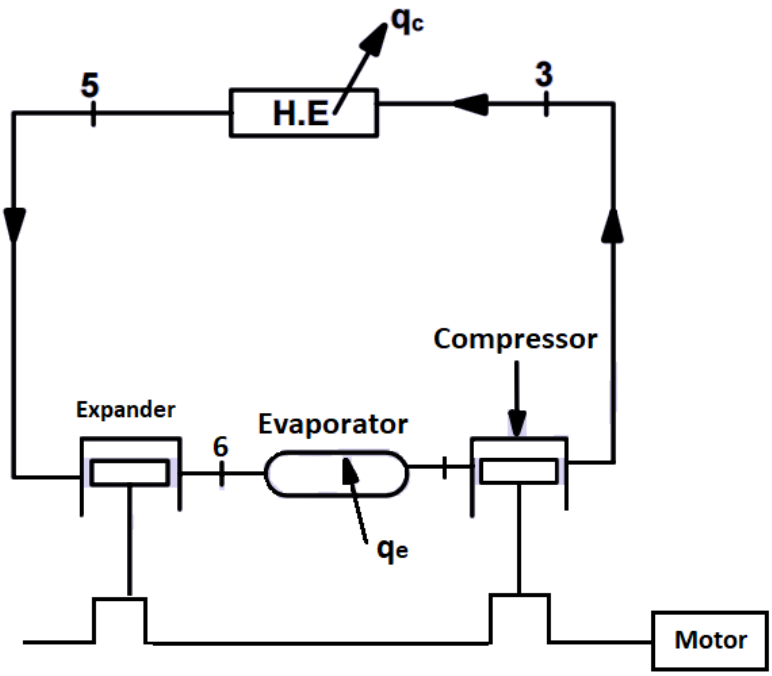
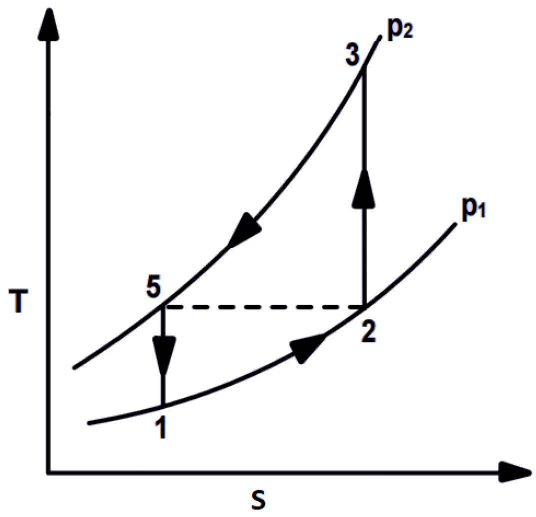
## 6.3 Air Refrigeration System And Bell-Coleman Cycle Or Reversed Brayton Cycle:




Air Refrigeration System




Air Refrigeration System

The components of the air refrigeration system are shown in Fig.6.3(a). In this system, air is taken into the compressor from atmosphere and compressed. The hot compressed air is cooled in heat exchanger upto the atmospheric temperature (in ideal conditions). The cooled air is then expanded in an expander. The temperature of the air coming out from the expander is below the atmospheric temperature due to isentropic expansion. The low temperature air coming out from the expander enters into the evaporator and absorbs the heat. The cycle is repeated again. The working of airrefrigeration cycle is represented on p-v and T-s diagrams in Fig.6.3(b) and (c). Process 1-2 represents the suction of air into the compressor. Process 2-3 represents the isentropic compression of air by the compressor. Process 3-5 represents the discharge of high pressure air from the compressor into the heat exchanger. The reduction in volume of air from v3 to v5 is due to the cooling of air in the heat exchanger. Process 5-6 represents the isentropic expansion of air in the expander. Process 6-2 represents the absorption of heat from the evaporator at constant pressure.

