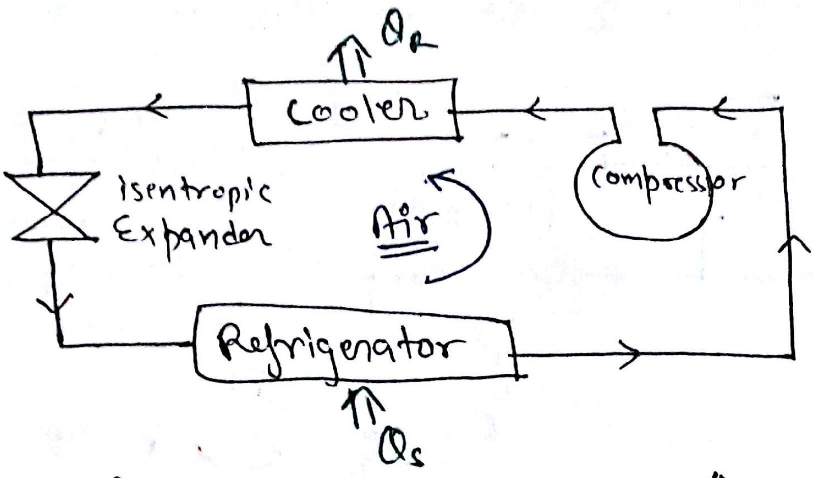
CHAPTER-4 [VARS]

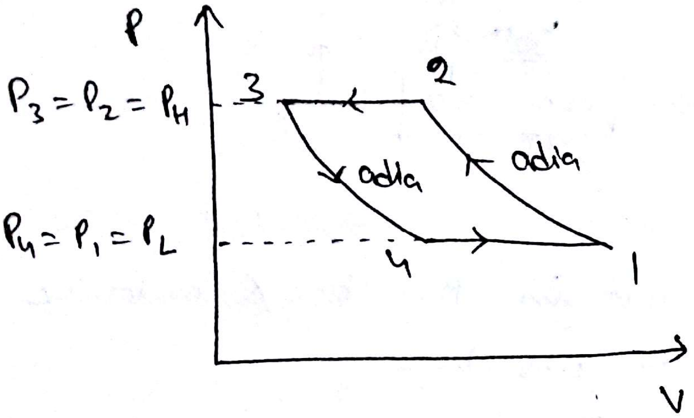


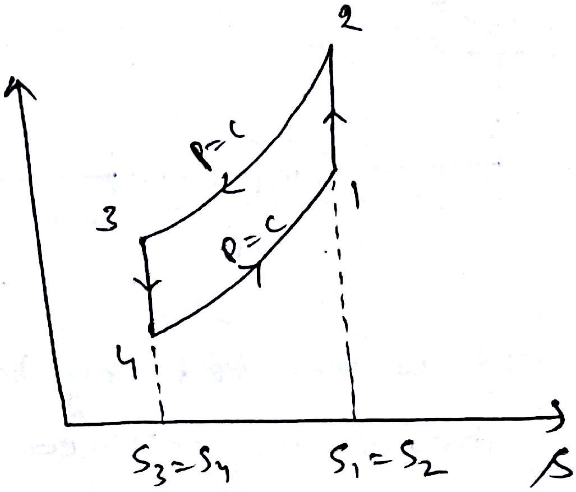
- Heat is rejected by Refrigerant in Absorber & Condenser
- Compressor is replaced by
  - Absorber
  - pump
  - Generator
- Solar absorption refrigeration is working on VARS
- $(COP)_{VARS} \Rightarrow$ 0.3 to 0.5 generally
- VARS runs on low grade energy (Heat operated)
- $NH_3 - H_2O \Rightarrow$ NH_3 : used as refrigrant
  H_2O : used as absorber
- $LiBr - H_2O \Rightarrow$ H_2O : used as refrigrant
  $LiBr$: used as absorber.
- $$(COP)_{VARS} = \frac{T_E}{T_g} \times \frac{(T_g - T_0)}{(T_0 - T_E)}$$
- $$(COP)_{actual} = \frac{Q_E}{Q_P + Q_g}$$
- Electrolux refrigerator : $NH_3 \rightarrow$ used as refrigrant
  $H_2O \rightarrow$ used as absorber
  $H_2 \rightarrow$ used to reduce partial pressure of NH_3 vapour

  ⇓ pump is not used

CHAPTER-5 [Reverse Brayton or Bell coleman cycle]







