Lecture Note on

Subject: REFRIGERATION AND AIRCONDITIONING

Code TH – 5

Branch: Mechanical Engineering

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Refrigeration:-

It is the process of maintaining lower temperature as compare to surrounding/ambient temperature.

-->The heat is rejected from sink (system) to source(surrounding).

-->It is an artificial cooling process.

Refrigerant:-

It is a substance which absorbs the heat from storage space (system) to produce lower temperature.

Eg:- R-11 , R-22 , R-134a , R-717

Refrigeration Effect (RE):-

It is the amount of heat removed from storage space to maintain lower temperature.

-->In case of Refrigerator RE=Q2

-->IN case of Heat Pump RE=Q1

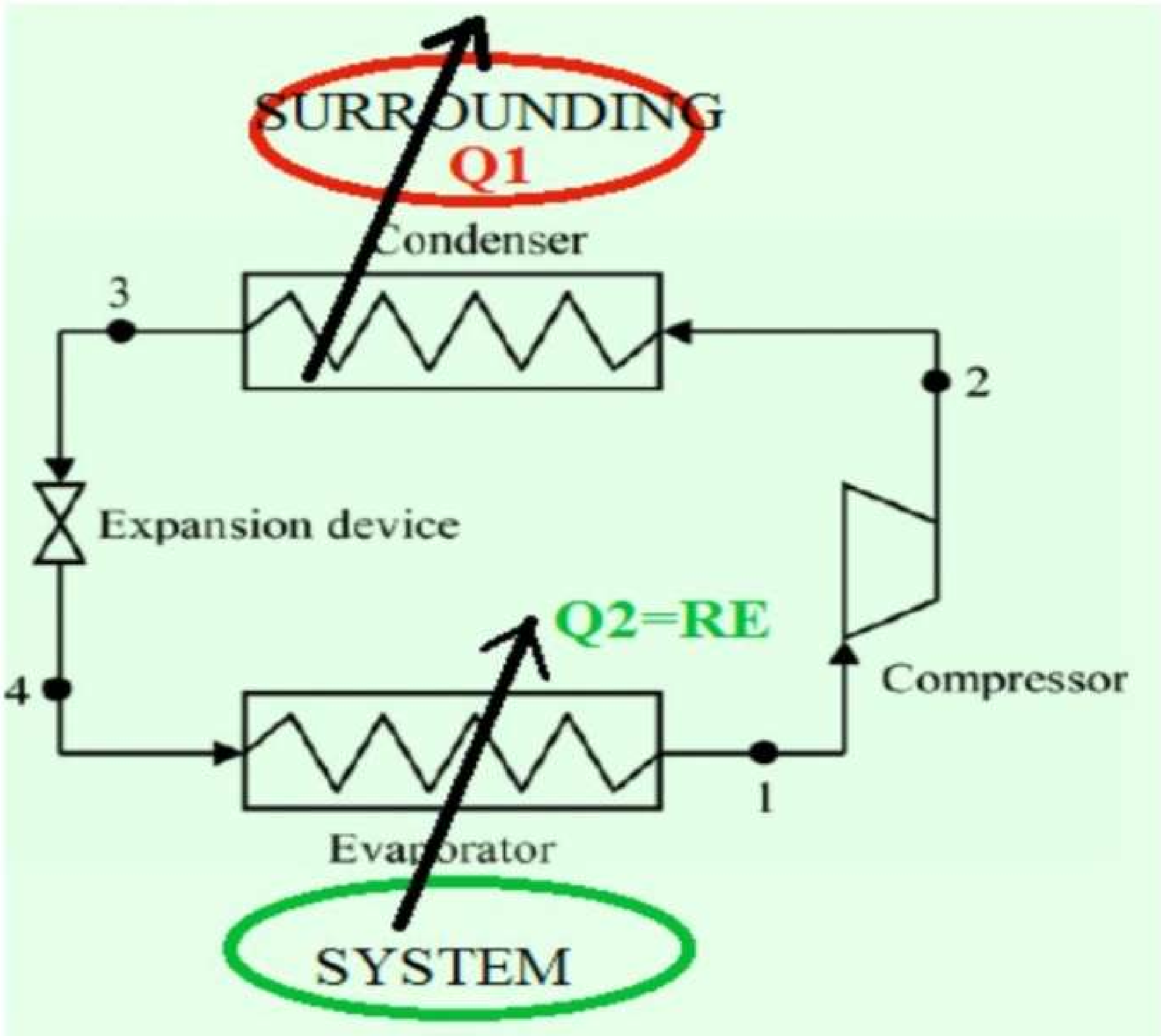
Unit of Refrigeration:-

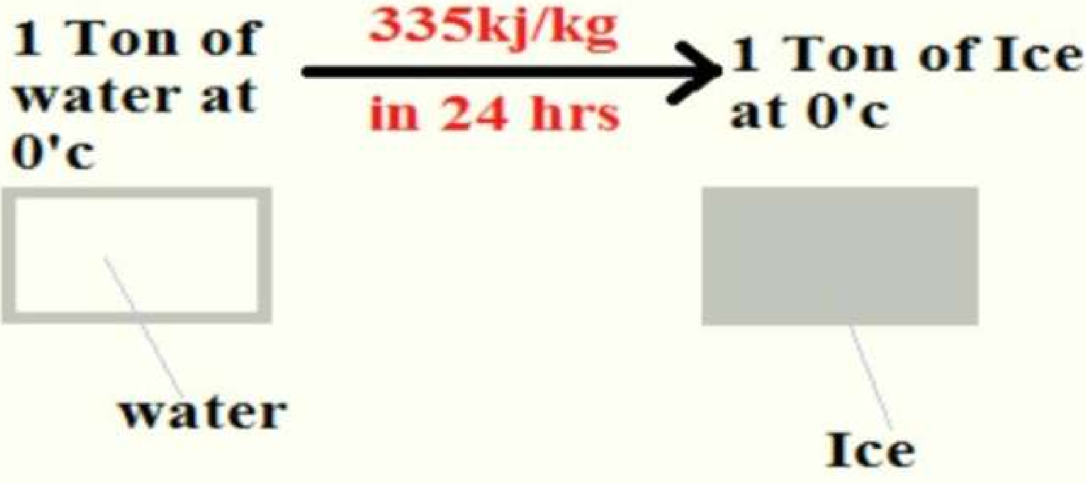
Ton of Refrigeration (TR or TOR)

-->1TR is defined as the amount of energy removed from 1 ton of water at 0'c in order to convert into ICE at 0'c in 24 hrs.

-->Phase transformation takes place at constant temp here at 0'c

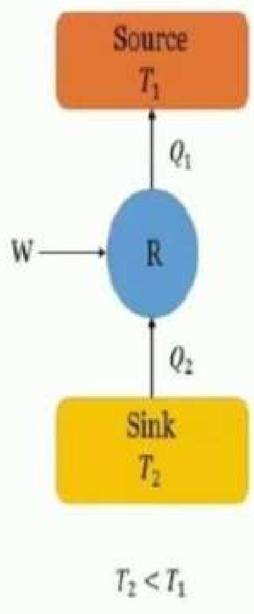
1TR = 3.5 kw





$$1TR = \frac{335 \times 1000}{24 \times 3600} \approx 3.5kw$$

Coefficient of Performance (COP) of refrigeration cycle:-



Where

Q_2 = Quantity of heat removed from a low temperature region

Q_1 = Quantity of heat supplied to a high temperature region

$$Q_1 = Q_2 + W$$

$$W = Q_1 - Q_2$$

$$(COP)_R = \frac{Net\ Refrigeration\ Effect}{Work\ Supplied}$$

$$(COP)_R = \frac{Q_2}{W} = \frac{Q_2}{Q_1 - Q_2} = \frac{T_2}{T_1 - T_2}$$

Air cycle refrigeration systems belong to the general class of gas cycle refrigeration systems, in which a gas is used as the working fluid.
-->Air cycle refrigeration works on the reverse Brayton or Bell-Coleman cycle. Air is compressed and then heat removed, this air is then expanded to a lower temperature than before it was compressed.

Air system of refrigeration

Air cycle refrigeration is one of the earliest methods used for cooling. The key features of this method is that, the refrigerant air remain gaseous state throughout the refrigeration cycle. Based on the operation, the air refrigeration system can be classified into

1. Open air refrigeration cycle
2. Closed refrigeration cycle

1. Open Air Refrigeration System:-

Open air refrigeration cycle

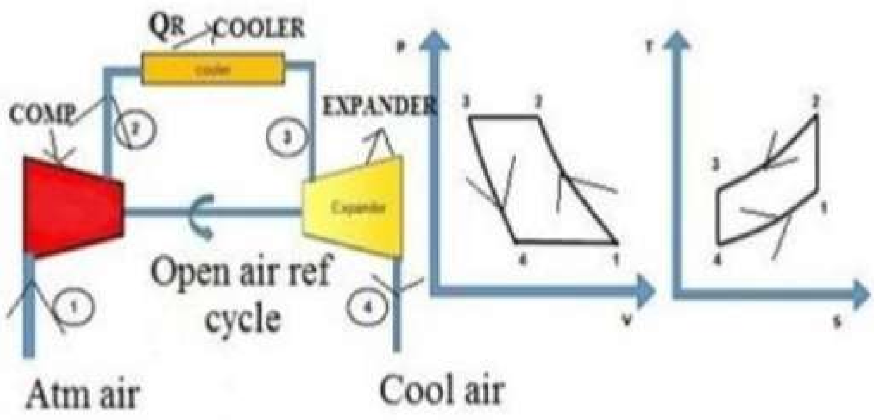
In an open refrigeration system, the air is directly passed over the space is to be cooled, and allowed to circulate through the cooler. The pressure of open refrigeration cycle is limited to the atmospheric pressure. A simple diagram of the open-air Refrigeration system is given below.

Advantages and application

- It eliminates the need of a heat exchanger.
- It is used in aircraft because it helps to achieve cabin pressurization and air conditioning at once

Disadvantages

One of the disadvantages of this system is that its large size. The air supplied to the refrigeration system is at atmospheric pressure, so the volume of air handled by the system is large. Thus the size of compressor and expander also should be large. Another disadvantage of the open cycle system is that the moisture is regularly carried away by the circulating air, this leads to the formation of frost at the end of the expansion process and clogs the line, and hence a use of dryer is preferable to the open air refrigeration system.



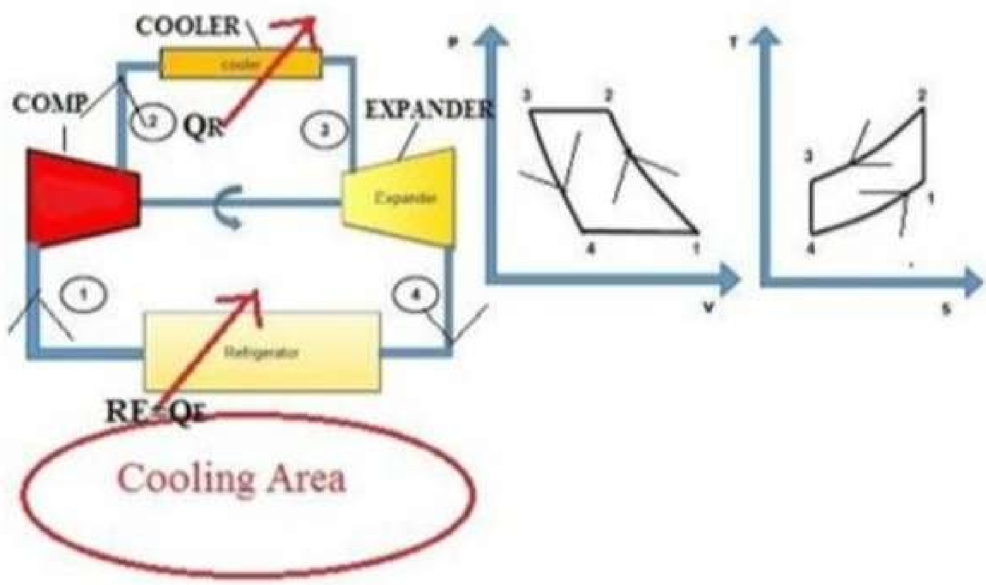
2. Closed Air Refrigeration System:-

Closed refrigeration system / Dense air refrigeration cycle

In closed or dense air refrigeration cycle, air refrigerant is contained within pipes and component part of the system at all time. The circulated air does not have to direct contact with the space to be cooled. The air is used to cool another fluid (brine), and this fluid is circulated into the space to be cooled. So the disadvantages listed in open air refrigeration can be eliminated. The advantages of closed air refrigeration system are

Advantages

- The suction to the compressor may be at high pressure, therefore the volume of air handled by the compressor and expander is low when compared to an open system. Hence the size of compressor and expander is small compared to the open air system.
- The chance of freezing of moister and choke the valve is eliminated.
- In this system, higher coefficient of performance can be achieved by reducing operating pressure ratio.



Working Principle of #Bell-Coleman Cycle (#Reverse Brayton or Joule Cycle):-

In this process, heat absorption and rejection follows at the constant pressure.

-->The compression and expansion of process are isentropic.

1-2: Isentropic Compression:-

The air drawn from refrigerator to air compressor cylinder where it compressed isentropically (constant entropy). No heat transfer by the air. During compression, the volume decreases while the pressure and temperature of air increases.

2-3: Constant pressure cooling process:-

The warm compressed air is then passed through cooler, where it cooled down at constant pressure.

The heat rejected per kg of air during this process is equal to

q2-3 = Cp(T2-T3)

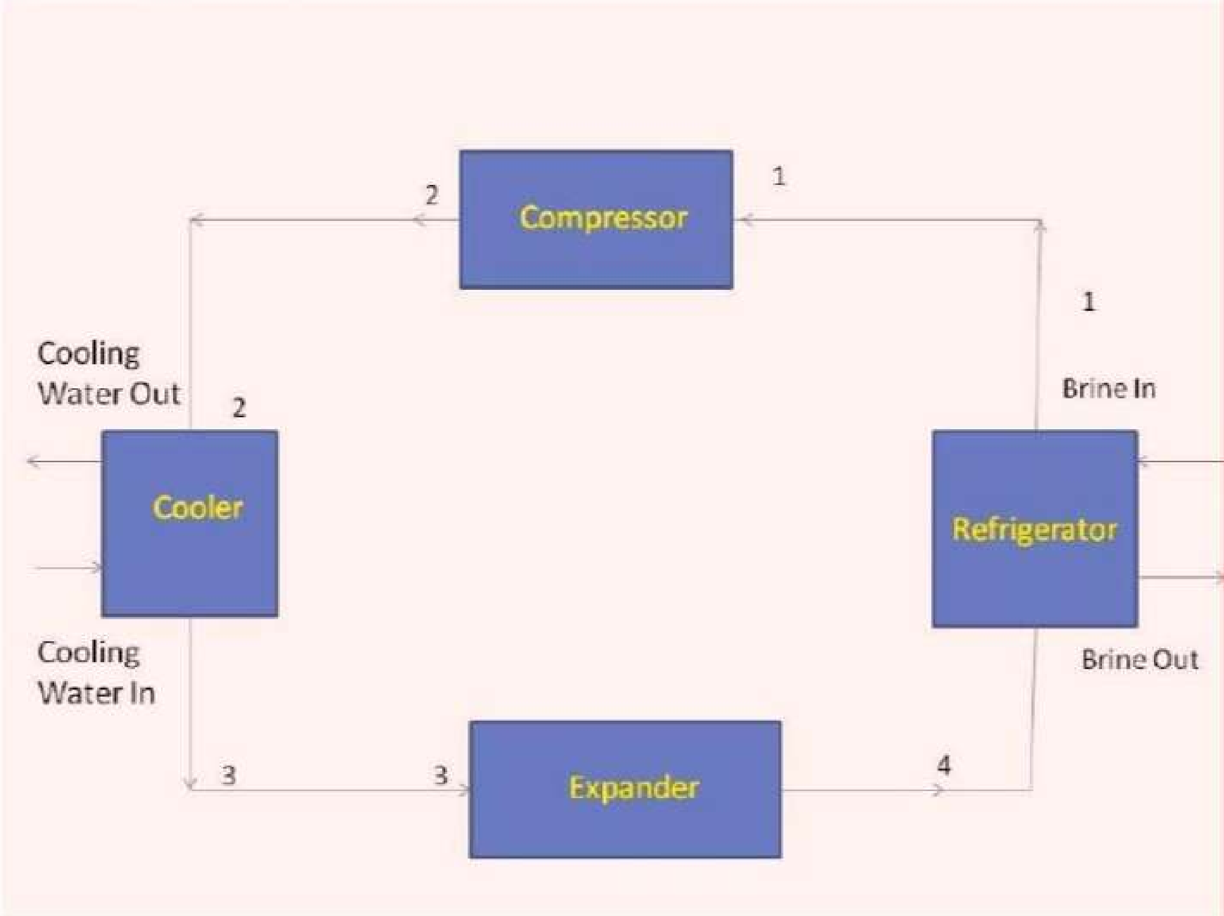
3-4: isentropic expansion:-

No heat transfer takes place. The air expands isentropically in expander cylinder. During expansion, the volume increases, Pressure P3 reduces to P4. (P4 = atmospheric pressure). Temperature also falls during expansion from T3-T4.

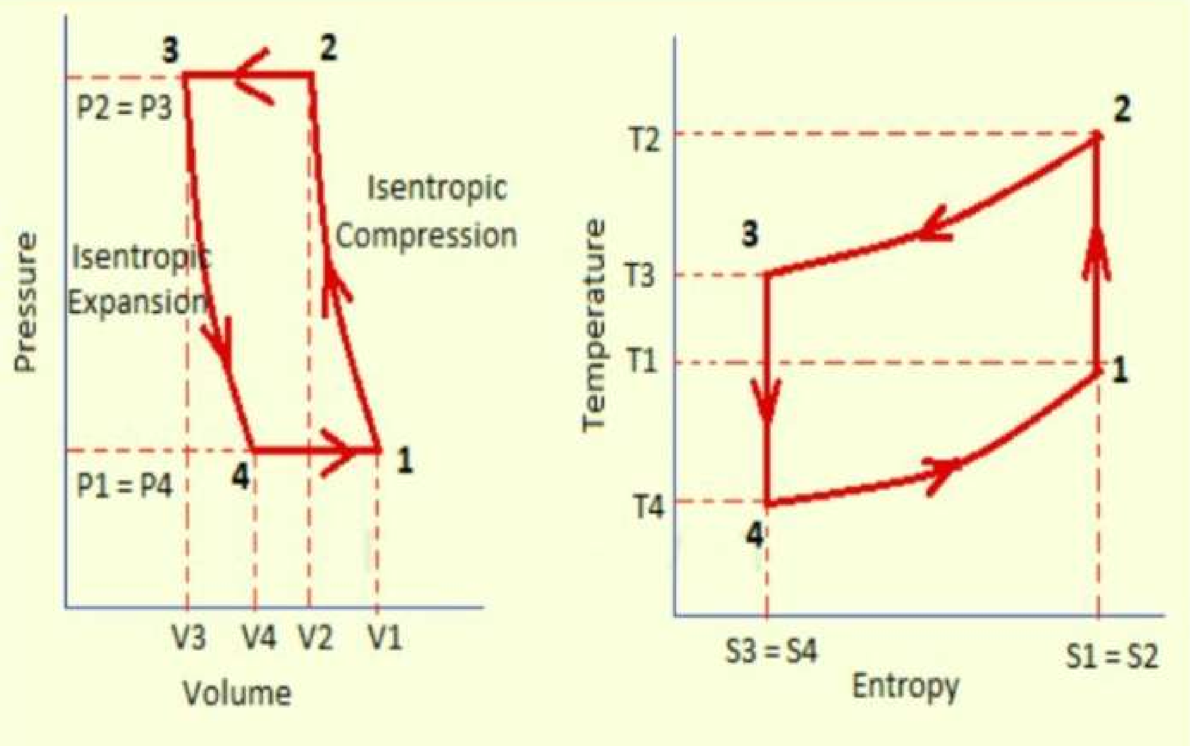
4-1: Constant pressure expansion:-

Heat transfer from the refrigerator to air. The temperature increases from T4 to T1. Volume increases to V4 due to heat transfer. Heat absorbed by air per kg during this process is equal to

q4-1 = Cp(T1-T4)



COP of Bell-Coleman Cycle (Reverse Brayton or Joule Cycle):-



(a) P-V Diagram (b) T-S Diagram

Heat absorbed during cycle per kg of air $q_{4\text{-}1} = Cp(T_1\text{-}T_4)$

Heat rejected during cycle per kg of air $q_{2\text{-}3} = Cp(T_2\text{-}T_3)$

Then the work done per kg of air during the cycle is = Heat rejected – Heat absorbed

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

Coefficient of performance;

$$C.O.P. = \frac{Heat\ absorbed}{Work\ done} = \frac{C_p(T_1 - T_4)}{C_p(T_2 - T_3) - C_p(T_1 - T_4)}$$

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

$$C.O.P. = \frac{T_4(\frac{T_1}{T_4} - 1)}{T_3(\frac{T_2}{T_3} - 1) - T_4(\frac{T_1}{T_4} - 1)} \quad (i)$$

For isentropic compression process 1-2

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

For isentropic expansion process 3-4

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

Since, P2 = P3 and P1 = P4, therefore from equation (ii) and (iii)

$$\frac{T_2}{T_1} = \frac{T_3}{T_4} \quad or \quad \frac{T_2}{T_3} = \frac{T_1}{T_4} \qquad \text{(iv)}$$

Substitute equation (iv) in (i)

$$C.O.P. = \frac{T_4}{T_3 - T_4} = \frac{1}{\frac{T_3}{T_4} - 1}$$

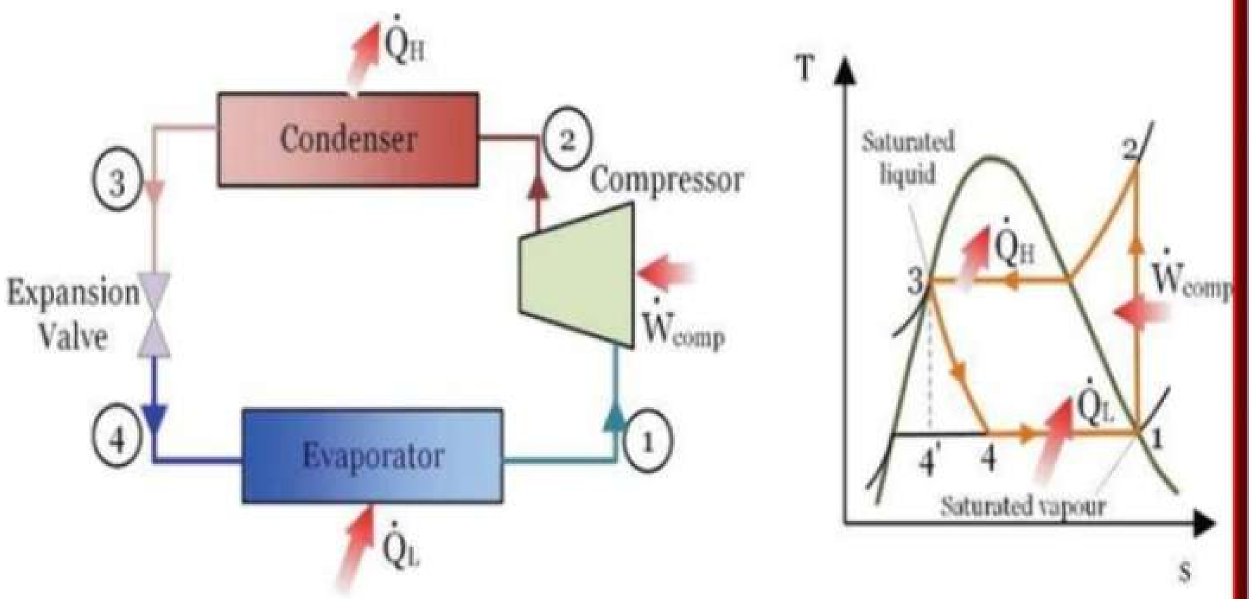
$$= \frac{1}{\left(\frac{P_3}{P_4}\right)^{\frac{\gamma-1}{\gamma}} - 1} = \frac{1}{\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1}$$

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

→ COP of Bell-Coleman Cycle

$$r_p = Compression\ or Expansion\ ratio = \frac{P_2}{P_1} = \frac{P_3}{P_4}$$

Schematic Diagram of Vapour Compression Refrigeration System:-



Vapor Compression Refrigeration System(VCRS) involves four components: evaporator, compressor, condenser, expansion valve/throttle valve.