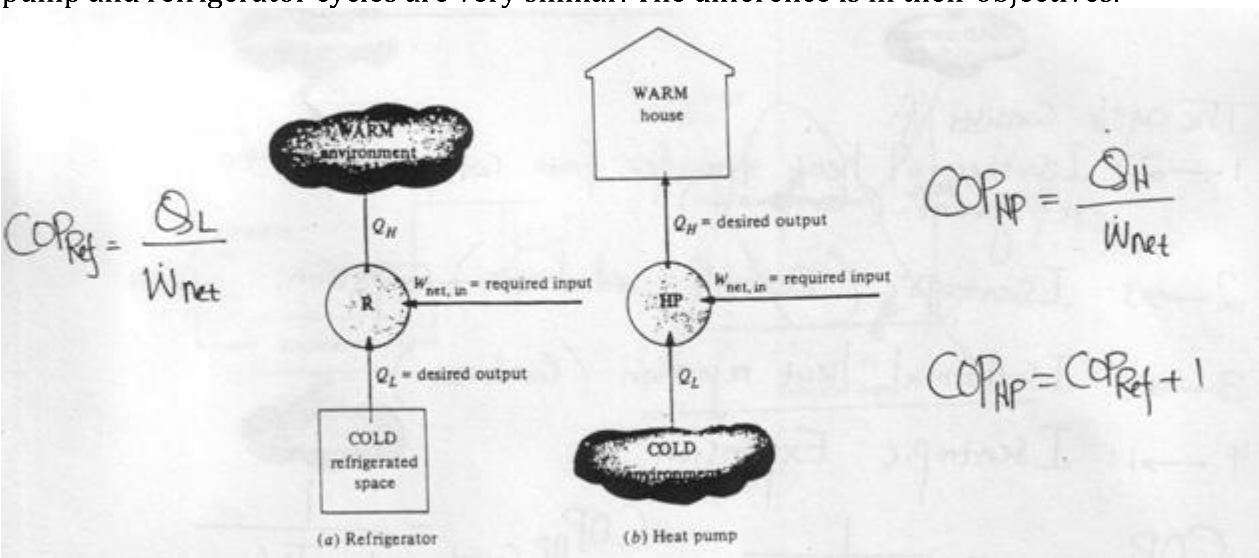
## Refrigeration Cycle

It is a well known fact that heat flows in the direction of decreasing temperature, i.e., from a high temperature region to a low temperature region.

But the reverse process (i.e. heat transfer from low to high temperature) cannot occur by itself (Claussius Definition of Second Law). This process requires a special device called Refrigerator.

## Refrigerator and heat pump

Another device which transfers heat from low to high temperature is a Heat Pump. Heat pump and refrigerator cycles are very similar. The difference is in their objectives.

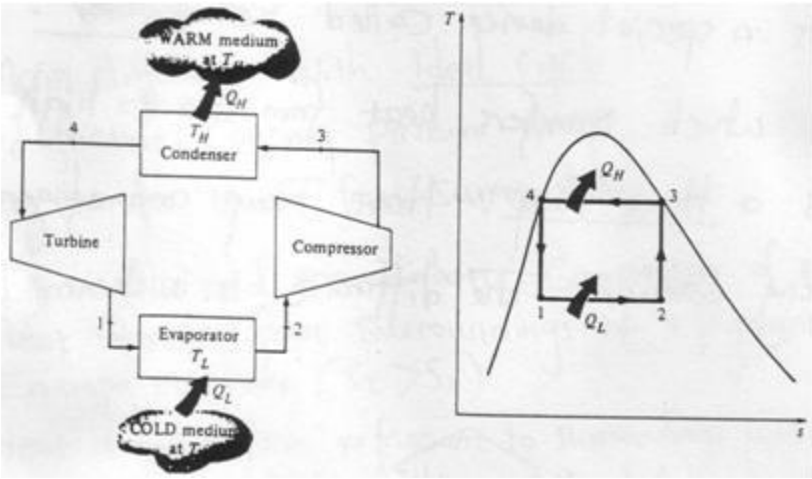


# Reversed Carnot Cycle

Carnot cycle is a totally reversible cycle which consists of two reversible isothermal processes and two isentropic processes.

