LECTURE NOTES

ON

REFRIGERATION AND AIR CONDITIONING (TH-5)

For

5TH SEM (MECHANICAL ENGG)

(SCTE&VT SYLLABUS)

Prepared by

Er.Bibhabaree Samal

Lecturer (Mechanical Engg.)
OSME , KEONJHAR

REFRIGERATION

The process of removing heat from an enclosed space or from a substance for the purpose of lowering the temperature.

UNIT OF REFRIGREATION

The unit of refrigeration is expressed in terms of ton of refrigeration (TR). One ton of refrigeration is defined as the amount of refrigeration effect (heat transfer rate) produced during uniform melting of one ton (1000kg) of ice at 0°C to the water at the 0°C in 24 hours.

Refrigeration effect and coefficient of performance

Refrigeration effect

A refrigeration machine can be called efficient only of it can create maximum refrigerating effect for the work allotted to it. Refrigeration effect means that cooling action should be done at the rate of heat absorption from any place in a cycle.

coefficient of performance

The rate of refrigerating effect to the heat equal to the supplied work is called coefficient of performance.

$$\text{C.O.P.} = \frac{\text{Refrigerating effect}}{\text{Input work}}$$

AIR REFRIGERATION SYSTEM

Air cycle refrigeration systems belong to the general class of gas cycle refrigeration systems, in which a gas is used as the working fluid. The gas does not undergo any phase change during the cycle, consequently, all the internal heat transfer processes are sensible heat transfer processes. Gas cycle refrigeration systems find applications in air craft cabin cooling and also in the liquefaction of various gases.

Air Standard Cycle analysis

Air cycle refrigeration system analysis is considerably simplified if one makes the following assumptions

i. The working fluid is a fixed mass of air that behaves as an ideal gas

ii. The cycle is assumed to be a closed loop cycle with all inlet and exhaust processes of open loop cycles being replaced by heat transfer processes to or from the environment

iii. All the processes within the cycle are reversible, i.e., the cycle is internally reversible

iv. The specific heat of air remains constant throughout the cycle An analysis with the above assumptions is called as cold Air Standard Cycle (ASC) analysis. This analysis yields reasonably accurate results for most of the cycles and processes encountered in air cycle refrigeration systems. However, the analysis fails when one considers a cycle consisting of a throttling process, as the temperature drop during throttling is zero for an ideal gas, whereas the actual cycles depend exclusively on the real gas behavior to produce refrigeration during throttling.

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

- Open air refrigeration cycle
- Closed refrigeration cycle

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.

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

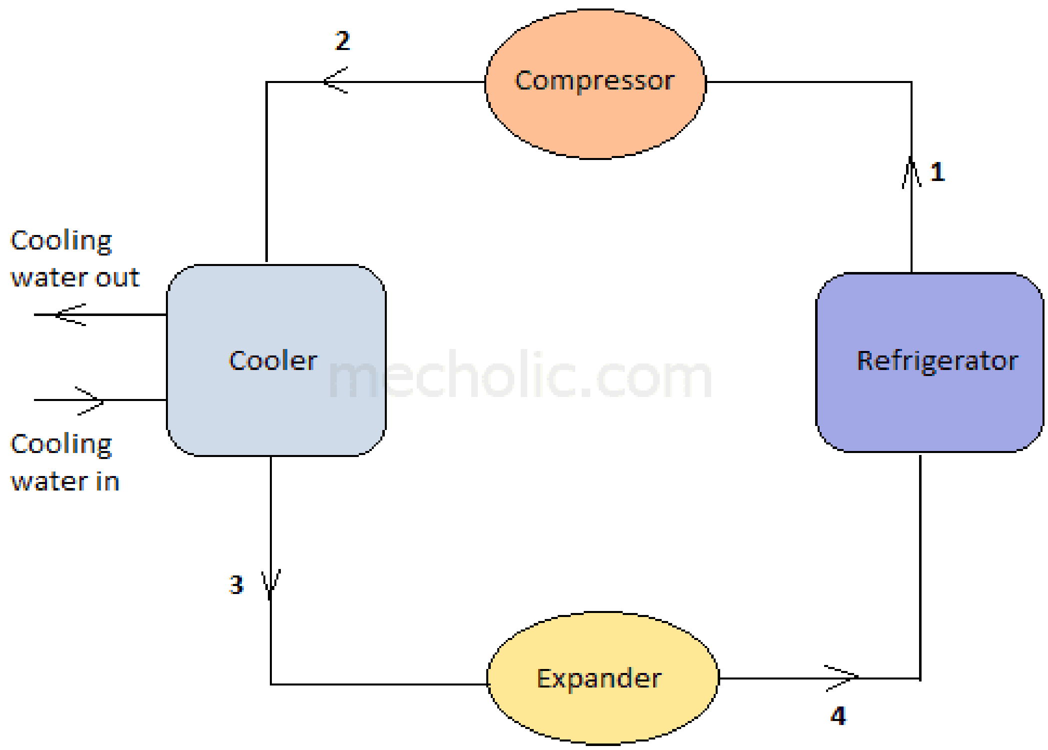
Advantages

- 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 COP can be achieved by reducing operating pressure ratio.

Comparison Chart

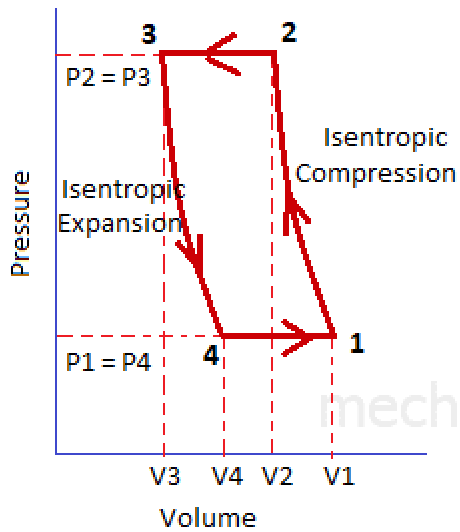
Open System	**Closed System**
Air is directly led to the space to be cooled.	Dense air passed through pipes all the time.
Since air is supplied to the refrigerator at atmospheric pressure, the volume of air handled by the compressor is large.	Suction pressure is higher than atmospheric pressure volume of air is to be handled by the compressor.
Moisture leads to the formation of frost at the end of expansion thus drier is used.	Pressure ratio can be reduced which results in higher

Air Refrigerator Working On Bell-Coleman Cycle with PV and TS Diagram (Reversed Brayton or Joule Cycle)

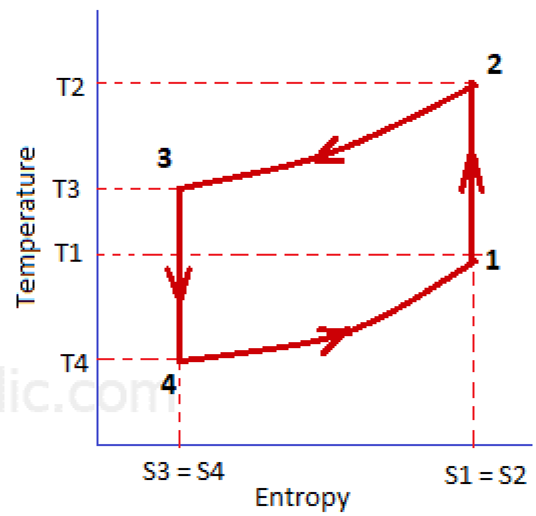


The above fig. shows a schematic diagram of Bell-Coleman refrigerator (reverse Brayton or joule cycle). This refrigeration system components consists of a compressor, cooler, Expander, and refrigerator. In this process, heat absorption and rejection follows at the constant pressure; the compression and expansion of process are isentropic.

Different process in Bell-Coleman refrigeration



(a) P-V Diagram



(b) T-S Diagram

Fig show P-V and T-S diagram of bell coleman refrigerator. Here P_1, V_1, T_1, S_1 represents the pressure, volume, temperature, entropy of air respectively at point 1. And so on. It represents the corresponding condition of air when it passed through the component.

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
$q_{2-3} = Cp(T_2-T_3)$

3-4: isentropic expansion
No heat transfer takesplcae. The air expands isentropically in expander cylinder. During expansion, the volume increases, Pressure P3 reduces to P_4. (P_4 = atmospheric pressure). Temperature also falls during expansion from T_3-T_4.

4-1: Constant pressure expansion
Heat transfer from the refrigerator to air. The temperature increases from T_4 to T_1. Volume increases to V_4 due to heat transfer. Heat absorbed by air per kg during this process is equal to
$q_{4-1} = Cp(T_1-T_4)$

Equation of Coefficient of performance (COP) of Bell Coleman cycle

Heat absorbed during cycle per kg of air $q_{4-1} = Cp(T_1-T_4)$
Heat rejected during cycle per kg of air $q_{2-3} = Cp(T_2-T_3)$
Then the work done per kg of air during the cycle is = Heat rejected – Heat absorbed
$= Cp(T_2-T_3) - Cp(T_1-T_4)$
Coefficient of performance;

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

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

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

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

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)

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

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

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

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

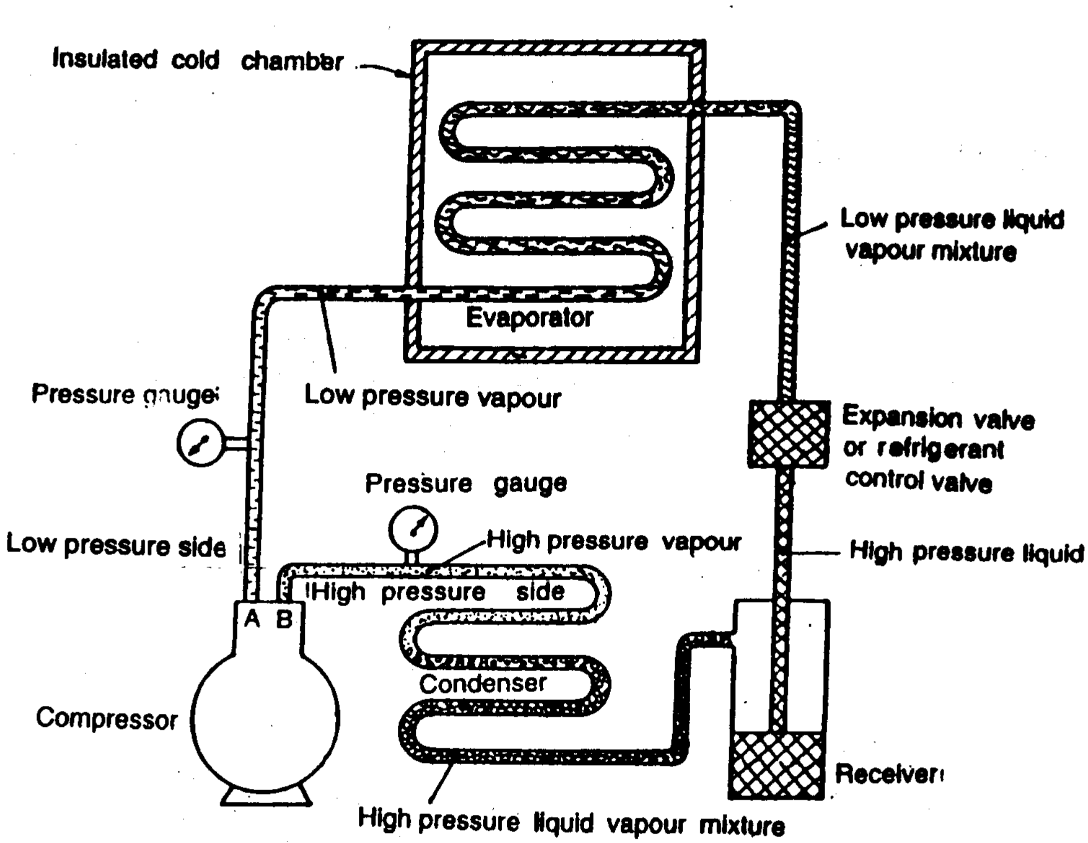
SIMPLE VAPOUR COMPRESSION REFRIGERATION SYSTEM

The simple vapor compression system can be explain as the heat engine which is works in reverse technically that can be known as Reverse Carnot engine. The simple vapor compression cycle transfer heat from lower temperature reservoir to higher temperature reservoir.

working fluid is a vapour. It readily evaporates and condenses or changes **It** is the most widely used refrigeration system. In this system, the alternatively between the vapor and liquid phase without leaving the refrigerating plant.

