Lecture Thirteen

Ton of refrigeration (TR)

Is the amount of heat absorbed by one U.S. ton of ice melting over a period of 24 hours.

TR = 2000 Ib *144 Btu/Ib =12000 Btu/hr.

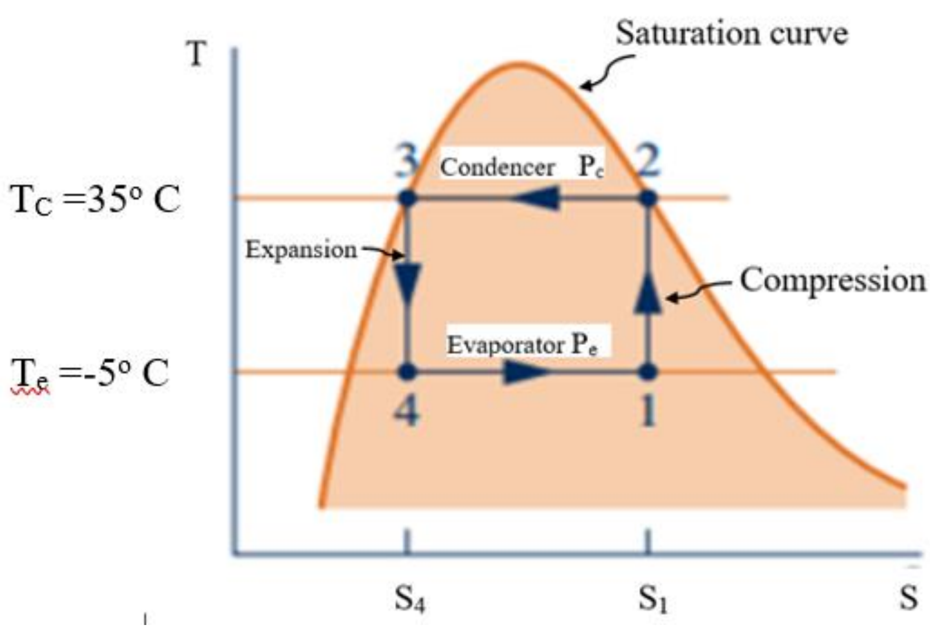
=12000/60 =200 Btu/min.

∴TR= the removal of heat at the rate of 12000 Btu/hr. or 200Btu/min.

In SI units TR=12000*0.293=3516 watt. =3.516 kw.

e.g.: A Carnot refrigerator operates at an evaporator temperature of (-5°C) and a condenser temperature of (35°C). for a refrigerating effect of 15kw calculate: a- the $cop)_c$ & $cop)_h$. b- the W.D. and the mass flowrate of the refrigerant if the refrigerant used is R-22 (refrigerant – 22).

Sol:



a- $Cop)_c = \frac{T_e}{T_c - T_e} = \frac{273+(-5)}{(273+35)-(273+(-5))} = \frac{268}{40} = 6.7$

$Cop)_h = Cop)_c + 1 = 6.7 + 1 = 7.7$

Or $Cop)_h = \frac{T_c}{T_c - T_e} = \frac{273+35}{(273+35)-(273+(-5))} = \frac{268}{40} = 7.7$

b- $W = \frac{X}{Cop)_c} = \frac{15}{6.7} = 2.24$ kw.

Or $W = \frac{2.24}{15} = 0.15$ kw/kw of refrigeration.

Refrigeration effect (Q_{in}) = $T_e(S_1 - S_4) = T_e(S_2 - S_3)$

From tables:

S_2=1.705kJ/kg°K. (saturated vapour at 35°C).

S_3=1.146kJ/kg°K. (saturated liquid at 35°C).

Q

$Q_{ref.}$ = (273+(-5))[1.705-1.146] =149.812 kJ/kg.

$m = \frac{X}{Q_{ref}} = \frac{15\ kJ/sec}{149.812 kJ/kg}$ =0.100125kg/sec.

3- Conditions for maximum coefficient of performance:

Remember that $W = \frac{X}{Cop}$.

∴ The higher the Cop, the lower the work required. Clearly, for any two evaporating & condensing temperatures, the Carnot refrigerator is the most efficient for absents of irreversibility.

