Note Copy of
Refreigereation & Aire Condeitioning

Puspita Baskey
Leet. (Mech. Engg.)

Air Refrigeration Cycle

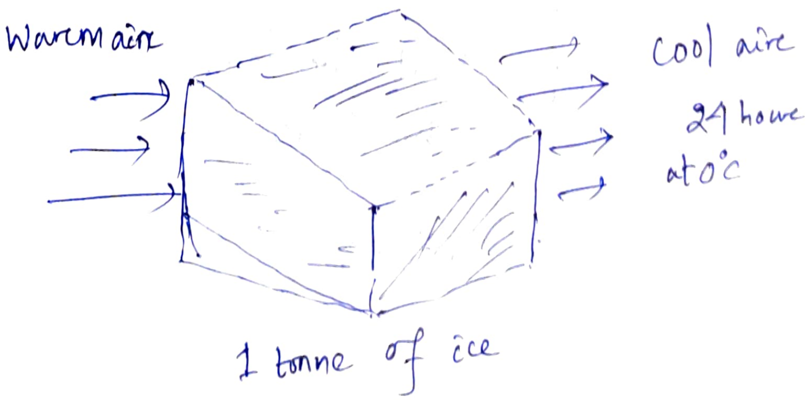
Defination of Refrigeration -

~~It refers~~ It is deals with the transfere of heat from a low temperature region to high temperature region, in order to maintain a desired region at a temperature below than that of surroumding.

The machine that produce refrigeration are called Refrigeratore and the cycles in which they operate are called Refrigeration cycle.

Unit of Refrigeration -

The practical unit of refrigeration is expressed in terms of 'tonne of refrigeration' (TR). Tonne of Refrigeration is defined as the amount of refrigeration effect produced by the uniform melting of one tonne (1000 kg) of ice from and at 0°c in 24 hours.



1 TR = 1000 × 335 kJ in 24 hours

$$= \frac{1000 \times 335}{24 \times 60} = 232.6 \text{ kJ/min} \text{ (Theoretically)}$$

(Since latent heat of ice is 335 kJ/kg)
heat required to convert solid to liquid

In actual practice, one tonne of refrigeration is taken as equivalent to 210 kJ/min or 3.5 kW i.e. (3.5 kJ/s).

Refrigeration effect - Quantity of heat absorbed from refrigerated space to produce cooling effect.

Co-efficient of Performance of Refrigerator ~~and heat pump engine~~

The Performance of refrigerators ~~and heat pumps~~ is expressed in terms of a parameter called Co-efficient of Performance (COP).

Defination - The coefficient of performance (COP) is the ratio of heat extracted in the refrigerator to the work done on the refrigerant.

$$COP = \frac{\text{heat extracted}}{\text{work done}}$$

$$= \frac{Q}{W}$$

Air Refrigeration Cycle -

Air refrigeration divided into two ways -

① Open air refrigeration cycle

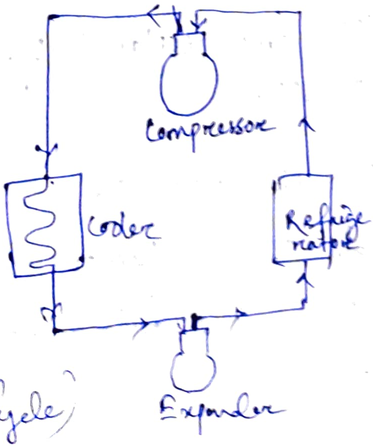
② closed air refrigeration cycle / Dense Air refrigeration

Open air refrigeration cycle -

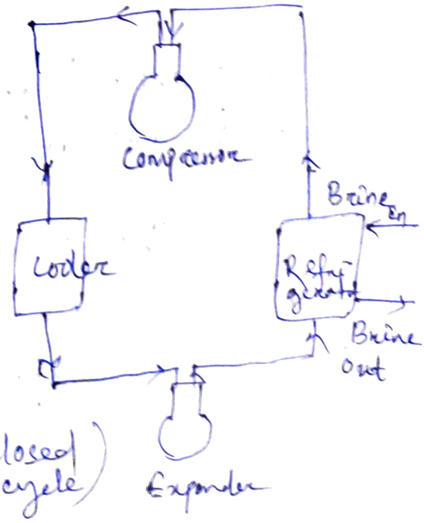
In this cycle, the air is directly led to the space to be cooled (a refrigerator), allowed to circulate through the cooler and then returned to the compressor to start another cycle.

