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A division of PhIE Learning Center

QUICK REVISION

FORMULA SHEET

for

GATE -ME REFRIGERATION & AIR-CONDITIONING

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REFRIGERATION & AIR-CONDITIONING

Chapter 1: BASIC CONCEPTS

$$(COP)_{\text{Heat pump}} = \frac{Q_H}{Q_H - Q_L} = \frac{T_H}{T_H - T_L}$$

$$(COP)_{Ref} = \frac{Q_L}{Q_H - Q_L} = \frac{T_L}{T_H - T_L}$$

$$(COP)_{HP} = (COP)_{Ref} + 1 = \frac{1}{\eta_{engine}}$$

(When working between same temperature limits)

COP = Coefficient of Performance

Unit of Refrigeration:

1 TR = 3.5167 kW = 210 kJ/min = 50.4 kcal/min

1TR: Amount of heat needed to extract from 1000 kg of water at 0°C, to convert it to 1000 kg ice at 0°C in a day (24 hrs).

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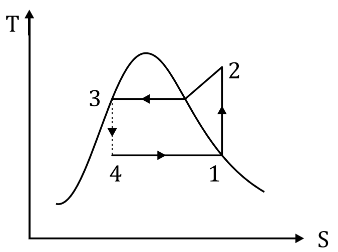
Chapter 2: VAPOUR COMPRESSION REFRIGERATION SYSTEM (VCRS)

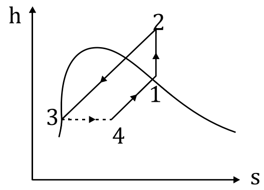


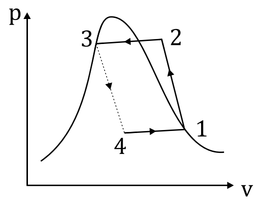
$$(COP) = \frac{RE}{W_{input}} = \frac{h_1 - h_4}{h_2 - h_1}$$

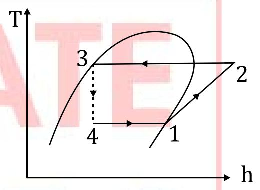
Refrigeration effect = RE

$$= h_1 - h_4 (kJ/kg)$$

$$W_{compressor} = h_2 - h_1$$

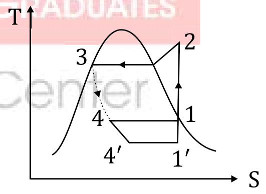






Modifications in VCRS:

1. **↓ in Evaporator pressure**



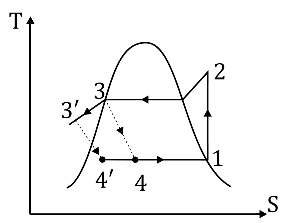
RE ↓

W_{input} ↑

η_{vol} ↓

COP ↓

2. **Subcooling:**



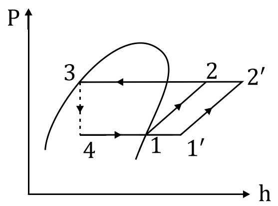
RE ↑

W_{input} → Same

η_{vol} → same

COP ↑

3. **Superheating of Vapour in Evaporator**



RE ↑

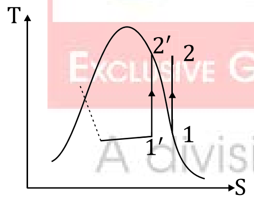
W_{input} ↑

COP (may ↓ or ↑)

η_{vol} → Same

Wet vs Dry Compression:

Disadvantages of wet over dry compression

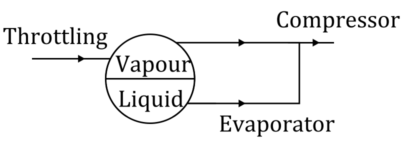


1. RE ↓
2. Refrigerants may wash away the lubricants.
3. Wear and tear
4. Damage compressor valve and body.

Use of Flash Chamber:

COP → No change

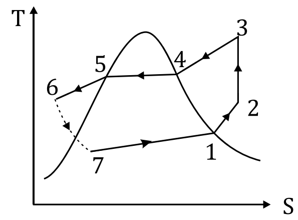
Evaporator size ↓



Use of Heat Exchanger:

Implies both subcooling and superheating.