STEP 1: EVAPORATION

-->The refrigerant evaporates and absorbs latent heat of vaporization from space to be cooled. Heat extraction by
the refrigerant happens at low pressure and temperature.

-->Here liquid refrigerant converts into vapour after extracting latent heat and this takes place at constant temperature.

-->There are different evaporator versions in the market, but the major classifications are liquid cooling and air cooling, depending whether they cool liquid or air respectively.

STEP 2: COMPRESSION

-->The refrigerant enters the compressor at low temperature and low pressure. It is in a vapour state. Here, compression takes place to raise the temperature and refrigerant pressure. The refrigerant leaves the compressor and enters to the condenser.

-->Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.

STEP 3: CONDENSATION

-->The condenser is essentially a heat exchanger. Heat is transferred from the refrigerant to a flow of water. This water goes to a cooling tower for cooling in the case of water-cooled condensation. As the refrigerant flows through the condenser, it is in a constant pressure and temperature.

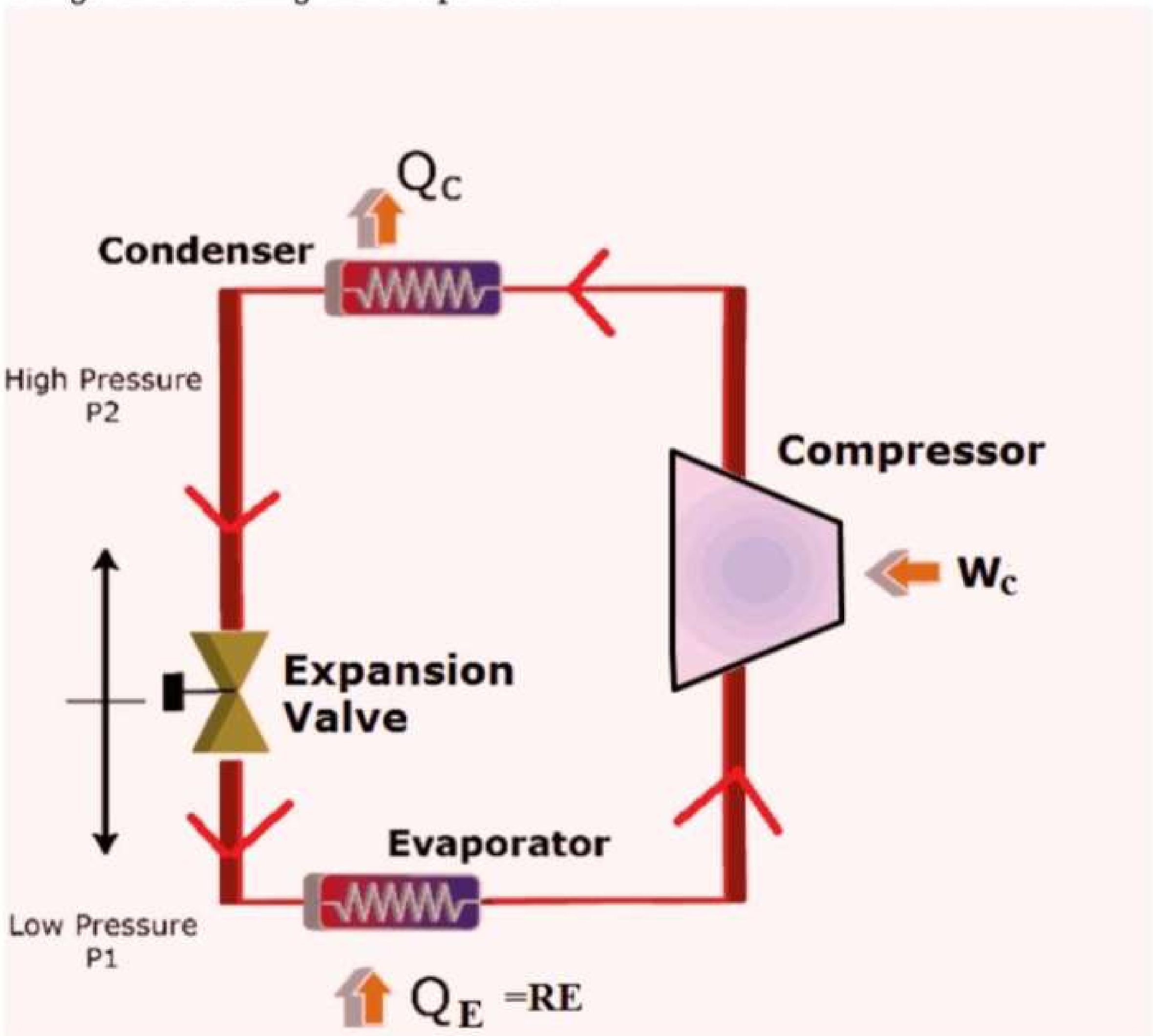
-->Here vapour refrigerant converts into liquid state by rejecting latent heat to water.

STEP 4: THROTTLING AND EXPANSION

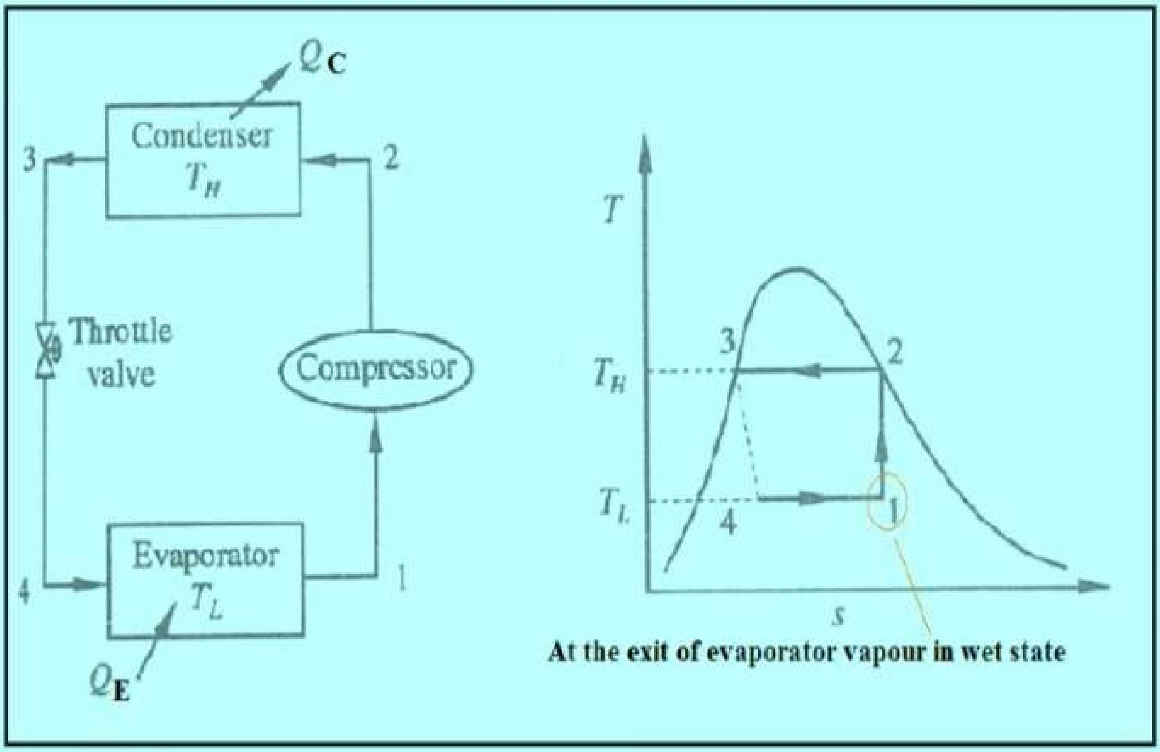
-->When the refrigerant enters the throttling valve, it expands and releases pressure. Consequently, the temperature drops at this stage.

-->Unfortunately, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around 75 % and 25 % respectively.

-->Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.



COP of vapour compression refrigeration system(VCRS):-



At the exit of evaporator vapour in wet state

Application of the first law of thermodynamics to the control volume compressor, condenser, throttle and evaporator gives

$W_C = h_2 - h_1$

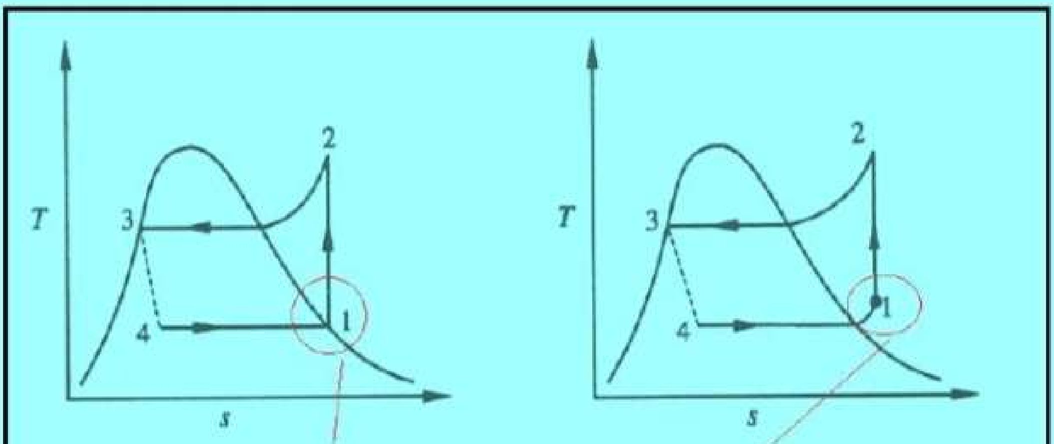
$Q_C = h_2 - h_3$

$h_3 = h_4$ and $Q_E = h_1 - h_4$

The COP of the refrigerator is given by,

$$(COP)_R = \frac{Q_E}{W_C} = \frac{h_1 - h_4}{h_2 - h_1}$$

In the ideal refrigeration cycle, the refrigerant leaves the evaporator as wet vapour.
In some cases the refrigerant leaves the evaporator as either saturated vapour or superheated vapour **look the T-S diagram of figure (a) and (b).**



T-s diagram for a vapour compression refrigeration cycle when the refrigerant leaves the evaporator as (a) saturated vapour (b) superheated vapour

Simple Vapour Absorption Refrigeration System(VARS):-

A Vapour absorption refrigeration system consists of evaporator, absorber,pump, generator, condenser, expansion valve & reducing valve.

1.Evaporator:-

-->The refrigerant(Ammonia) at very low pressure and temperature enters the evaporator and produces the cooling effect.

-->Then this refrigerant flows to the absorber(Water) that acts as the suction part of the refrigeration cycle.

2.Absorber:-

-->The absorber is a sort of vessel consisting of water that acts as the absorbent.

-->When ammonia from the evaporator enters the absorber, it is absorbed by the absorbent due to which the pressure inside the absorber reduces further leading to more flow of the refrigerant from the evaporator to the absorber.

-->At high temperature water absorbs lesser ammonia, hence it is cooled by the external coolant to increase it ammonia absorption capacity.

3.Pump:-

-->When the absorbent absorbs the refrigerant strong solution of refrigerant-absorbent (ammonia-water) is formed. This solution is pumped by the pump at high pressure to the generator.

4.Generator:-

-->The refrigerant-ammonia solution in the generator is heated by the external source of heat. Due to heating the temperature of the solution increases. The refrigerant in the solution gets vaporized and it leaves the solution at high pressure. The high pressure and the high temperature refrigerant then enters the condenser.

-->When the vaporized refrigerant leaves the generator weak solution is left in it. This solution enters the pressure reducing valve and then back to the absorber, where it is ready to absorb fresh refrigerant. In this way, the refrigerant keeps on repeating the cycle.

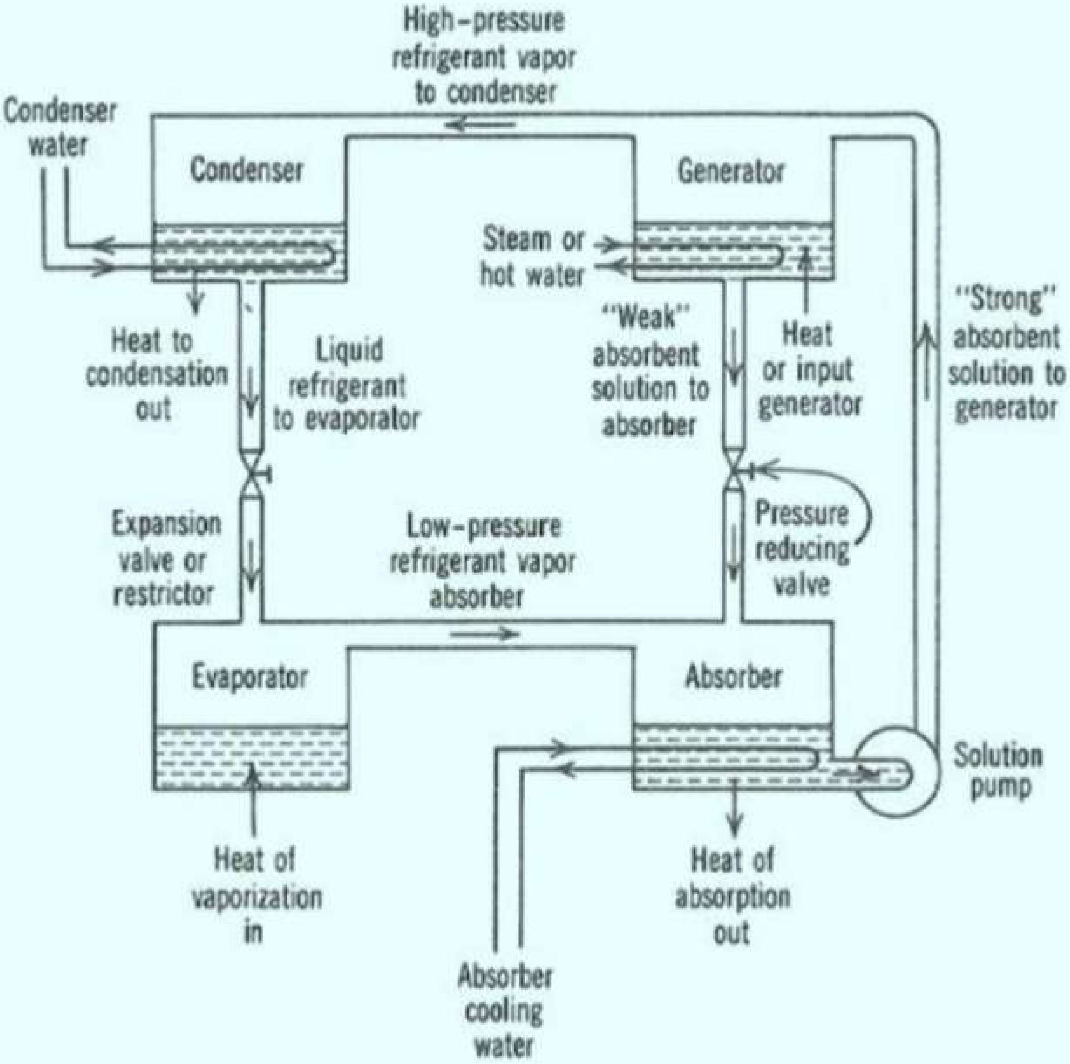
5.Condenser:-

-->Just like in the traditional condenser of the vapor compression cycle, the refrigerant enters the condenser at high pressure and temperature and gets condensed. The condenser is of water cooled type.

6.Expansion valve or restriction:-

-->When the refrigerant passes through the expansion valve, its pressure and temperature reduces suddenly. This refrigerant (ammonia in this case) then enters the evaporator.

In this way cycle is going on.



Simple Vapour Absorption Refrigeration System

Practical Vapour Absorption Refrigeration System:-

The simple vapour absorption refrigeration system is not very economical. So it is fitted with an analyzer, a rectifier and two heat exchangers as shown in figure, to make it more practical.

1.Analyzer:-

-->In the simple system some water also vaporizes along with ammonia in the generator. If these unwanted water particles are not removed before entering condenser, they will enter into expansion valve and will freeze and choke the pipeline.

-->Therefore, an analyzer is used above the generator. It consists of series of trays such that strong solution from absorber and aqua from rectifier are introduced on the top tray and flow downwards The vapor rising from generator is cooled due to exposure to considerable liquid surface area and most of water vapour condenses. Since aqua is heated by vapour, less external heat is required in generator.

2.Rectifier:-

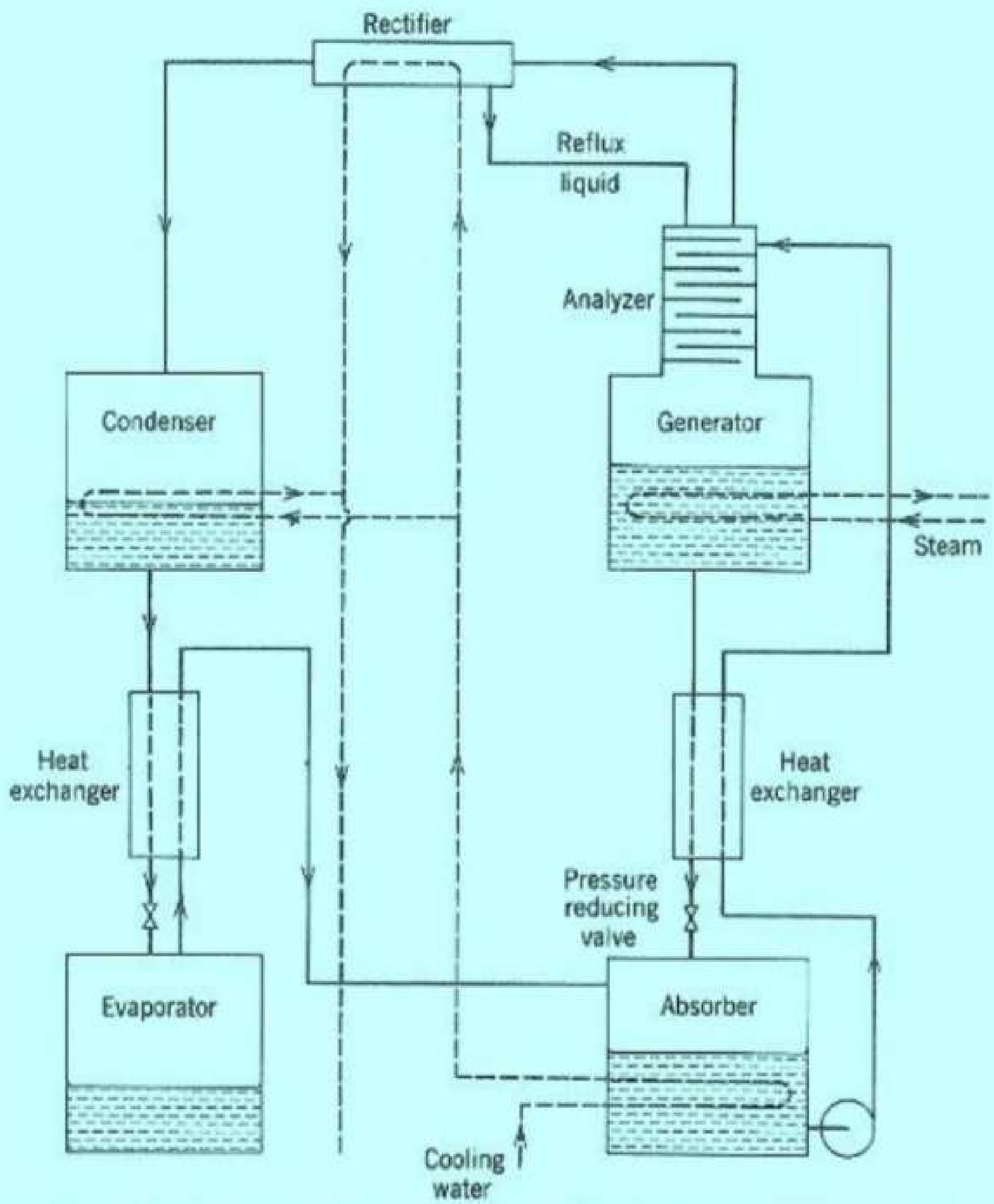
-->Its function is to cool further the ammonia vapours leaving analyzer so that the vapours condense. This condensate is returned to top of analyzer by a drip return pipe. It is also known as dehydrator.

3.Heat Exchangers: The heat exchanger provided between pump and generator is used to cool the weak hot solution returning from generator to absorber and to heat the strong solution leaving the pump and going to generator.

-->This reduces heat supplied to generator and amount of cooling required for absorber, thus increasing plant economy.

-->The heat exchanger between condenser and evaporator is called liquid sub-cooler since it sub-cools the liquid refrigerant leaving condenser by low temperature ammonia vapour from evaporator.

--->Other Components work as usual like in simple vapour absorption refrigeration system.