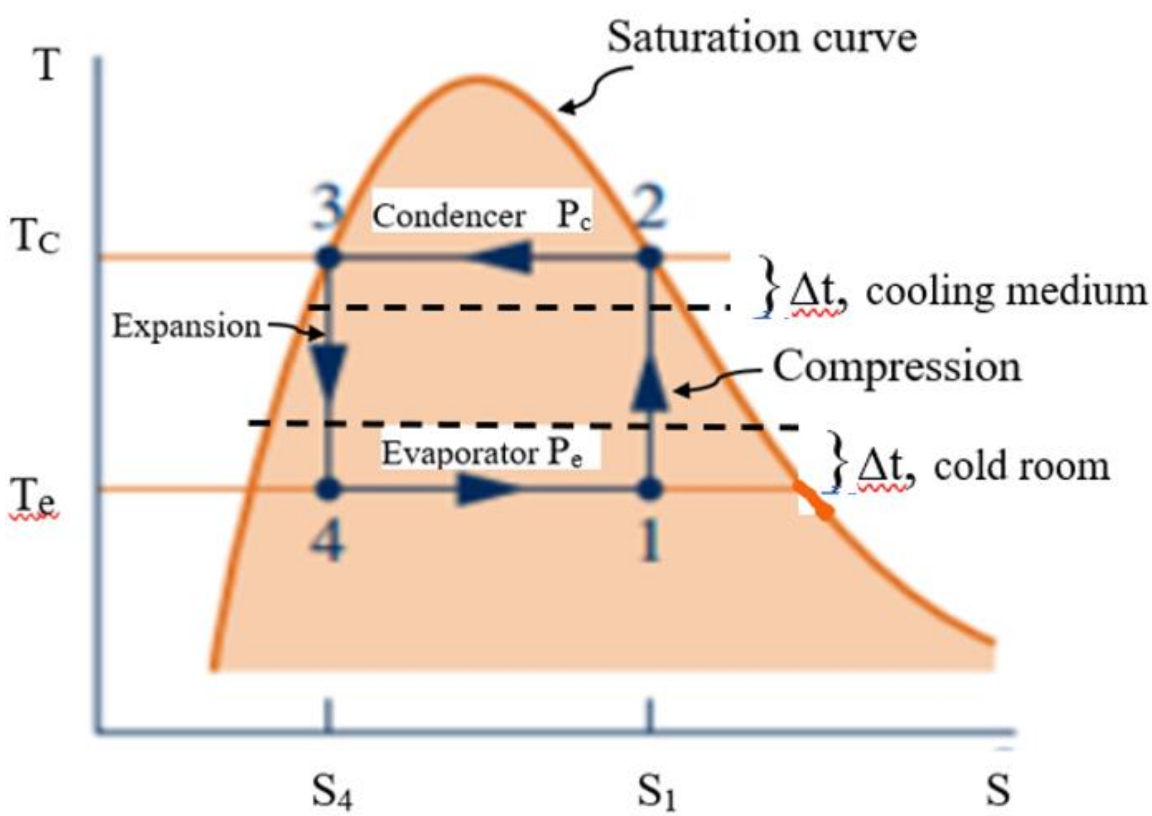
Now $Cop = \frac{T_e}{T_c - T_e}$.

To maximize Cop either maximize T_e holding T_c constant or minimize T_c holding T_e constant. i.e. the difference (T_c-T_e) should be made as small as possible.

However, practical limitations impose limits on either T_e or T_c or both. Also, heat transfer between evaporator & the cooling medium takes place with a temperature difference → irreversible process.

So, Carnot refrigerator is most efficient between any two temperatures &(T_c-T_e) should be kept to minimum. Also, (Δt) must be minimized by increasing the heat transfer area(A) or the overall heat transfer coefficient (U): [$Q=UA\Delta t$].

∴ Practical limitations on (U & A) together with the selection of (T_c& T_e) dictate the limits on the Cop.



4- standard vapour compression cycle (Ideal): -

Two main draws back with the Carnot refrigerator.