Closed or Dense air refrigeration cycle -

In this cycle, the air is passed through the pipes and components parts of the system at all times. The air is used for absorbing heat from the other fluid (say brine) and this cooled brine is circulated into the space to be cooled. The air in the closed system doesn't come in contact directly with the space to be cooled.



(Open cycle)



(closed cycle)

The basic components ~~used in~~ of the air refrigerator system are

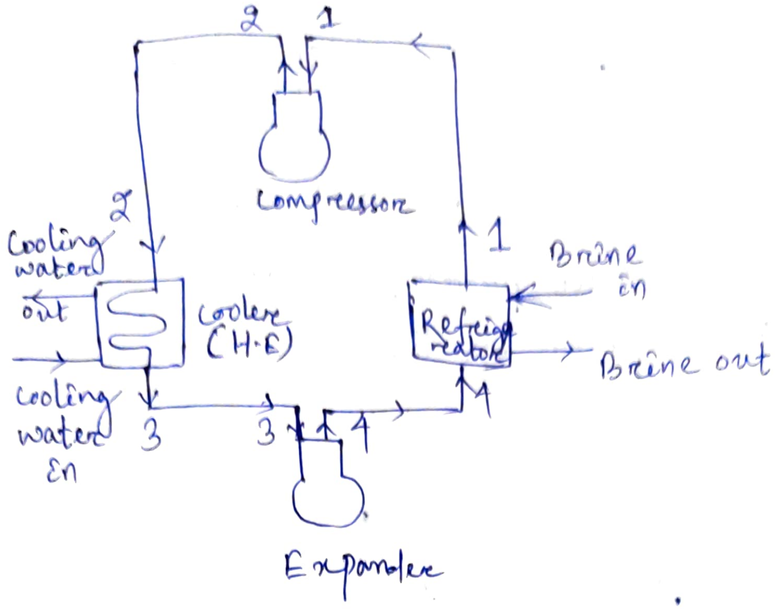
(i) Compressor
(ii) Heat exchanger / cooler
(iii) Expander
(iv) Refrigerator

The difference between the Open system and closed system is that the air used in refrigerator is thrown into the atmosphere instead of re-circulating it in closed system.

BELL-COLEMAN AIR REFRIGERATOR

A Bell-coleman air refrigeration machine was developed by Bell-coleman and Light foot. It was one of the earliest types of refrigerators used in ships carrying frozen meat. The Bell-coleman cycle also known as Reversed Brayton or Joule cycle is a modification of Reversed Carnot cycle. The isothermal processes are replaced by constant pressure processes.

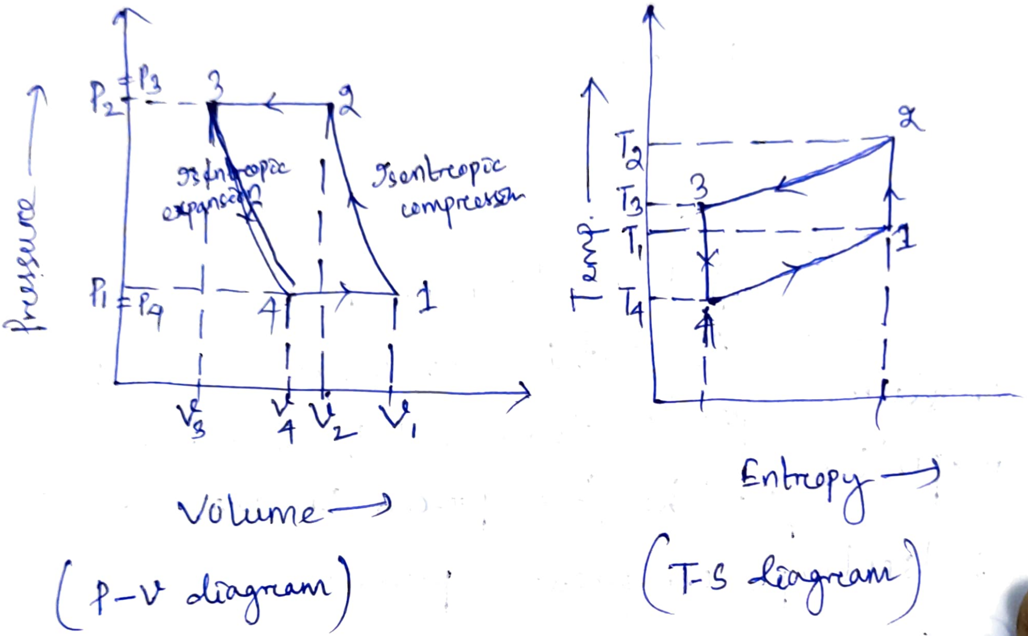
The schematic diagram of such a machine which consists of a compressor, a cooler, an expander and a refrigerator.