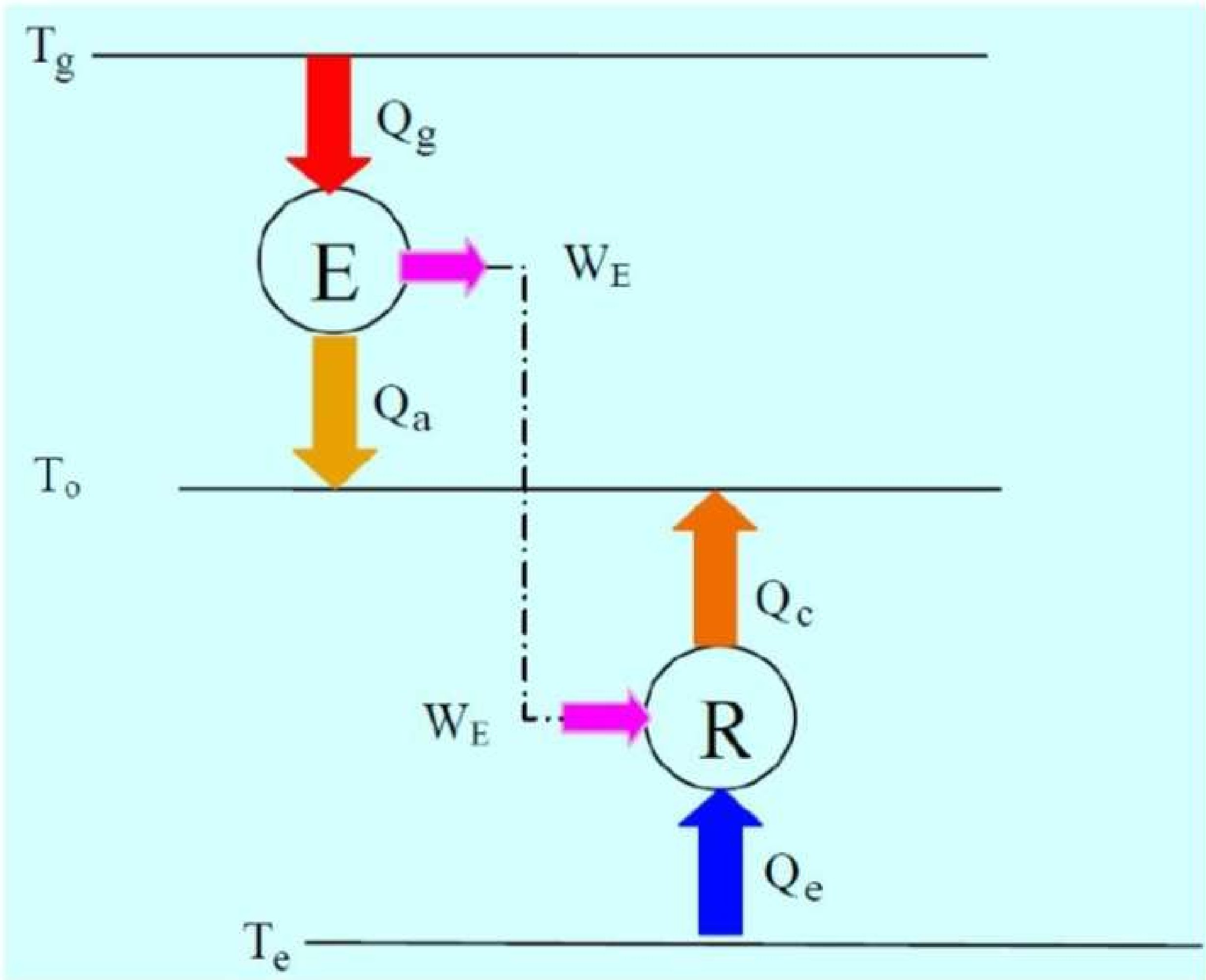
Practical Vapour Absorption Refrigeration System

COP of an Ideal VARS System:- It is equal to the product of efficiency of a Carnot heat engine operating between (Tg) and (To) and COP of a Carnot refrigeration system operating between (To) and (Te)

-->Thus an ideal vapour absorption refrigeration system can be considered to be a combined system consisting of a Carnot heat engine and a Carnot refrigerator.

-->Thus the COP of an ideal VARS increases as generator temperature (Tg) and evaporator temperature (Te) increase and heat rejection temperature (To) decreases.

-->However, the COP of actual VARS will be much less than that of an ideal VARS due to various internal and external irreversibilities present in actual systems.



$$COP_{\text{ideal VARS}} = \frac{Q_e}{Q_g} = \left(\frac{T_e}{T_o - T_e}\right)\left(\frac{T_g - T_o}{T_g}\right) = COP_{\text{Carnot}} \cdot \eta_{\text{Carnot}}$$

COMPRESSOR enables the flow of the refrigerant. The compressor works by increasing the pressure and temperature of the vaporized refrigerant.

-->There are different types of compressors for refrigeration applications. Reciprocating, rotary, and centrifugal compressors are the most common among refrigeration units.

CLASSIFICATION OF COMPRESSOR BASED ON DIFFERENT CRITERIA:-

Classification of compressors in different ways

I. Based on working principle

- A) Positive displacement type compressors
  - i) Reciprocating type compressor
    - a) Single acting
    - b) Double acting
  - ii) Rotary type with sliding vanes compressor
  - iii) Rotary screw type compressor
  - iv) Rotary scroll type compressor
  - iv) Orbital compressor
  - v) Acoustic compressor
- B) Roto-Dynamic type compressors
  - i) Axial Flow type compressor
  - ii) Radial flow type compressor
    - a) Centrifugal compressor

II. Based on the arrangement of compressor motor/external drive

- 1) Open type
- 2) Hermetic/sealed type
- 3) Semi-hermetic type

RECIPROCATING COMPRESSOR:-

Construction:-->

1)Piston: It does reciprocating motion in the cylinder and responsible for the compression of the air.

2)Cylinder: It is a chamber in which air is compressed.

3)Connection Rod: It connects the piston and crankshaft.

4)Crankshaft: It is connected to the shaft of electric motor. And transfers its rotary motion to the piston.

5)Suction valve: The air is sucked through suction valve when piston moves to BDC.

6)Discharge valve: The compressed air is discharged through the discharge valve to the storage tank.

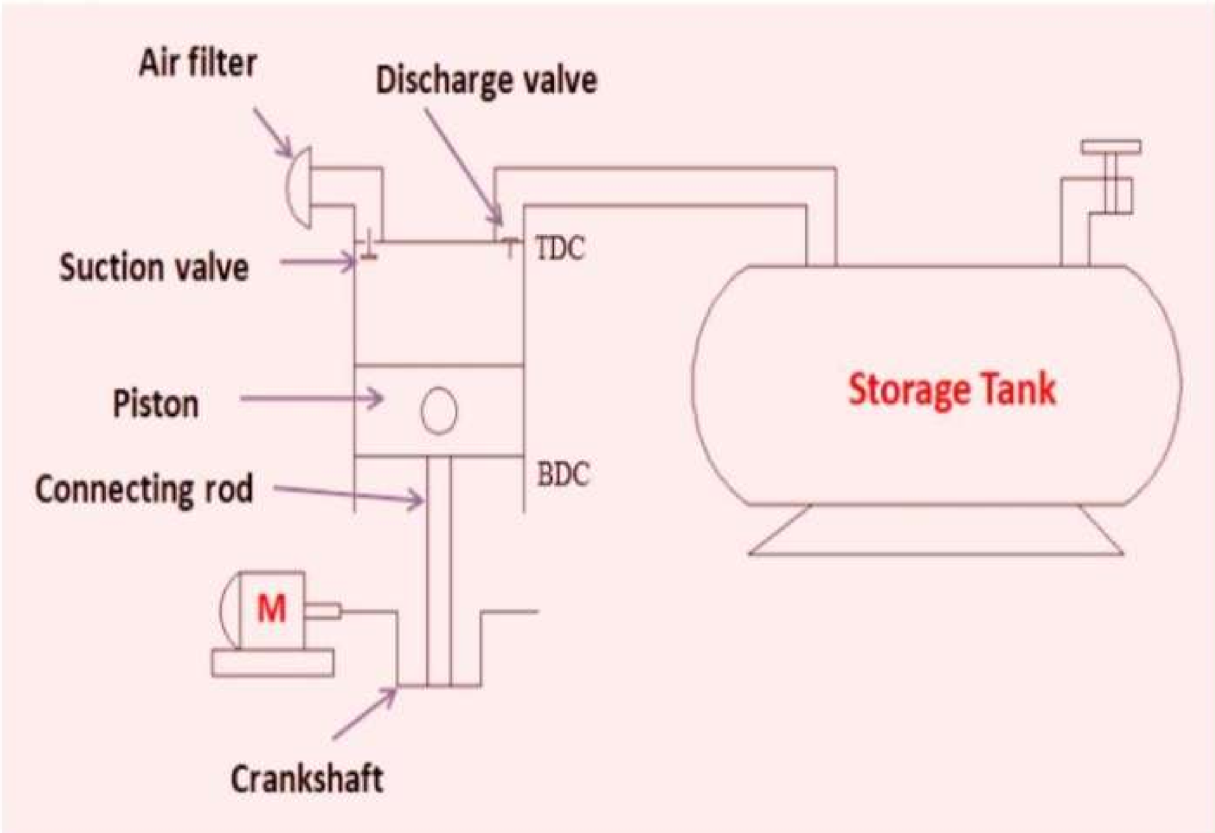
Working Principle:-->

As power is On, the electric motor starts rotating and also rotates the crankshaft attached to it. The piston starts to and fro motion inside the cylinder.

-->As the piston moves downward (towards BDC), the air from the atmosphere enters into the chamber of the cylinder.

-->Now the piston after reaching at BDC, starts moving upward (i.e. towards TDC), the compression of the air starts and its pressure begins to increase.

-->When the pressure inside the cylinder increases above the pressure of the discharge valve, the discharge valve opens and the compressed air is delivered to a air storage tank from where it is utilized for the work.



ROTARY COMPRESSOR:-
Construction & Working Principle:->

The general construction of the rotary compressor has a cylinder with an intake and discharge port, and it has a roller inside the cylinder. The roller rub against the inside wall of the cylinder while it rotates. The fluid (refrigerant) is get trapped between the space between rotor and cylinder. The trapped fluid is then progressively get compressed by decreasing the annular space between the rotor and cylinder. The process can be described in four intermediate steps.

1. Introduction of fluid into the compartment between roller and cylinder.
2. Sealing the suction port and trapping the fluid inside the chamber.
3. Compression of fluid by decreasing the volume of the chamber.
4. Discharging of high-pressure fluid through the discharge port.

There are mainly two types of rotary compressor
1. Stationary blade type rotary compressor
2. Rotating blade type rotary compressor

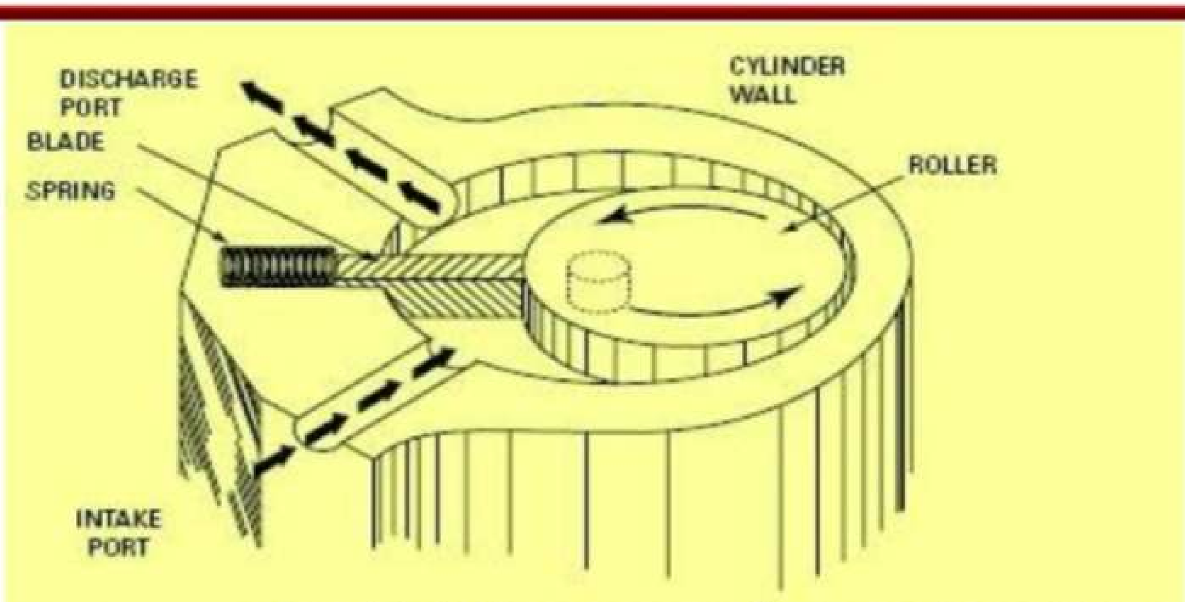
The rotary compressor is usually arranged as a single unit, sometimes it arranged as series of the compressor with or without an intercooler.

Advantages

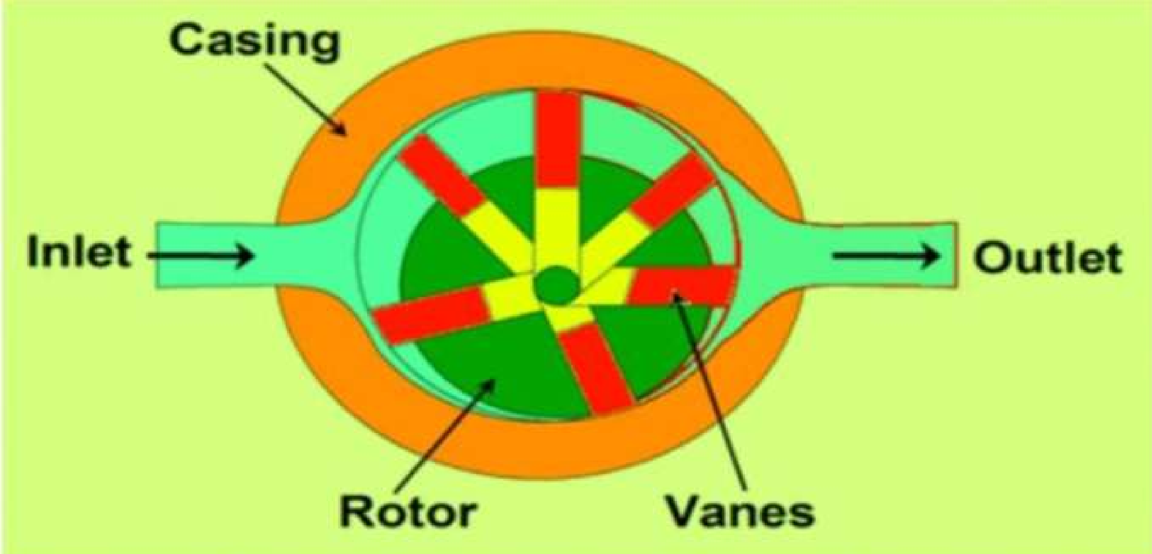
- Rotary compressor is compact and light.
- It does not exhibit vibration and shaking forces as that of the reciprocating compressor. So it does not require a rigorous foundation.
- High volumetric efficiency since the clearance volume for a rotary compressor is negligible.
- It operates at high speed, so it can handle a large quantity of fluid.
- Machine parts are well balanced. Less noisy.
- Maintenance of low.
- Lubrication is simple, and the output fluid is free from dirt/ oil.
- Unlike the reciprocating compressor which discharges intermittent, the rotary compressor supply compressed air continuously
- Low initial cost.

Disadvantages

- Discharge pressure per stage is low compared to the reciprocating compressor.
- No flexibility in capacity and compression ratio.



Parts labeled for a stationary blade rotary compressor.

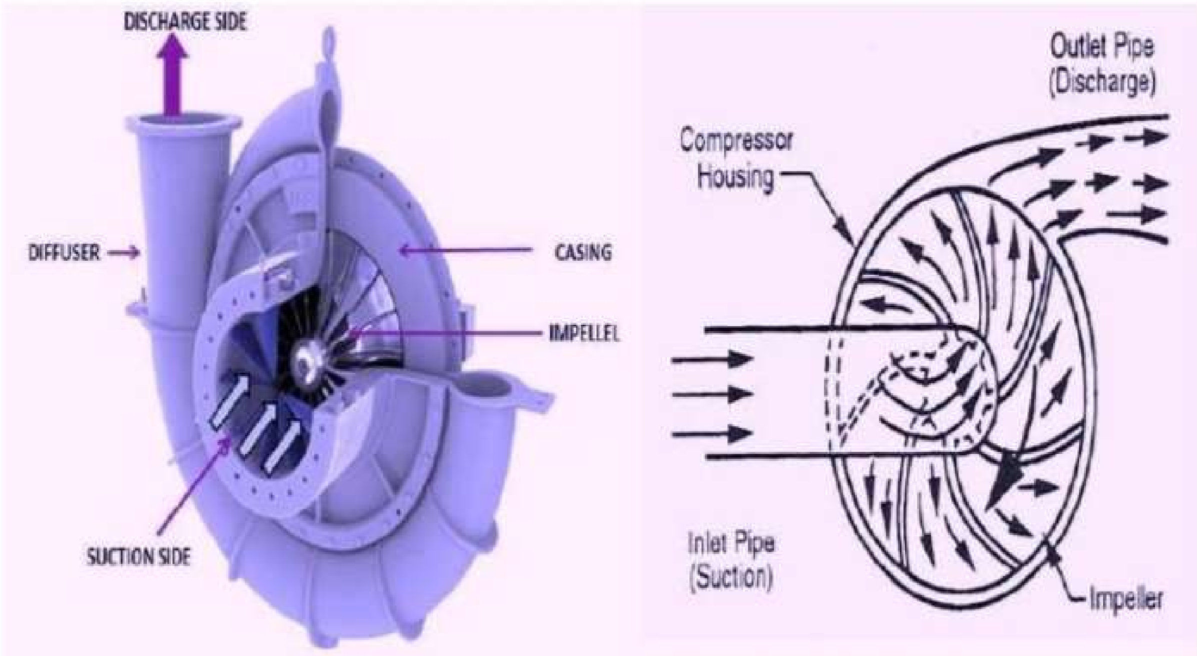


Differentiate between Reciprocating & Rotary Compressor:-

Reciprocating compressor	Rotary compressor
1. Compression of air takes place with help of piston and cylinder arrangement with reciprocating motion of piston.	1. Compression of air takes place due to rotary motion of blades.
2. Delivery of air intermittent.	2. Delivery of air is continuous.
3. Delivery pressure is high i.e. pressure ratio is high.	3. Delivery pressure is low, i.e. pressure ratio is low.
4. Flow rate of air is low.	4. Flow rate of air is high.
5. Speed of compressor is low because of unbalanced forces.	5. Speed of compressor is high because of perfect balancing.
6. Reciprocating air compressor has more number of moving parts.	6. Rotary air compressor has less number of moving part.
7. It needs proper lubrication and more maintenance.	7. It required less lubrication and maintenance.
8. Due to low speed of motion it can't be directly coupled to prime mover	8. Rotary air compressor can be directly coupled to prime mover.
9. It is used when small quantity of air at high pressure is required.	9. It is used where large quantity of air at lower pressure is required.

Centrifugal Compressor:-

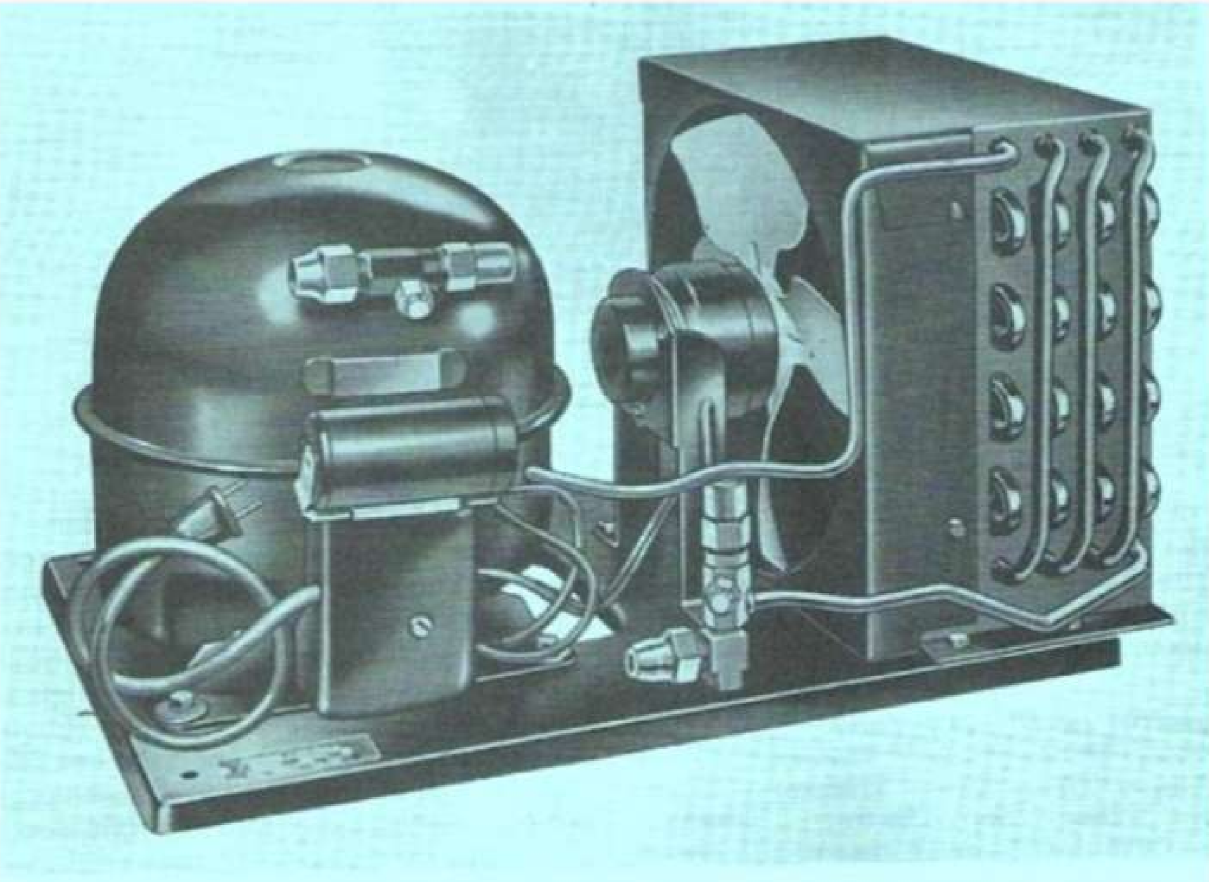
Centrifugal compressor is a type of dynamic compressor, with a radial design. Unlike displacement compressors that work at a constant flow, dynamic compressors work at a constant pressure and the performance is affected by external conditions such as changes in inlet temperatures.
-->Air is drawn into the center of a rotating impeller with radial blades and is pushed toward the center by centrifugal force. This radial movement of air results in a pressure rise and the generation of kinetic energy. Before the air is led into the center of the impeller, the kinetic energy is also converted into pressure by passing through a diffuser and volute.



