operation each year.

CO_2: This refrigerant is sometimes used for direct-contact freezing of food. Its high condensing pressure usually limits its application to the low temp side of a cascade system where a different operates in high-temp suction.

R-11: Along with R-113 this refrigerant is popular for centrifugal compressor systems.

R-12: This refrigerant is used primarily with reciprocating compressors for service in domestic refrigeration appliances and in automotive air conditioners.

R-22: Because of smaller and lower cost compressor can be used with R-12, this refrigerant has taken over many air conditioning applications from R-12.

R-502 :

This is one of the newer refrigerants, with some of the advantages of R22 but with the further advantage of better behaviour with oil and lower Compressor discharge tempr than refrigerant R-22.

* The standard Comparison of refrigerants as used in refrigeration industry is based on an evaporator tempr of -15°C and Condensing tempr of +30°C.

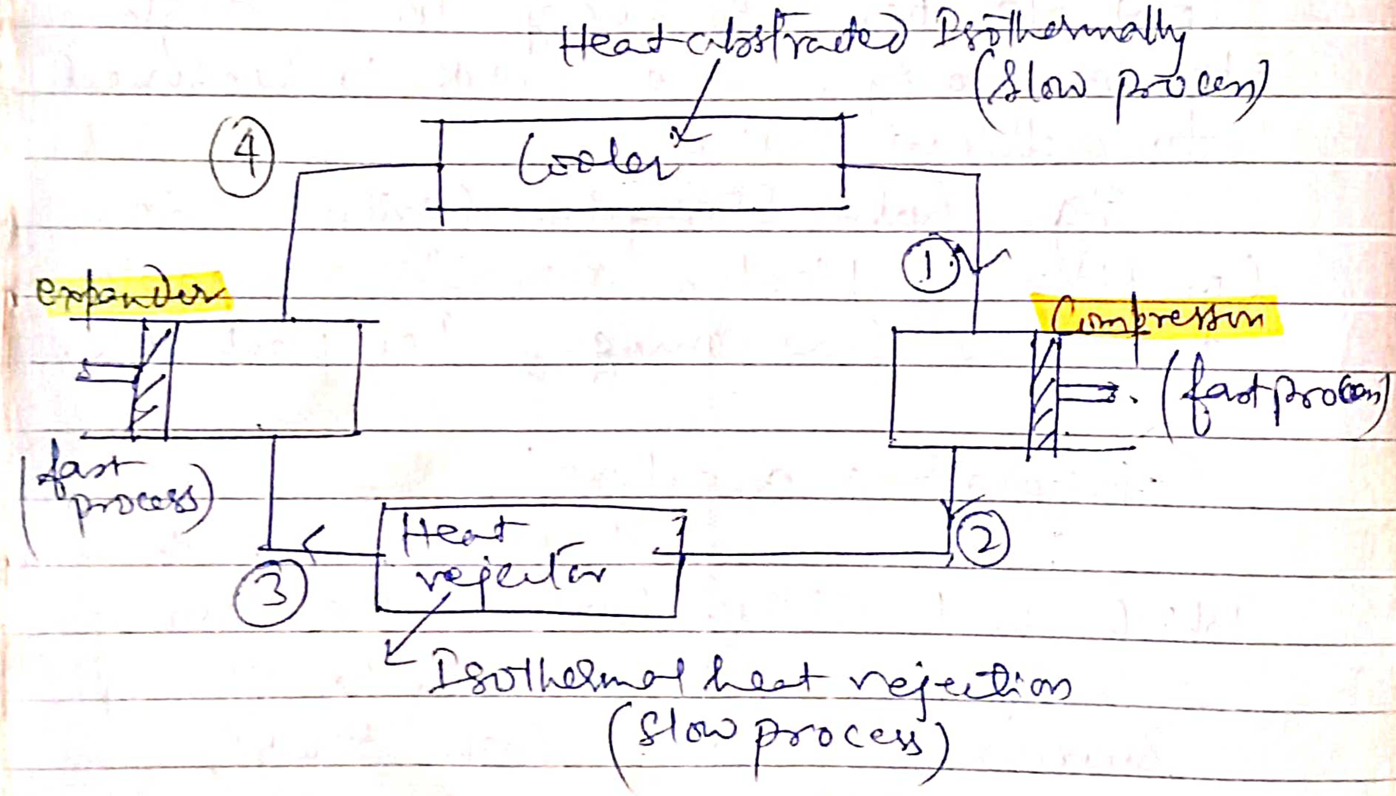
There are essentially two categories of thermal plants.
These are:
(i) Thermal power plant or work producing plant (or heat engines). Heat engines lead to the conversion of heat to work.
(ii) Refrigerator/ heat pump plants or work consuming plants.
The objective of work consuming plants, actually, is to lead to the flow of heat from a low temperature body to a high temp body. The work to consumed to achieve this.
eg. Cold storages, Central air conditioning plants, Domestic refrigerator, Room air conditioninger, Ice plants etc.

