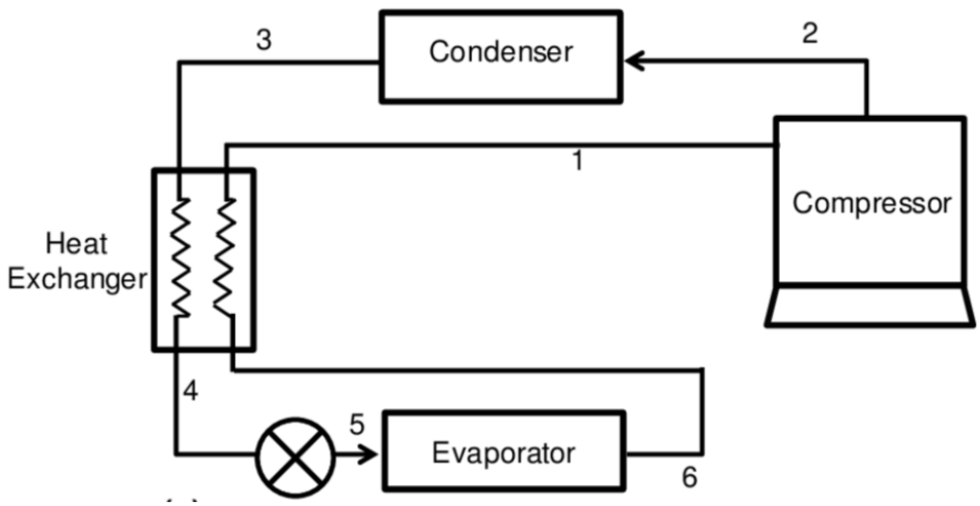
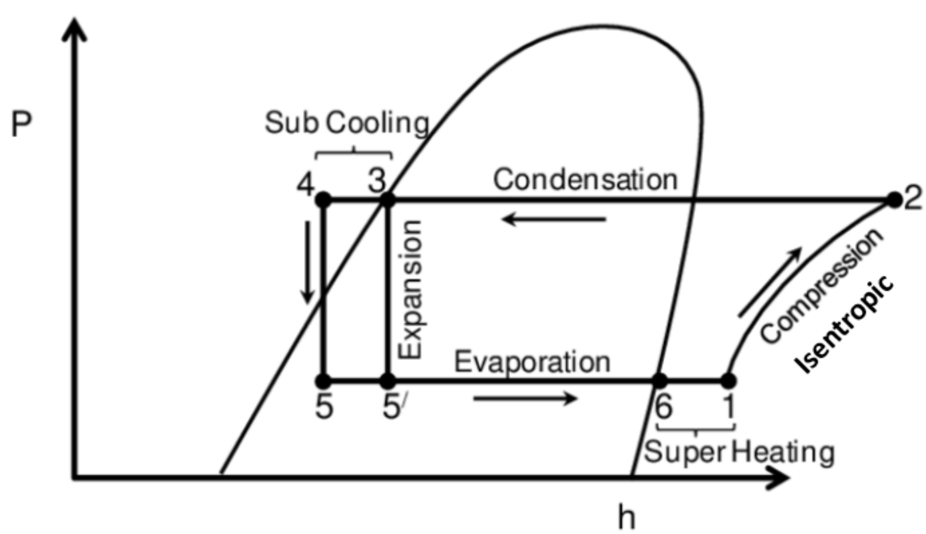
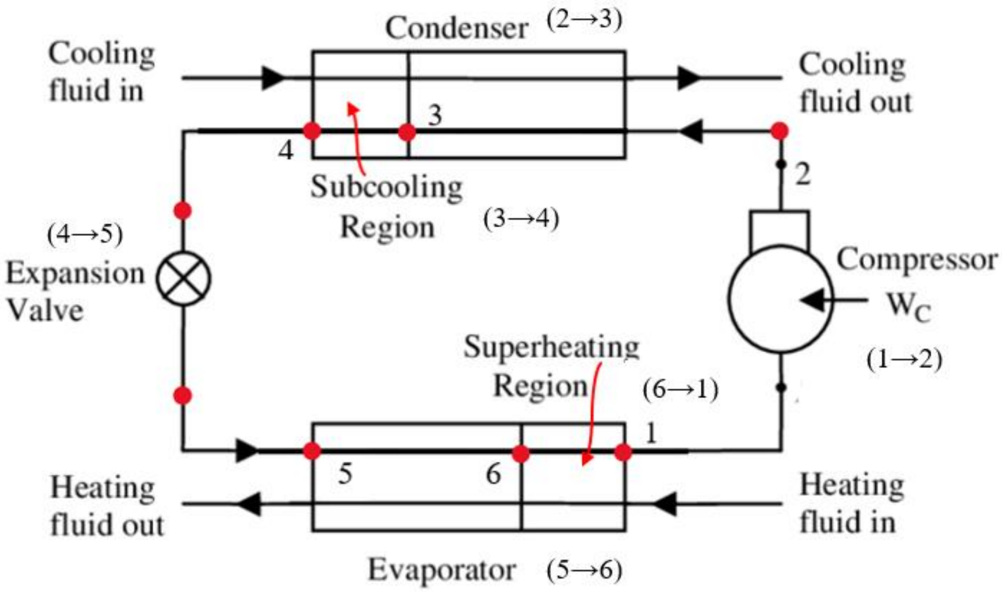
Lecture sixteen

