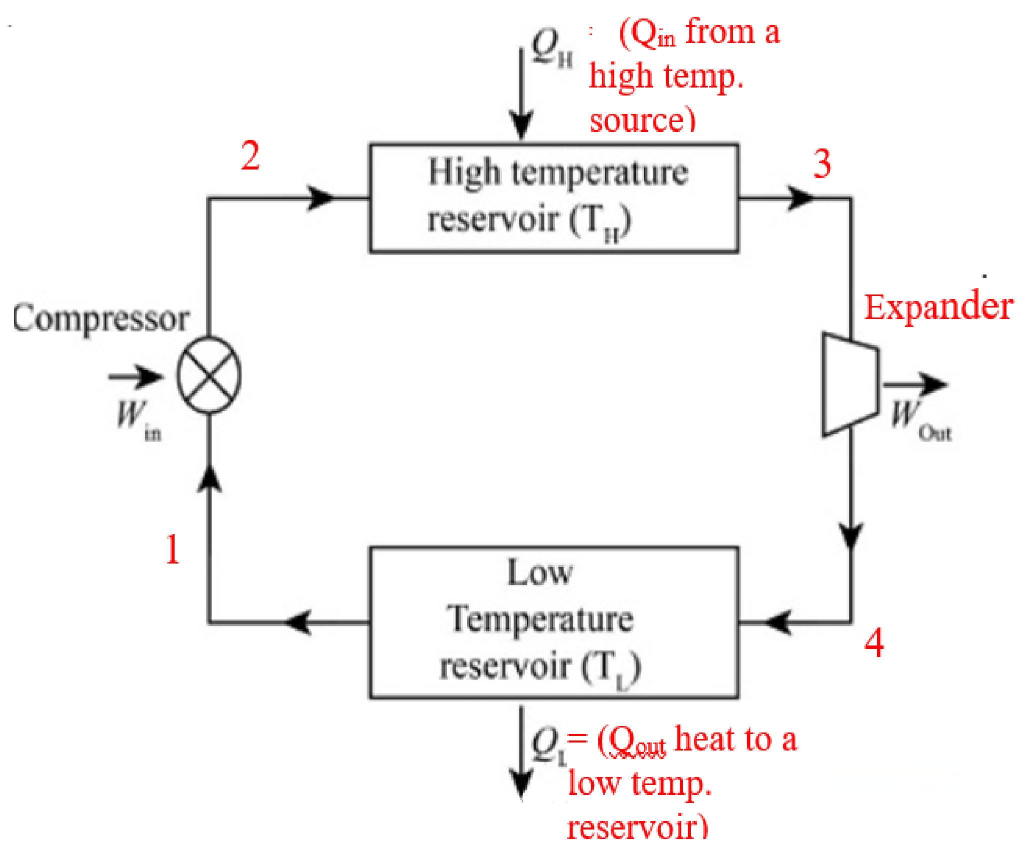
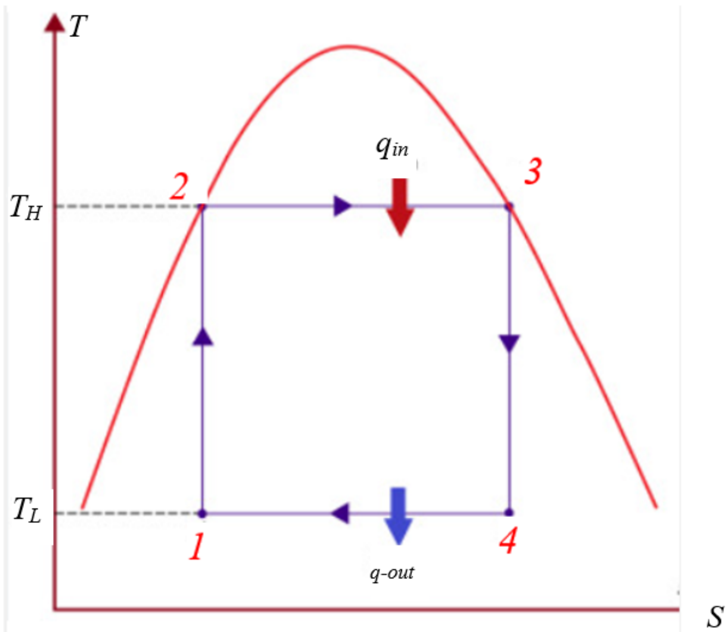
Lecture twelve

2-The Carnot refrigeration cycle. Recall the Carnot heat engine.