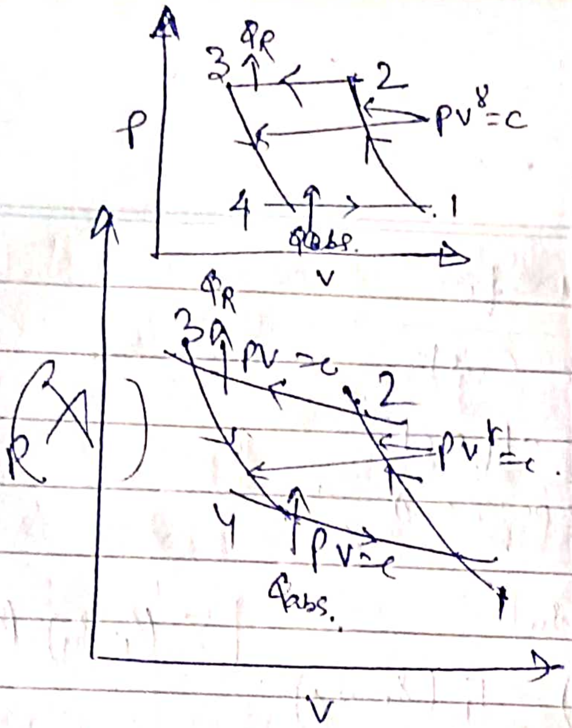
Refrigerating machine:
It is a device which will either cool or maintain a body at a lower temperature to the surroundings which is at high temp.

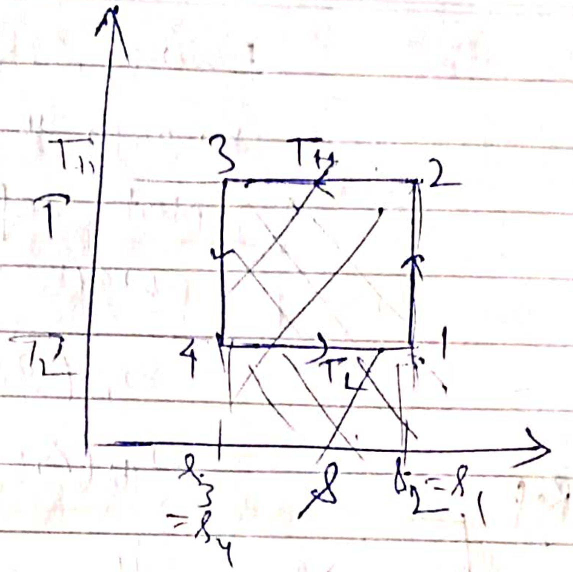
Energy ratio or Coefficient of performance :

The performance of a heat engine is described by its thermal efficiency. The performance of a refrigerating machine or a heat pump is expressed by the ratio of useful heat to work, called the energy ratio or coefficient of performance (C.O.P).

Reversed Carnot Cycle







Process 1-2: Isentropic Compression. No heat transfer.

Process 2-3: Isothermal heat rejection.
$= T_H (s_2 - s_3)$

Process 3-4: Isentropic expansion. No heat transfer.