It has the maximum efficiency for a given temperature limit.

Since it is a reversible cycle, all four processes can be reversed. This will reverse the direction of heat and work interactions, therefore producing a refrigeration cycles.




The cycle consists of

1-2: Isothermal heat transfer from cold medium to refrigerant (Evaporator)

2-3: Isentropic (Reversible adiabatic) compression

3-4: Isothermal heat rejection (condenser)

4-1: Isentropic Expansion

$$COP_{ref,Carnot} = \frac{1}{\frac{T_H}{T_L} - 1} \; \& \; COP_{HP,Carnot} = \frac{1}{1 - \frac{T_L}{T_H}}$$

Practical Difficulties of Carnot cycle

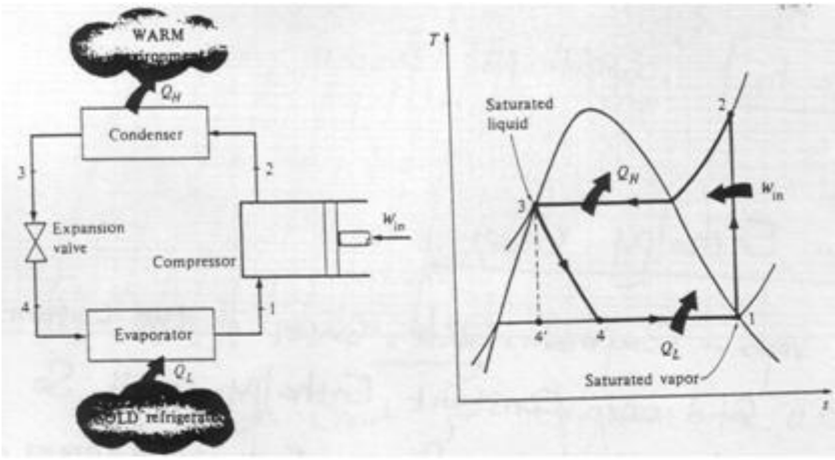
compression of two-phase mixture from 1-2

Expansion from 4-1 results in a very wet refrigerant, causing erosion of turbine blades.

# Ideal vapour compression refrigeration cycle

The impracticalities of the reversed Carnot Cycle can be eliminated by:

Vaporising the refrigerant completely before it is compressed replacing the turbine by a throttle valve by implication; isothermal processes are replaced by constant pressure processes.




The cycle consists of:

1-2: Isentropic compression

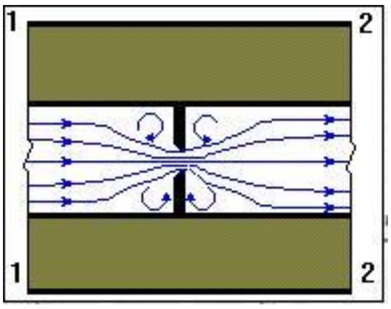
2-3: Constant pressure heat rejection (Condenser)

3-4: Adiabatic expansion in a throttling device

4-1: Constant pressure heat absorption (Evaporator)

# The throttling process

Imagine a steady flow process in wich a restriction is introduced into a flow line or pipe. As a result a pressure drop occurs. The process is irreversible.