COMPONENTS OF VAPOUR COMPRESSION REFRIGERATION SYSTEM

1. Compressor
2. Condenser
3. Receiver
4. Expansion Valve
5. Evaporator



The detailed explanation of the above parts is as follows.

1. Compressor:

The vapour at low pressure and low temperature enters the compressor from the evaporator where it is compressed to high pressure and high temperature.

This high pressure and temperature vapour refrigerant are discharged into the condenser through the discharge valve.

2. Condenser:

The condenser or cooler consists of coils of pipe in which the high pressure and temperature vapour refrigerant are cooled and condensed.

The refrigerant while passing through the condenser gives up its latent heat to the surroundings condensing medium which is normally air or water.

3. Receiver:

The condensed liquid refrigerant from the condenser is stored in a vessel known as a receiver from where it is supplied to the evaporator through the expansion valve.

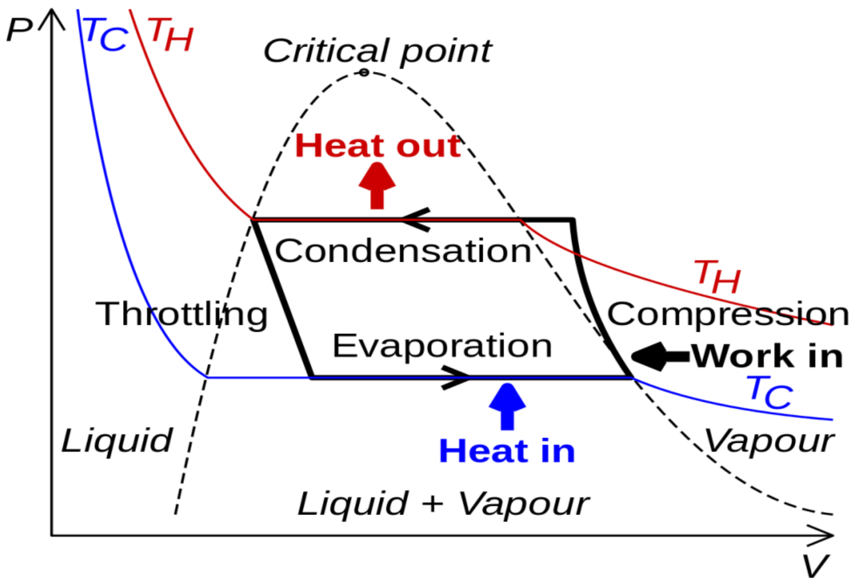
4. Expansion Valve:

It is also called a throttle valve. Its function is to allow the liquid refrigerant under high pressure and temperature to pass through it where it reduces its temperature and pressure.

5. Evaporator:

It also consists of coils of pipe in which liquid-vapour refrigerant at low pressure and temperature is evaporated and converted into vapour refrigerant at low pressure and temperature.

VAPOUR COMPRESSION REFRIGERATION CYCLE



The Vapor compression cycle process is proceeding in four steps. They are listed below

1. **Compression**
2. **Condensation**
3. **Throttling**
4. **Evaporation**

<u>Compression (Reversible adiabatic compression):</u>

The refrigerant of vapor compression cycle at low temperature and pressure stretched from evaporator to compressor where the refrigerant is compressed isentropically. The pressure is rises from p_1 to p_2 and temperature is rises from T_1 to T_2. The total work done per kg of refrigerant happened during isentropic compression can be express as,

$$w = h_2 - h_1$$

Where,

h_1 = Amount of enthalpy of vapor compression cycle in temperature T_1, at the step of suction of compressor

h_2 = Amount of enthalpy of vapor compression cycle in temperature T_2, at the step of discharge of compressor

Condensation (Constant pressure heat rejection):

The refrigerant of vapor compression cycle is passes through from **compressor to condenser** at high temperature and pressure. At constant pressure and temperature the refrigerant is completely condensed. The refrigerant changes its state from vapor to liquid

Throttling (Reversible adiabatic expansion):

At high temperature and high pressure the refrigerant of vapor compression cycle is expanded through the process of throttling. That time the expansion valve is stays in low temperature and pressure. A little amount of liquid refrigerant is evaporating by the help of expansion valve and a huge amount of liquid refrigerant is vaporised by the help of evaporator.

Evaporation (Constant pressure heat addition):

The refrigerant mixture of vapor and liquid is completely evaporated and changed itself into vapor refrigerant. During this evaporation process the refrigerant is absorb latent heat which state is cool. The amount of **latent heat absorption by the refrigerant in vapor cycle is known as Refrigerating effect**

Performance of vapour compression cycle in the refrigeration system:

The vapour compression cycle in the refrigeration system is working at evaporator in the law of Steady Flow Energy Equation,

$h_4 + Q_e = h_1 + 0$

$Q_e = h_1 - h_4$

The vapour compression cycle in the refrigeration system is working at condenser in the law of Steady Flow Energy Equation,

$h_2 + Q_c = h_3 + 0$

$Q_c = h_3 - h_2$

The vapour compression cycle in the refrigeration system is working at expansion valve in the law of Steady Flow Energy Equation,

$h_3 + Q = h_4 + W$

We know, value of Q and W is 0

So, we can write

$h_3 = h_4$

COP=RE/Work done

So **$COP=h_1 - h_4/h_2 - h_1$**

Advantages of Vapor Compression refrigeration cycle

1. Coefficient of performance is too high.
2. Size is not too big for this reason installation is easy.
3. Running cost is low.
4. Temperature can be easily handled by the help of regulating expansion valve.
5. Evaporator size is not big.

Disadvantages of Vapor Compression refrigeration cycle

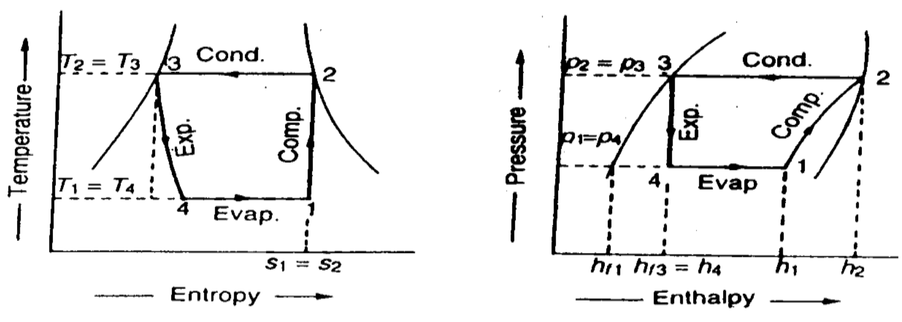
1. The refrigerants which are used they are toxic.
2. Initial cost is high.
3. Leakage is present.

TYPES OF VAPOR COMPRESSION CYCLES

The types of Vapor Compression Cycles which are important from the subject point of view are as follows.

1. Cycle with dry saturated vapor after compression
2. Cycle with wet vapor after compression
3. Cycle with superheated vapor after compression
4. Cycle with superheated vapor before compression
5. Cycle with under cooling or subcooling of the refrigerant

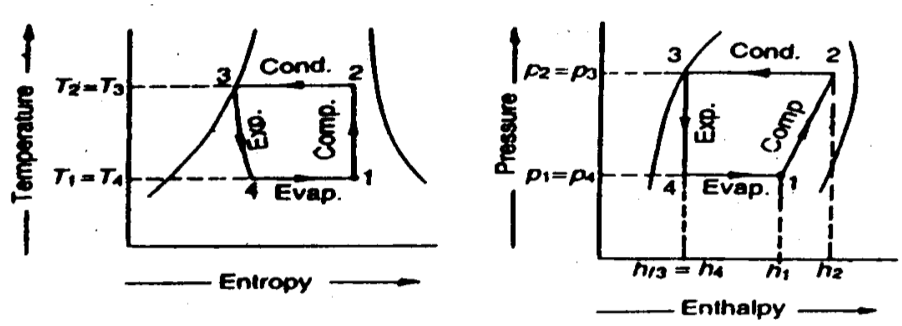
CYCLE WITH DRY SATURATED VAPOR AFTER COMPRESSION



(a) T-s diagram. (b) p-h diagram.