CENTRIFUGAL COMPRESSOR

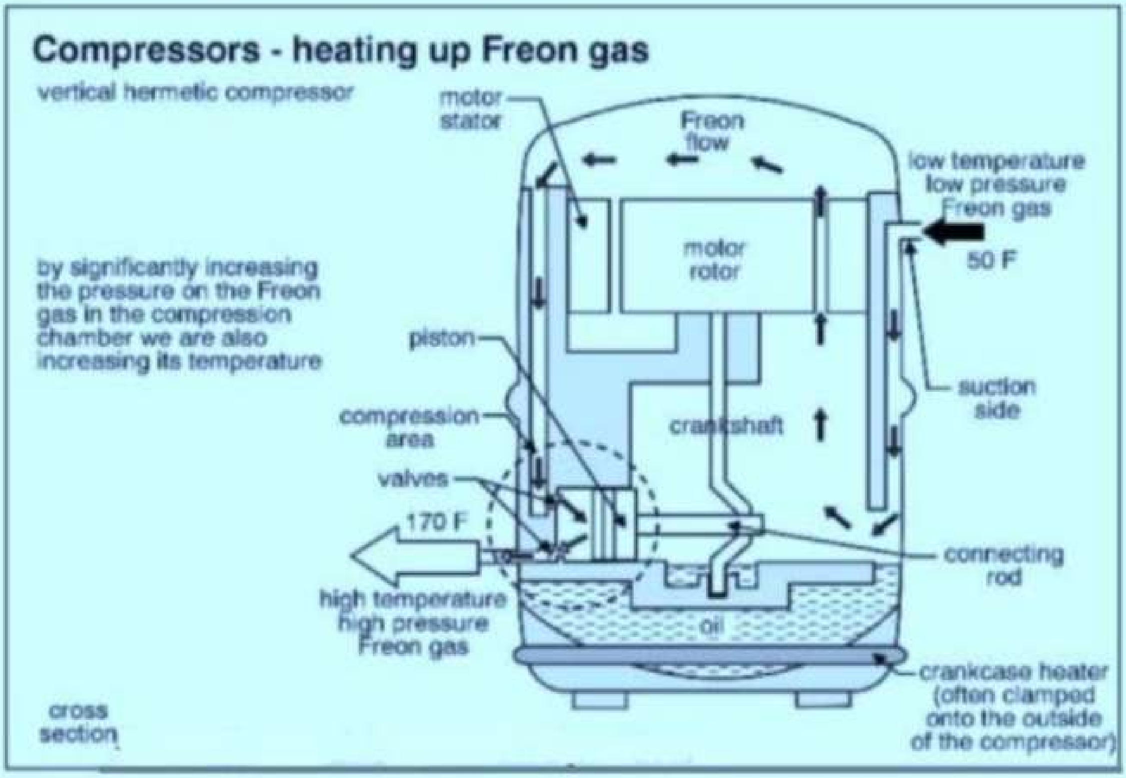
Hermetically Sealed Compressor:-

The compressor and the motor are enclosed in the welded steel casing and the two are connected by a common shaft. This makes the whole compressor and the motor a single compact and portable unit that can be handled easily.
-->It is very different from the traditional open type of compressors in which the compressor and the motor are different entities and the compressor is connected to the motor by coupling or belt.



Air-cooled condensing unit employing hermetic motor compressor. Note separate fan to circulate air over condenser. (Courtesy of Tecumseh Products Company.)

❑Hermetic sealed compressor



- **Advantages**

i. No leakage
ii. Less noise as compared
iii. Compact in size
iv. Dust free

- **Disadvantages**

i. Not used for wide range
ii. Heat cannot rejected to surrounding
iii. Maintenance of piston & valves is difficult or not possible

- **Applications**

Used for

- Small capacity refrigeration system
- Domestic refrigerators, freezers & AC
- Window AC & Water cooler etc.

Semi-hermetically Sealed Compressor:-

It encloses the motor compressor by common housing.It prevents the leakage of fluid.

-->The casing is bolted together instead of rigidly welding

-->The casing can be opened to repair motor and other components.

Semi-hermetic sealed compressor

Developed to avoid the disadvantages of Hermetic compressor.

- **Advantages -**
  - Maintenance is easy
  - Efficiency is high - cooling motor is provided
- **Disadvantage-**
  - Cost is higher compared to hermetic compressor
- **Applications**

Used for

- Refrigerants R-134a, R-407C, R-404A, R-507A, & R-22.

Principle of Working & Construction of Air Cooled Condenser:-

The atmospheric air is used as a medium of heat transfer in air cooled condenser. The heat rejected by the refrigerant is received by the air.

-->The air circulation over an air cooled condenser may be either natural convection or by the action of blower or fan. Accordingly, they are classified as Natural Draft or Mechanical Draft Condenser.

-->The air cooled condenser consists of finned tubing of copper or other suitable metal in which the vapour of the refrigerant enters from the top and the liquid refrigerant leaves from the bottom of the condenser.

-->The heat transfer area, temperature of the air, velocity of the air, overall heat transfer co-efficient etc. are important parameters affecting the performance of the condenser.

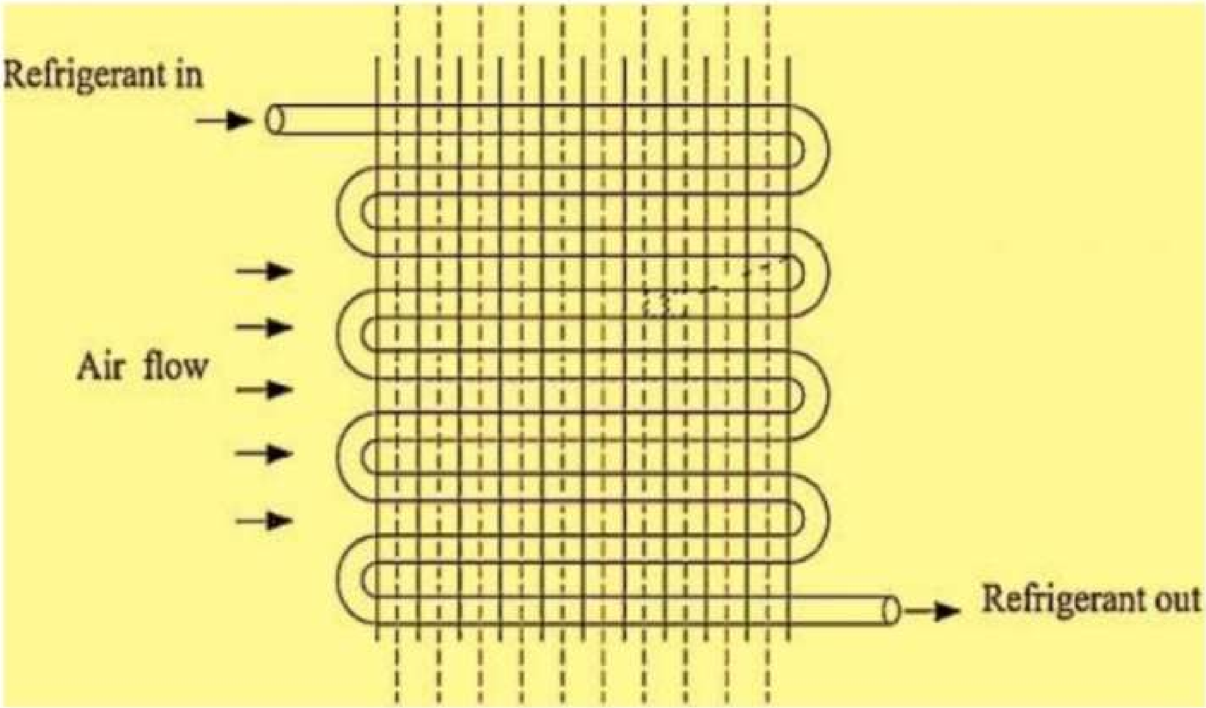
-->This type of condenser is used for relatively small capacity system as heat rejection rate per unit area of the tube is less as compared to other type of condensers. The air velocities normally employed are 2 m/s to 6 m/s.

-->In case of Natural Convection Air Cooled Condenser, the air quantity circulated over the condenser is low and hence condensing surface required is relatively larger as compared to Mechanical Draft Air Cooled Condenser.

-->Air cooled condensers are used in small capacity refrigeration systems such as window air conditioners, water coolers, split air conditioners etc. as the overall heat transfer co-efficient is low as compared to other types of condensers.

-->The capacity of an air cooled condenser depends on heat transfer area, temperature difference, air velocity and overall heat transfer co-efficient between refrigerant and cooling air.

-->So far as maintenance is concerned, removal of dust, dirt, lint etc. settled on the surface of the condenser is to be removed periodically by using air blower in order to maintain better heat transfer rate.



Principle of Working & Construction of Water Cooled Condenser:-

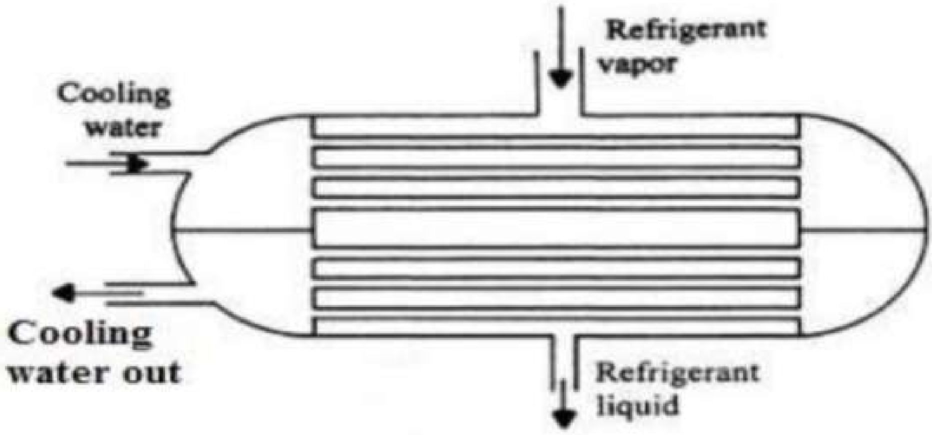
In water cooled condenser, heat is rejected in the water which is cooled in the cooling tower and the same water is circulated in the water cooled condenser. Based on the constriction, water cooled condenser are of three types 1.Shell and tube type, 2.Double pipe 3.Shell and coil type.

-->In Double Pipe arrangement, the refrigerant condenses in the outer pipe and the cooling water flows through the inner pipe in counter current direction. The #Shell and Coil type condenser consists of shell in which water coil is placed for the circulation of water. Both of these types are not commonly used on account of difficulty of cleaning the water side surface of the pipe or coil.

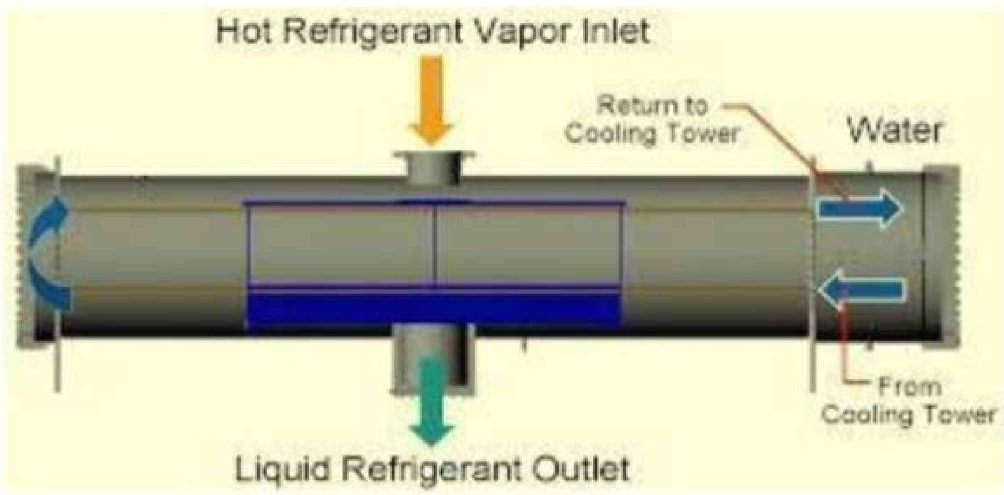
-->Shell and Tube type water cooled condensers are widely used in commercial refrigeration plant. It consists of a cylindrical shell in which a number of tubes are arranged in parallel and held in place at the ends by tube sheets. The condensing water is circulated through the tubes and the refrigerant is contained in the shell.

-->The end plates being baffled to act as manifolds to guide the water flow through the tubes. The arrangement of the end plate determines the number of passes the water makes through the condenser before leaving the condenser.

-->The shell diameter range from 100 mm to 1500 mm, whereas length varies from 1000 mm to 6500 mm. The number and the diameter of the tube depend on the diameter of the shell. The tube diameter varies from 16 mm to 50 mm.



Shell and Tube Type Condenser



Heat Rejection Ratio (Heat Rejection Factor) in Condenser:- HRF

-->It is defined as the ratio of heat gained by the gas/water in the condenser to the heat absorbed by refrigerant in the evaporator

-->This ratio gives the heat rejected in the condenser per unit load of refrigeration handled by the Evaporator.

-->In other words, when we say that HRF is 1.5, it means that for every tonne of refrigeration load handled by the evaporator, the condenser will have to reject heat equivalent to 1.5 tonne.

Cooling Tower:-

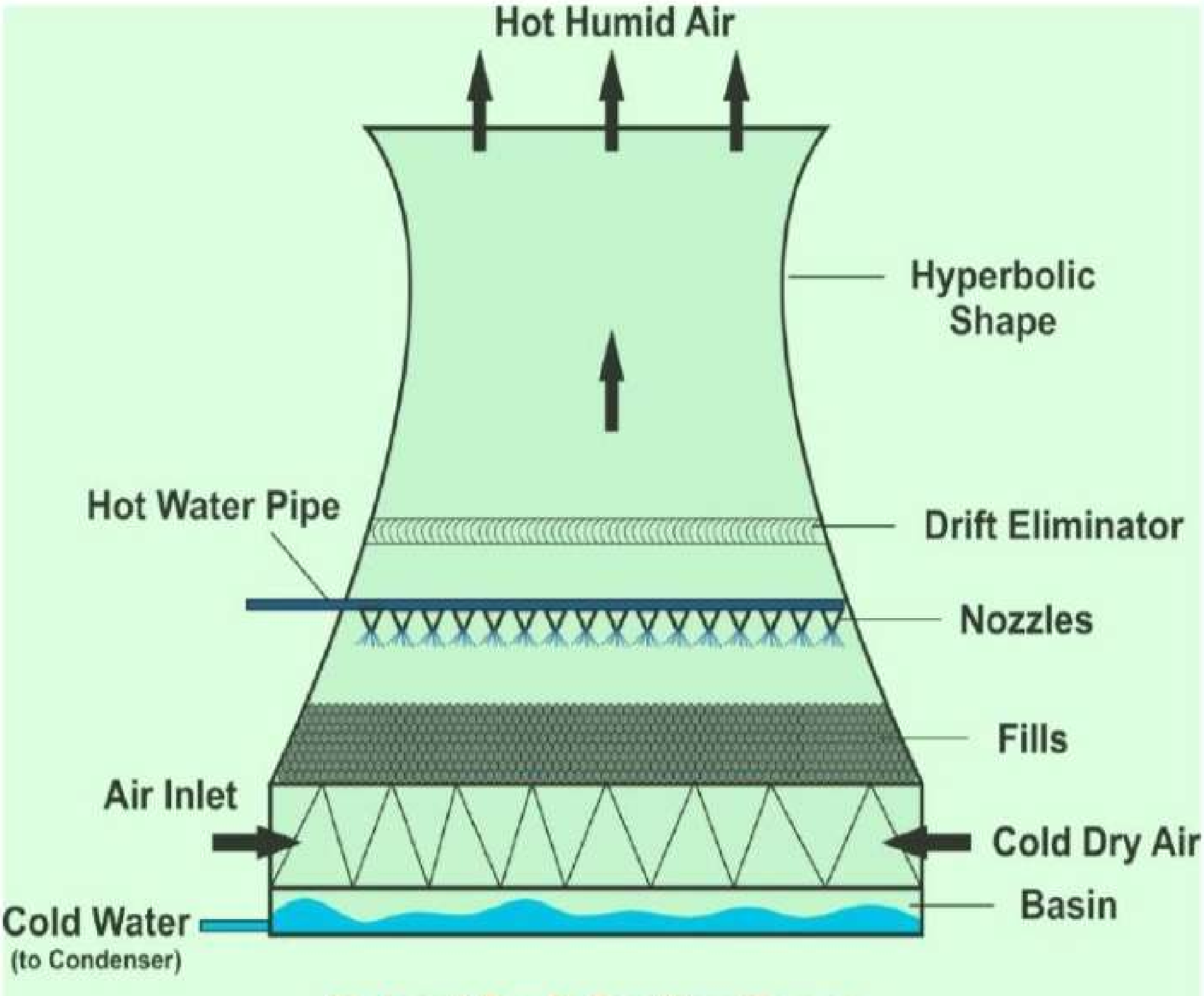
A cooling tower is a specialized heat exchanger in which air and water are brought into direct contact with each other in order to reduce the water's temperature. As this occurs, a small volume of water is evaporated, reducing the temperature of the water being circulated through the tower.

-->Water, which has been heated by an industrial process or in an air-conditioning condenser, is pumped to the cooling tower through pipes. The water sprays through nozzles onto banks of material called "fill," which slows the flow of water through the cooling tower, and exposes as much water surface area as possible for maximum air-water contact.

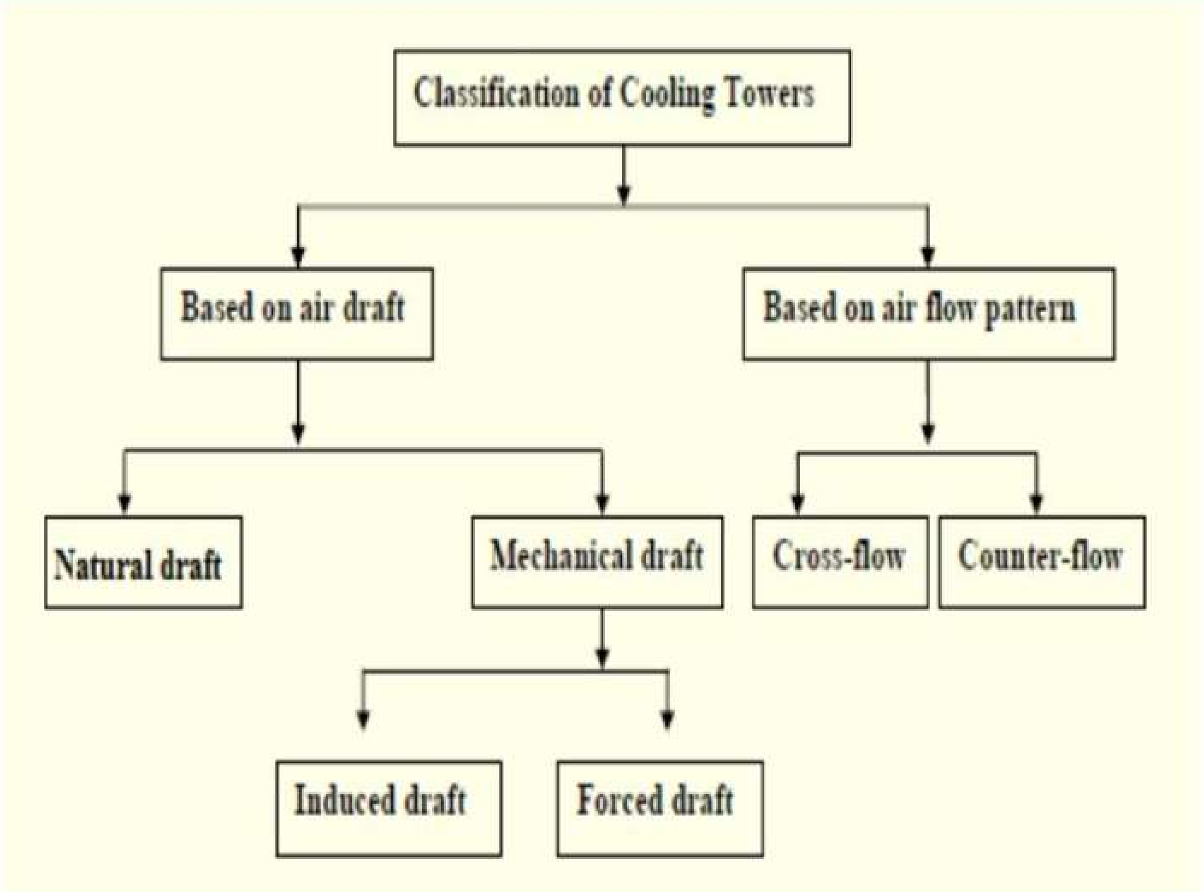
-->As the water flows through the cooling tower, it is exposed to air, which is being pulled through the tower by the electric motor-driven fan.

-->When the water and air meet, a small amount of water is evaporated, creating a cooling action.

-->The cooled water is then pumped back to the condenser or process equipment where it absorbs heat. It will then be pumped back to the cooling tower to be cooled once again.



Natural Draft Cooling Tower



Spray Pond or Cooling Pond:-

A spray pond is a reservoir in which warmed water (e.g. from a power plant) is cooled before reuse by spraying the warm water with nozzles into the cooler air. Cooling takes place by exchange of heat with the ambient air, involving both conductive heat transfer between the water droplets and the surrounding air and evaporative cooling (which provides by far the greatest portion, typically 85 to 90%, of the total cooling).

-->The primary purpose of spray pond design is thus to ensure an adequate degree of contacting between the hot injection water and the ambient air, so as to facilitate the process of heat transfer.

-->The spray pond is the predecessor to the natural draft cooling tower, which is much more efficient and takes up less space but has a much higher construction cost. A spray pond requires between 25 and 50 times the area of a cooling tower. However, some spray ponds are still in use today.