Purpose ⇒ to ↓ size of evaporator



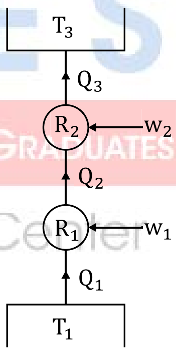
$$h_2 - h_1 = h_5 - h_6$$

$$C_{pv}(T_2 - T_1) = C_{pL}(T_5 - T_6)$$

Cascade Refrigeration System:

$$(COP)_{CC} = \frac{(COP)_1 \times (COP)_2}{1 + (COP)_1 + (COP)2}$$

$$(COP)_{CC} = \frac{Q_1}{W_1 + W_2}$$



Volumetric Efficiency:

$$\eta_{vol} = \frac{\text{Actual volume}}{\text{Theoretical swept volume}}$$

$$\eta_{vol} = \frac{\dot{m}v_{entry}}{\frac{\pi}{4} d^2\ell \times \frac{N}{60} \times K}$$

$$n_{vol} = 1 + C - C\left(\frac{p_H}{p_L}\right)^{\frac{1}{n}}$$

Where N = rpm

K = No. of cylinder

v_{entry} = Specific volume at enry of compressor

$C = \frac{v_c}{v_S}$

n = Polytropic index

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Chapter 3: REFRIGERANTS

Refrigerants:

Working substance which is used to extract heat from storage space.

1. **Primary Refrigerant:**

   Used directly to absorb heat from storage space by changing their phase (L → V) in evaporator.

   Eg: R-11, R-12, R-22, R-134a

2. **Secondary Refrigerant:**

   Absorbs heat from the storage space and further transfer the same to primary refrigerants.

   Eg: H_2O, Brine

Designation of Refrigerants:

a. **Saturated Hydrocarbon**

   $C_mH_nF_pClq$

   Then $\boxed{n + p + q = 2m + 2}$

   $R(m-1)(n+1)p$ → Designation.

   Eg: R-011 ,R11, R-012, R-134a

b. **Unsaturated Hydrocarbons:**

   $C_mH_nF_pClq$

   $\boxed{n + p + q = 2m}$

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

   Eg: R1150 (C_2H_4)

c. **Inorganic Refrigerant:**

   Designation: R700 + Molecular weight.

   Eg: NH_3 → R717

Ozone Depletion:

- Ozone layer is in stratosphere.
- Protects against UV radiation of sun.
- Cl atoms in CFC causes ozone depletion.
- R-134a ($C_2H_2F_4$) is eco-friendly refrigerant.

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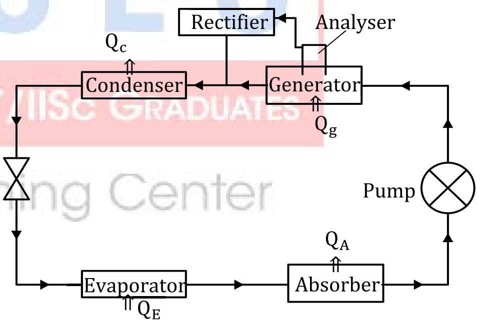
Chapter 4: VAPOUR ABSORPTION REFRIGERATION SYSTEM (VARS)



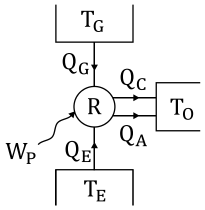
- Compressor is replaced by
  a. Absorber
  b. Pump
  c. Generator
- Heat rejected by refrigerant in absorber and condenser.
- Solar absorption refrigeration system is working on VARS.
- $(COP)_{VARS}$ = 0.3 to 0.5 (Generally)
- $NH_3 - H_2O$(ref system)

NH_3 used as refrigerant, H_2O used as absorber.

- $LiBr - H_2O$

  H_2O used as refrigerant.

