# Lecture eleven

## Refrigeration:

A process by which, for a given space, a lower temperature is provided than that which exists in an adjacent space. [achievement of a temperature below that of the immediate surrounding].

## -Use of refrigeration:

a- food preparations (dairy products, frozen products, cold stores, house hold refrigerators & freezers) … etc.

b- industrial processes:

1. separation of gases, air is separated into its constituents by cooling, liquifying & then fractional distillation.

2. Dehumidification of air.

3. drug industries.

4. removal of heat of reaction (exothermic reactions) …etc.

c- Industrial and comfort (Air Conditioning) (A/C).

i. Comfort A/C of offices, buildings, houses, hotels, ..etc.
ii. Industrial laboratories-clean comfortable atmosphere.
iii. Control of humidity (ex: photographic products, ….)
iv. Printing industry particularly color printing.

## Methods of refrigeration.

### a. Rise in temperature of a coolant:

The objects are brought into contact with a coolant (i.e. air, brine, chilled water or even solid).

The quantity of heat removed by the coolant for a constant pressure process or a steady flow process.

$Q=m.\,C_p\,.\,(T_h-T_c)$ Watt or Joule depending on (m) or ($\dot{m}$) (1).

m= mass rate of flow.

$C_p$= specific heat J/kg °K.
T= temperature °K.

b. Change of phase:

Heat absorbed in either melting, vaporization or sublimation can be utilized for refrigeration.

Q=m.L J or watt. (2).

M= mass of the coolant kg or kg/sec.

L= latent heat.

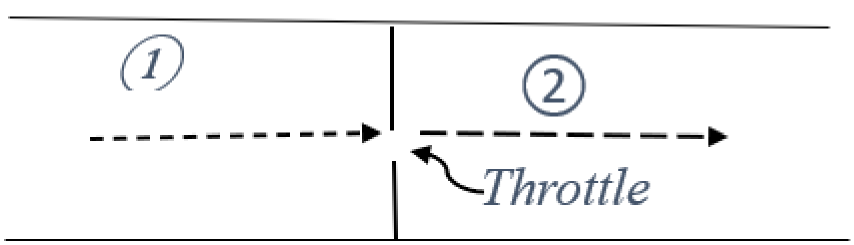
c. steady flow expansion of gas:

The steady flow energy equation (S. F. E. E.) is given by:

$$Q\text{-}W=\dot{m}[\tfrac{1}{2}(u_2^2-u_1^2)+(z_2-z_1)+(h_2\text{-}h_1)] \qquad (3).$$

Q- heat added, W- work, u- velocity, z-elevation & h- enthalpy.

1- Adiabatic throttling:




W=0, Q=0, Δu=0, Δz=0

$\therefore h_2=h_1$ from equation (3).

$C_p.(T_2-T_1)=0 \rightarrow (T_2=T_1)$, as $C_p \neq 0$.

i.e. no drop in temperature in an adiabatic throttling process of an ideal gas.

However, in an actual situation $p_2<p_1$. & $\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$.

For no appreciable change in temperature $\rightarrow v_2>v_1$ as $p_2<p_1$.

From continuity: [ρ.A.u=constant $\rightarrow \frac{1}{V}$.A.u=constant] $\rightarrow \frac{u_1A_1}{V_1}=\frac{u_2A_2}{V_2}$.

$u_2 > u_1$ as $v_2 > v_1$.

i.e. increase in velocity accompanying reduction in pressure.
If we substitute in the (S. F. E. E.) with W=Q=Δz=0.

$\dot{m}[\frac{1}{2}(u_2^2 - u_1^2) + (h_2 - h_1)] = 0.$

$\dot{m} \neq 0 \rightarrow \quad \frac{1}{2}u_2^2 + h_2 = \frac{1}{2}u_1^2 + h_1$

But $u_2 > u_1 \quad \therefore \; h_2 < h_1$.