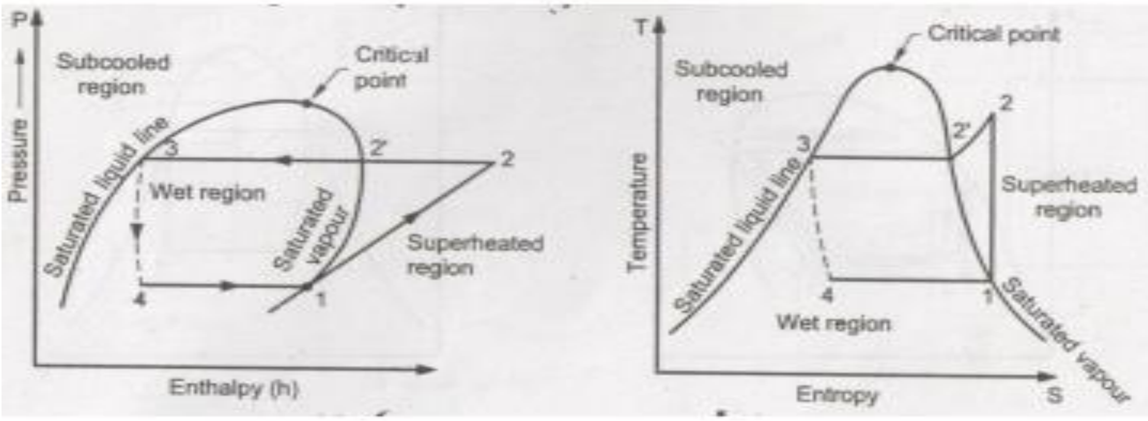
COP of the cycle= $h_1 - h_4 / h_2 - h_1$

CYCLE WITH WET VAPOR AFTER COMPRESSION

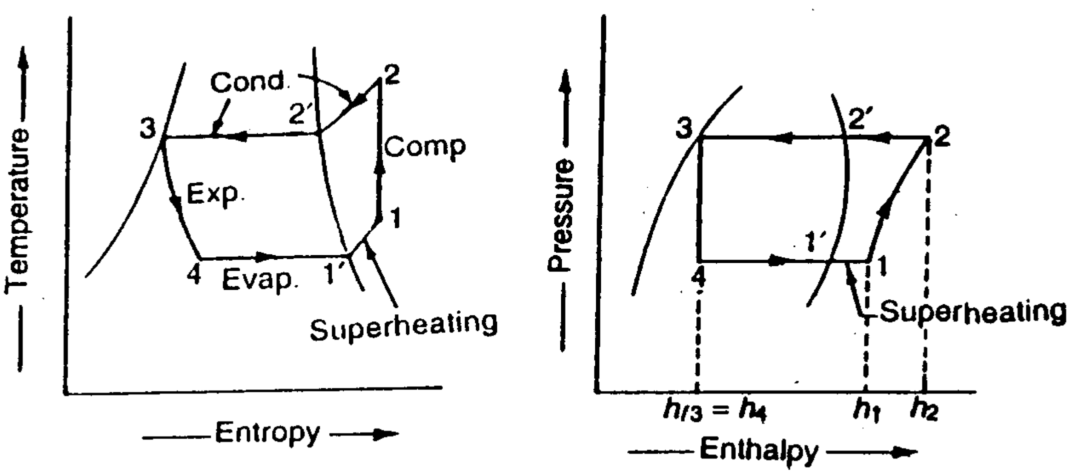


(a) T-s diagram. (b) p-h diagram.

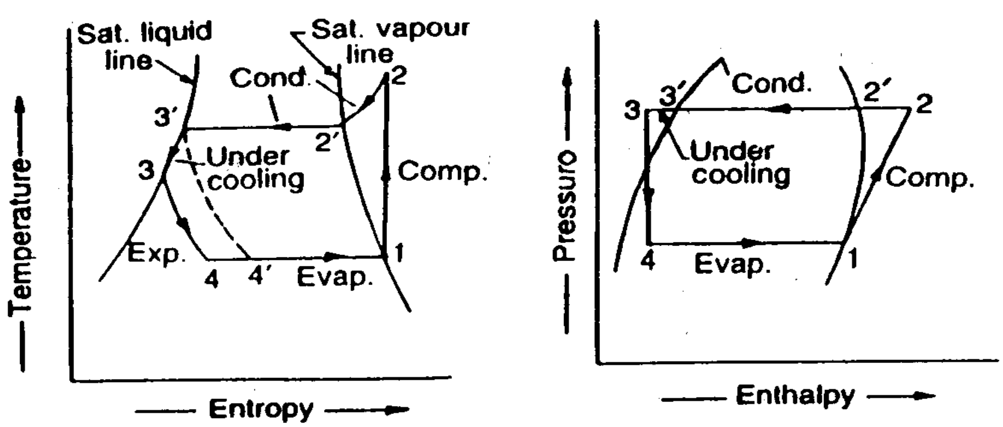
CYCLE WITH SUPERHEATED VAPOR AFTER COMPRESSION



CYCLE WITH SUPERHEATED VAPOR BEFORE COMPRESSION



CYCLE WITH UNDER COOLING OR SUBCOOLING OF THE REFRIGERANT



VAPOUR ABSORPTION REFRIGERATION SYSTEM

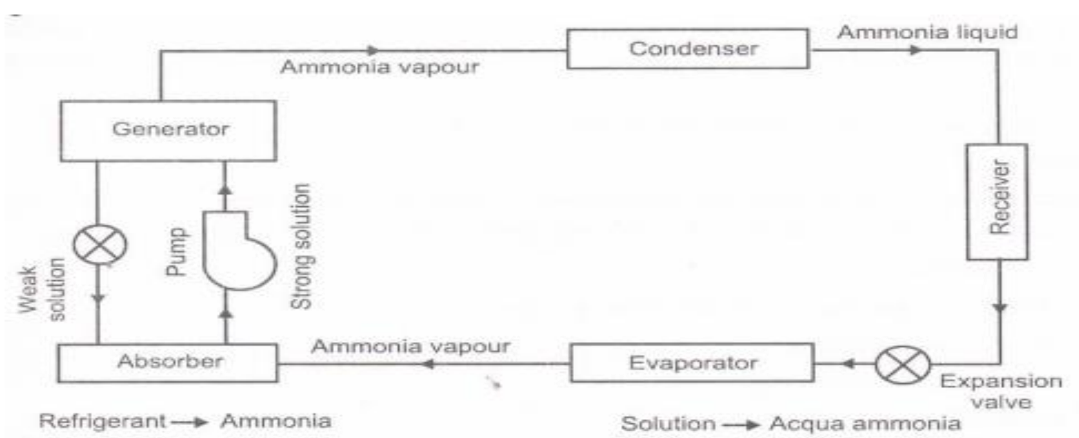
Vapour absorption refrigeration is quite similar to the Vapour compression refrigeration (VCR) system as it replaces the compressor in VCR with the absorber, pump and generator.
A vapour absorption refrigeration system (VARS) is a kind of refrigeration in which after evaporation the vapours of refrigerant are absorbed in an absorber solution. This kind of refrigeration is used in bigger plants to handle larger refrigeration loads. In such plants, the generator is run with the help of waste heat from the boilers, turbine exhaust steam, waste heat from D.G., etc. Sometimes it also uses solar energy for the generator.

SIMPLE VAPOUR ABSORPTION REFRIGERATION SYSTEM

The simple VARS system consists of the following components:

Absorber, Pump, Generator, Pressure relief valve, Condenser, Expansion device, and Evaporator.

.The VARS refrigeration system uses two working fluids for refrigeration i.e. refrigerant and absorbent. In the NH3–H2O refrigeration system, ammonia is used as a refrigerant while the water is used as an absorbent. In H2O–LiBr, VARS refrigeration water is used as a refrigerant while the LiBr is used as an absorbent



A) ABSORBER:-

The purpose of the absorber is to absorb the low-pressure refrigerant vapours in the solution of the refrigerant and absorbent.

The weaker solution from the generator and the low-pressure refrigerant vapours from the evaporator enters the absorber. Here the refrigerant vapours are absorbed to form a stronger solution.

During the absorption, the vapours of the refrigerant lose the latent heat to change their phase from vapour to liquid. Thus it raises the temperature inside the absorber which can lower the absorption capacity of the absorbent. To avoid this, the solution is cooled with the help of cooling water.

B) PUMP:- It is used to suck the strong solution from the absorber & deliver it to the generator at higher pressure.

C) GENERATOR:- It is used to heat the strong solution by use of heating coils, solar energy or waste heat. As the refrigerant has a lower boiling point than the absorbent, the refrigerant inside the solution gets vapourised leaving the solution weaker.

If this weak solution goes to the condenser, it may damage the system. Hence the weak solution from the generator returns to the absorber through pressure reducing valve (PRV).

D) CONDENSER:- The high-pressure refrigerant vapours from the generator enter the condenser. The condenser has a cooling medium to cool the hot vapours of the refrigerant. Here the refrigerant vapours get converted into the high-pressure saturated liquid refrigerant.

E) PRESSURE REDUCING VALVE (PRV):- The pressure-reducing valve is connected between the generator (works at high pressure) and absorber (works at low pressure). It lowers the pressure of weak solution coming from the generator and then it is passed to the absorber.

F) Expansion valve:- Expansion valve is located between the condenser & evaporator. After the condenser, the high-pressure liquid refrigerant enters the expansion valve. Here the high-pressure liquid refrigerant is converted into a mixture of low-pressure refrigerant (liquid + vapour).

G) Evaporator:- The evaporator is located in the enclosed space where cooling is carried out. In the evaporator, the low-pressure liquid refrigerant absorbs the heat in the enclosed space to provide a cooling effect. due to the absorption of heat, the liquid refrigerant gets converted into low-pressure refrigerant vapours.

PRACTICAL VAPOUR ABSORPTION REFRIGERATION SYSTEM

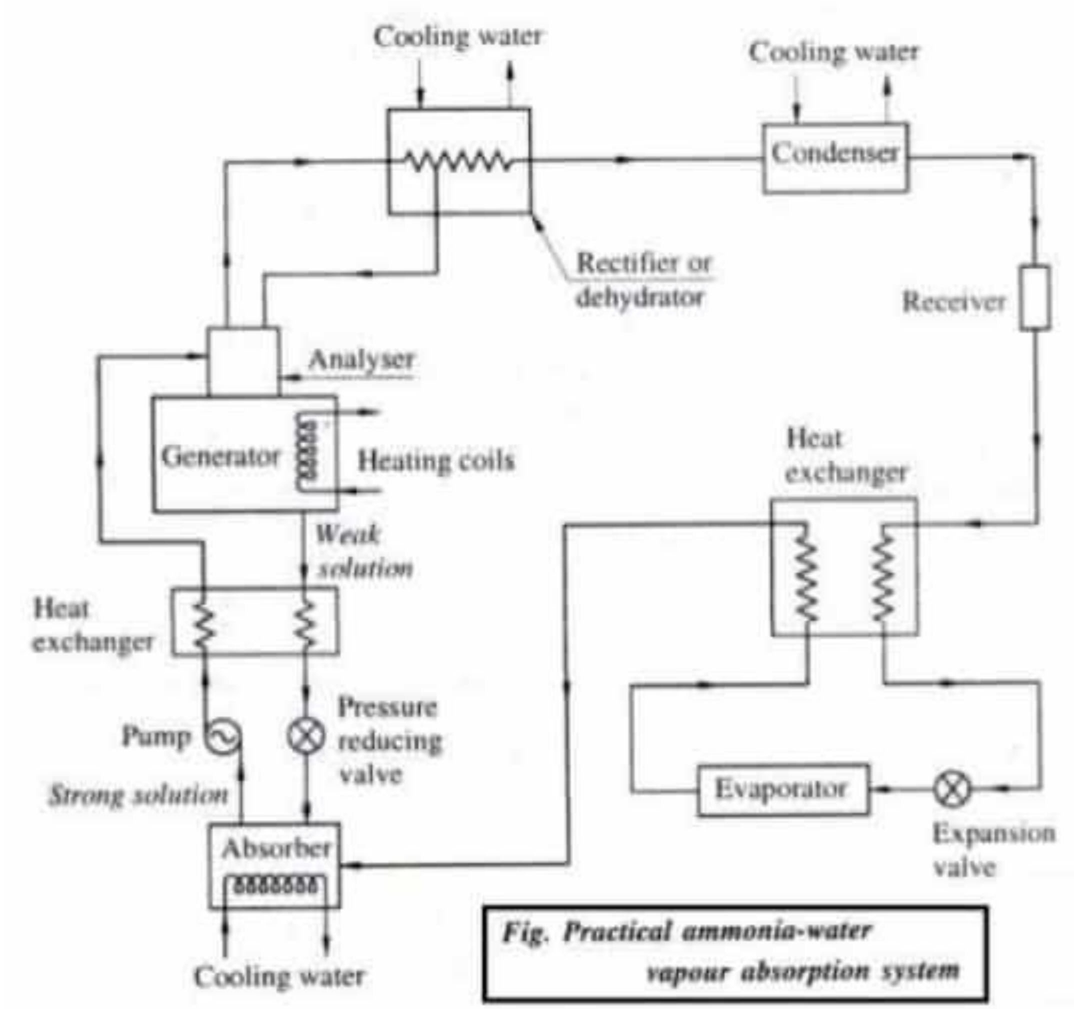


Fig. Practical ammonia-water vapour absorption system

Construction

- The vapour absorption system consists of a condenser, an expansion valve and an evaporator.
- They perform the same as they do in vapour compression method.
- In addition to these, this system has an absorber, a heat exchanger, an analyser and a rectifier.