  LiBr used as absorber.



$$((COP)_{VARS})_{max}$$

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

$\Rightarrow$ Neglected pumpwork

$$(COP)_{actual} = \frac{Q_E}{W_P + Q_G}$$

W_P = Pump work

Electrolux Refrigeration System:

(3 fluid system)

1. NH_3 used as refrigerant.
2. H_2O used as absorber.
3. H_2 used to reduce partial pressure of NH_3 Vapour.

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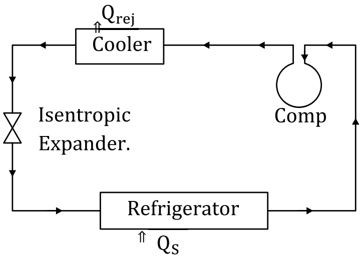
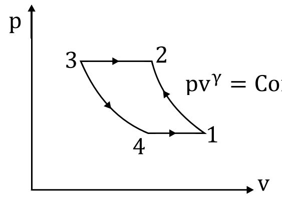
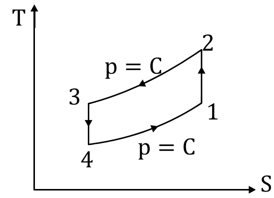
Chapter 5: REVERSE BRAYTON/BELL COLEMAN CYCLE





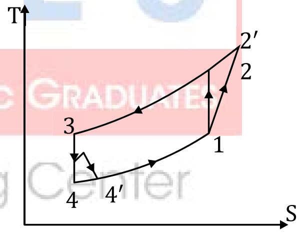


$$r_p = \text{pressure ratio} = \frac{p_H}{p_L}$$

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

This is used when expansion and compression are isentropic.

$$(COP)_{actual} = \frac{RE}{W_{Comp} - W_{Expander}}$$



$$(\eta_{isentropic})_{Comp} = \frac{T_2 - T_1}{T_2' - T_1}$$

$$(\eta_{isentropic})_{Turbine\ or\ Expander} = \frac{T_3 - T_4'}{T_3 - T_4}$$

$$HRR = \frac{Q_{Condenser}}{RE}$$

HRR = Heat rejection ratio

RE = Refrigeration effect (process 4-1)

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

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Chapter 6: AIR CONDITIONING

Specific Humidity/Humidity Ratio (w)

$$w = \frac{0.622\, p_v}{p_T - p_v}$$

Relative humidity $(\phi) = \frac{m_v}{m_{vs}} = P_v/p_{vs}$

Wet Bulb Depression (WBD):

WBD = DBT − WBT

Note:

For saturated air:

DBT = WBT = DPT

$\phi = 1$ or 100%, $\quad p_v = p_{vs}$

$\Rightarrow$ WBD = 0

DBT= dry bulb temperature

DPT = dew point temperature

WBT= wet bulb temperature

VERY IMPORTANT

Temp	Temp Notation	Corresponding saturation pressure
DBT	t	p_{vs}
WBT	t'	p_v'
DPT	DPT	p_v

Apjohn Formula (used when WBT is given in the equation):

$$p_v = p_v' - \frac{1.8p(t - t')}{2700}$$

Degree of Saturation (μ)**:**

$$\mu = \frac{w}{w_s}$$

$$\mu = \phi\left(\frac{p - p_{vs}}{p - p_v}\right)$$

Enthalpy of moist Air (h)**:**

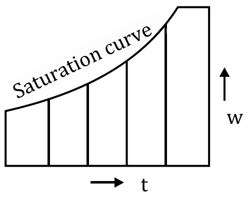
$h = 1.005t + w(2500 + 1.88t)$

where $t = $ DBT(in °C)

$w = $ kg/kg of dry air

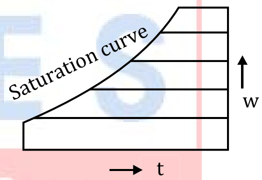
Various line on Psychrometric Chart:

a. **Constant DBT Lines:**



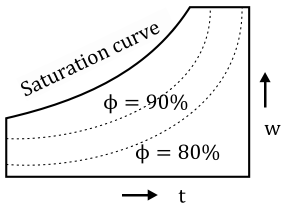
- Uniformly spaced
- Increases in + x direction