Spray Pond or Cooling Pond

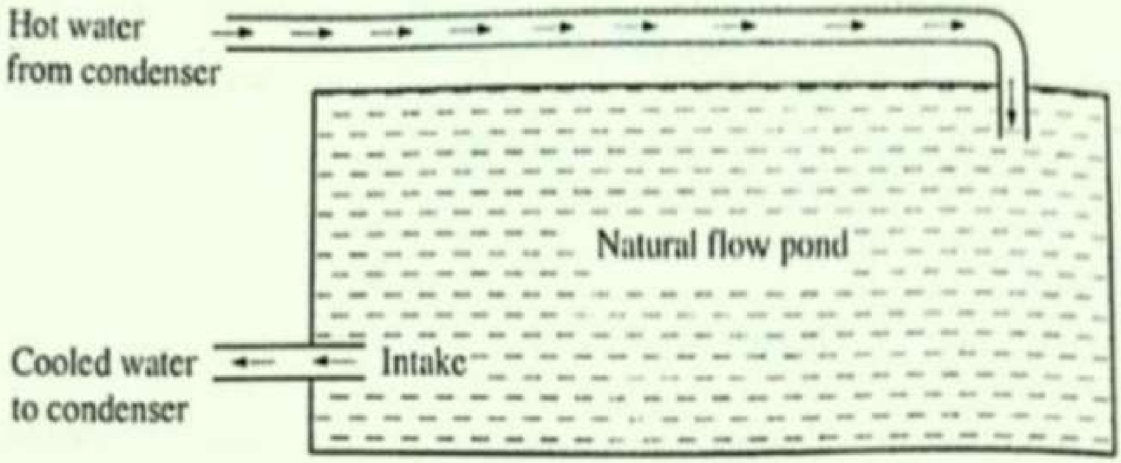
- A cooling pond is a man-made body of water primarily formed for the purpose of supplying cooling water to a nearby power plant.
- Cooling ponds are used where sufficient land is available, as an alternative to cooling towers.
- The cooling pond is one of the simple method of cooling the condenser water.
- This method is less efficient than cooling water.

- **Types of the cooling ponds:**

1. Natural and directed flow cooling pond.
2. Single deck and double deck cooling pond.
3. Spray pond with louvre fence

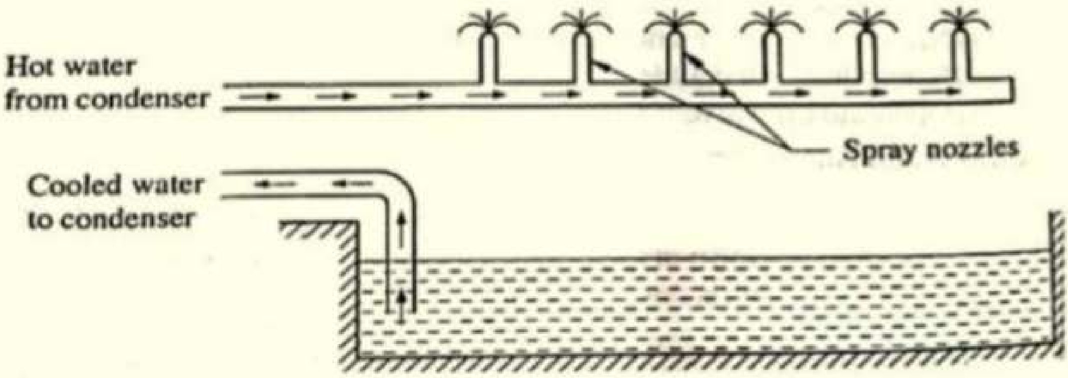
Cooling Ponds :

Natural flow cooling pond

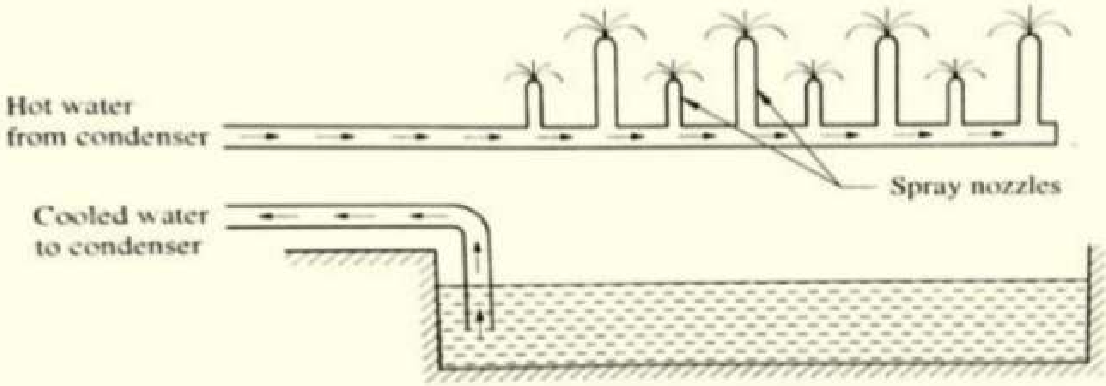


Cooling Ponds :

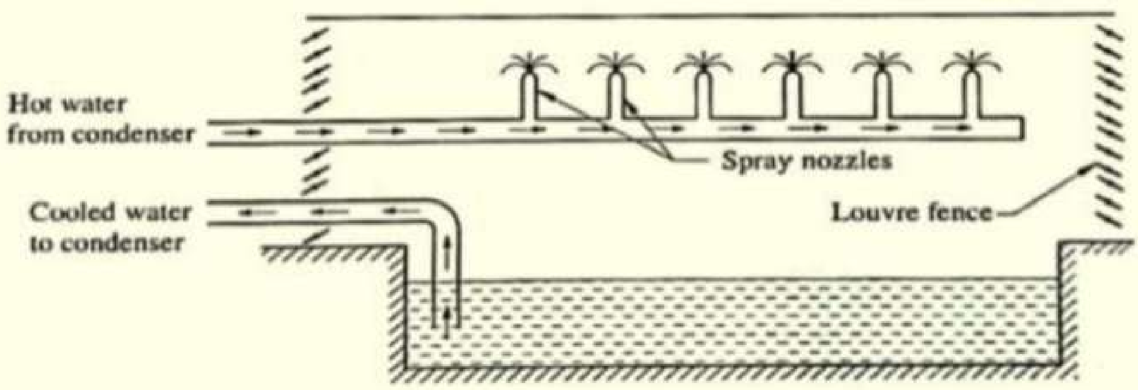
Single deck cooling pond



Double deck spray pond



Spray pond with Louvre fence



Working Principle & Construction of an Evaporator in refrigeration system:-

The evaporator is the main part of the refrigeration system. The evaporators are heat exchanger surfaces that transfer the heat from the substance to be cooled to the refrigerant, thus removing the heat from the substance.

-->The evaporators are used for wide variety of diverse applications in refrigeration and air conditioning processes and hence they are available in wide variety of shapes, sizes and designs. They are also classified in different manner depending on the method of feeding the refrigerant, construction of the evaporator, direction of air circulation around the evaporator, application and also the refrigerant control.

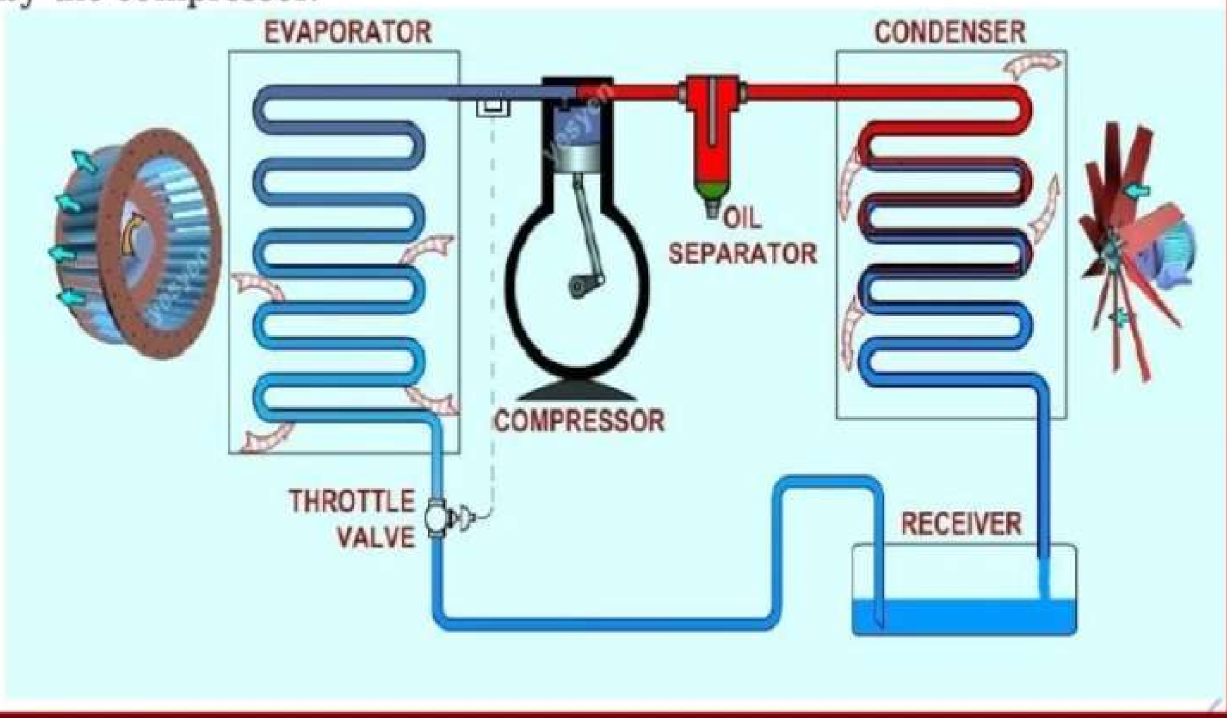
-->In the domestic refrigerators the evaporators are commonly known as the freezers since the ice is made in these compartments.

-->In case of the window and split air conditioners and other air conditioning systems where the evaporator is directly used for cooling the room air, it is called as the cooling coil.

-->In case of large refrigeration plants and central air conditioning plants the evaporator is also known as the chiller since these systems are first used to chill the water, which then produces the cooling effect.

-->In the evaporator the refrigerant enters at very low pressure and temperature after passing through the expansion valve.

-->This refrigerant absorbs the heat from the substance that is to be cooled so the refrigerant gets heated while the substance gets cooled. Even after cooling the substance the temperature of the refrigerant leaving the evaporator is less the than the substance. -->The refrigerant leaves the evaporator in vapor state, mostly superheated and is absorbed by the compressor.



There are two types of evaporator:-

1)Forced Convection Type uses a fan or pump to force the liquid being cooled over the evap.

2)Natural Convection Type has the liquid being cooled flows naturally to the evap. due to the density differences of the chilled and warm liquid.

The evaporators are classified based on the construction as:-

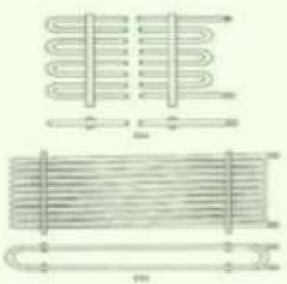
1)Bare tube evaporators
2)Plate surface evaporators
3)Finned evaporators
4)Shell & Tube type

TYPES OF EVAPORATORS

- According to type of construction
  1. Bare tube coil evaporator
  2. Finned tube evaporator
  3. Plate evaporator
  4. Shell and tube evaporator
  5. Shell and coil evaporator
  6. Tube in tube evaporator

- According to the manner in which liquid refrigerant is fed
  1. Flooded evaporator
  2. Dry expansion evaporator

Bare tube coil evaporator



- Prime surface evaporator
- Easy to clean and defrost
- s/f contact area is less
- Limited applications

Finned tube evaporator

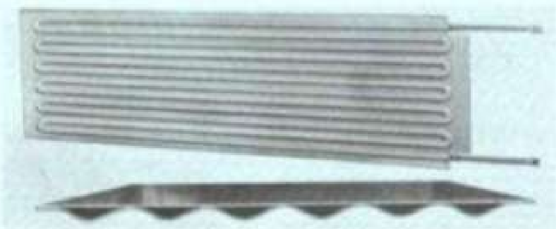
- Over the bare tube metal fins are fastened
- Shape, size, spacing can be adapted for better rate of heat transfer
- Extended surface evaporators

Finned evaporator:-

-->The fins are added to the bare-tube to increase the heat transfer capability. They act as heat collector that pick up heat from the surrounding air and conduct it to the refrigerant inside the tube hence improving the efficiency in cooling the air of the surrounding.

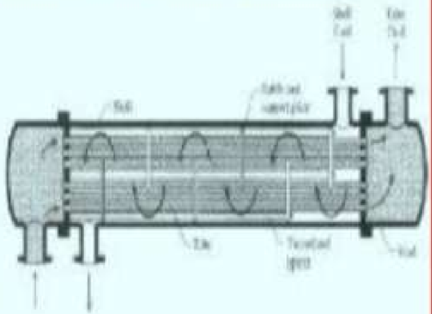
-->Having fins mean the surface area for heat transfer has been extended. This means that the finned coils can have more compact in design compared to the bare-tube type of similar capacity.

Plate evaporator



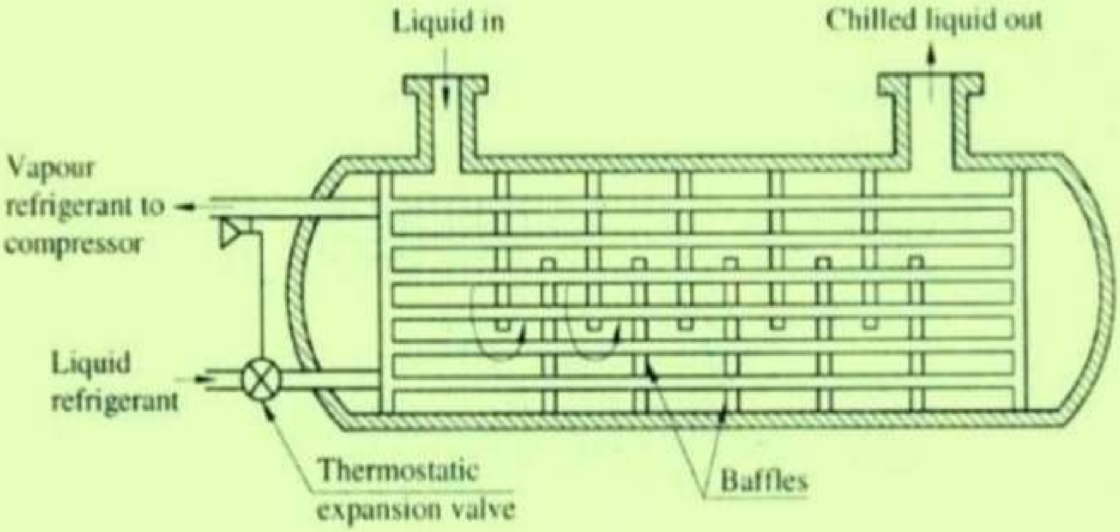
- The bare coils are either welded on the plate or between the two plates which are welded together
- Used in household refrigerators, beverage cooler, ice cream cabinets

Shell and tube evaporator



- Contraction is same as shell and tube type of condenser
- Available in flooded as well as dry expansion type
- Baffle plates are provided for good turbulence of liquid
- Capacity 2TR to 250TR

- **Shell and tube evaporator**



Shell and tube evaporator

Refrigerant:-

It is a substance which absorbs the heat from storage space (system) to produce lower temperature. Refrigerant may be classified as Primary refrigerants and Secondary refrigerants.

Primary refrigerants are those which can be directly used for the purpose of refrigeration. The refrigerants used in home refrigerators like Freon-12 are primary refrigerants. On the other hand, there may be certain situations in which we cannot allow the refrigerant to come in direct contact with the items being refrigerated, and then the refrigerant used is termed as a secondary refrigerant. Example: Water, Brine, Glycol

Again primary refrigerant can be classified as follows:-

1) Halo carbon/ Organic
2) Azeotrope
3) Inorganic
4) Hydro carbon

Halocarbon Refrigerant:- They are all synthetically produced and were developed as the Freon family of refrigerants. They are fluorocarbons of methane and ethane series. They contain 1 or more of these halogens (chlorine, bromine, fluorine)

→Non toxic, non-flammable, non-explosive, non- corrosive, non-irritant to human body and eyes. odourless, colourless, Will not react with food product stored in the refrigerated space. Will not react with lubricating oil. Has excellent thermodynamic properties Only disadvantage is ozone layer is damaged.

→Examples : CFC's : R11, R12, R113, R114, R115

HCFC's : R22, R123

HFC's : R134a, R404a, R407C, R410a

Azeotrope Refrigerants:- This group of refrigerants consist of mixture of different refrigerants which can not separated under pressure and temperature and have fixed thermodynamic properties.

→A stable mixture of two or several refrigerants whose vapour and liquid phases retain identical compositions over a wide range of temperatures.

→Azeotropic mixtures are designated by 500 series

→Examples : R-500 :(73.8% R12 and 26.2% R152) R-502 : (8.8% R22 and 51.2% R115) R-503 : (40.1% R23 and 59.9% R13)

Inorganic Refrigerants:- Inorganic refrigerant were exclusively used before the introduction of halocarbon. These refrigerant are still in use due to their inherent thermodynamic and physical properties.
→Example:Carbon Dioxide, Water. Ammonia, Air, Sulphur dioxide

Hydrocarbons:- Most of the hydrocarbon refrigerant are successfully used in industrial and commercial installation . They possess satisfactory thermodynamic properties but are highly flammable and explosive. Growing use in very small commercial systems like car air-conditioning system
→Examples: R170, Ethane, C2H6 R290 , Propane C3H3 R600, Butane, C4H10 R600a, Isobutane, C4H10 Blends of the above Gases.

Designation of Refrigerants:-

1) If the refrigerants are saturated hydrocarbon:
Chemical formula of refrigerant is $C_mH_nF_pCl_q$ such a refrigerant designated as $R_{(m-1)(n+1)p}$
Where, n+p+q = 2m+2

2) If the refrigerants are un-saturated hydrocarbon:
Chemical formula of refrigerant is $C_mH_nF_pCl_q$ such a refrigerant designated as $R_{1\ (m-1)(n+1)p}$
Where, n+p+q = 2m

3) Inorganic refrigerants:
These are designated by number 7 followed by the molecular weight of the refrigerant (rounded-off).
Ex.: Ammonia: Molecular weight is 17, the designation is R 717
Carbon dioxide: Molecular weight is 44, the designation is R 744
Water: Molecular weight is 18, the designation is R 718

4) Azeotrope : It is mixture of two or more refrigerants behave like pure substance and designated as R500, R501, R502

Desirable Properties of an ideal Refrigerant:-

Desirable properties that a refrigerant should possess those are:

1. Thermodynamic Properties:

(i) Low boiling point
(ii) Low freezing point
(iii) Positive pressures (but not very high) in condenser and evaporator.
(iv) High saturation temperature
(v) High latent heat of vapourization

2. Chemical Properties:

(i) Non-toxicity
(ii) Non-flammable and non-explosive
(iii) Non-corrosiveness
(iv) Chemical Stability
(v) No effect on the quality of stored (food and other) products

3. Physical Properties:

(i) Low specific volume of vapour
(ii) Low specific heat
(iii) High thermal conductivity
(iv) Low viscosity
(v) High electrical insulation

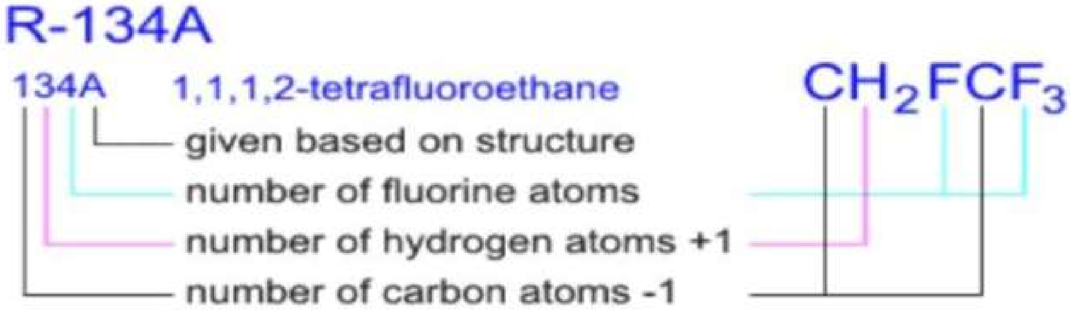
4. Others Properties:

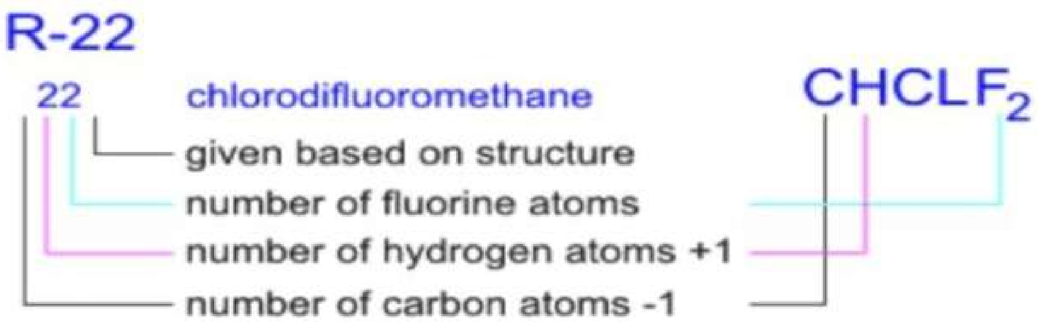
(i) Ease of leakage location
(ii) Availability and low cost
(iii) Ease of handling
(iv) High COP
(v) Low power consumption per tonne of refrigeration
(vi) Low pressure ratio and pressure difference

Refrigerant R12 or Freon 12 :- It is said to be the most widely used of all the refrigerants being used for different applications. The chemical name of refrigerant R12 is dichlorodifluoromethane and its chemical formula is CCl_2F_2. The molecular weight of R12 is 120.9 and its boiling point is -21.6 degree F.

Ammonia (NH_3) R-717 :- Used for commercial purposes. Mainly in cold stored and ice plants. The boiling temperature of NH_3 at atmospheric pressure is -33 ºc and melting point from solid is -78ºC

→The low boiling points makes it possible to have refrigeration considerably below 0ºC without using pressure below atmospheric in the evaporator. Its latent heat of vaporization at -15ºC is 1315 k/kg. It is colorless gas with a sharp pungent smell. Has good thermodynamic properties It is neutral to all metals, highly soluble in oil. Volatile and non toxic but in higher conc.