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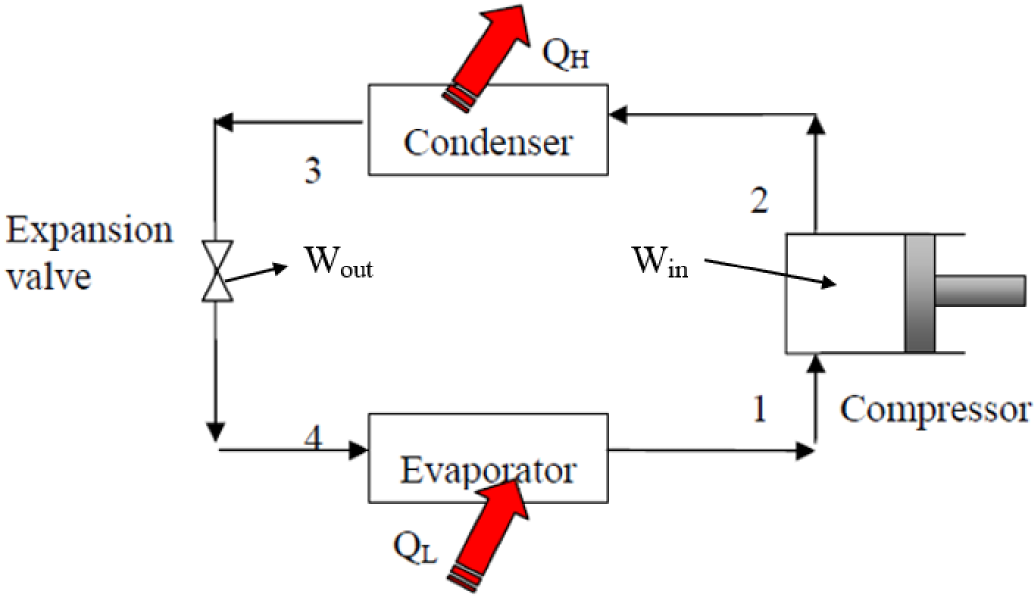
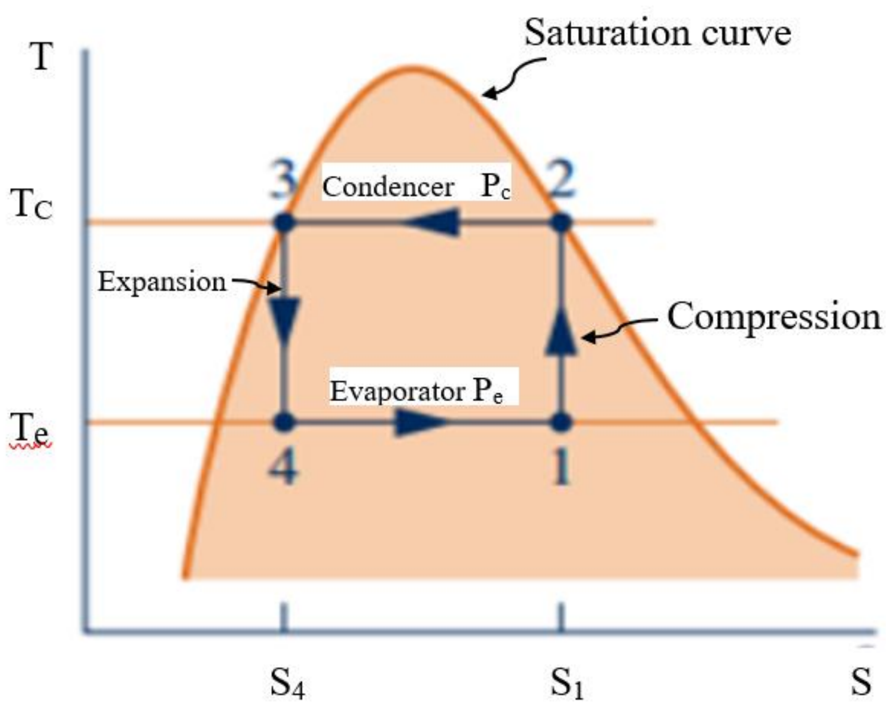
if we were to reverse the cycle such that instead of expansion we have compression, instead of compression we have expansion and transfer is also reversed. We obtain the carnot refregerator.