6- Liquid subcooling and vapour superheating:

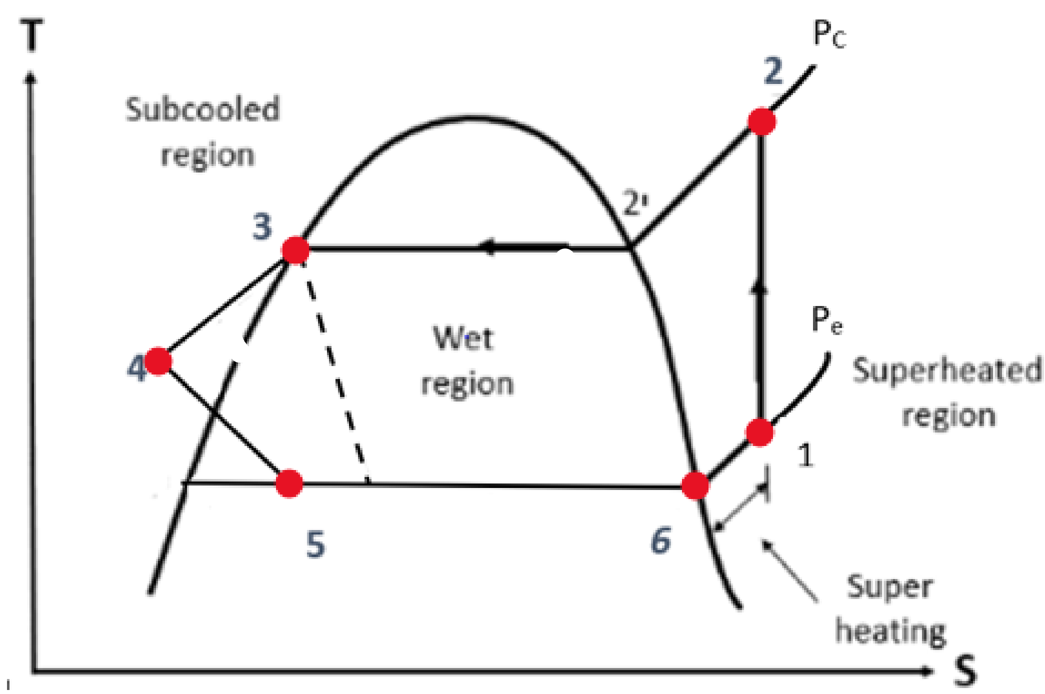
The refrigerant vapor out of the evaporator (6→1) is used to cool the saturated liquid leaving the condenser (3→4). Thus, liquid entering evaporator is subcooled & vapour entering the compressor is superheated.







Subcooled and superheated refrigeration cycle.



*Saturated liquid is cooled from (3 to 4) by saturated vapour which heates from (6 to 1). i.e.:

$h_3-h_4 = h_1-h_6$ [heat exchanger only).

*refrigerating effect = $h_6-h_5 = h_1-h_3$ (for heat exchanger only).