Working

1. Dry ammonia vapour at low pressure passes in to the absorber from the evaporator.
2. In the absorber the dry ammonia vapour is dissolved in cold water and strong solution of ammonia is formed.
3. Heat evolved during the absorption of ammonia is removed by circulating cold water through the coils kept in the absorber.
4. The highly concentrated ammonia (known as Aqua Ammonia) is then pumped by a pump to generator through a heat exchanger.
5. In the heat exchanger the strong ammonia solution is heated by the hot weak solution returning from the generator to the absorber.
6. In the generator the warm solution is further heated by steam coils, gas or electricity and the ammonia vapour is driven out of solution.
7. The boiling point of ammonia is less than that of water.
8. Hence the vapours leaving the generator are mainly of ammonia.
9. The weak ammonia solution is left in the generator is called weak aqua.
10. This weak solution is returned to the absorber through the heat exchanger.
11. Ammonia vapours leaving the generator may contain some water vapour.
12. If this water vapour is allowed to the condenser and expansion valve, it may freeze resulting in chocked flow.
13. Analyser and rectifiers are incorporated in the system before condenser.
14. The ammonia vapour from the generator passes through a series of

trays in the analyser and ammonia is separated from water vapour.
15. The separated water vapour returned to generator.
16. Then the ammonia vapour passes through a rectifier.
17. The rectifier resembles a condenser and water vapour still present in ammonia vapour condenses and the condensate is returned to analyser.
18. The virtually pure ammonia vapour then passes through the condenser.
19. The latent heat of ammonia vapour is rejected to the cooling water circulated through the condenser and the ammonia vapour is condensed to liquid ammonia.
20. The high pressure liquid ammonia is throttled by an expansion valve or throttle valve.
21. This reduces the high temperature of the liquid ammonia to a low value and liquid ammonia partly evaporates.
22. Then this is led to the evaporator.
23. In the evaporator the liquid fully vaporizes.
24. The latent heat of evaporation is obtained from the brine or other body which is being cooled.
25. The low pressure ammonia vapour leaving the evaporator again enters the absorber and the cycle is completed.
26. This cycle is repeated again to provide the refrigerating effect.

Refrigerant Compressors

The compressor is referred to as the heart of mechanical refrigeration systems. The compressor is used to compress the vapour refrigerant coming from the evaporator and to raise its pressure and temperature more than that of the cooling medium. It also continuously circulates the refrigerant through the refrigerating system. Since the compression of refrigerant requires some work to be done on it, therefore a compressor must be driven by some prime-mover.

Necessity of compressor in a vapour compression system

It is that part in a vapour compression system which sucks the refrigerant vapours at low temperature and low pressure and compresses it into a lower volume at higher temperature and pressure and also it creates the flow of refrigerant from one part to other. The pressure difference between high and low side makes the refrigerant goes forcibly into cooling coil through refrigerant flow controls. Therefore the main job of compressor is to keep the difference in pressure at high side and low side of refrigeration system

Classification of compressor

The compressors may be classified in many ways, but the following are important from the subject point of view.

- According to the method of compressor
  - Reciprocating compressors
  - Rotary compressors
  - Centrifugal compressor
- According to the number of working strokes
  - Single acting compressor
  - Double acting compressors
- According to the number of stages
  - Single stage compressors
  - Multi stage compressor
- According to the method of drive employed
  - Direct drive compressor
  - Belt drive compressor
- According to the location of the prime movers

- Semi hermetic compressor (direct rive motor and compressor in separate housings)
- Hermetic compressors (Direct drive motor and compressor in same housing

Three main groups of compressor,

- Reciprocating compressor
- Rotary compressor
- Centrifugal compressor

Reciprocating compressors

Reciprocating compressors are those in which piston moves in a cylinder in reciprocating motion with the help of connecting rod, crank shaft etc. to compress the refrigerant.

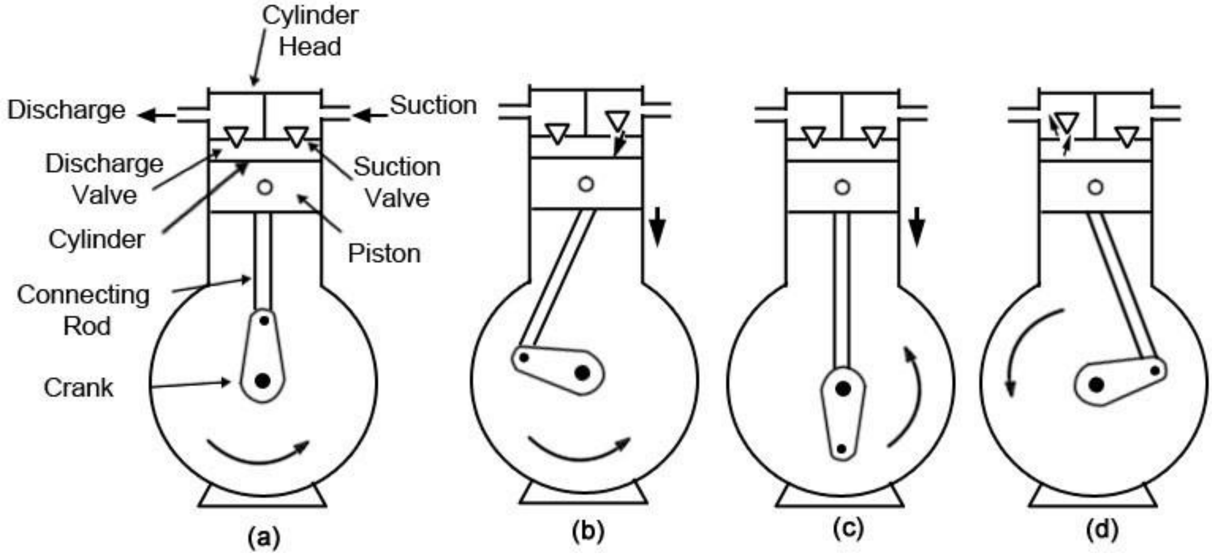
The functions of reciprocating compressor in vapor compression refrigeration system are as follows.

* It sucks and discharge the refrigerant
* It compresses the low temperature and low pressures vapor into high temperature and high pressure vapor.
* It creates the flow of refrigerant.

Reciprocating compressors are used for refrigerants which have comparatively low volume per kg and a large differential pressure, such as R717, R12,R22 and R-40. The reciprocating compressors are available in sizes from 1/12kw which are used in small domestic refrigerators and up to about 150kw for large capacity installations.

The two types of reciprocating compressor in general use are single acting vertical compressors and double acting compressors. The single acting compressors usually have their cylinders arranged vertically, radially or in a V or w form. The double acting compressors have their cylinders arranged horizontally.

Working principle of Reciprocating compressor



Let us consider that the piston is at the top of its stroke fig (a). This is called top dead centre position of the piston. In this position the suction valve is held closed because of the pressure in the clearance space between the top of the piston and the cylinder head. The discharge valve is also held closed because of the cylinder head pressure acting on the top of it.

When the piston moves down word (i.e during suction stroke) as shown in Fig (b) the refrigerant left in the clearance space expands. Thus the volume of the cylinder increases and the pressure inside the cylinder decreases. When the pressure becomes slightly less than the suction pressure or atmosphere pressure, the suction valve gets opened and the vapour refrigerant flows into the cylinder. This flow continues until the piston reaches the bottom of its stroke (i.e. Bottom Dead Centre). At the bottom of the stroke, as shown in Fig (c), the suction valve closes because of spring action. Now when the piston moves upward (i.e, during compression stroke) as shown in fig (d), the volume of the cylinder decrease and the pressure inside the cylinder increases. When the pressure inside the cylinder becomes greater than that on the top of the discharge valve, the discharged valve gets opened and the vapour refrigerant is discharged into the condenser and the cycle is repeated.

Different parts of the Reciprocating compressorPiston

The piston is made of cast-iron and is mechanically well polished. It has a drilled hole to fit the piston or wrist pin. This pin is fitted for joining the connecting rod to the piston. Piston it fitted with close tolerance in cylinder. The function of the piston is only to compress the refrigerant in an enclosed cylinder.

Piston rings

Piston rings are made of cast-iron which are fitted on pistons but some piston rings are made of bronze metal also. This metal works for long time and not rubbed. These rings are installed in grooves on the piston. Generally piston has two or more rings. The main function of the piston ring is to maintain the proper lubrication and to prevent the gas from escaping between the piston wall and cylinder wall.

Crank shaft

Crank shaft is a moving lever. It is used for inducing the torque. When it is used with the connecting rod it moves with the reciprocating motion. Crank shafts are made of carbon steel, cast steel or nickel chromium steel. Crank shafts are equipped with counter weights and are carefully balanced to ensure smooth and vibration less compressor operation. This counter weight is made of cast-iron.

Connecting rod

Connecting rod is used for connecting the piston and crank shaft. One end is connected to the piston by means of hardened, ground and highly polished steel wrist pin. It is made of cast steel or cast-iron. The wrist pin upper end of the connecting rod have an oscillating or reciprocating motion while the lower end of the connecting rod combines a reciprocating and rotary motion.

Rings

There are two types of rings i.e, compression rings and oil scrapper rings. The compression ring is provided on the top of the piston and is used to seal the difference between the piston and the cylinder wall. The oil scraper ring is provided below the piston.

Suction and discharge valve

The valve that controls the flow of refrigerant from the suction line into cylinder head is known as suction valve. The valve that discharges the compressed gas towards the discharged line is called discharged valve. These valves are named according to the function they perform.

Important terms used in reciprocating compressor

B.D.C

When the piston reaches at the bottom of the cylinder of compressor is called Bottom Dead Center.

T.D.C

When the piston reaches at he top of the cylinder of compressor is called Top Dead Centre.

Piston stroke

The distance covered by the piston from B.D.C to T.D.C or T.D.C to B.D.C is called piston stroke.

Suction stroke

when the piston moves from T.D.C to B.D.C and sucks gas through the suction valve then it is called suction stroke.

Compression stroke

when the piston moves from B.D.C to T.D.C and compresses and discharges the gas through the discharge valve then it is called compression stroke.