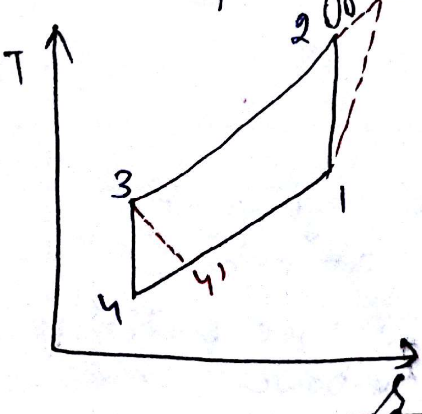
- Pressure ratio $= r_p = \dfrac{P_H}{P_L}$

- $$(COP)_{RBC} = \frac{1}{\frac{T_2}{T_1} - 1} = \frac{1}{(r_p)^{\frac{r-1}{r}} - 1}$$

above eqn is used only when Expansion & compression are isentropic

- $$(COP)_{actual} = \frac{RE}{W_C - W_T} = \frac{\dot{m} C_p (T_1 - T_{4'})}{\frac{n_1}{n_1 - 1} \cdot \dot{m} R (T_{2'} - T_1) - \frac{n_2}{n_2 - 1} \dot{m} R (T_3 - T_{4'})}$$

- Isentropic efficiency



$$(\eta_{isen})_C = \frac{h_2 - h_1}{h_{2'} - h_1} = \frac{T_2 - T_1}{T_{2'} - T_1}$$

$$(\eta_{isen})_T = \frac{T_3 - T_{4'}}{T_3 - T_4} = \frac{h_3 - h_{4'}}{h_3 - h_4}$$

- Heat rejection ratio (HRR)

$$HRR = \frac{\text{Heat rejected by condenser}}{\text{Refrigeration effect}} = \frac{Q_c}{RE.}$$

$$(COP)_R = \frac{1}{HRR - 1}$$

CHAPTER-6 [Refrigeration Equipments]

- Compressor should be designed for Peak hour conditions.
- Purging : removal of Air from the condenser.
- Types of condenser
  - → Air cooled ⟶ 3 TR ⇒ 10.5 KW
  - → water cooled
    - → Double tube → 10 TR = 35 KW
    - → Shell & coil → 50 TR = 175 KW
    - → Shell & tube → 1000 TR = 3500 KW
  - → Evaporative condenser
- Types of ~~Evaporator~~ Expansion device
  - → Const. Area type ⇒ eg:- capillary tube [dia ≤ 6 mm]
    - used in – Domestic Refrigerator
      - water cooler
      - window AC
    - Friction in tube & fluid accelration are reasons for pressure Drop.
  - → Const. Volume type

Automatic Expansion	Thermostatic Expansion
→ It is used to maintain const. Pressure in evaporator irrespective of load.	→ It is used to maintain constant degree of superheat irrespective of load.

CHAPTER-7 [Air Conditioning]

- Psychrometry is branch of science which deals with the properties of moist Air.
- Specific humidity or humidity ratio (ω)

$$\omega = \frac{0.622\, P_v}{P - P_v} = \frac{m_v}{m_a} \quad \text{Kg/Kg of dry air}$$

- Relative humidity (ϕ)

$$\phi = \frac{m_v}{m_{vs}} = \frac{P_v}{P_{vs}}$$

- WBD = DBT − WBT
- for saturated air ⇒ DBT = WBT = DPT

  ⇒ $\phi = 1$ or 100% ⇒ $P_v = P_{vs}$

  ⇒ WBD = 0
- Sling Psychrometer is used to measure both DBT & WBT
- Degree of saturation or %age humidity (μ)

$$\mu = \frac{\omega}{\omega_s} = \frac{P_v}{P_{vs}} \times \left(\frac{P - P_{vs}}{P - P_v}\right) = \phi \times \left[\frac{P - P_{vs}}{P - P_v}\right]$$

- Enthalpy of moist Air (h)

$$h = 1.005\,t + \omega\,(2500 + 1.88\,t)$$

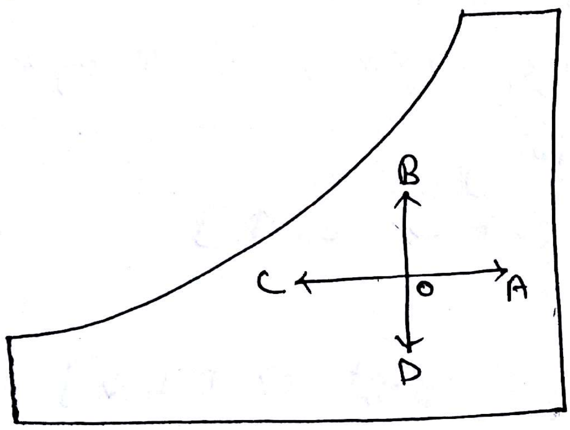
($2500 + 1.88\,t$ ⇓ Enthalpy of water vapour)