The cycle is shown on P-v and T-S diagrams. At point 1, let P_1, v_1 and T_1 be the pressure, specific volume and temperature respectively. The four process of the cycle are-

① Isentropic compression process
② Constant pressure cooling process
③ Isentropic expansion process
④ Constant pressure expansion process

① Isentropic compression process (1-2) - The cold air from the refrigerator is drawn into the compressor cylinder where it is compressed isentropically in the compressor as shown by the curve 1-2 on P-v and T-S diagram. During the compression stroke, both pressure and temperature increases and sp. volume of air at delivery from compressor reduces v_1 to v_2. We know that during isentropic compression process, no heat is absorbed or rejected by the air.



② Constant Pressure cooling process (2-3) –

The warm air from the compressor is now passed into the cooler where it is cooled at constant pressure $P_3 (= P_2)$, reducing the temp. from T_2 to T_3 as shown by curve 2-3 on P-v and T-S diagram. The sp. volume also reduces from v_2 to v_3. Then, heat rejected by the air during constant Pressure per kg of air.

$$q_R = Q_{2-3} = C_p(T_2 - T_3)$$

③ Isentropic expansion process (3-4) -

The air from the cooler is drawn into the expander cylinder where it expanded isentropically from pressure P_3 to the refrigerator pressure P_4 which equal to the atmospheric pressure. The temp. of air during expansion falls from T_3 to T_4 as shown by the curve 3-4 on the P-V and T-S diagram. The sp. volume of air at entry to the refrigerator increases from v_3 to v_4. We know that during isentropic expansion of air, no heat is absorbed or rejected by the air.

④ Constant Pressure expansion process (4-1) -

The cold air from the expander is passed to the refrigerator where it is expanded at constant pressure $P_4 (= P_1)$. The temperature of air increases from T_4 to T_1 is shown by curve 4-1 on the P-V and T-S diagram. Due to heat from the refrigerator, the specific of the air changes from v_4 to V_1.

Heat absorbed by the air or heat extracted from the refrigerator or the refrigerating effect produced during const. pressure expansion per kg of air,

$$q_A = Q_{4-1} = C_p(T_1 - T_4)$$

We know that work done during the cycle per kg of air,

W = Heat rejected − Heat absorbed

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

∴ coefficient of performance,

$$COP = \frac{\text{heat extracted}}{\text{Work done}}$$

$$= \frac{q_A}{W} = \frac{C_p(T_1 - T_4)}{C_p(T_2 - T_3) - C_p(T_1 - T_4)}$$

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

$$= \frac{T_4\left(\frac{T_1}{T_4} - 1\right)}{T_3\left(\frac{T_2}{T_3} - 1\right) - T_4\left(\frac{T_1}{T_4} - 1\right)} \quad \text{—— (1)}$$

We know that, for isentropic compression process 1−2,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{—— (2)}$$

Ily, for isentropic expansion process,

$$\frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{—— (3)}$$

since $P_2 = P_3$ and $P_1 = P_4$, from eqn (2) and (3)

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} = \left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} \Rightarrow \frac{T_2}{T_3} = \frac{T_1}{T_4} \quad \text{—— (4)}$$

Now substituting the value of eqn (4) in eqn (1)

$$COP = \frac{T_4\left(\frac{T_1}{T_4}-1\right)}{T_3\left(\frac{T_2}{T_3}-1\right)-T_4\left(\frac{T_1}{T_4}-1\right)}$$

$$= \frac{T_4\left(\frac{T_1}{T_4}-1\right)}{T_3\left(\frac{T_1}{T_4}-1\right)-T_4\left(\frac{T_1}{T_4}-1\right)} = \frac{T_4}{T_3-T_4}$$

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

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

r_p = compression or expansion ratio $= \frac{P_2}{P_1} = \frac{P_3}{P_4}$

$$\boxed{C.O.P = \frac{1}{(r_p)^{\frac{\gamma-1}{\gamma}}-1} = \frac{T_4}{T_3-T_4}}$$

When the compression and expansion process ... Pv^n = const.

Disadvantages of the Open air refrigeration Cycle

1. The size of compressure and expander should be large.
2. Moisture leads to the formation of frost at the end of the expansion ~~motion~~ process and clog the line.