QH
Condenser
3
2
Expansion valve
Wout
Win
1
Compressor
4
Evaporator
QL


Saturation curve
T
TC
Te
3
Condencer Pc
2
Expansion
Compression
Evaporator Pe
4
1
S4
S1
S

Refrigeration cycle.

- Process (1-2): isentropic compression of refrigerant from P_e to P_c, temperature rises from T_e to T_c. [The small amount of liquid at point (1) evaporates]. The refrigerant leaves the compressor as a saturated vapour. Process (1-2) is reversible adiabatic compression, i.e. (isentropic), (work is done by an external source).
- Process (2-3): saturated refrigerant vapour is liquified at constant pressure P_c and constant temperature T_c by the removal of latent heat of vaporization by an external cooling agent.
- Process (3-4): saturated liquid leaves the condenser & expands isentropically. The pressure drops from P_c to P_e & the temperature from T_c to T_e. Cooling the liquid refrigerant from (T_c to Te) is achieved by the vaporization of a small amount of liquid known as (flash gas). Thus, we are inside the phase envelope.
- Process (4-1)- the refrigerant evaporates at a constant temperature (T_e)& constant pressure (P_e) by absorbing heat from the surrounding medium. Thus, cooling the surrounding medium, supplies the latent heat of vaporization and as a result it is cooled (refrigerated).

Area of T-S diagram represent heat.

Heat received at the evaporator (Refrigeration Effect).

$$Q_{in} = T_e(S_1 - S_4) \qquad (1).$$

Heat rejected at the condenser.

$$Q_{out} = T_c(S_1 - S_4) \qquad (2).$$

Net work done: $W_{net} = Q_{out} - Q_{in}$

$$= T_c(S_1 - S_4) - T_e(S_1 - S_4)$$

$$\therefore W_{net} = (T_c - T_e)(S_1 - S_4) \qquad (3).$$

Define the coefficient of performance:

C.O.P.=The ratio of the energy received at the evaporator to the energy supplied to the machine.

i.e. $$C.O.P.)_c = \frac{T_e(S_1 - S_4)}{(T_c - T_e)(S_1 - S_4)} = \frac{Refrigeration\ effect}{Net\ Work}$$

$$=\frac{T_e}{(T_{c-T_e})} \quad \text{(for Carnot Ref. only).} \qquad (4).$$

The refrigerator can also be used to heat up a space by the heat rejected at the condenser. In this case the useful energy obtained is the heating effect rather than the cooling effect. In such a case the machine is called a heat pump.

$$C.O.P.)_h=\frac{heat\ delivered}{Net\ Work\ done}=\frac{T_c(S_1-S_4)}{(T_{c-T_e})(S_1-S_4)}$$

$$=\frac{T_c}{(T_{c-T_e})} \quad \text{(for Carnot heat pump only).} \qquad (5).$$

Add to the numerator (T_e-T_c).

$$(COP)_h=\frac{T_c+T_e-T_e}{T_c-T_e}=\frac{T_c-T_e}{T_c-T_e}+\frac{T_e}{T_c-T_e}=1+(COP)_c$$

$$(COP)_h=(COP)_c+1 \quad \text{(for Carnot only).} \qquad (6).$$

For a certain amount of refrigerating effect say (X) (kw).

$$Cop=\frac{X}{W} \quad \text{or} \quad W=\frac{X}{Cop} \ \text{kw} \qquad (7).$$

For 1kw of refrigeration. $W=\frac{1}{Cop}$ kw/kw of refrigeration.