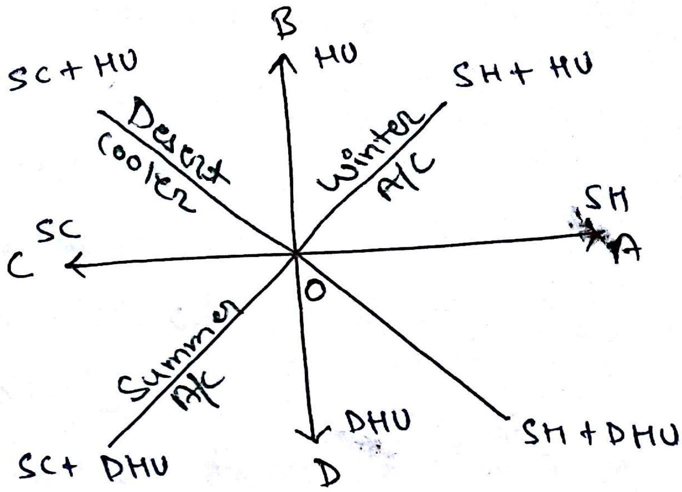
t = DBT (in °C)
ω = Kg/Kg of d.a.

- Apjohn formula

$$P_v = P'_v - \frac{1.8\,P\,(t - t')}{2700}$$

Temperature	Tempr notation	Corresponding Saturation Pressure
DBT	t	P_{vs}
WBT	t'	P'_v
DPT	DPT	P_v

- Constant specific volume lines are more steeper than const. enthalpy lines.
- 



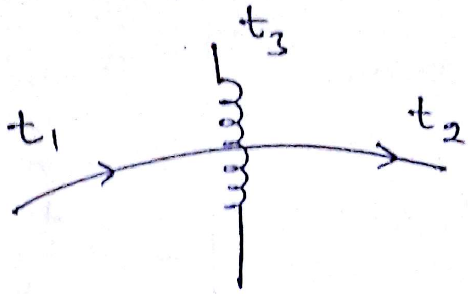
- In desert cooler cooling & humidification occurs or Adiabatic saturation process occurs (i.e. chemical humidification upto saturation curve)
- Chemical humidification & Dehumidification are along const. Enthalpy lines.
- When $(t - t')$ is high $\phi \downarrow$ & Desert cooler becomes effective.
- Sensible heat factor

$$SHF = \frac{SH}{SH + LH}$$

Conditions	SHF
Residence & Private office	0.9
Restaurant & Busy office	0.8
Auditorium & cenema hall	0.7
Dance hall room	0.6

- By Pass factor (X)

$$X = \frac{|t_3 - t_2|}{|t_3 - t_1|}$$



- By Pass factor of 'n' coils in Series = X^n
- Factors effecting Effective tempr (ET)
  - → Climate & Seasonal difference
    [warmer region reletively higher ET]
  - → Age & Gender
    [child, old age, women , ET ↑ by 2-3°c]
  - → Kind of activity
    [person in rest ⇒ ET ↑]
  - → Density
    [high Dense occupant ⇒ ET ↓]
- comfort chart is made by ⇒ WBT ⇒ y-axis
  DBT ⇒ x-axis

Human comfort : 20°c to 21.6°c [ET)
24°c to 26°c (normal tempr)
50% to 60% RH

- Ventilation

1 → 2 ⇒ GSHF [coil]

2 → i ⇒ RSHF [Room]