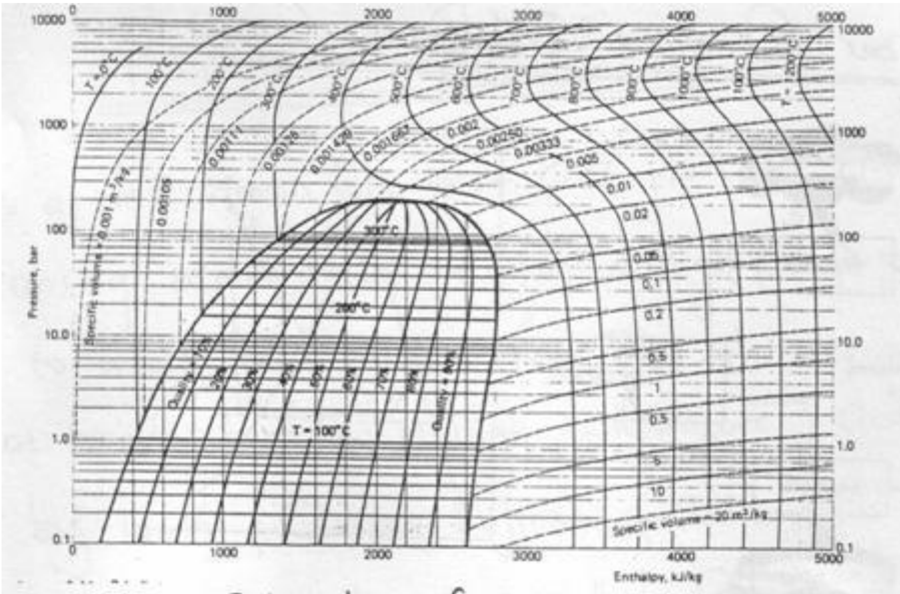

Applying SFEE:

$$\frac{\dot{Q}-\dot{W}}{\dot{m}} = (h_2 - h_1) + \frac{1}{2}\left(V_2^2 - V_1^2\right) + g(Z_2 - Z_1)$$

