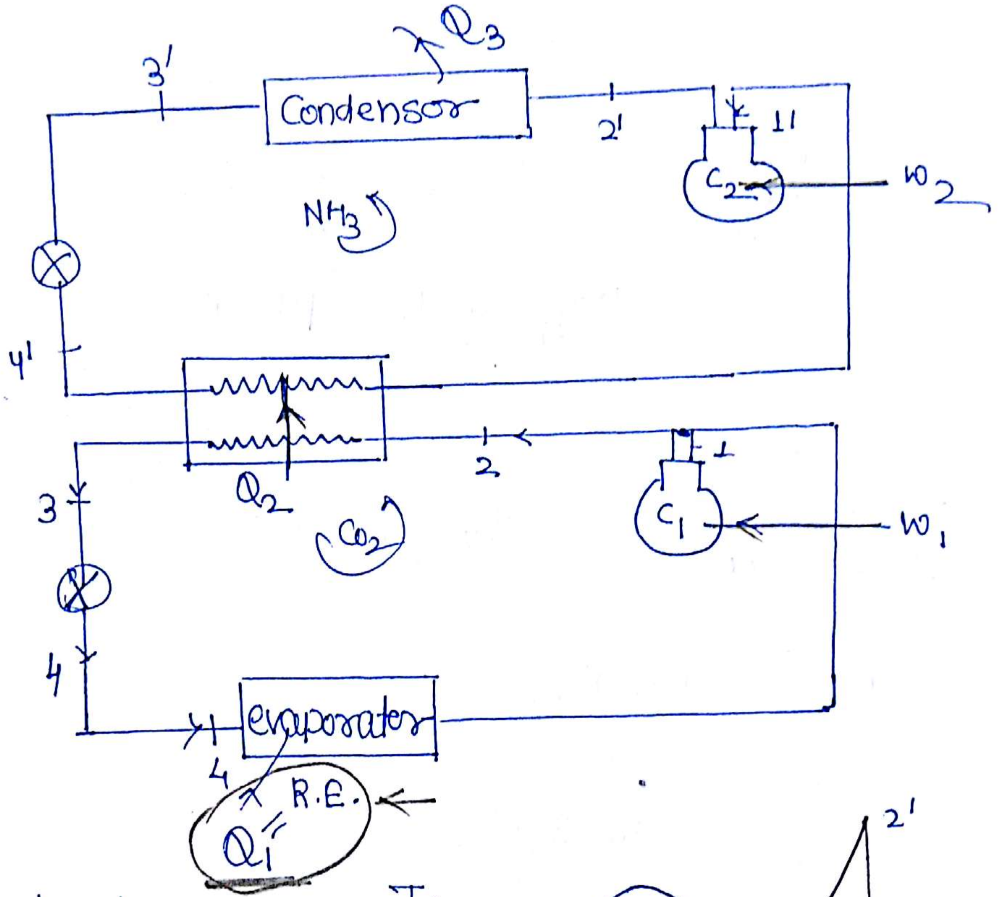
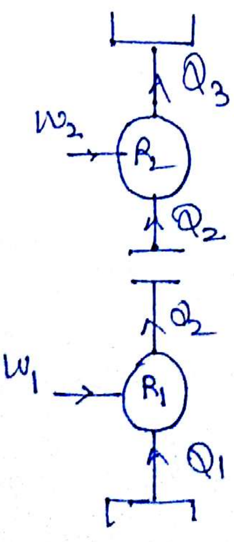
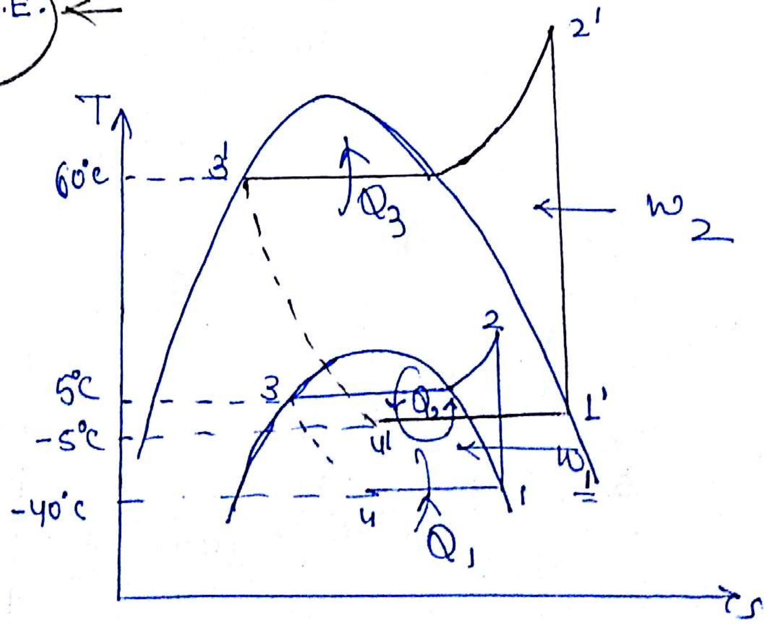
Cascade Refrigeration System:-