$\therefore C_p.T_2 < C_p.T_1 \rightarrow T_2 < T_1$. [Not very effective in producing low temperature]

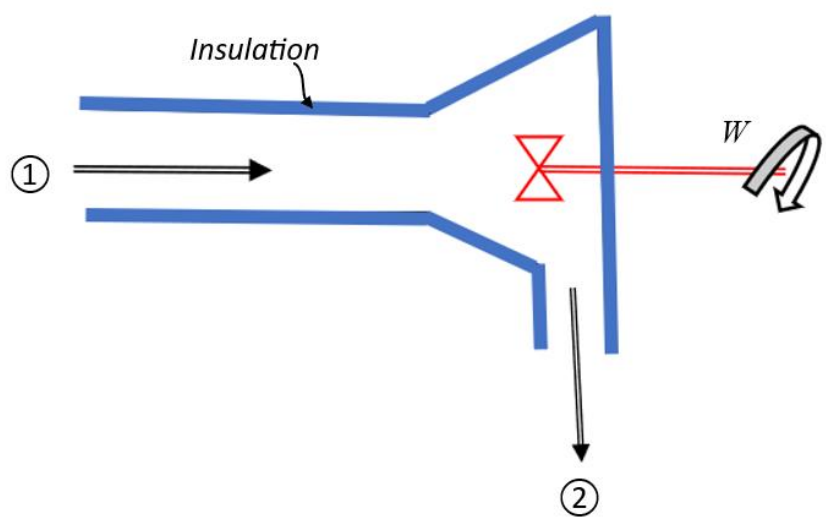
2- Expansion through a turbine.

S.F.E.E., Q=0, Δz=0

$h_1 = h_2 + W$

since work is positive $\therefore h_2 < h_1$

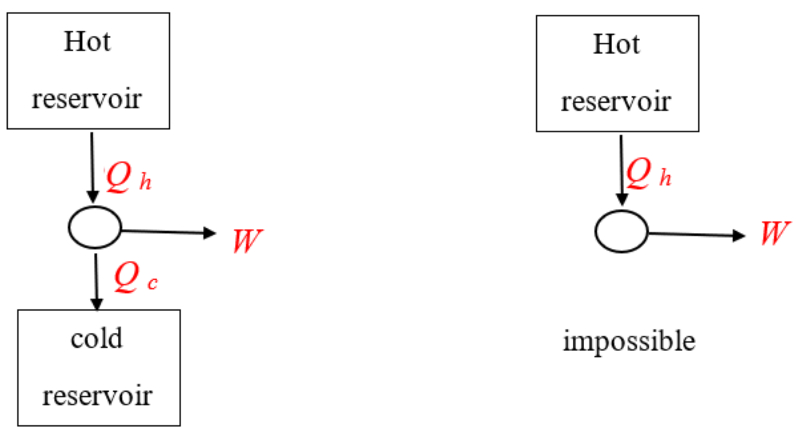
i.e. $T_2 < T_1$




Employed in the air cycle refrigeration system.

## Fundamental of vapour compression refrigeration:

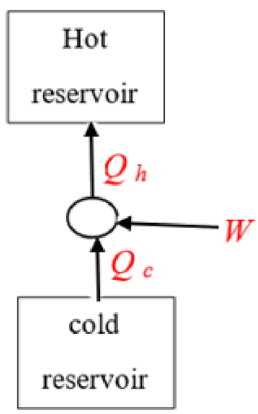
1- The second law of thermodynamics:
Kelvin-Plank statement: (heat engine): [ No cyclic process is possible whose sole result is the absorption of heat from a reservoir and the conversion of this heat into work]

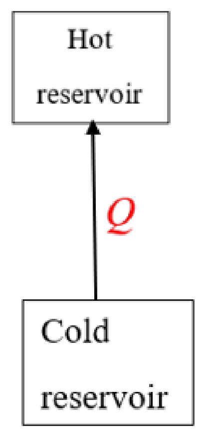



If the heat engine is reversed, we obtain a refrigerature. That is removal of heat from a low temperature reservoir to a high temperature reservoir.

## Clausius statement: (Refrigerator)

(No cyclic process is possible whose sole result is the transfer of heat from a cooler to a hotter reservoir).




Impossible