Process 4-1:
Isothermal heat abstracted.
(Net refrigerating effect)
$= T_L (s_1 - s_4)$

Work required = Heat rejected − Heat abstracted
$= T_H (s_2 - s_3) - T_L (s_1 - s_4)$

$C.O.P = \frac{\text{output}}{\text{Input}}$

$$= \frac{\text{Energy sought for}}{\text{Energy that Costs}}$$

$$= \frac{\text{Net ref. effect}}{\text{work required}}$$

$$= \frac{T_L(s_1 - s_4)}{T_H(s_2 - s_3) - T_L(s_1 - s_4)} \quad [\because (s_1 - s_4) = (s_2 - s_3)]$$

Ref

$$C.O.P = \frac{T_L}{T_H - T_L}$$

Heat pump:

$$C.O.P = \frac{\text{Output}}{\text{Input}} = \frac{\text{Heating effect}}{\text{work required}}$$

$$= \frac{\text{Heat rejected}}{\text{work required}}$$

$$= \frac{T_H(s_2 - s_3)}{T_H(s_2 - s_3) - T_L(s_1 - s_4)}$$

Heat pump

$$C.O.P = \frac{T_H}{T_H - T_L}$$

$$(C.O.P)_{H.P} - (C.O.P)_{ref.} = 1$$

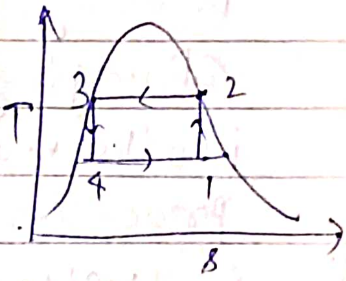
To obtain maximum C.O.P in any application,

(i) the cold body tempr T_L should be as high as possible, and

(ii) the hot body temp' T_H should be as low as possible.

(*) Limitation of reversed Carnot cycle

① Vapour as a working substance:



In the reversed Carnot cycle with vapour as refrigerant, the isothermal process of condensation and evaporation are internally reversible process, and they are easily achievable in practice although there may be some problem in having only partial evaporation.

It is difficult to design an expander to handle a mixture of largely liquid and partly vapour.

Also, because of internal irreversibilities in the compressor and the expander, the actual COP of the cycle is very low.

(2) Gas as a working substance :

(i) Firstly, it is not possible to produce a device, in practice, which operates using isothermal process of heat absorption and rejection with gas as a working substance.

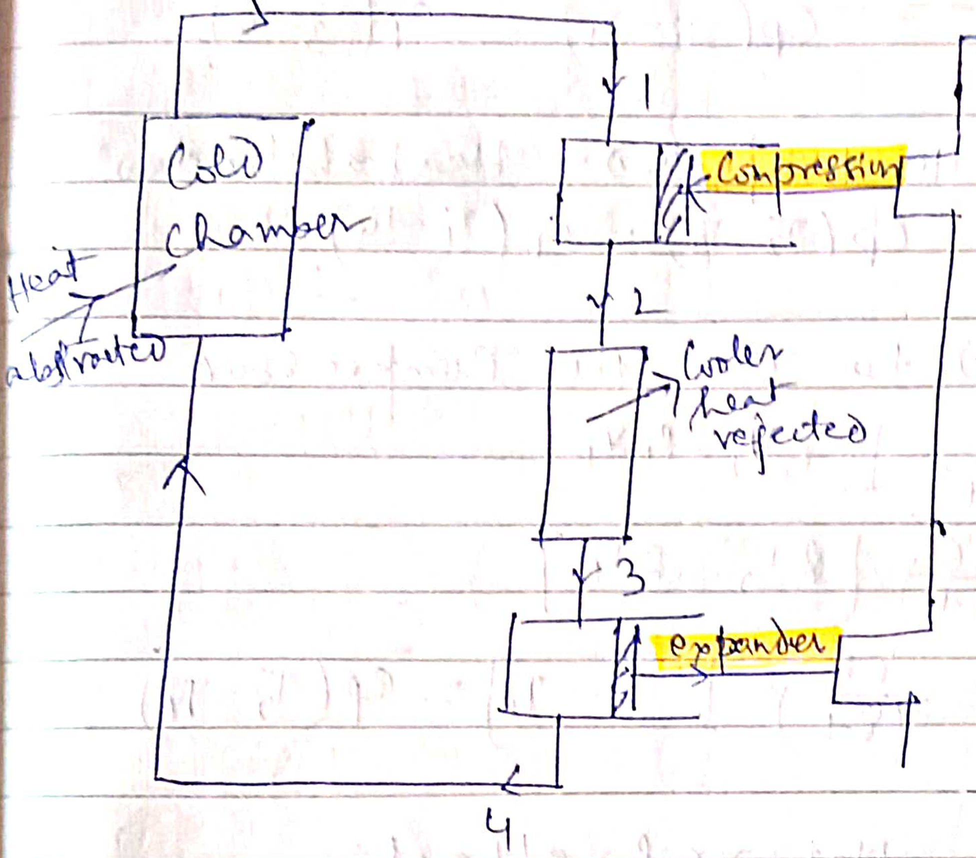
(ii) Secondly, the cycle on P-v diagram is very narrow since the volume is changing both during the reversible isothermal and reversible adiabatic processes. The Carnot P-v diagram is very thinner. As a result, the stroke volume of the cylinder is very large. The cycle; therefore, suffers from poor actual COP as a result of irreversibilities of the compressor and expander.