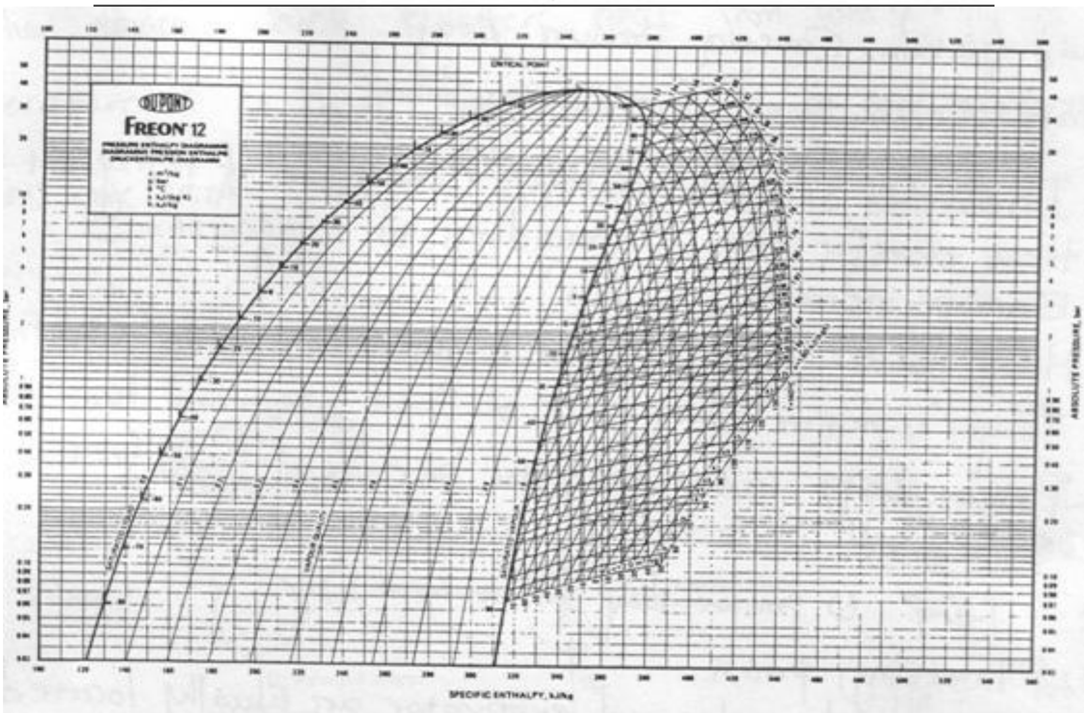
Therefore, *h2 = h1*

# Pressure-enthalpy chart

The ideal vapour compression cycle consists of two constant pressure process and one constant enthalpy process. So in preliminary cycle calculations pressure-enthalpy diagrams are particularly useful.




P_h Chart for Steam



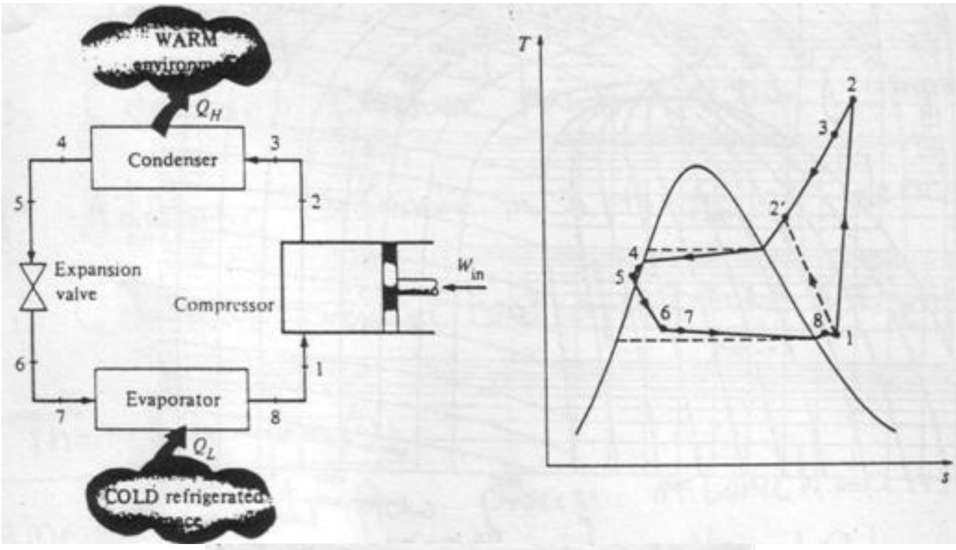

P-h chart for refrigerant 12.

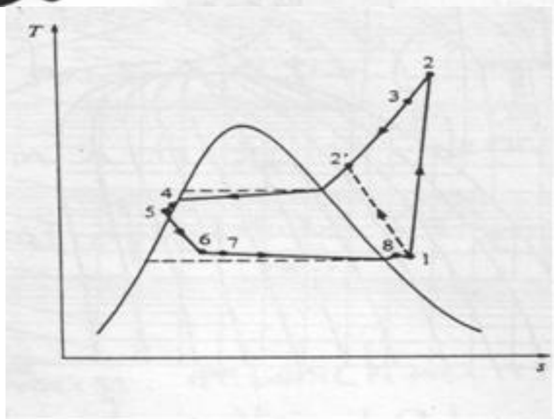
# Actual vapour-compression cycle

Two main differences with ideal cycle:

Fluid frictions, causing pressure drop

Heat transfer to or from surroundings.




1-2: Irreversible and non-adiabatic compression of refrigerant. Heat transfer from surroundings to refrigerant è Entropy increases (S2>S1).

1-2': Heat transfer from refrigerant to surroundings è S2'<S1 (preferred)

2-3: Temperature (& pressure) drop due to fluid friction and heat transfer

3-4: pressure drops in the condenser because of fluid friction

4-5: temperature and pressure drop (as in 2-3)

5-6: Throttling process

6-7: The throttle valve and evaporator are usually located very close to each other, so pressure drop in connecting line is small.