Piston displacement volume

Total cylinder volume swept by the piston in any certain time is called piston displacement volume. It is expressed in cubic meter per minute

Compression ratio

compressor ratio is the ratio of absolute discharge pressure or head pressure to the absolute suction Pressure.

Volumetric efficiency

It is the ratio of actual weight of refrigerant in a cylinder to the weight that the cylinder can theoretically hold.

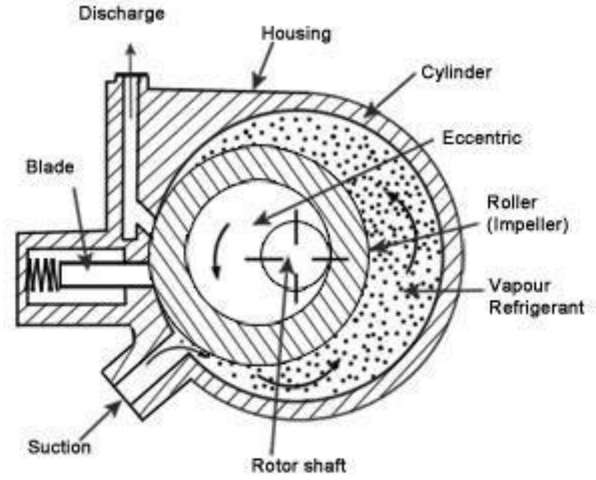
Rotary Compressors

In rotary compressors, the vapour refrigerant from the evaporator is compressed due to the movement of blades. The rotary compressors are positive displacement type compressors. Since the clearance in rotary compressors is negligible, therefore they have high volumetric efficiency. These compressors may be used with refrigerants R-12, R-22, R-114 and ammonia. These rotary compressors may be divided roughly into two types .In the first type one or more stationary blades are used for sealing the suction from the dicharge gases. The second type uses sealing blades which rotate with the shaft.

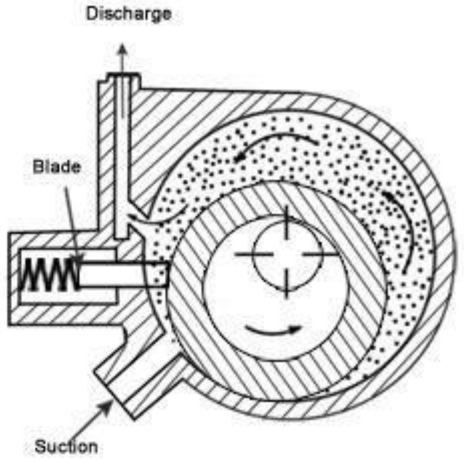
Single stationary blade type rotary compressor

A single stationary blade type rotary compressor is shown in figure. This consists of a stationary cylinder, a roller (or impeller) and a shaft has an eccentric on which the roller is mounted. A blade is set into the slot of a cylinder in such a manner that it always maintains contacts with the roller by means of a spring. The blade moves in and out of the slot to follow the rotor when it rotates. Since the blade separates the suction and discharge ports as shown in figure, therefore it is often called a sealing blade. When the shaft rotates, the roller also rotates so that it always touches the cylinder wall.

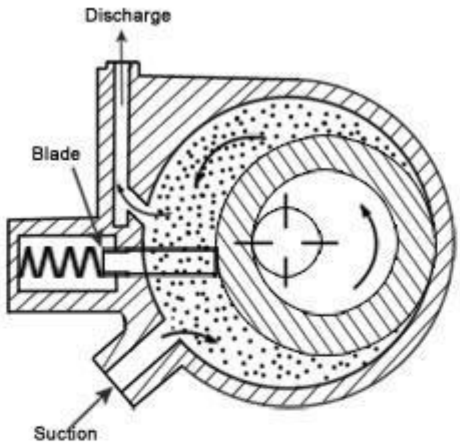
In figure (a) to (d) shows the various positions of roller as the vapour refrigerant is compressed. Figure (a) shows the completion of intake stroke (i.e. the cylinder is full of low pressure and temperature vapour refrigerant) and the beginning of compression stroke. When the roller rotates, the vapour refrigerant ahead of the roller is being compressed and the new intake from the evaporator is drawn into the cylinder, as shown in figure (b). As the roller turns mid position as shown in figure, more vapour refrigerant is drawn into the cylinder while the compressed refrigerant is discharged to the condenser. At the end of compression stroke as shown in figure (d), most of the compressed vapour refrigerant is passed through the discharge port to the condenser. A new charge of refrigerant is drawn into the cylinder. This, in turn is compressed and discharged to the condenser. In this way, the low pressure and temperature refrigerant is compressed gradually to a high pressure and temperature.



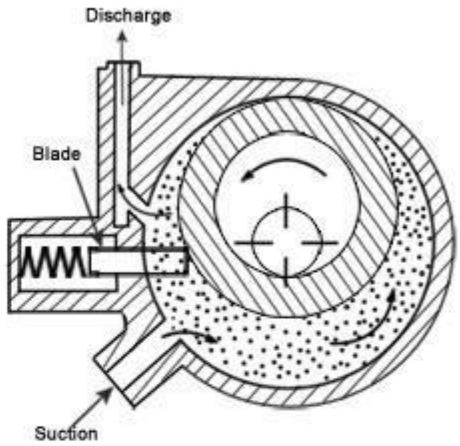
(a) Completion of intake stroke and beginning of compression



(b) Compression stroke continued and new intake stroke started



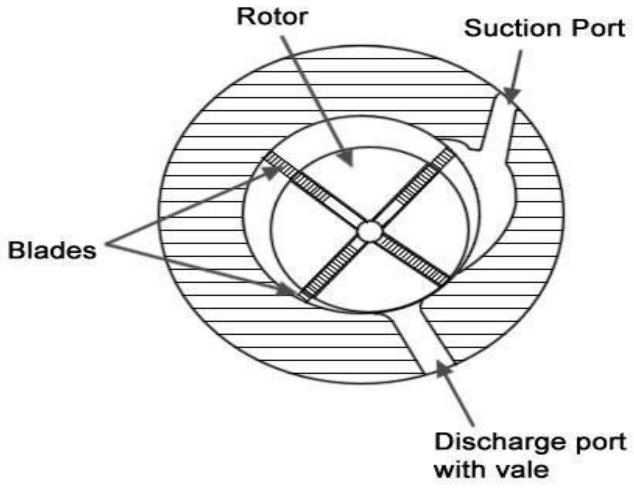
(c) Compression continued and new intake stroke continued



(d) Compressor vapour discharged to condensor and new intake stroke continued

Rotating blade type rotary compressor

The rotating blade type rotary compressor is shown in Fig.This compressor consists of a cylinder and a slotted rotor containing a number of blades. The centre of the rotor is eccentric with the centre of the cylinder. The blades are forced against the cylinder wall by the centrifugal action during the rotation of the motor.

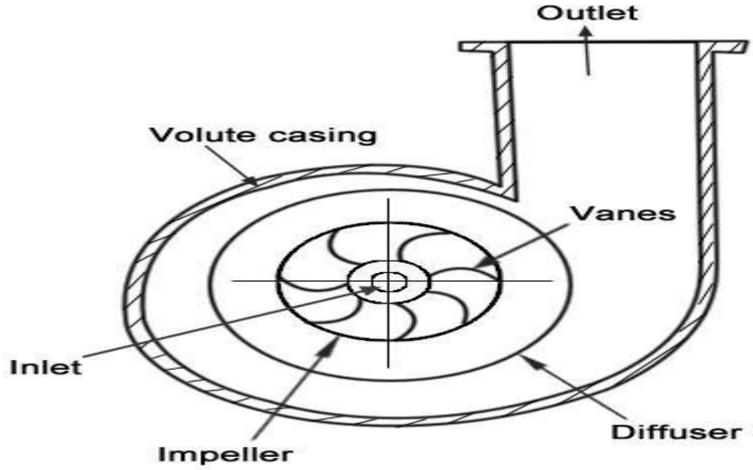


Rotating Blade type rotary Compressor

Centrifugal Compressors

Working principle

The centrifugal compressor for refrigeration systems was designed and developed by Dr. Willis H. Carrier in 1922. This compressor increases the pressure of low pressure vapour refrigerant to a high pressure vapour refrigerant by means of centrifugal force. The centrifugal compressor is generally used for refrigerant that require large displacement and low condensing pressure, such as R-Il and R-l13. However, the refrigerant R-12 is also employed for large capacity applications and low-temperature applications.



Centrifugal compressor

A single stage centrifugal compressor, in its simplest form, consists of an impeller to which a number of curved vanes are fitted symmetrically, as shown in Fig. The impeller rotates in an air tight volute casing with inlet and outlet points
The impeller draws in low pressure vapour refrigerant from the evaporator. When the impeller rotates, it pushes the vapour refrigerant from the centre of the impeller to its periphery by centrifugal force. The high speed of the impeller leaves vapour refrigerant at a high velocity at the vane tips of the impeller. The kinetic energy thus attained at the impeller outlet is converted into pressure energy when the high velocity vapour refrigerant passes over the diffuser. The diffuser is normally a vaneless type as it permits more efficient part load operation which is quite usual in any air-conditioning plant. The volute casing collects the refrigerant from the diffuser and it further converts the kinetic energy into pressure energy

before it leaves the refrigerant to the evaporator.

Note :

- In case of a single stage centrifugal compressor. The compression ratio that an impeller can develop is limited to about 4.5. But when high compression ratio is desired, multi-stage centrifugal compressors with inter coolers are employed.
- The centrifugal compressors have no valves, pistons and cylinders. The only wearing parts are the main bearings

Advantages and disadvantages of Centrifugal Compressors

Advantages

- Since the centrifugal compressors have no valves, pistons, cylinders, connecting rod, etc., therefore the working life of these compressors is more as compared to Reciprocating compressors.
- These compressors operate with little or no vibration as there are no unbalanced masses.
- The operation of centrifugal compressors is quiet and calm.
- The centrifugal compressors run at high speeds (3000 r.p.m. and above), therefore these can be directly connected to electric motors or steam turbines.
- Because of the high speed, these compressors can handle large volume of vapour refrigerant, as compared to reciprocating compressors.
- The centrifugal compressors are especially adapted for systems ranging from 50 to 5000 tonnes. They are also used for temperature ranges between - 90°C and + 10°C.
- The efficiency of these compressors is considerably high.
- The large sizes centrifugal compressors require less floor area as compared to reciprocating compressors.

Disadvantages

- The main disadvantage in centrifugal compressors is *surging. It occurs when the refrigeration load decreases to below 35 percent of the rated capacity and causes severe stress conditions in the compressor.
- The increase in pressure per stage is less as compared to reciprocating compressors.
- The centrifugal compressors are practical below 50 tonnes capacity load.
- The refrigerants used with these compressors should have high specific volume.