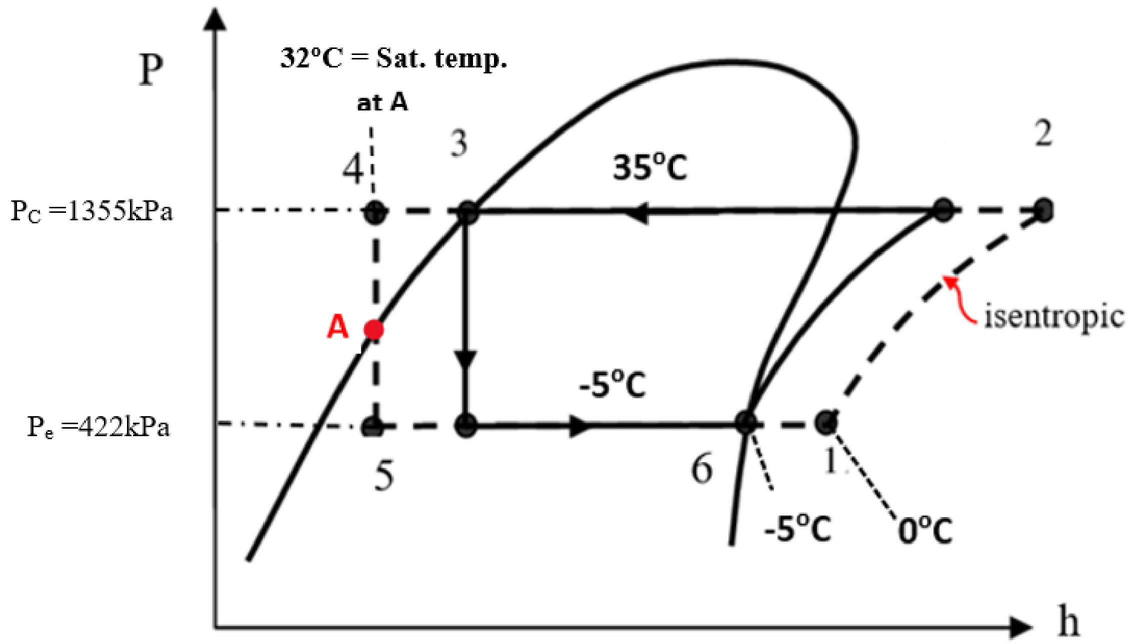
Heat rejected at condenser = h_2-h_3 (for heat exchanger only).

- liquid subcooling & vapour superheating can also be achieved without a heat exchanger.
  Superheating is done in the evaporator by adjusting the mass flowrate, subcooling is done in the condenser by increasing heat transfer (heat rejected). Then without heat exchanger:
  $Q_{ref.} = h_1-h_5$
  $Q_{conderser} = h_2-h_4$

Using the heat exchanger, the refrigeration effect is improved but the compressor work is increased since ($\upsilon_1 > \upsilon_6$). Main advantage is to ensure only vapour enters the compressor. This method is employed mainly in vapour compression machines that employ R -12 & R-22 with increased capacity.

e.g: A system using R-22 produces 15 kw of refrigeration at an evaporator temperature of -5°C and condenser temperature of 35°C. A liquid to vapour heat exchanger is used where the vapour is superheated 5°C before entering the compressor. Determine: a) piston displacement, ($\dot{\upsilon}$). b) $Q_{cond.}$, c) f.
d)W if compression is isentropic. e) Cop.

Sol:



From tables for R-22.

h_6=403.15 kJ/kg. (Saturated vapour at -5°C).

P_e=422 kP_a. (Saturated vapour at -5°C).

h_3 =243.1 kJ/kg . (Saturated liquid at 35°C).

P_c=1355 $kP_{a.}$. (Saturated liquid at 35°C).

From chart:

h_1=407kJ/kg (at p_e & 0°C).

T_A=32°C (Saturated temperature at point A) [note: obtained from knowing h_4, which equal to h_f (from table)]. As follows:

$h_1-h_6=h_3-h_4$

$h_4=h_3-(h_1-h_6)=(243.1-(407-403.15) = 239.25\text{kJ/kg} = h_5 \rightarrow t_4=32°C$ (from table).

$T_A = t_4 = 32^oC$. (Vertical temperature line 4→A in the subcooled region until saturation line).

a) $\dot{\upsilon} = \dot{m}.\upsilon_1$, $\dot{m} = \frac{X}{Q_{ref}} = \frac{15}{h_6 - h_5} = \frac{15}{(403.15-239.25)} = 0.0915$ kg/sec.

$\upsilon_1 = 0.057\ m^3/kg$ from chart at point 1. ($h_5 = h_4 = 239.25$kJ/kg).

$\dot{\upsilon} = \frac{X}{Q_{ref}}\ \upsilon_1 = \frac{15}{h_6 - h_5} * \upsilon_1 = 0.0915*0.057 = 0.005216 m^3/sec$.

b) $Q_{out} = \dot{m}(h_2 - h_3)$

$h_2 = 439$ kJ/kg, from chart at point 2, (from 1→2 constant entropy line).

$Q_{out} = 0.0915*(439-243.1) = 17.924$ kw.

c) $h_4 = h_5 = f*h_6 + (1-f)*h_{le}$

$h_{le} = 194.15$ kJ/kg (from table at -5^oC).

$f = \frac{h_5 - h_{le}}{h_6 - h_{le}} = \frac{239.25-194.15}{403.15-194.15} = 0.215 = 21.5\%$.

d) $w = \dot{m}(h_2 - h_1) = 0.0915*(439-407) = 2.928$kw.

or $W = Q_{out} - Q_{in} = 17.924 - 15 = 2.924$ kw.

e) $Cop = \frac{X}{W} = \frac{15}{2.924} = 5.13$ (decreased in comparation with a previous example as the work increased to pump more refrigerant).

$Cop = \frac{(h_6 - h_5)\dot{m}}{(h_2 - h_1)\dot{m}}$