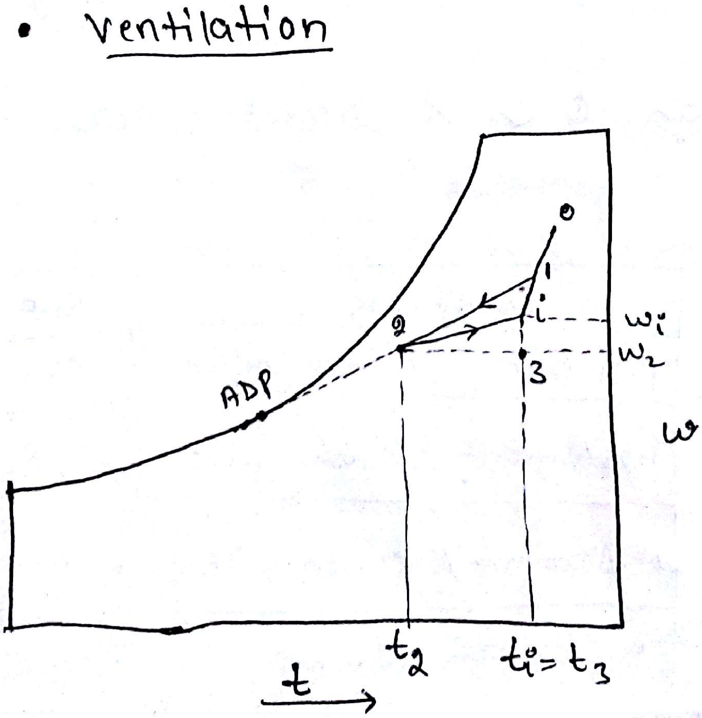


fig:- example of Summer A/c with ADP of coil with X ≠ 0

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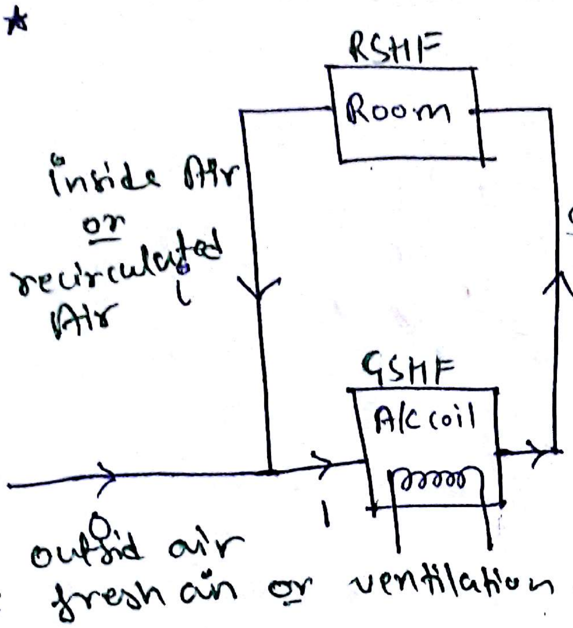


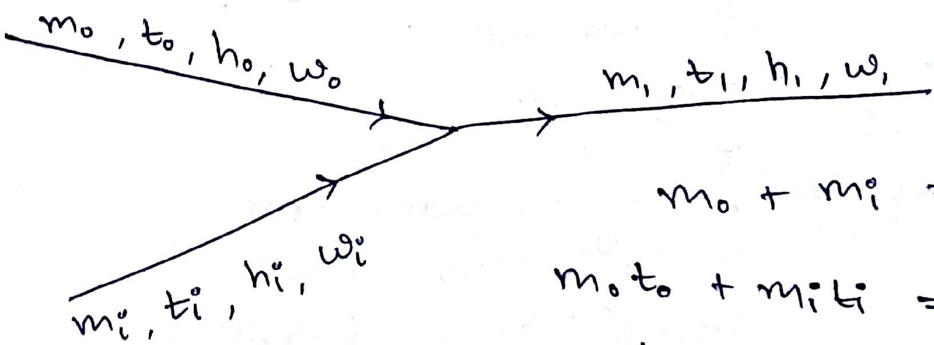
$$RSHF = \frac{RSH}{RSH + RLH}$$

RSH = 0.0204 cmm ΔT kW

RLH = 50 cmm Δω kW

cmm = [no. of Air flow × vol. of room] m^3/min

* For the stream mixing, below formula are used



$$m_o + m_i = m_1$$

$$m_o t_o + m_i t_i = m_1 t_1$$

$$m_o h_o + m_i h_i = m_1 h_1$$

$$m_o \omega_o + m_i \omega_i = m_1 \omega_1$$

In above equations [m_o, m_i, m_1] are mass of dry air (m_a), but total mass can be used for calculations.

- $$X = \frac{t_2 - t_s}{t_1 - t_s} = \frac{\omega_2 - \omega_s}{\omega_1 - \omega_s} = \frac{h_2 - h_s}{h_1 - h_s}$$
- Degree of freedom of moist Air is 3.
- 100% fresh Air is sent in ICU & operation theatre
- During compression ⇒ ω = const.
  or when there is no flow of mass.
- minimum possible tempr that can be obtained in cooling tower is WBT of inlet Air.