* For producing very low temp the corresponding pressure ratio becomes very high hence the volumetric efficiency becomes very low therefore cascading of refrigeration system is done.
* It is ~~Ud~~ used in medical industry.







$$COP_1 = \frac{Q_1}{W_1} \quad , \quad COP_2 = \frac{Q_2}{W_2}$$

$$\boxed{COP = \frac{Q_1}{W_1 + W_2}}$$

To proove $$COP = \frac{COP_1 . COP_2}{1 + COP_1 + COP_2}$$

$$COP = \frac{Q_1}{W_1 + W_2} = \frac{Q_1}{\frac{Q_1}{COP_1} + W_2} = \frac{COP_1 \times Q_1}{Q_1 + W_2 COP_1}$$

$$COP = \frac{COP_1}{1 + \frac{W_2}{Q_1} \times COP_1}$$

$$\boxed{Q_1 + W_1 = Q_2}$$

$$1 + \frac{W_1}{Q_1} = \frac{Q_2}{Q_1}$$

$$COP_2 = \frac{Q_2}{W_2}$$

$$1 + \frac{1}{COP_1} = \frac{Q_2}{Q_1}$$

$$COP = \frac{COP_1}{1 + \frac{COP_1}{Q_1} \times \frac{Q_2}{COP_2}} = \frac{COP_1}{1 + \frac{COP_1}{COP_2} . \frac{Q_2}{Q_1}}$$

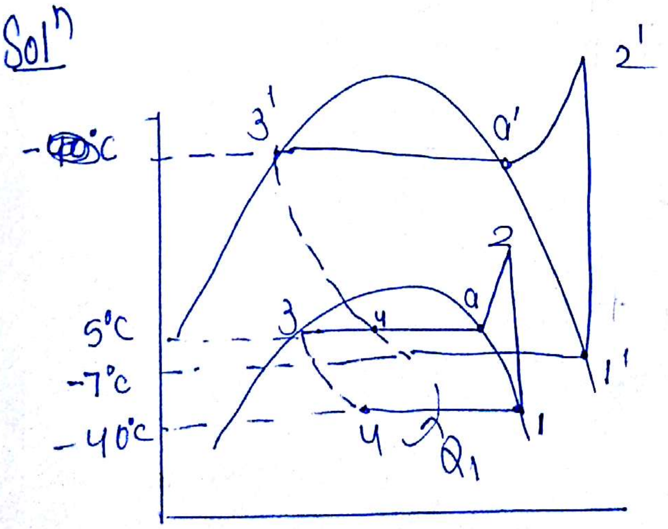
$$\boxed{COP = \frac{COP_1 \cdot COP_2}{1 + COP_1 + COP_2}}$$

Q. A cascade refrigeration system of 100 TR capacity used NH_3 & CO_2 The evoparating & Condensing temp. of CO_2 are $-40^\circ C$ and $5^\circ C$ respectevely. The evaporating temp. for NH_3 is $-7^\circ C$ Power supplied to NH_3 Compressor is 96.5 kW Both CO_2 and NH_3 cycles are simple VC cycles. Calculate
(i) Mass flow rate of refrigerant CO_2 (kg/s)
(ii) COP of the ref. system.

For CO_2 $C_{pv} = 0.85$ kJ/kgK

t_s(°C)	P(bar)	h_f	h_g	s_f	s_g
−40°C	10.05	332.7	652.8	3.8531	5.2262
5°C	39.7	431.0	649.8	4.2231	5.0037

Sol^n



$Q_1 = R.E. = 100$ TR

$R.E. = 351.67$ kW

$h_1 = 652.8$ kJ/kg.

$h_3 = 431.$ kJ/kg $= h_4$

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

$351.67 = \dot{m}(652.8 - 431)$

$\dot{m} = 1.58$ kJ/s

$$(COP)_1 = \frac{h_1 - h_4}{h_2 - h_1}$$

$$h_2 = h_a + C_{pv}(T_2 - T_a)$$

$$s_2 = s_1$$

$$s_1 = s_a + C_{pv} \ln \frac{T_2}{T_a}$$

$$\cancel{5.0037} = $$
$$5.2262 = 5.0037 + 0.85 \ln \frac{T_2}{278}$$

$$T_2 = \cancel{374.17\ K}\ 361.18\ K$$

$$h_2 = 649.8 + 0.85(\cancel{374.17}\ 361.18 - 278)$$

$$\cancel{h_2 = 712\ kJ/kg} \quad \underline{h_2 = 720.503\ k}$$

$$(COP)_1 = \frac{\cancel{625}.652.8 - 431}{\cancel{702} \cancel{701}\ 720.50 - 652.8} = \cancel{3.74}\ 3.27$$

$$\frac{Q_1}{W_1} = 3.27 \Rightarrow W_1 = \frac{1.58(652.8 - 431)}{\cancel{3.74}\ 3.27}$$

$$\cancel{W_1 = 93.70}\ kW. \quad W_1 = 106.97$$

$$W_2 = 96.5\ kW$$

$$\boxed{COP = \frac{Q_1}{W_1 + W_2}} = \frac{1.58(652.8 - 431)}{203.47}$$

$$COP = 1.72 \quad Ans$$