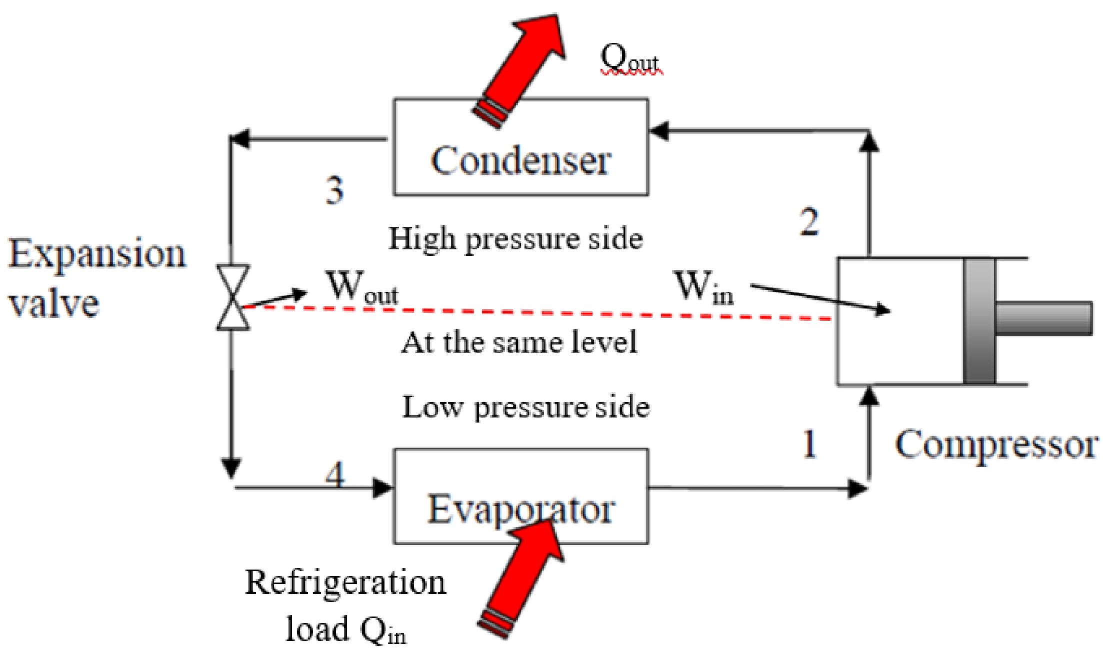
i- Wet compression.

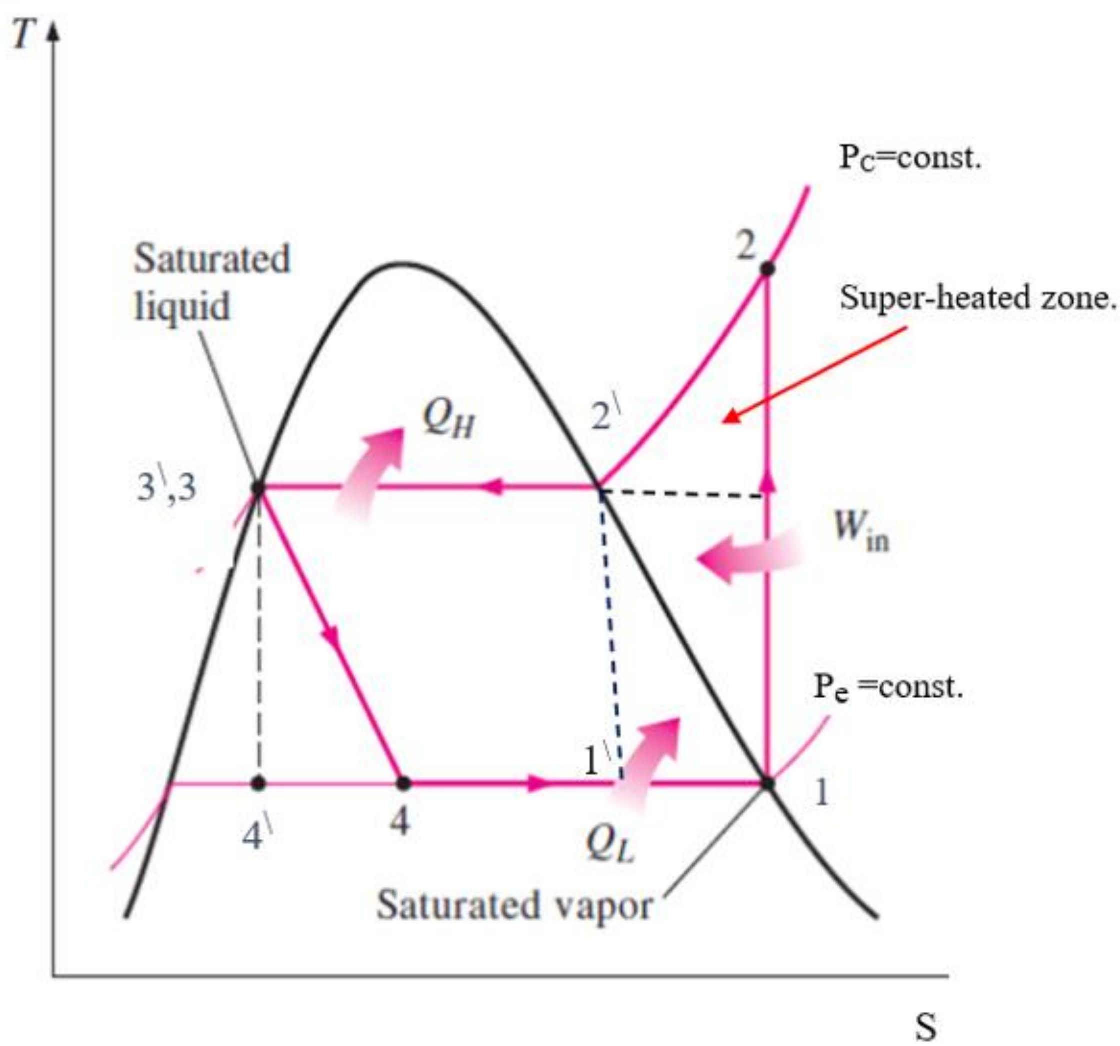
ii- Isentropic expansion (work helps drive the compressor).