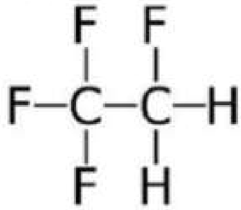




R134a

- **R134a (1bar = -26°C)**
- Molecular formula $C_2H_2F_4$
- Molar mass 102.03 g/mol
- Appearance Colorless gas
- Density 4.25 kg/m³, gas
- Melting point -103.3°C (169.85 K)
- Boiling point -26.3°C (246.85 K)

- ODP = 0
- GWP = 1430

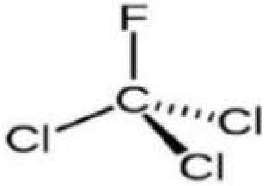


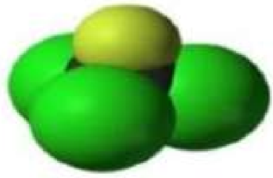
- Replacement for R11 & R12 (not a drop-in)

R11

- **R11 (1bar = 24°C)**
- Molecular formula CCl_3F
- Molar mass 137.37 g/mol
- Appearance Colorless liquid/gas
- Density 1.494 g/cm^3
- Melting point -110.48 °C
- Boiling point 23.77 °C

- ODP = 1
- GWP = 4000





Substitute for CFC refrigerant:-

The best choices from an environmental point of view are the natural refrigerants:

- Ammonia
- Hydrocarbons
- Carbon dioxide : Mainly for Vehicle AC and mobile refrigeration

Replacements of CFCs

CFCs	Replacements	Uses
CFC-12 (CCl_2F_2), CFC-13($CClF_3$), HCFC-22 ($CHClF_2$), CFC-113 ($Cl_2FCCClF_2$), CFC-114 ($CClF_2CClF_2$), CFC-115 (CF_3CClF_2) etc.	HFC-23 (CHF_3), HFC-134a (CF_3CFH_2), HFC-507 (a 1:1 azeotropic mixture of HFC 125 (CF_3CHF2) and HFC-143a (CF_3CH_3) etc.	Refrigeration & air-conditioning.
CFC-114 ($CClF_2CClF_2$) etc.	HFC-134a (CF_3CFH_2), HFC-227ea (CF_3CHFCF_3) etc.	Propellants in medicinal aerosols.
CFC-11 (CCl_3F); CFC 113 ($Cl_2FCCClF_2$); HCFC-141b (CCl_2FCH_3) etc.	HFC-245fa ($CF_3CH_2CHF_2$); HFC-365 mfc ($CF_3CH_2CF_2CH_3$) etc.	Blowing agents for foams.

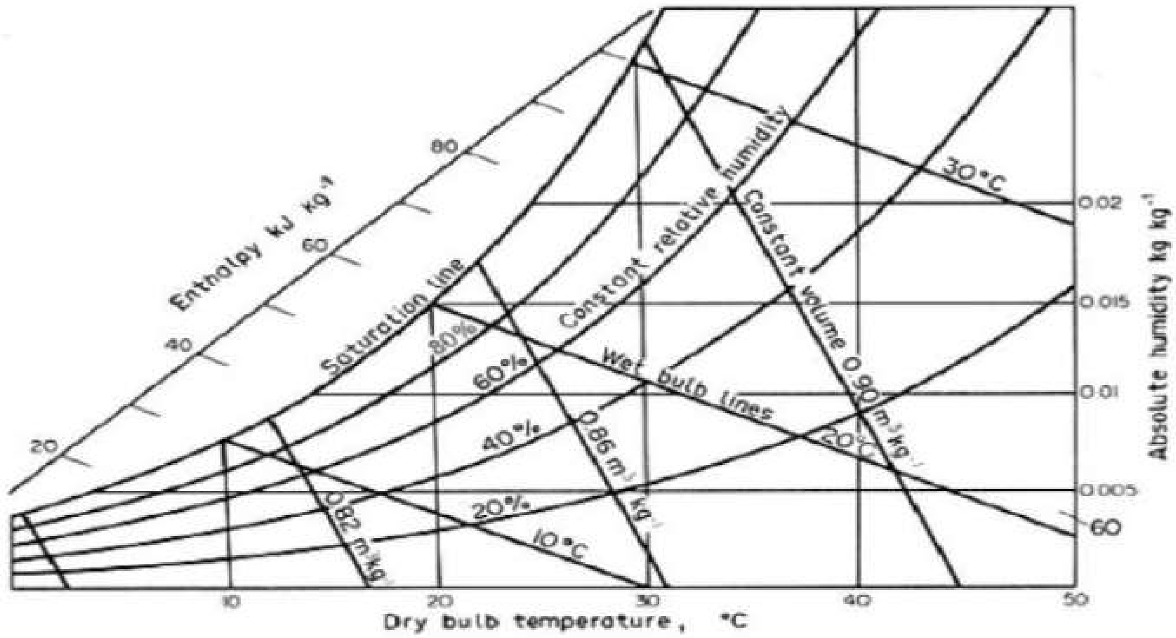
Psychrometry:-

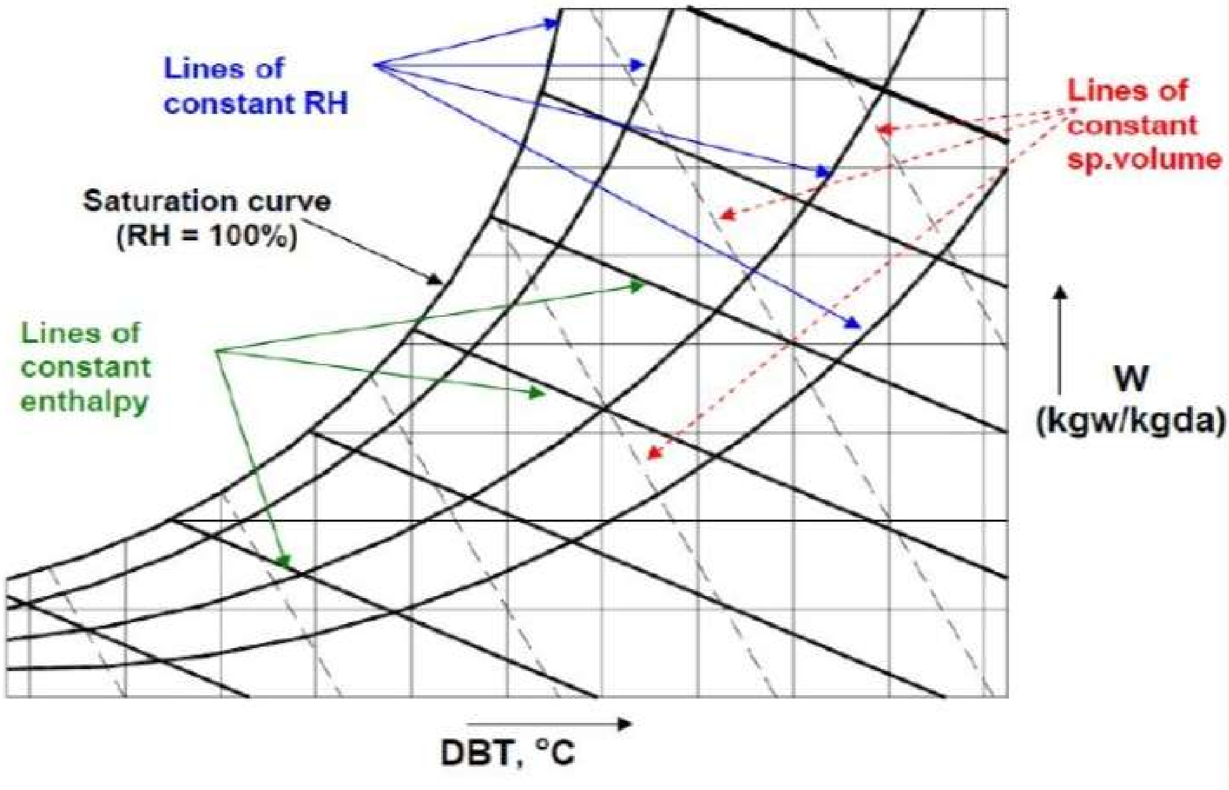
It is the science of studying thermodynamic properties of moist air and the use of these to analyze humid air conditions and processes. Air conditioning processes can be determined with psychrometric charts and Mollier diagrams.

Psychrometric Chart:-

Psychrometric charts are graphic representations of the psychrometric properties of air.

All the properties of air indicated in the psychrometric chart are calculated at the standard atmospheric pressure. The psychrometric chart looks like a shoe. The various lines shown in the chart are as follows:





Uses of psychrometric charts:-

Psychrometric charts are complex graphs that can be used to study the physical and thermodynamic properties of gas-vapour mixtures at a constant pressure. They are often used to assess the properties of moist air.

By using it, Heating, ventilation, and air conditioning (HVAC) engineers can graphically analyze different types of psychrometric processes and find solution to many practical problems without having to carry out long and tedious mathematical calculations.

Properties of Psychrometry:-

Dry-bulb temperature
Wet bulb temperature
Dew point temperature
Relative humidity
Humidity ratio
Humidity
Specific humidity
Absolute humidity
Psychrometric ratio

Dry Bulb (DB) temperature lines: The dry bulb temperature scale is shown along the base of the shoe shaped psychrometric chart forming the sole. The DB temperature increases from the left to the right. The vertical lines shown in the chart are the constant DB temperature lines and all the points located along a particular vertical line have same DB temperature.

Wet Bulb (WB) Temperature Lines: The outermost curve along the left side indicates the Wet Bulb (WB) temperature scale. The constant WB temperature lines are the diagonal lines extending from WB temperature curved scale downwards towards the right hand side of the chart. All the points located along the constant WB temperature line have the same temperature.

Dew Point (DP) Temperature Lines: Since the dew point temperature of the air depends on the moisture content of the air, constant moisture lines are also constant DP temperature lines. The scale of the DP and WB temperature is the same, however, while the constant WB temperature lines are diagonal lines extending downwards, the constant

DP temperature lines are horizontal lines. Thus the constant DP and WB temperature lines are different.

Specific humidity or Humidity Ratio:- It is defined as the mass of water vapour per unit mass of the moist air sample (dry air plus the water vapour) at constant volume and temperature.

$w = m_v/m_a$

$w = 0.622\ P_v/(P_t-P_v)$

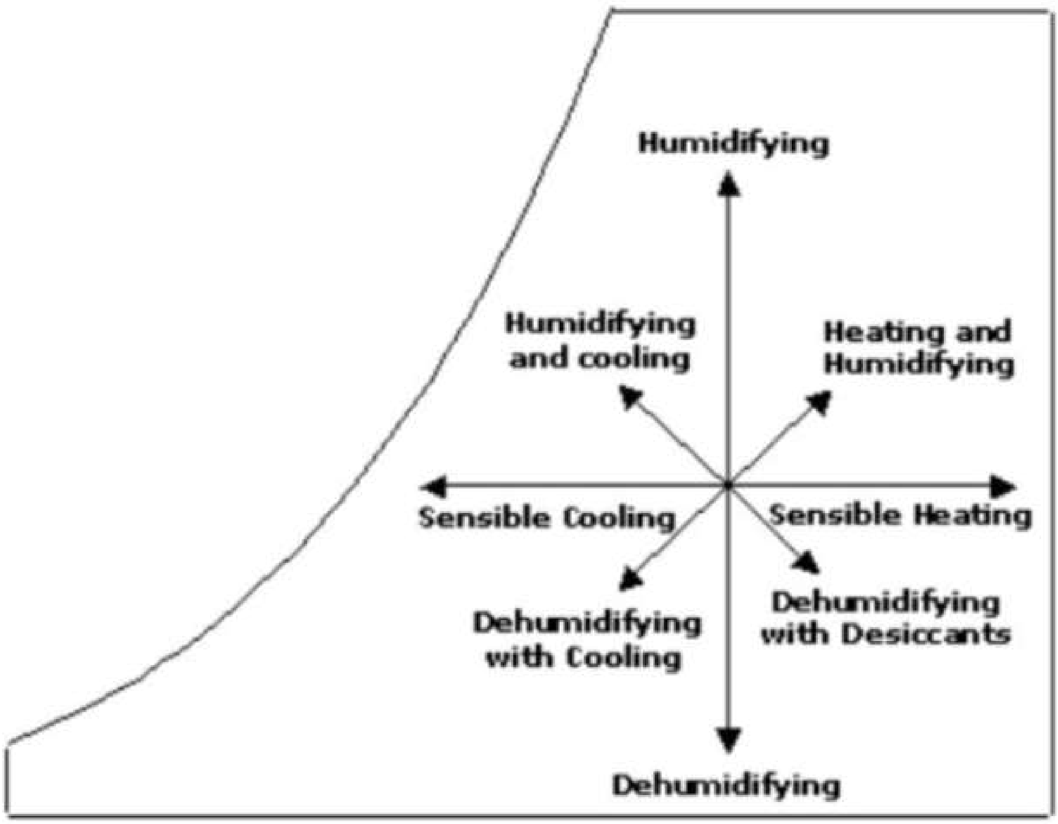
where, mv – mass of vapour, ma- mass of dry air, Pv, Pt, Pa-vapor, total, air press

Relative Humidity(RH):- It is defined as the ratio of mass of water vapour to the mass of water vapour at saturated temp at constant volume and temperature

$RH = m_v/m_{vs} = P_v/P_{vs}$ For saturated air, RH=100%

Psychrometric Processes:-

In the design and analysis of air conditioning plants, the fundamental requirement is to identify the various processes being performed on air. Once identified, the processes can be analyzed by applying the laws of conservation of mass and energy. All these processes can be plotted easily on a psychrometric chart. This is very useful for quick visualization and also for identifying the changes taking place in important properties such as temperature, humidity ratio, enthalpy etc. The important processes that air undergoes in a typical air conditioning plant are discussed below.



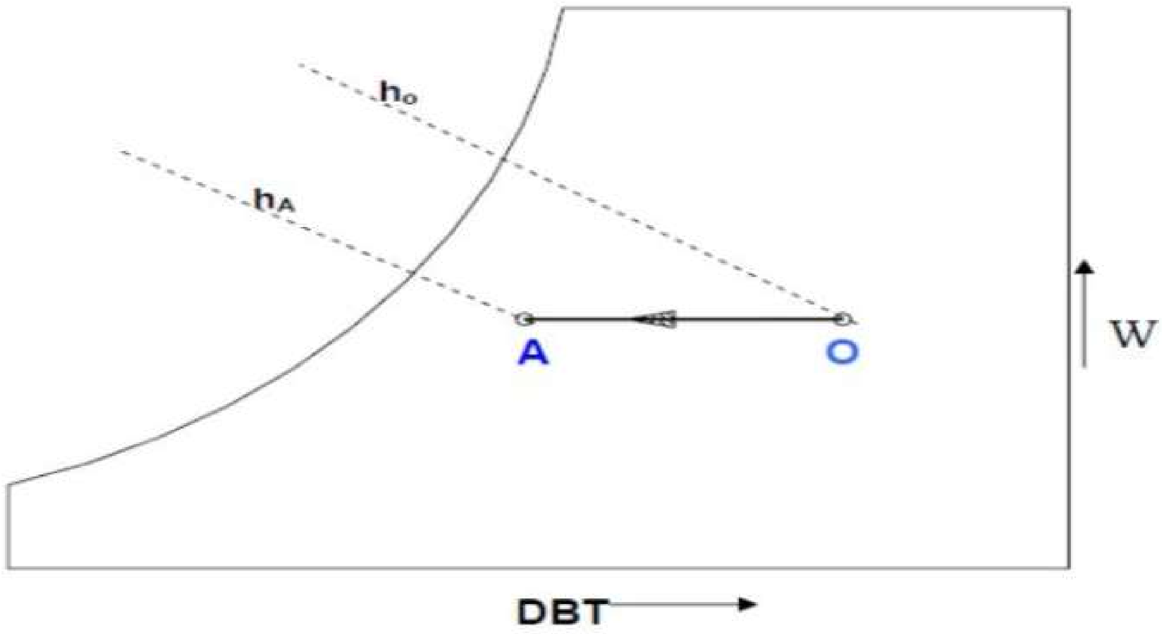
1) Sensible Cooling:

During this process, the moisture content of air remains constant but its temperature decreases as it flows over a cooling coil. For moisture content to remain constant, the surface of the cooling coil should be dry and its surface temperature should be greater than the dew point temperature of air. If the cooling coil is 100% effective, then the exit temperature of air will be equal to the coil temperature. However, in practice, the exit air temperature will be higher than the cooling coil temperature. Figure below shows the sensible cooling process O-A on a psychrometric chart.

The heat transfer rate during this process is given by:

$$Q_c = m_a (h_O - h_A) = m_a.C_{pm}(T_O - T_A)$$

$$Q_c = m_a (h_O - h_A) = m_a c_{pm} (T_O - T_A)$$

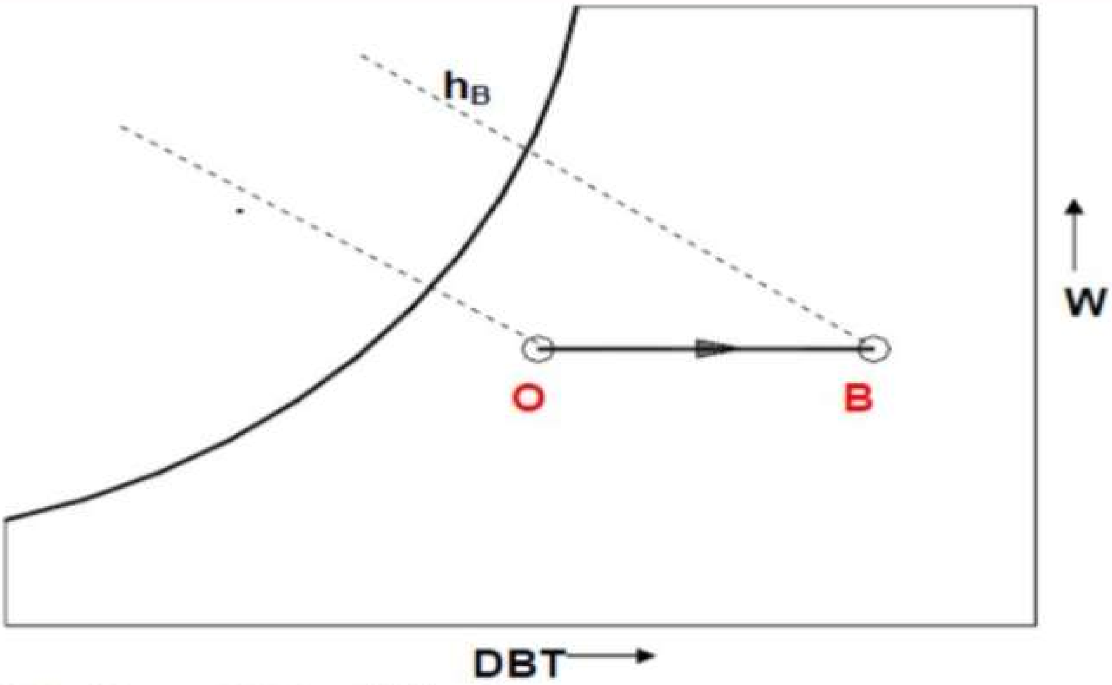


2) Sensible Heating:

During this process, the moisture content of air remains constant and its temperature increases as it flows over a heating coil. The heat transfer rate during this process is given by:

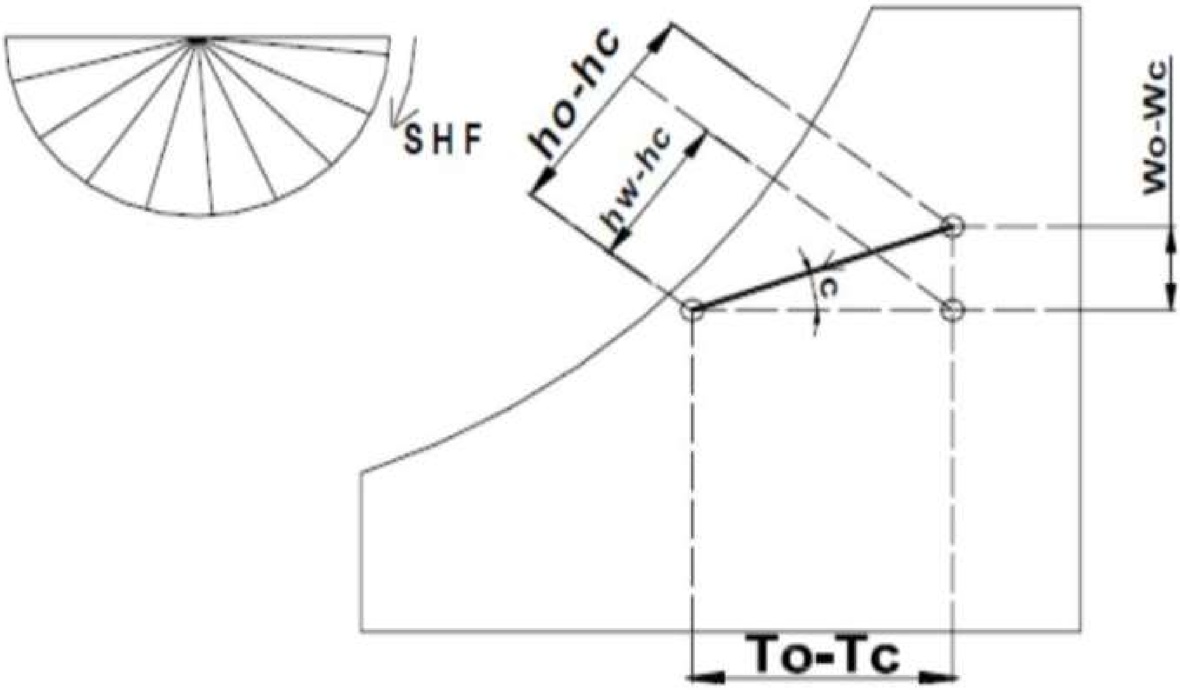
$$\mathbf{Q_h = m_a (h_B - h_O) = m_a.C_{pm}(T_B - T_O)}$$

where $\mathbf{C_{pm}}$ is the humid specific heat (≈1.0216 kJ/kg dry air) and $\mathbf{m_a}$ is the mass flow rate of dry air (kg/s).