Note:

(i) Vapour compression refrigeration system works on reversed Carnot cycle.

(ii) Air refrigeration cycle works on Bell Coleman cycle.

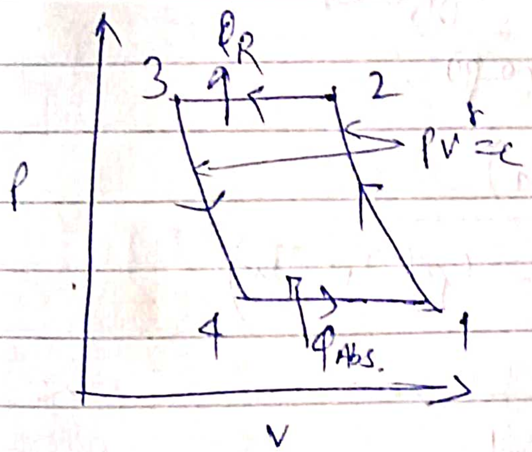
Bell Coleman Cycle

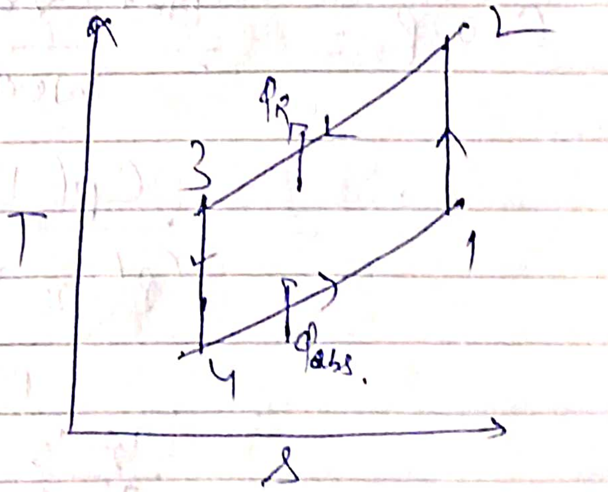


$h_1 + W_C = h_2$

$W_C = h_2 - h_1$

$= C_p(T_2 - T_1)$





Process 1-2 : Isentropic Compression. No heat transfer

Process 2-3 : Constant pressure heat rejected

$= C_p(T_2 - T_3)$

Process 3-4 : Isentropic expansion. No heat transfer.

Process 4-1 : Constant pressure heat abstraction

$= C_p(T_1 - T_4) =$ Net refrigerating effect

Work required = Compressor work − expander work

$= Cp(T_2 - T_1) - Cp(T_3 - T_4)$

or → Heat rejected − Heat abstracted

$= Cp(T_2 - T_3) - Cp(T_1 - T_4)$

[Work reqd. to run the Compressor

$$= \frac{\gamma}{(\gamma-1)}[P_2V_2 - P_1V_1]$$

$$= \left(\frac{\gamma}{\gamma-1}\right)[RT_2 - RT_1]$$

$$= \frac{\gamma R}{(\gamma-1)}[T_2 - T_1] = Cp(T_2 - T_1)$$

$$C.O.P = \frac{\text{Net. ref. effect}}{\text{Work reqd.}}$$

$$= \frac{Cp(T_1 - T_4)}{Cp(T_2 - T_3) - Cp(T_1 - T_4)}$$

$$= \frac{1}{\frac{T_2 - T_3}{T_1 - T_4} - 1}$$

1−2 :

$$\frac{T_1}{P_1^{\frac{\gamma-1}{\gamma}}} = \frac{T_2}{P_2^{\frac{\gamma-1}{\gamma}}} \text{ or } \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$$

3−4

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = r_p^{\frac{\gamma-1}{\gamma}}$$