Condensors

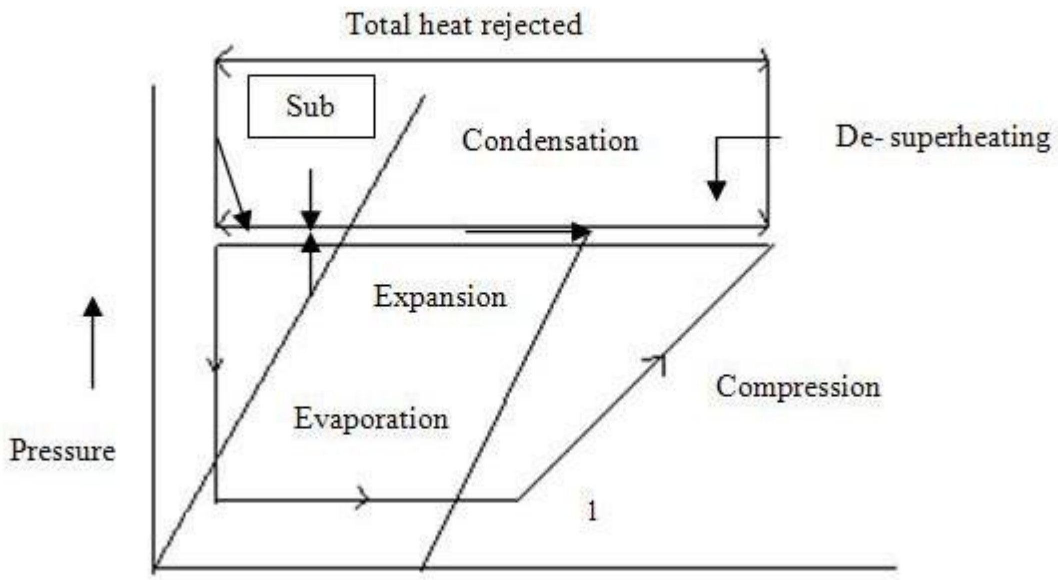
The condenser is an important device used in the high pressure side of a refrigeration system. Its main function is to transfer heat from the refrigeration system to condensing medium. The hot vapour refrigerant consists of the heat absorbed in the evaporator and the heat of compression added by the mechanical energy of the compressor. The heat from the hot vapour refrigerant in a condenser is removed first by transferring it to the walls of the condenser tubes and then from the tubes to the condensing or cooling medium. The cooling medium may be air or water or a combination of the two. The selection of a condenser depends upon the capacity of the refrigerating system, the type of refrigerant used and the types of cooling medium available.

Working of condenser

The compressor drawn in the superheated vapour refrigerant that contains the heat it absorbed in the evaporator and the compressor which adds more heat (i.e. the heat of compression) to the superheat vapour. This highly superheated vapour from the compressor is pumped to the condenser through the discharge line.

The condenser cools the refrigerant in the following three stages.

- First of all superheated vapour is cooled to saturation temperature to the pressure of the refrigerant



- Now the saturated vapour refrigerant gives up its latent heat and is condensed to a saturated liquid refrigerant. This process is called condensation.
- The temperature of the liquid refrigerant is reduced below its saturation temperature (i.e. sub cooled) in order to increase the refrigeration effect.

Factors Affecting the Condenser Capacity

The condenser capacity is the ability of the condenser to transfer heat from the hot vapour refrigerant to the condensing medium. The heat transfer capacity of a condenser depends upon the following factor.

Material

Different materials have different abilities of heat transfer, therefore the size of a condenser of a given capacity can be varied by selecting the right material. It may be noted that higher the ability of a material to transfer heat, the smaller will be the size of condenser.

Amount of contact

The condenser capacity may be varied by controlling the amount of contact between the condenser surface and the condensing medium This can be done by varying the surface area of the condenser and the rate of flow of the condensing medium over the condenser surface. The amount of liquid refrigerant level in the condenser also affects the amount of contact between the vapour refrigerant and the condensing medium.

Temperature Difference

The heat transfer capacity of a condenser greatly depends upon the temperature difference between the condensing medium and the vapour refrigerant. As the temperature difference increases, the heat transfers rate increases and therefore the condenser capacity increases.

Types of the condenser

- Air cooled condenser
- Water cooled condense
- Evaporative condenser

Air-cooled condensers

An air cooled condenser is one in which the removal of heat is done by air. It consists of steel or copper tubing through which the refrigerant flows. The size of tube usually ranges from 6 mm to 18 mm outside diameter depending upon the size of the condenser. Generally copper tubs are used because of its excellent heat transfer ability. The condenser with steel tubes is used in ammonia refrigerating systems.The main disadvantage of an air cooled condenser is that it operates at a higher condensing temperature than a water cooled condenser. The higher condensing temperature causes the compressor to work more

Types of air cooled condenser

- Natural convection air-cooled condenser

In natural convection air-cooled condenser the heat transfer from the condenser coils to the air is by natural convection. As the air comes in contact with the warm condenser tubes, it absorbs heat from the refrigerant and thus the temperature of air increases. The warm air being lighter, rises up and the cold air from below rises to take away the heat from the condenser since the rate of heat transfer in natural convection condenser is slower therefore they require a large surface area as compared to forced convection condensers. The natural convection air cooled condenser are used in small capacity applications such as domestic refrigerators, freezers, water cooler and air-conditioners.

- Forced convection air cooled condenser:

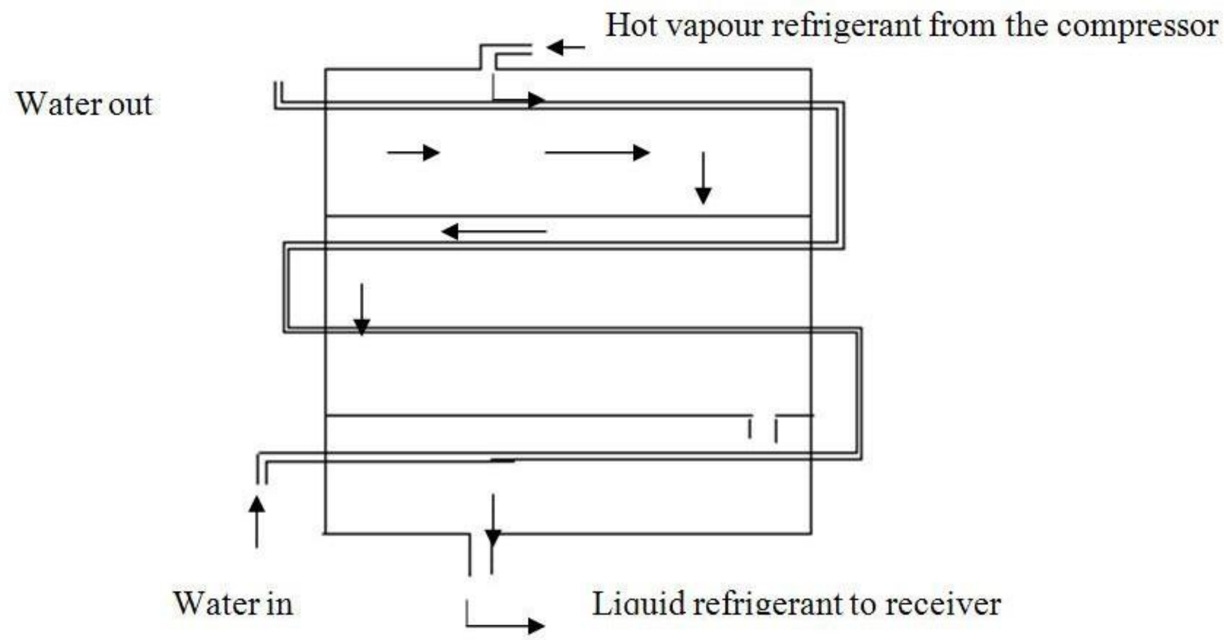
In forced convection air cooled condenser, the fan is used to force the air over the condenser coils to increase the heat transfer capacity.

Water cooled condenser

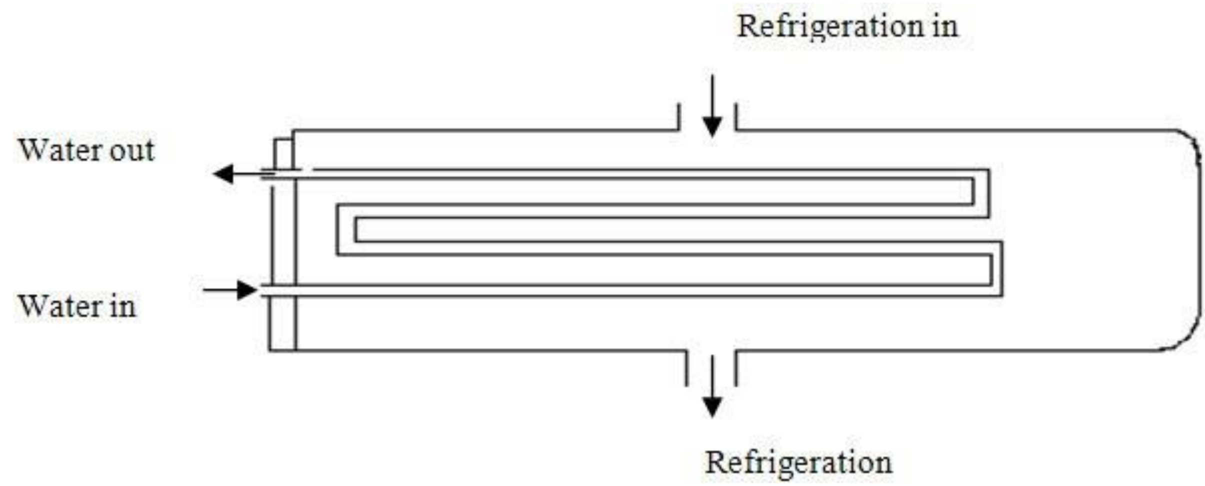
A water cooled condenser is one in which water is used as the condensing medium. They are always preferred where as adequate supply of clear expensive water and means of water disposal are available. These condenser are commonly used in commercial and industrial refrigerating units.

Tubes in tube or double tube condenser

This type of condenser consists of a water tube inside a large refrigerant tube. In this type of condenser the hot vapour refrigerant enters at the top of the condense



The water absorbs the heat from the refrigerant and the condensed liquid refrigerant flows at the bottom since the refrigerant tubes are exposed to ambient air, Therefore some of the heat is also absorbed by ambient air by natural convection. The cold water in the inner tubes may flow in either direction. Opposite to the refrigerant, it is said to be a counter flow system on the other hand, when the water enters at the top and flows in the same direction as the refrigerant, it is said to be parallel flow system.