3) Cooling and dehumidification:

When moist air is cooled below its dew-point by bringing it in contact with a cold surface as shown, some of the water vapor in the air condenses and leaves the air stream as liquid, as a result both the temperature and humidity ratio of air decreases as shown. This is the process air undergoes in a typical air conditioning system. Although the actual process path will vary depending upon the type of cold surface, the surface temperature, and flow conditions, for simplicity the process line is assumed to be a straight line. The heat and mass transfer rates can be expressed in terms of the initial and final conditions by applying the conservation of mass and conservation of energy equations as given below:



By applying mass balance for the water: $\mathbf{m_a.w_o = m_a.w_C + m_w}$
By applying energy balance: $\mathbf{m_a\,.h_O = Q_t + m_w\,.h_w + m_a\,.h_C}$

from the above two equations, the load on the cooling coil, Qt is given by: $\mathbf{Q_t = m_a\,(h_O - h_C) - m_a\,(w_O - w_C)h_w}$

the 2nd term on the RHS of the above equation is normally small compared to the other terms, so it can be neglected. Hence,

$\mathbf{Q_t = m_a\,(h_O - h_C)}$

It can be observed that the cooling and de-humidification process involves both latent and sensible heat transfer processes, hence, the total, latent and sensible heat transfer rates (Qt, Q_l and Q_s) can be written as:

$$Q_t = Q_l + Q_s$$

$$\text{where} \quad Q_l = m_a(h_O - h_w) = m_a.h_{fg}(w_O - w_C)$$

$$Q_s = m_a(h_w - h_C) = m_a.c_{pm}(T_O - T_C)$$

By separating the total heat transfer rate from the cooling coil into sensible and latent heat transfer rates, a useful parameter called **Sensible Heat Factor (SHF)** is defined. **SHF is defined as the ratio of sensible heat to total heat transfer rate**, i.e., $\mathbf{SHF = Qs/Qt = Qs/(Qs + Q_l)}$

It can be seen that the slope of the process line O-C is given by:

$\mathbf{\tan c = \Delta w / \Delta T}$

From the definition of SHF,

$$\frac{1-SHF}{SHF} = \frac{Q_l}{Q_s} = \frac{m_a h_{fg}\Delta w}{m_a c_{pm}\Delta T} = \frac{2501\Delta w}{1.0216\Delta T} = 2451\frac{\Delta w}{\Delta T}$$

$$\tan c = \frac{1}{2451}\left(\frac{1-SHF}{SHF}\right)$$

Thus we can see that the slope of the cooling and de-humidification line is purely a function of the sensible heat factor, SHF. Hence, we can draw the cooling and dehumidification line on psychrometric chart if the initial state and the SHF are known. In some standard psychrometric charts, a protractor with different values of SHF is provided. The process line is drawn through the initial state point and in parallel to the given SHF line from the protractor as shown in the figure above.

The temperature Ts is the effective surface temperature of the cooling coil, and is known as **apparatus dew-point (ADP) temperature**. In an ideal situation, when all the air comes in perfect contact with the cooling coil surface, then the exit temperature of air will be same as ADP of the coil. However, in actual case the exit temperature of air will always be greater than the apparatus dew-point temperature due to boundary layer development as air flows over the cooling coil surface and also due to temperature variation along the fins etc. Hence, we can define a **by-pass factor (BPF)** as:

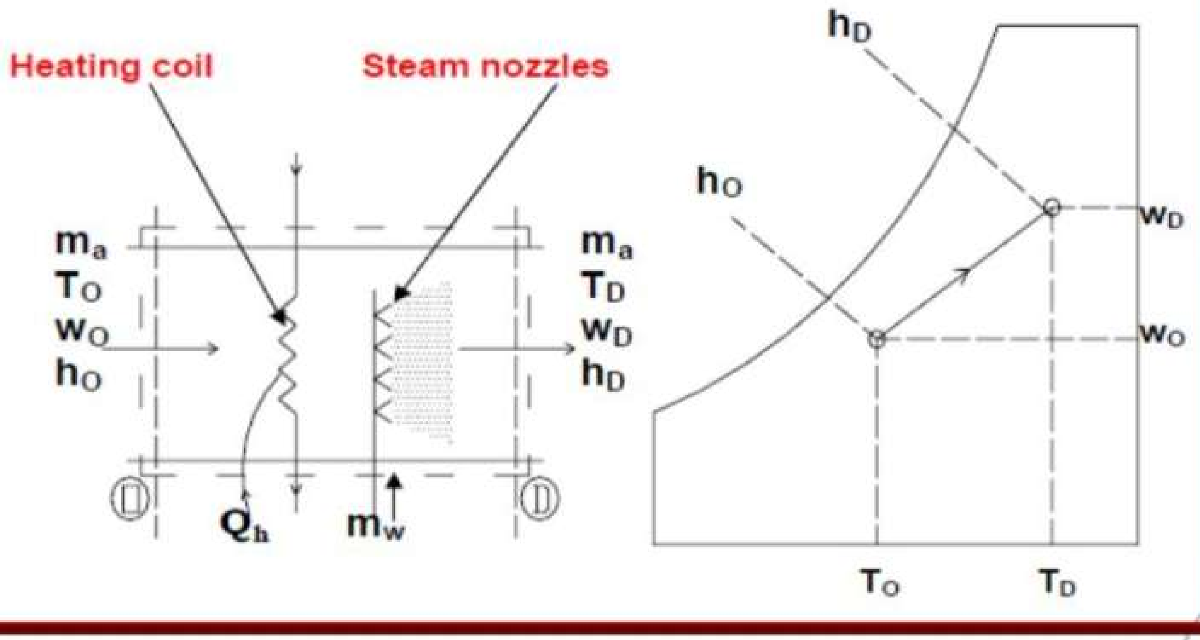
$$BPF = \frac{T_C - T_S}{T_O - T_S}$$

It can be easily seen that, higher the by-pass factor larger will be the difference between air outlet temperature and the cooling coil temperature. When BPF is 1.0, all the air by-passes the coil and there will not be any cooling or de-humidification. In practice, the by-pass factor can be increased by increasing the number of rows in a cooling coil or by decreasing the air velocity or by reducing the fin pitch. Alternatively, a **contact factor (CF)** can be defined which is given by:

$$CF = 1 - BPF$$

4) Heating and Humidification:

During winter it is essential to heat and humidify the room air for comfort. This is normally done by first sensibly heating the air and then adding water vapour to the air stream through steam nozzles as shown in the figure.



Mass balance of water vapor for the control volume yields the rate at which steam has to be added, i.e., **mw**:

$$m_w = m_a (w_D - w_O)$$

where ma is the mass flow rate of dry air.

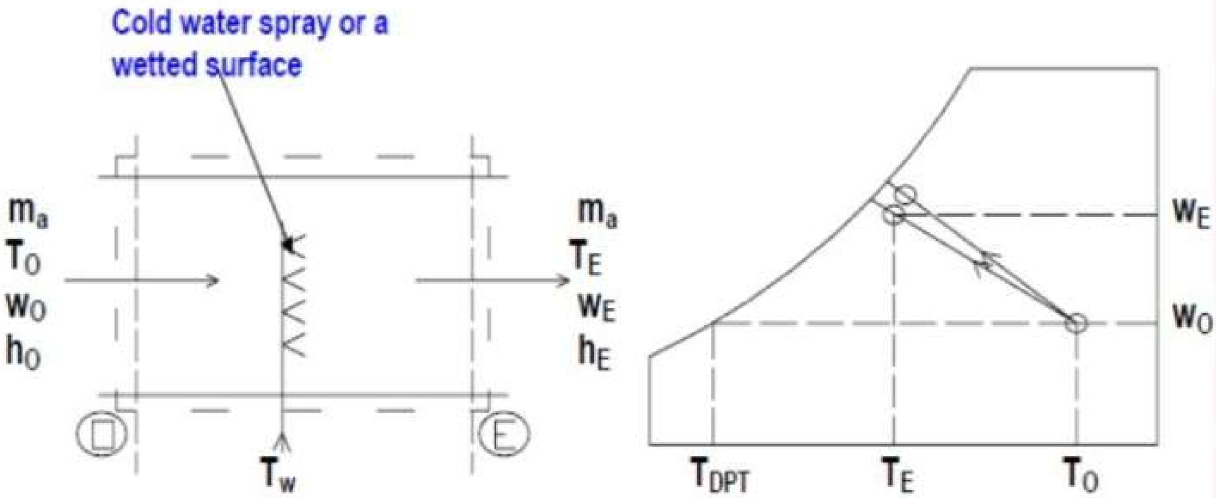
From energy balance: $Q_h = m_a (h_D - h_O) - m_w.h_w$

where Q_h is the heat supplied through the heating coil and hw is the enthalpy of steam.

Since this process also involves simultaneous heat and mass transfer, we can define a sensible heat factor for the process in a way similar to that of a cooling and dehumidification process.

5) Cooling & humidification:

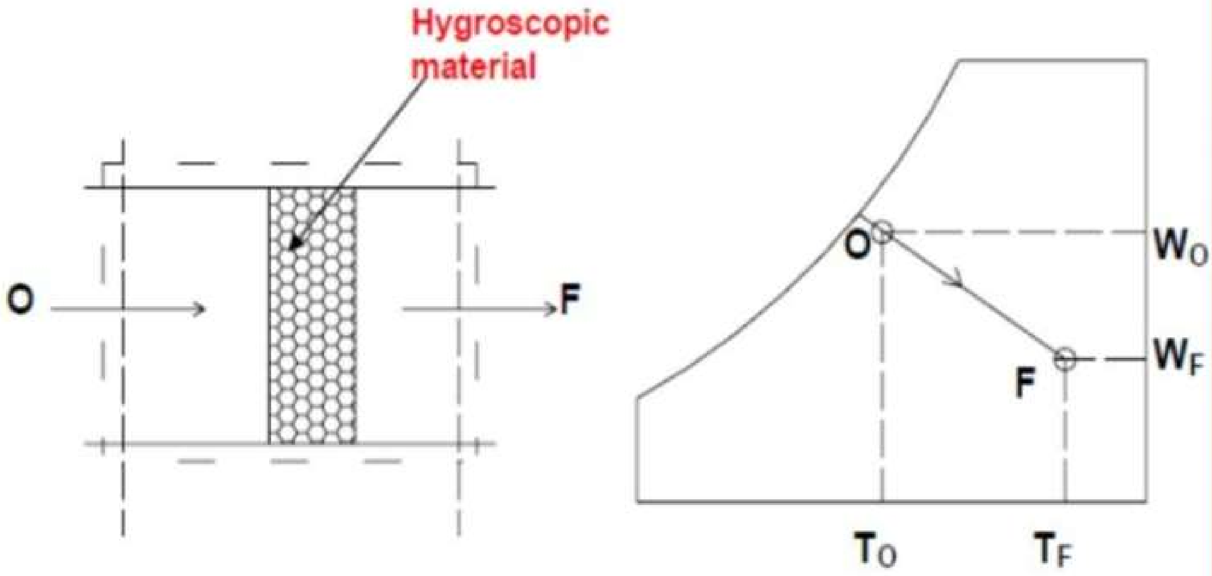
As the name implies, during this process, the air temperature drops and its humidity increases. As shown in the figure, this can be achieved by spraying cool water in the air stream. The temperature of water should be lower than the dry-bulb temperature of air but higher than its dew-point temperature to avoid condensation (Tdpt < Tw < To).

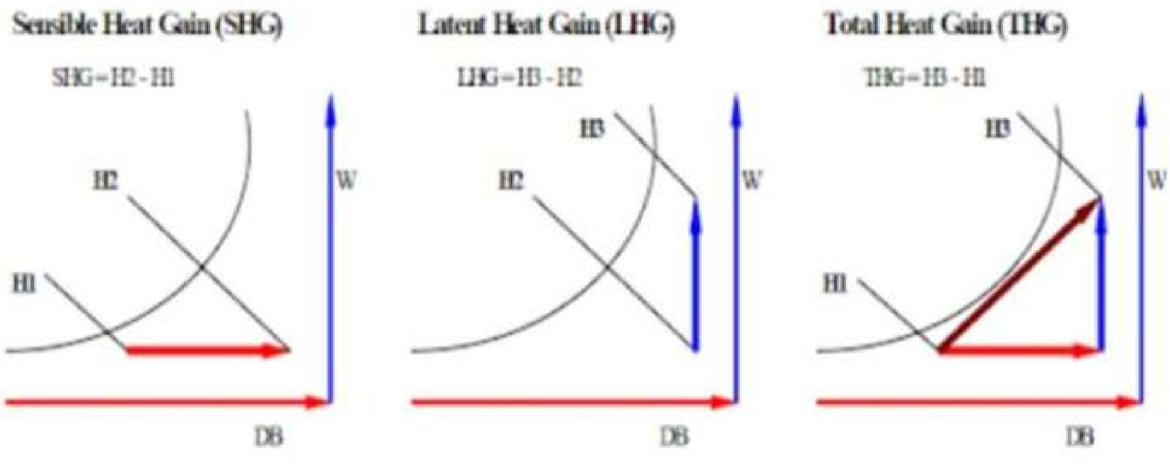


It can be seen that during this process there is sensible heat transfer from air to water and latent heat transfer from water to air. Hence, the total heat transfer depends upon the water temperature. If the temperature of the water sprayed is equal to the wet bulb temperature of air, then the net transfer rate will be zero as the sensible heat transfer from air to water will be equal to latent heat transfer from water to air. If the water temperature is greater than WBT, then there will be a net heat transfer from water to air. If the water temperature is less than WBT, then the net heat transfer will be from air to water. Under a special case when the spray water is entirely recirculated and is neither heated nor cooled, the system is perfectly insulated and the make-up water is supplied at WBT, then at steady-state, the air undergoes an adiabatic saturation process, during which its WBT remains constant. This is the process of adiabatic saturation. The process of cooling and humidification is encountered in a wide variety of devices such as evaporative coolers, cooling towers etc.

6) Heating and de-humidification:

This process can be achieved by using a hygroscopic material, which absorbs or adsorbs the water vapor from the moisture. If this process is thermally isolated, then the enthalpy of air remains constant, as a result the temperature of air increases as its moisture content decreases. This hygroscopic material can be a solid or a liquid. In general, the absorption of water by the hygroscopic material is an exothermic reaction, as a result heat is released during this process, which is transferred to air and the enthalpy of air increases.





Effective Temperature:-

- People feel comfortable only when all three parameters, say DBT, RH and air velocity are within certain limits.
- Effective temperature is a single parameter at which people feel comfortable. Effective temp. is an index of measure of comfort i.e. it is a measure of feeling warmth or cold by human body in response to air temp., RH and air motion.
- This factor combines the effects of dry bulb temperature and air humidity into a single factor.
- It is defined as the temperature of the environment at 50% RH which results in the same total loss from the skin as in the actual environment.
- This means effective temp. is DBT of a uniform enclosure at 50% RH in which people have same net heat exchange by radiation, convection and evaporation as they do in varying humidities of the test environment.

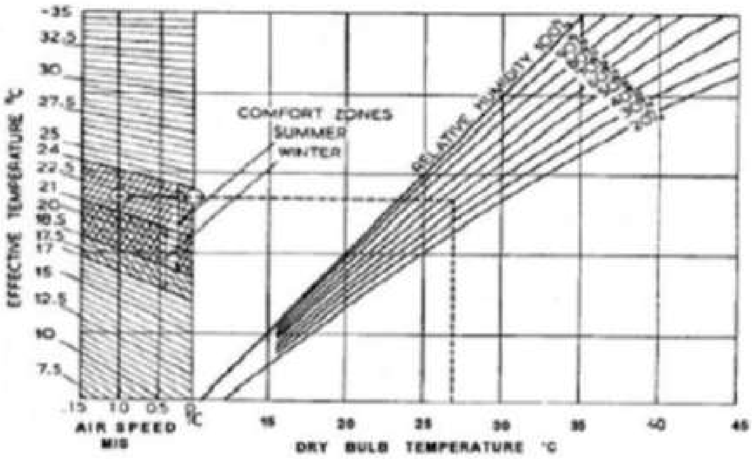
Effective temp = 20^0C to 23^0C in summer

Effective Temp = 18^0C to 22^0C in winter

For Indian conditions 25^0C with 60% relative humidity to 30^0C with 45 % relative humidity, with air velocity not exceeding 10 m/min

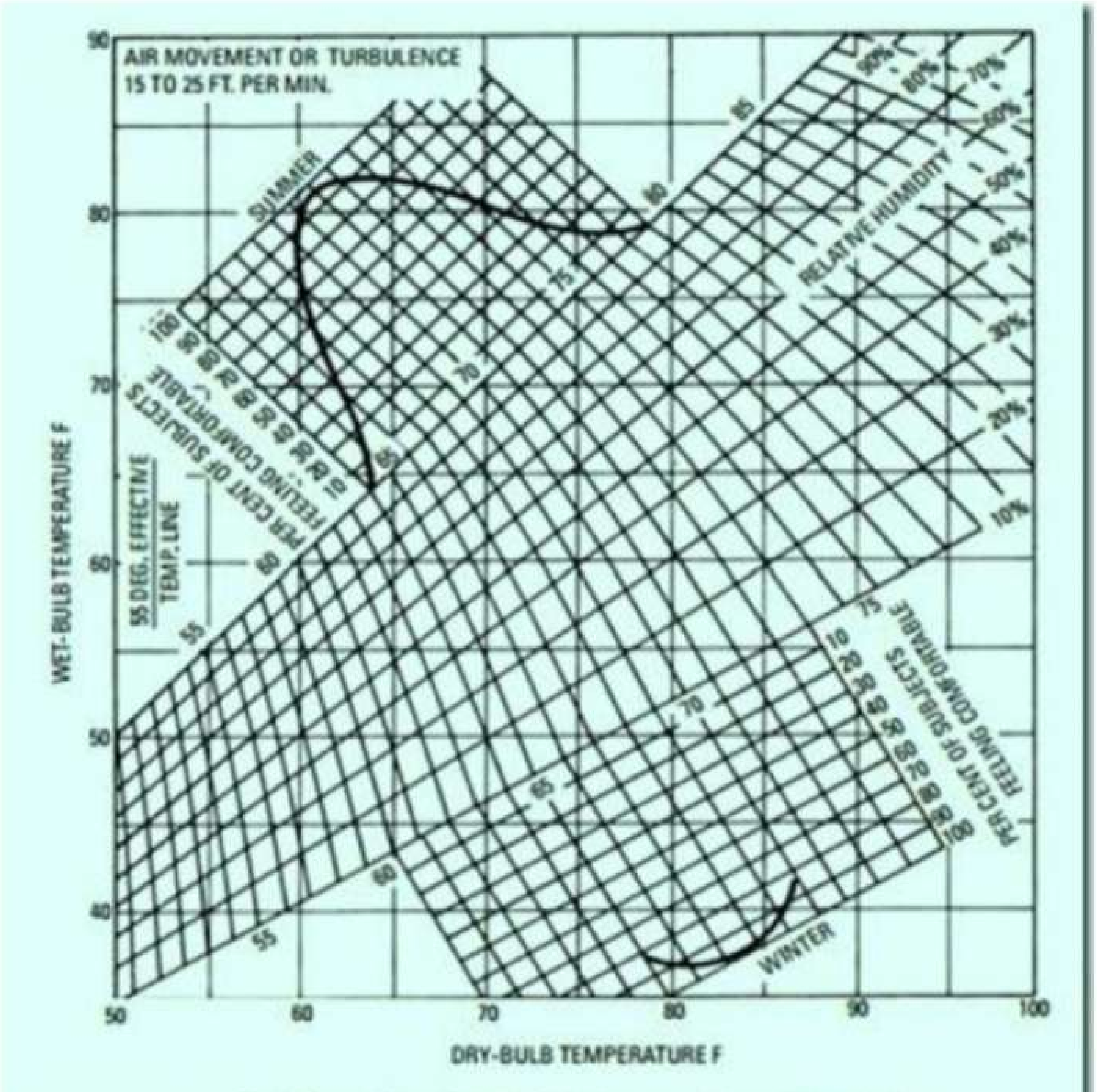
Effective Temperature

- It is the temperature of still, saturated air which would produce the same feeling of warmth.



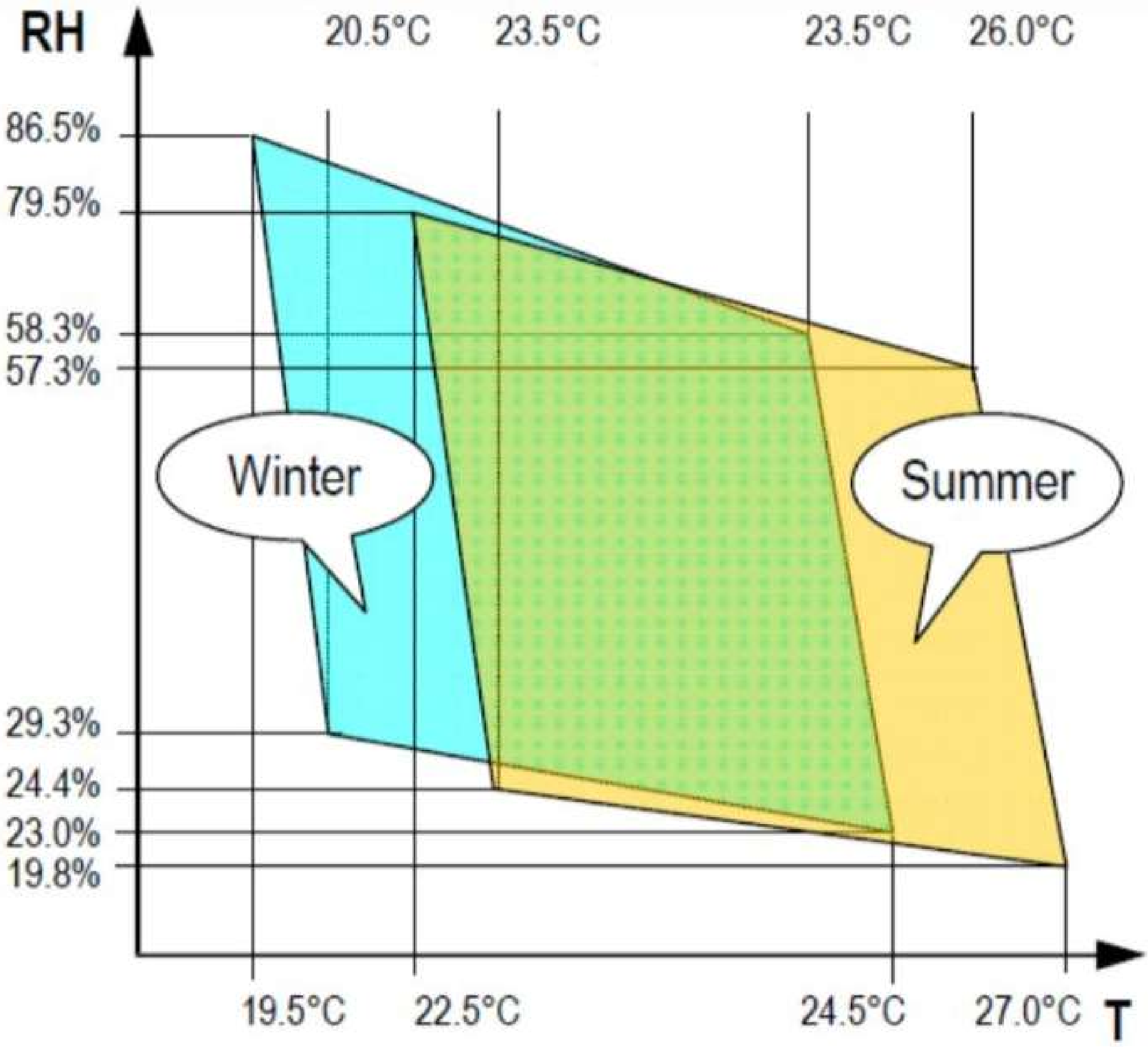
Comfort Chart:-

Comfort charts are the practical application of concept of effective temperature. This chart is the result of research made on different kinds of people subjected to wide range of environmental temperature, relative humidity and air movement by ASHRAE (American Society of Heating, Refrigeration and Air conditioning Engineers).