- Wet compression damages the compressor & final stage of refrigerant is an average of mixture of super-heated vapour & liquid.
- Expansion machine is impractical & the work obtained is minimal--- use a throttling device to reduce the pressure--- So process is irreversible, i.e. entropy increases.

  1\ - 2\- 3\ - 4\ Carnot refrigerator.

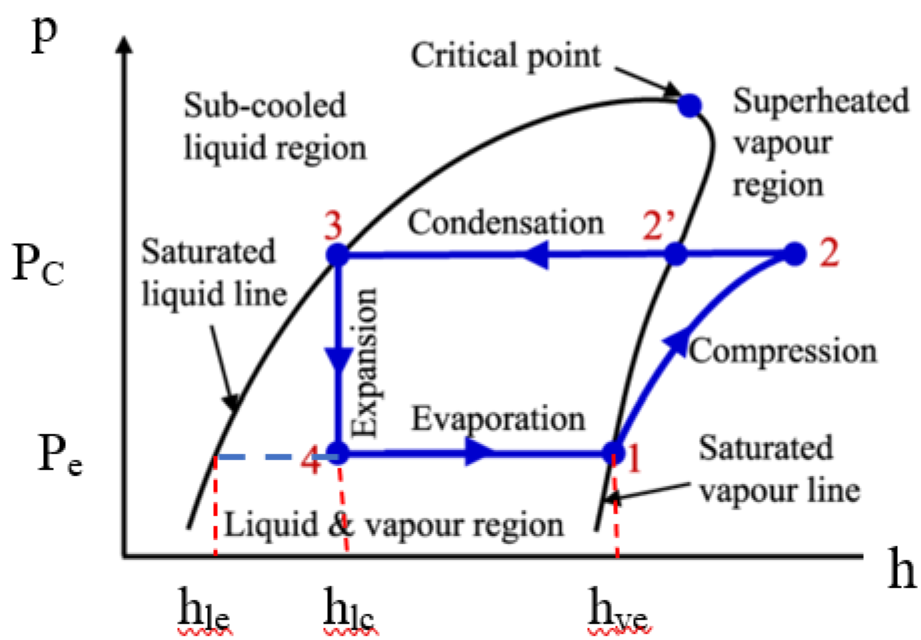
  1- 2- 3- 4 Ideal vapour compression refrigerator.





Every vapour compression system is composed of four essential parts.

1. Compressor (isentropic compression).
2. Condenser (constant pressure heat rejection).
3. Expansion valve (constant enthalpy expansion).
4. Evaporator (constant pressure heat addition).



Standard (ideal) vapour compression cycle.

Where: h_{ve}= vapour enthalpy at evaporator temperature (T_e).

h_{le}= liquid enthalpy at evaporator temperature (T_e).

h_{lc} = liquid enthalpy at condenser temperature (T_c).