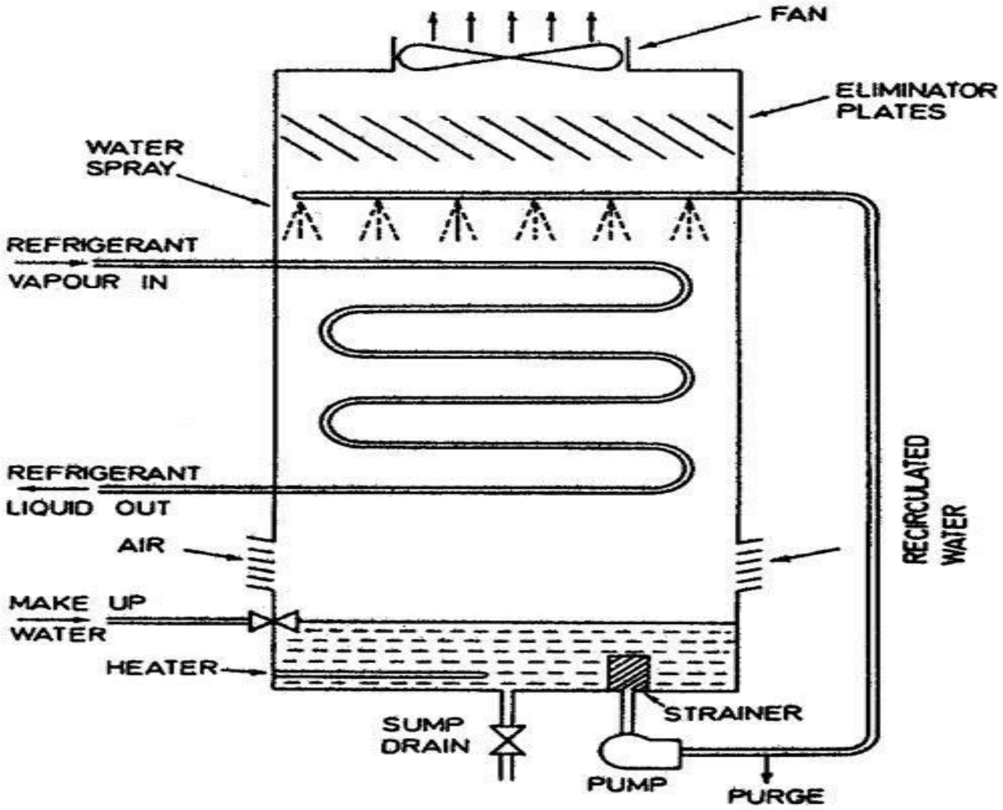


Shell and coil condenser

hell and coil water cooled condensers are widely used in the smaller size up to 10 tones capacity. They have the advantage of being compact in size and serve the dual function of condenser and receiver. As the name implies, a water coil is wound inside a shell. The refrigerant gas within the shell condenses on the outside of the water coils. The liquid refrigerant collects at the bottom of the shell where it is then removed through a bottom outlet.

Evaporative Condenser

The evaporative condenser use both air and water as condensing mediums to condense the hot vapour refrigerant to liquid refrigerant. These condenser combines the effectiveness of forced convection currents with the ability of a vaporizing liquid to absorb heat.



In its operation, the water is pumped from the sump to a spray header and sprayed through nozzles over the condenser coils through which the hot vapour refrigerant from the compressor is passing. The heat transfers from the refrigerant to the condensing tube walls and into the water that is wetting the outside surface of the tubes. At the same time, a fan draws air from the bottom side of the condenser and discharged out at the top of the condenser.The air causes the water from the surface the condenser coils to evaporate and absorb the latent heat of evaporation from the remaining water to cool it. Though most of the cooling takes place by evaporation, the air can also absorb some sensible heat from water. Since the heat for vaporizing the water is taken from the refrigerant therefore the vapour refrigerant condenses in to a liquid refrigerant.
The cold water that drops down into a sump is recirculated. In order to make up the deficiency caused by the evaporated water additional water is supplied to the sump. A float valve in the sump controls the make up supply. The eliminator is provided above the spray header to stop particles of water escaping along with the discharge air.

Comparison between Air cooled and water cooled condensers

s.l no	Air cooled condenser	Water cooled condenser
1	Construction of air cooled condenser is very simple. Therefore the initial cost is low. The maintenance cost is also low	Construction of water cooled condenser is complicated therefore the initial cost is high. The maintenance cost is also high.
2	There is no handling problem with air cooled condenser	The water cooled condenser are difficult to handle
3	The air cooled condenser do not require piping arrangement for carrying the air	The pipes are required to take water to and from the condenser
4	There is no problem in disposing of used air	There is a problem of disposing the used water unless recirculation system is provided.
5	There is no corrosion therefore fouling effect is low	There is a corrosion occurs inside water tubes therefore the fouling effects is high
6	The air cooled condenser have low heat transfer capacity due to low thermalconductivity of air	The water cooled condenser have high heat transfer capacity due to high thermalconductivity of water
7	These condenser are used for low capacity plans (less than STR)	These condenser are used for large capacity plants
8	The distribution of air on condenser surface is not uniform	There is even distribution of water on the condensing surface.

Evaporators

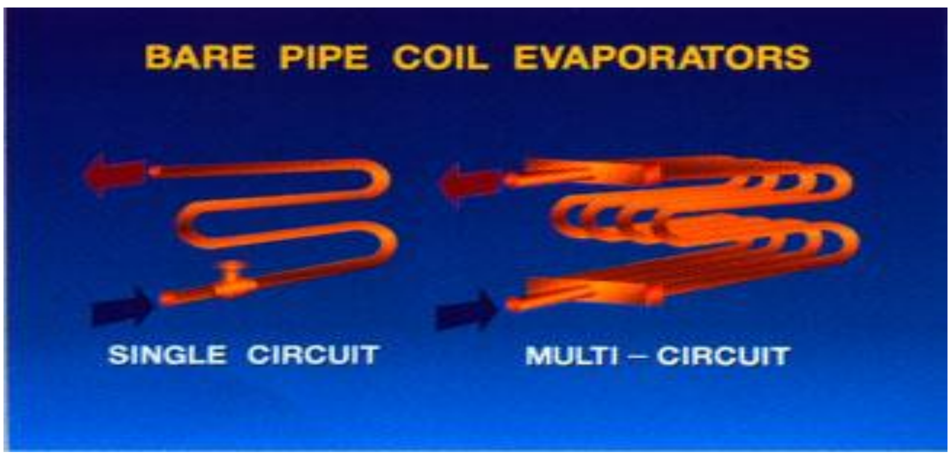
The evaporator's job is to absorb heat, which provides cooling. The type of evaporator depends on what type of appliance it is used in. This makes sense, since the requirements for a refrigeration system would be different than the requirements for an air conditioning system.

All evaporators are made of metals like copper and aluminum because they are **good conductors of heat**. A good conductor allows heat to transfer freely from air outside the coils to the refrigerant inside the coils.

There are four main types of evaporators.

- **Bare Tube** Evaporators,
- **Plate Surface** Evaporators,
- **Finned Tube** Evaporators, and
- **Shell and Tube** Evaporators.

Bare Tube Evaporator



Bare tube evaporators are the simplest type of evaporator. These evaporators are generally just refrigerant tubes that are made of either copper or aluminum.
There is refrigerant inside the refrigerant tube that absorbs heat from the air and vaporizes inside the tube. Heat transfers across the surface area of the metal refrigerant tubes.
We generally find these evaporators in household refrigerators and freezers. This is because bare tube evaporators are less effective than the other evaporators we will

talk about. These evaporators will not work for large cooling requirements in commercial uses.

Bare tube evaporators do have some advantages. They are:

- Easy to clean, and
- Easy to defrost.

Plate Surface Evaporator

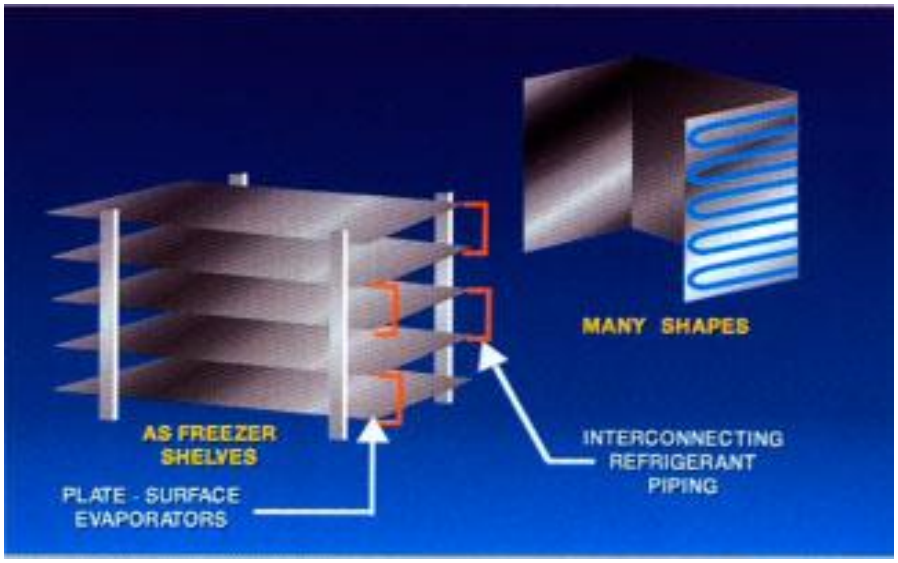


Plate surface evaporators are flat, as shown in this image. These evaporators are made up of two plates that are joined together. Usually the two plates are made of aluminum because it conducts heat well.
Liquid refrigerant flows through a tube made between the two plates. This tube carrying refrigerant is the raised part of the plate

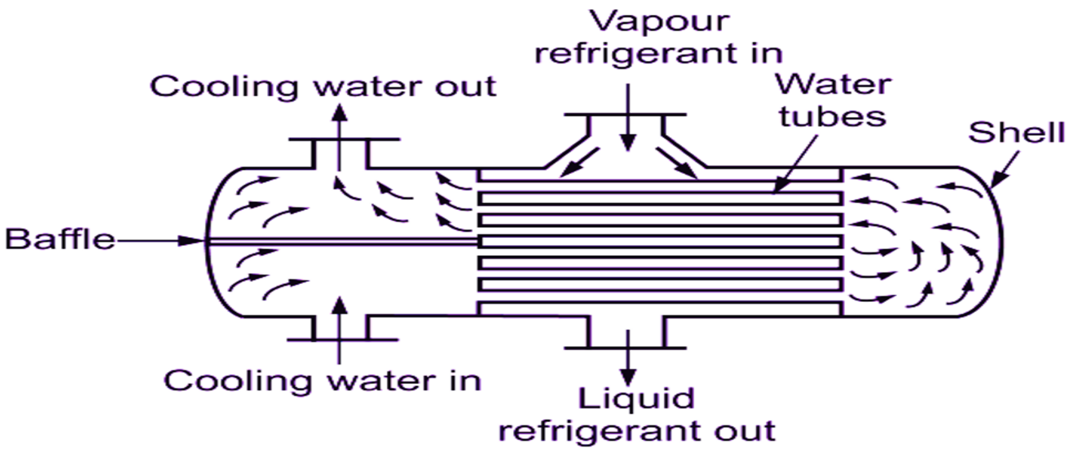
The benefits of plate surface evaporators are that they are:

- Easy to clean and defrost,
- Less likely to leak refrigerant, since the plates protect the tube carrying refrigerant, and
- Safe to handle

Finned Tube Evaporator

The finned tube evaporator is more complex and more effective. A fin is a very small plate that is attached to the body of the evaporator. As you can see in this image, finned tube evaporators have a lot of fins attached to its body.