Comfort chart for still air. (Courtesy ASHRAE 1960 Guide)

Comfort zone within 22 to 27 degrees Celsius and air speed of 0.15 m/s to 1.5 m/s



RH
20.5°C
23.5°C
23.5°C
26.0°C
86.5%
79.5%
58.3%
57.3%
Winter
Summer
29.3%
24.4%
23.0%
19.8%
19.5°C
22.5°C
24.5°C
27.0°C
T

Factors Affecting Comfort Air Conditioning:-

1) Temperature
2) Humidity
3) Air movement
4) Air Purity

1) Temperature : Convection Heat transfer depends upon the temperature difference. So an adequate difference between body temperature and ambient temperature would ensure the convection heat transfer. Temperature difference would cause chilling effect as in winter. So preferred temperature are in between 20- 25 Degree.

2) Humidity : At higher ambient temperature convection heat transfer is either not adequate or is in reverse direction. The evaporation of perspiration by body heat is the only means of heat dissipation. Ambient air contains some water vapour in it and water evaporation depends upon vapour pressure difference.
-->So we can say that higher humidity would reduce evaporation of sweat from out body. Even at low temperature water vapour is given out through body pores due to vapour pressure difference. So humidity should be in between 30 to 70 % .

3) Air Movement : Convection heat transfer depends upon air movement and evaporation rate also can be maintained by constantly carrying away the vapour from evaporation surface. So it would be helpful for giving comfort and heat dissipation takes place properly. If the air movement is high it would cause the noise discomfort. Similarly we maintained higher air movement of fan in summer and slow air movement in winter for better comfort. The limited air velocity ranging in between 8–15 m/min.

4) Air Purity : Since air conditioner supplies conditioning air for comfort. Atmospheric air has many impurities in it.The range of impurities like dust, pollen, other carbon particles is in microns i e. nearly 180 micron and for virus and bacteria size rang is 0.05 micron. At some point odorous gases makes you feel discomfort.
-->So air conditioner needs to be remove unwanted impurities as per requirement.

Factors Affecting Human Comfort:

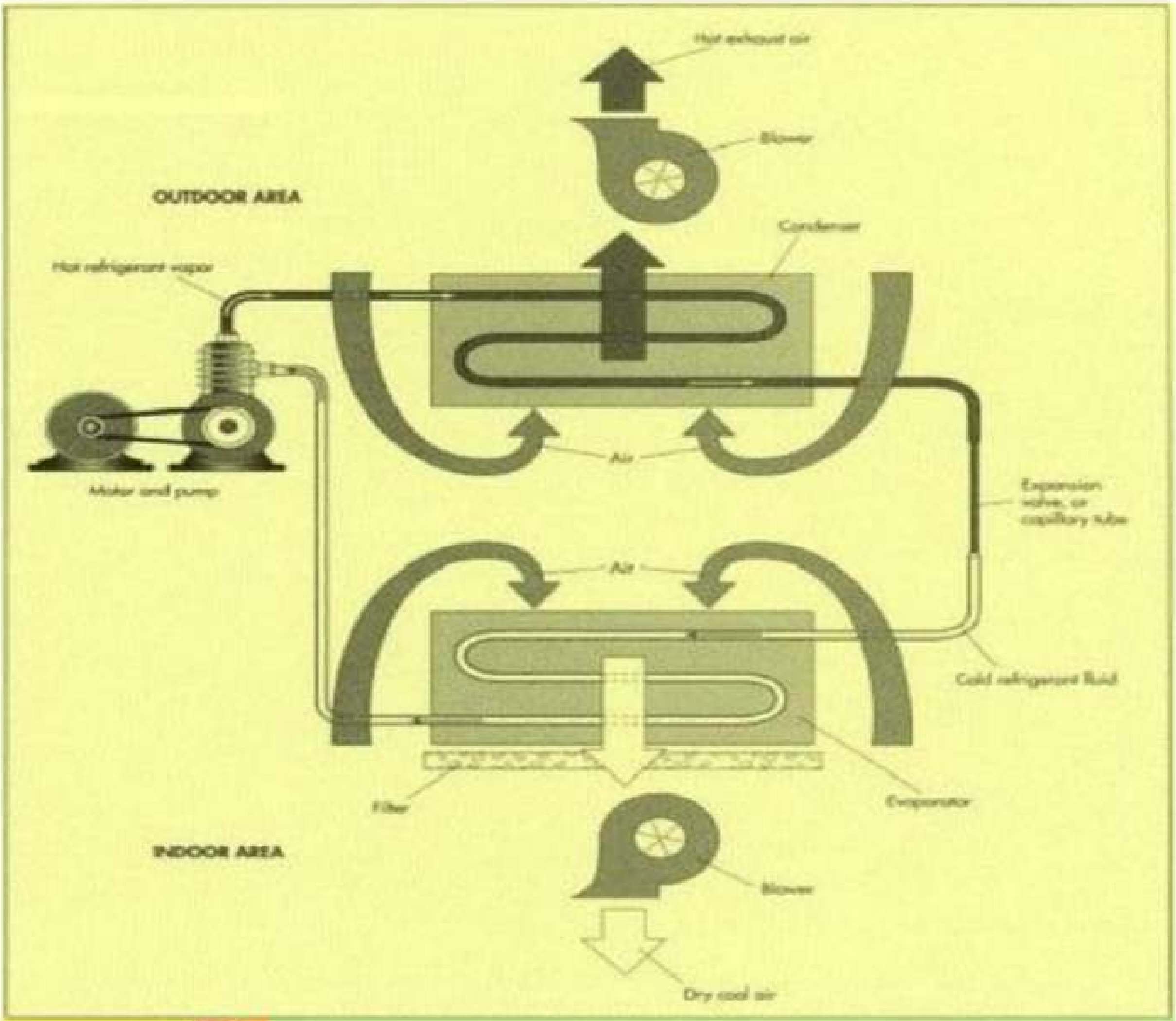
1. Temperature
2. Humidity
3. Air Movement
4. Air Purity

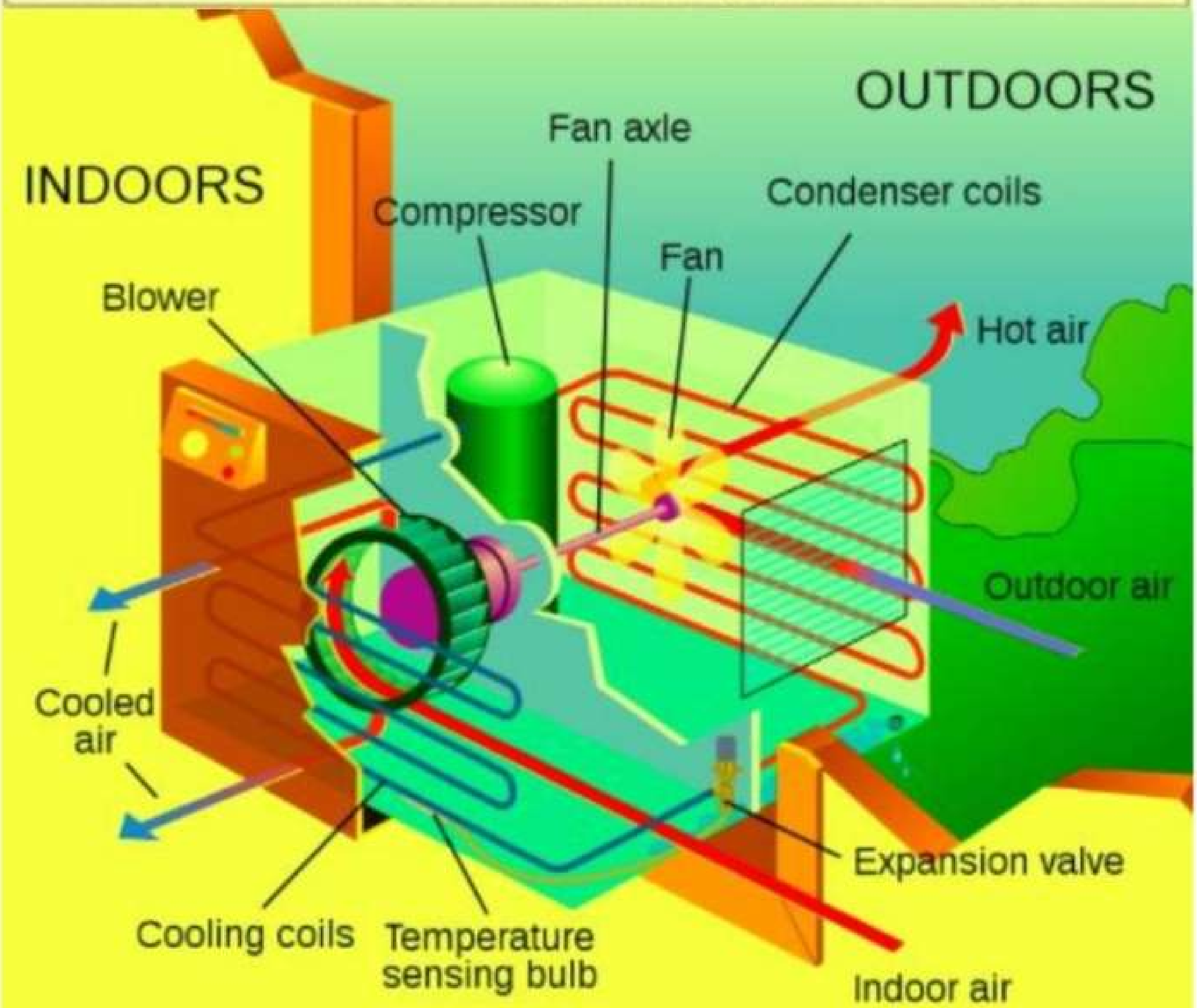
Equipment Used in an Air Conditioning System:-

An air conditioning system generally consists of components which are given below:

1)Compressor
2)Fan
3)Condenser Coil (Hot)
4)Evaporator Coil (Cool)
5)Expansion Valve
6)Chemical Refrigerant

An air conditioner transfers heat from the inside of a building, where it is not wanted, to the outside. Refrigerant in the system absorbs the excess heat and is then pumped through a closed system of piping to an outside coil. A fan blows outside air over the hot coil, transferring heat from the refrigerant to the outdoor air. Because the heat is removed from the indoor air, the indoor area is cooled.


Hot exhaust air
Blower
OUTDOOR AREA
Condenser
Hot refrigerant vapor
Motor and pump
Air
Expansion valve, or capillary tube
Air
Cold refrigerant fluid
Filter
Evaporator
INDOOR AREA
Blower
Dry cool air


OUTDOORS
Fan axle
INDOORS
Compressor
Condenser coils
Fan
Blower
Hot air
Outdoor air
Cooled air
Expansion valve
Cooling coils
Temperature sensing bulb
Indoor air

Classification of air conditioning system:-

- Based on way of air cooling:
  - Direct cooling system
  - Indirect cooling system
- Based on major function
  - Comfort air conditioning system
  - Industrial air conditioning system
- Based on season of year
  - Winter air conditioning system
  - Summer air conditioning system
  - Year round air conditioning system

Winter Air Conditioning System:-

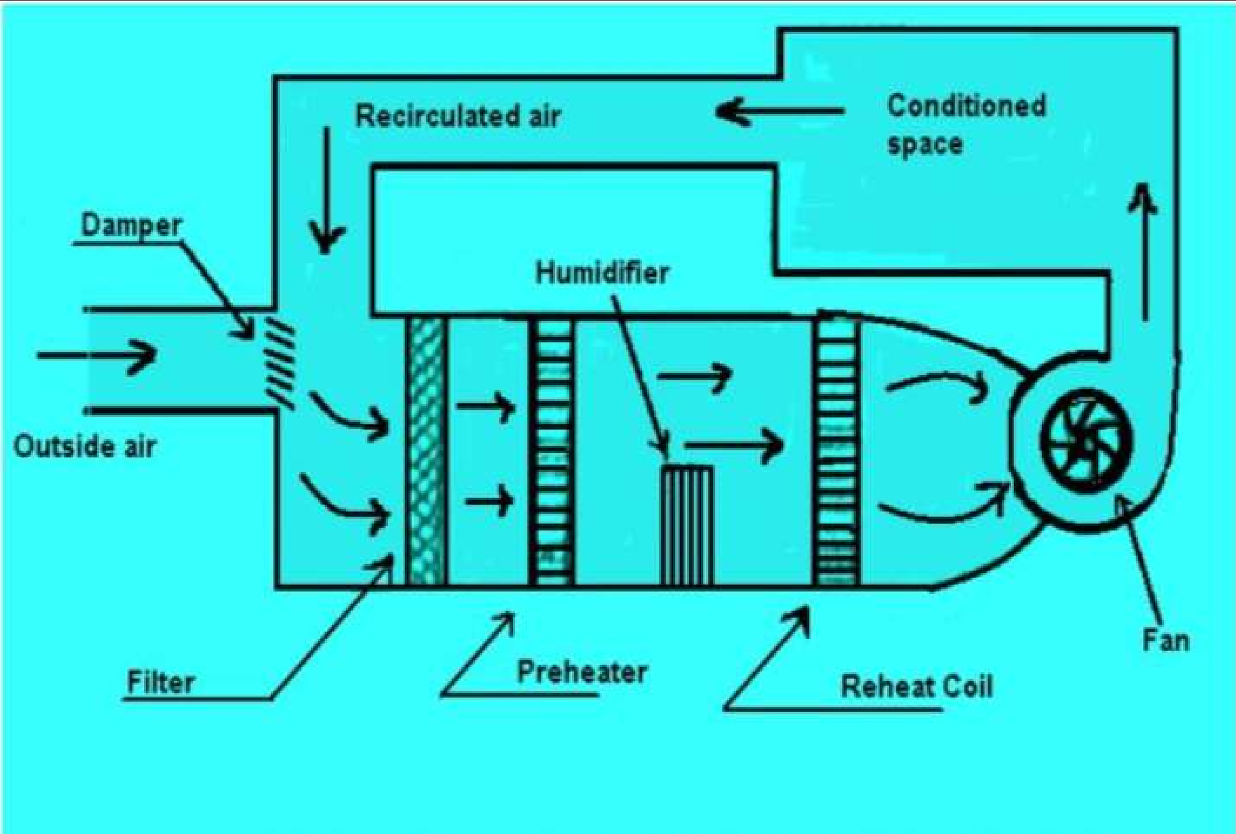
Working principle:-

In winter air conditioning system, the air is burnt and heated, which is generally followed by humidification. The outside air flows through a damper and mixes with the recirculated air. The mixed air passes through a filter to remove the dirt, dust, and impurities.

→The air now passes through a preheat coil to prevent the possible freezing of water and to control the evaporation of water in the humidifier.

→After that, the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature.

→Now, the conditioned air is supplied to the conditioned space by a fan. From the conditioned space, a part of the air is exhausted to the atmosphere by the exhaust fans. The remaining part of the used air is again conditioned and this will repeat again and again.



WINTER AIR CONDITIOING SYSTEM

Summer Air Conditioning System:-

Working principle:-

In this system, the air is cooled and generally dehumidified.

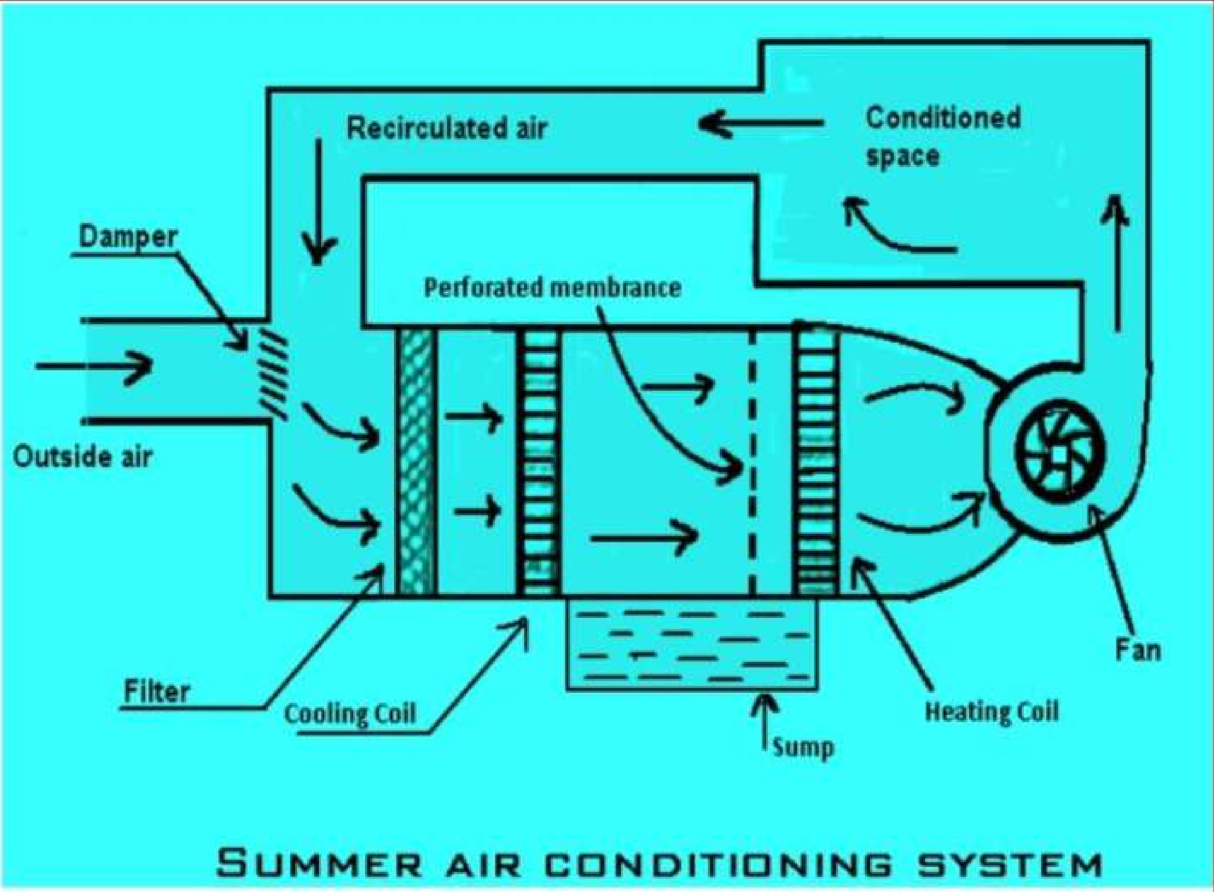
The outside air flows through the damper and mixed with recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove the dirt, dust and impurities.

→The air now passes through a cooling coil. The coil has a temperature much below the required dry bulb temperature of the air in the conditioned space.

→The cooled air passes through a perforated membrane and loses its moisture in the condensed from which is collected in the sump. After that, the air is made to pass through a heating coil which heats the air slowly.

→This is done to bring the air to the designed dry bulb temperature and relative humidity. Now the conditioned air is supplied to the conditioned space by a fan. From conditioned space, a part of the used air is rejected to the atmosphere by the exhaust fan. The remaining air is again conditioned and this repeated for again and again.

→The outside air is sucked and made to mix with recirculated air to make for the loss of conditioned air through exhaust fan from the conditioned space.



Year Round Air Conditioning System:-

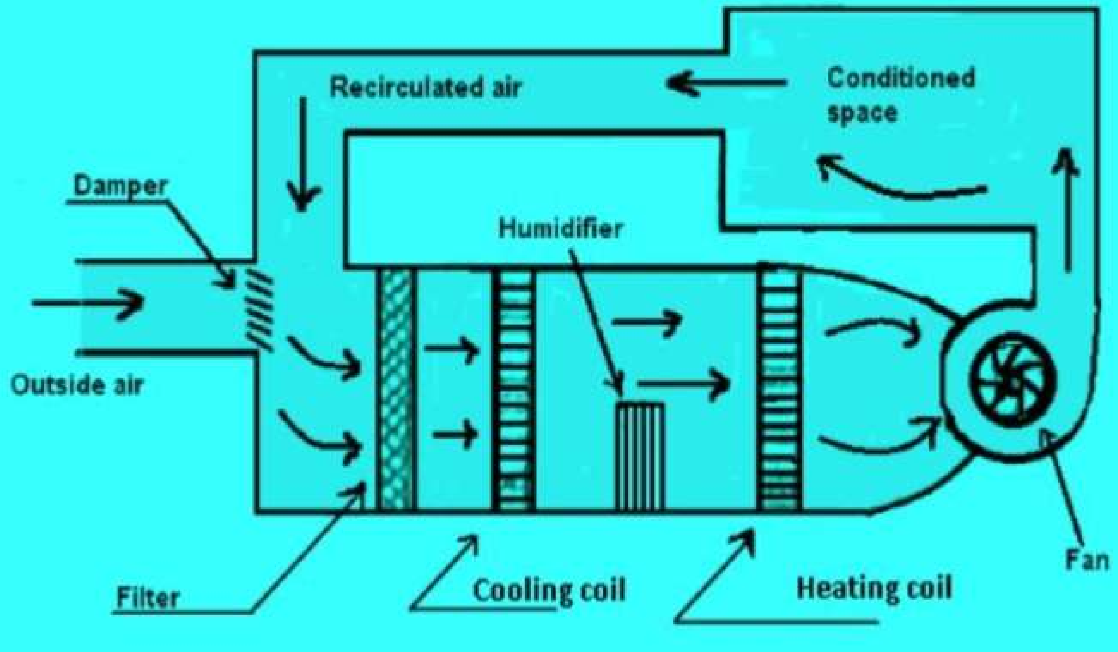
Working principle:-

In a year-round air conditioning system, it should have equipment for both the summer and winter air conditioning. Schematic for a modern summer year-round air conditioning was shown below.

→In year-round air conditioning system, the outside air flows through the damper and mixed with the recirculated air. The mixed air passes through a filter to remove dirt, dust, and impurities.

→In the summer air conditioning system, the cooling operates to cool the air to the desired valve. The dehumidification is obtained by operating the cooling coil at a lower temperature than the dew point temperature.

→In the winter air conditioning system, the cooling coil is made inoperative and the heating coil operates to heat the air. The spray type humidifier is also used in the dry season to humidify the air.



YEAR-ROUND AIR CONDITIONING SYSTEM

------Thank You------