b. **Constant Specific Humidity (w)Line:**

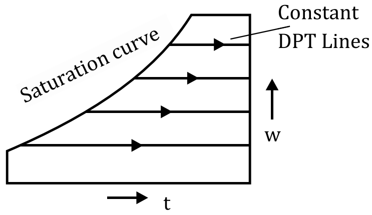


- Uniformly spaced
- increases in + y direction

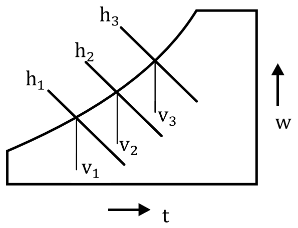
c. **Constant ϕ Line**



d. **Constant DPT Lines**



- Non-uniformly spaced

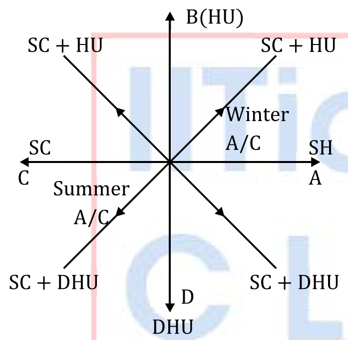


Constant h: Uniformly spaced

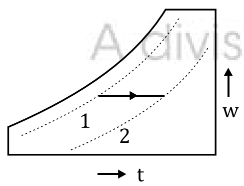
WBT_{line}: Non-uniformly spaced

Same degree of inclination.

Various Psychrometric Processes:



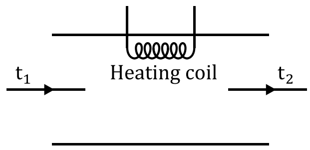
SH (Sensible Heating):



Effects:

1. Temperature increases
2. w = constant
3. DPT =constant
4. ϕ decreases
5. h increases
6. WBT increases , v increases

   v (Specific volume)



$Q_s = m_a(h_1 - h_2)$

$Q_s = m_aC_{pa}(t_1 - t_2)$
$+ m_vC_{pv}(t_1 - t_2)$

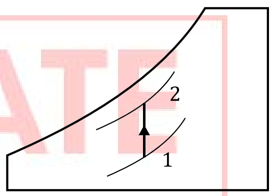
$Q_s = m_a(1.005 + 1.88w)(t_1 - t_2)$

Or

$Q_s = 0.0204\ (C_{mm})\Delta t\ \ kW$

C_{mm} =Volume flow rate of air in m^3/min

Humidification (HU):



Effects:

1. t = constant
2. ϕ increases
3. w increases

   (h, WBT, v) increases
4. DPT increases

$Q_L = m_a(h_2 - h_1)$

$= m_a\left((C_pt_2 + h_{fg}w_2)\right.$
$\left. - (C_pt_1 + h_{fg}\,w_1)\right)$

$= m_ah_{fg}(w_2 - w_1)$

h_{fg} = Latent heat of vaporization

or

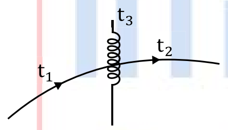
$Q_L = 50\ C_{mm}(\Delta w)$ kW

- In desert cooler, cooling and humidification occurs or adiabatic saturation process occurs (i.e., chemical humidification upto saturation curve)
- Chemical humidification and dehumidification are along constant enthalpy lines.

Sensible Heat Factor(SHF):

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

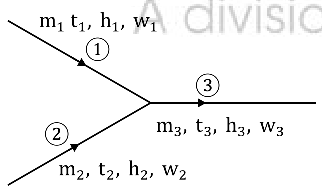
By Pass Factor (X):



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

By pass factor of 'n' coils in series $= X^n$

Adiabatic Mixing of Air Streams:



Mass Equation:

- For dry air

  $m_{a_1} + m_{a_2} = m_{a_3}$ ... eqn 1

- For water Vapour

  $m_{v_1} + m_{v_2} = m_{v_3}$ ... eqn 2

Energy Equation:

$$m_{a_1}h_1 + m_{a_2}h_2 = (ma_1 + m_{a_2})h_3$$

From equation 2

$$w_1 m_{a_1} + w_2 m_{a_2} = w_3(m_{a_1} + m_{a_2})$$

$$\frac{m_{a_1}}{m_{a_2}} = \frac{w_3 - w_2}{w_1 - w_3}$$

$$\frac{m_{a_1}}{m_{a_2}} = \frac{h_3 - h_2}{h_1 - h_3} \approx \frac{t_3 - t_2}{t_1 - t_3}$$

(If only dry air is considered.)

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