Shell and Tube Evaporator



A shell and tube evaporator consists of a copper tube bundle inside a large outer shell. They are generally very efficient at cooling **large quantities of water.** This is why shell and tube evaporators are used for chillers in industrial or commercial settings where large quantities of cold water are needed.

The copper tubes contain the water that we are trying to chill. In this video, the red represents the hot water flowing through the inner copper tubes in the evaporator.

The outer shell of the evaporator is a large container of refrigerant fluid. This shell is sealed off and leakproof to prevent refrigerant from escaping. Heat will transfer from the water to the outer shell that contains refrigerant, which will cool the water.

REFRIGERANT FLOW CONTROL DEVICE

EXPANSION VALVE

Expansion valves are devices used to control the refrigerant flow in a refrigeration system. They remove pressure from the liquid refrigerant to allow expansion or change of state from a liquid to a vapor in the evaporator. Expansion valves serve two purposes: controlling the amount of refrigerant entering the evaporator and maintaining the pressure difference between the condenser (high-pressure side) and the evaporator (low-pressure side).

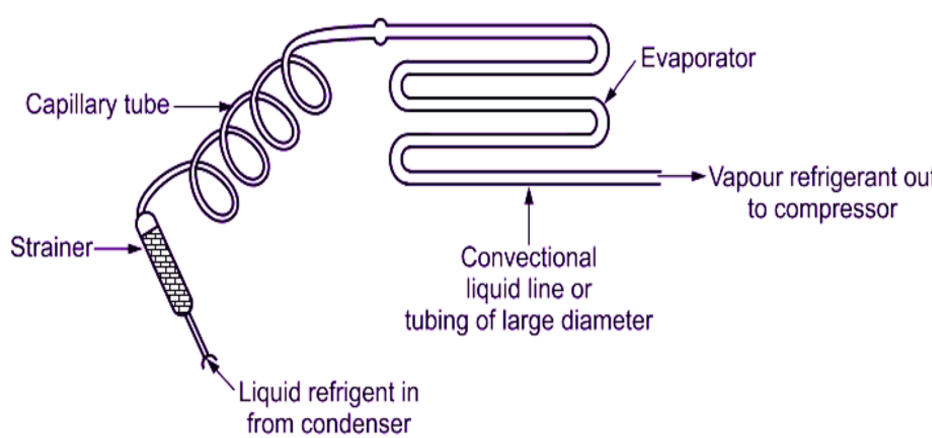
DIFFERENT TYPES OF EXPANSION VALVES

The Main Types of Expansion Valves are as Follows.

1. **Thermal Expansion Valves (TEVs)**
2. **Manual Valves**
3. **Capillary Tubes**
4. **Automatic Valves**
5. **Electronic Expansion Valves**
6. **Float Valves**

CAPILLARY TUBES

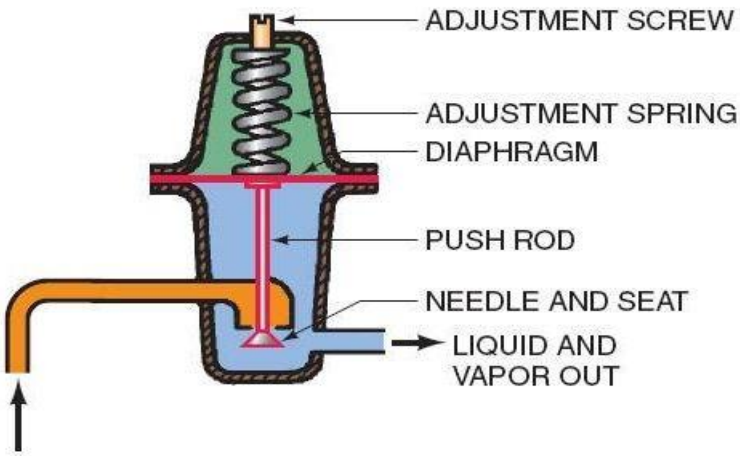
A capillary tube is a long, wound-up copper tube with a tiny opening that receives hot, high-pressure liquid refrigerant from the condenser. This small opening holds high pressure on one side of the tube and low pressure on the opposite side. The friction from the walls of the tube rapidly reduces the pressure of the refrigerant flowing through it.

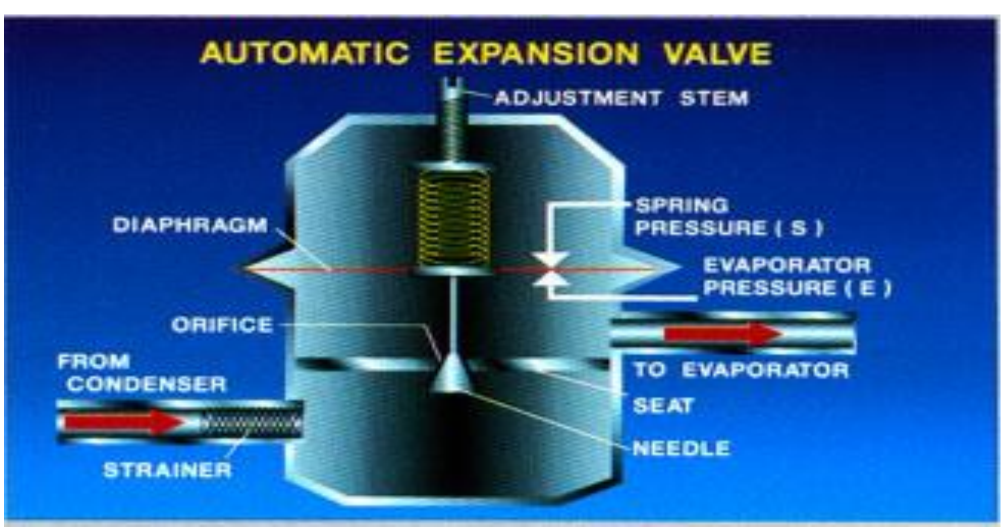


AUTOMATIC EXPANSION VALVES

Automatic Expansion Valve regulates the flow of refrigerant from the liquid line to the evaporator by using a pressure-actuated diaphragm. It maintains a constant pressure in the evaporator.

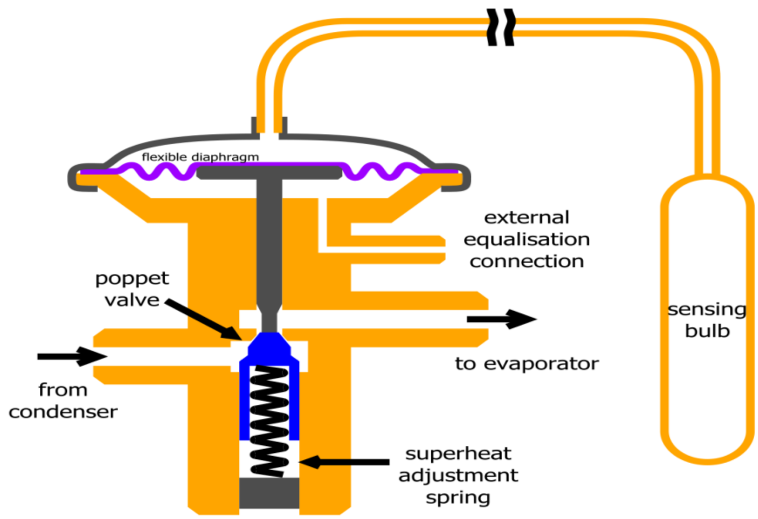
These types of expansion valves consist of a needle with a seat and a pressure bellows or diaphragm with a torsion spring capable of adjustment. Operated by evaporator pressure their chief disadvantage is their relatively poor efficiency compared with other types. Constant pressure in the evaporator also requires a constant rate of vaporization, which in turn calls for severe throttling of the liquid. There is also the danger of liquid being allowed to return to the compressor when the load falls below a certain level





THERMAL EXPANSION VALVES

Thermal expansion valves, or thermostatic expansion valves (often abbreviated as TEV, TXV, or TX valve), are the refrigeration and air conditioning throttling device that controls the amount of refrigerant liquid injected into a system's evaporator (based on the evaporator outlet temperature and pressure) called the superheat.



Components of thermostatic expansion valve

- **The valve body:** It holds the components and has an orifice inside to restrict the flow of refrigerant
- **The diaphragm:** It is a strong, thin flexible material, typically metal, which can flex to apply pressure to the pin.
- **The pin, or needle:** It moves up and down to vary the size of the opening within the orifice to control the refrigerant flow.
- **The spring:** It counteracts the force of the pin.
- **The sensing bulb and capillary line:** They measure the refrigerant temperature, at the evaporator exit, and react to causes the valve to open or close.

Thermal Expansion Valves Working Principle

- When the load on the evaporator increases, it causes the liquid refrigerant to boil faster in the evaporator coil. Since the feeler bulb is installed on the suction line, it is at the same temperature as the refrigerant at that point. So the temperature of the bulb increases due to the early vaporization of refrigerant.
- Thus the feeler bulb pressure increases and gets transmitted through the capillary tube to the diaphragm. The diaphragm moves downwards, opening the valve to admit more liquid refrigerant into the evaporator.
- This continues till pressure equilibrium on the diaphragm is reached, at which feeler bulb pressure acting at top of the diaphragm is balanced by spring and evaporator pressure acting at bottom of the diaphragm.
- When the evaporator load decreases, less liquid refrigerant evaporates in the coil, and the excess liquid flows towards the outlet. This cools the feeler bulb and its pressure and temperature decrease.
- This pressure makes the diaphragm move upward, reducing the valve opening and in turn decreasing refrigerant flow to the evaporator. This causes a decrease in evaporator pressure and again continues till diaphragm pressure equilibrium is reached

PSYCHROMETRY

The psychrometric is that branch of engineering science which deals with the study of. moist air i.e., dry air mixed with water vapour or humidity. It also includes the study of. behavior of dry air and water vapour mixture under various sets of conditions.

PSYCHROMETRIC TERMS

Dry air - Pure dry air is a mixture of various gases. Theoretical sample of air that has no water vapor. Pure dry air doesn't exist in nature

Moist Air - Mixture of dry air and water vapour

Saturated Air - Air that contains the maximum amount of water vapour that is possible at the given temperature and pressure

Dry-bulb temperature (DBT)(tdb) -The dry-bulb temperature is the temperature indicated by a thermometer exposed to the air in a place sheltered from direct solar radiation.

Wet-bulb temperature (WBT)(twb) - It is the temperature of air when it is affected by moisture. Wet Bulb temperature can be measured by using a thermometer with the bulb wrapped in wet muslin

Wet bulb depression - Difference between dry and wet bulb temperature

Dew point temperature(tdp) - The saturation temperature of the moisture present in the sample of air. It can also be defined as the temperature at which the vapour changes into liquid (condensation). It is the temperature at which a moist air sample at the same pressure would reach water vapor saturation.

Dew point Depression - Difference between tdb and tdp

Humidity - Humidity is the amount of water vapor present in the air.

Absolute humidity - The mass of water vapor per unit volume of air containing the water vapor at a given temperature and pressure. This quantity is also known as the water vapor density It is expressed in gram per cubic metre.

Relative humidity - is the ratio of actual mass of water vapour present in a given volume of moist air to the mass of water vapour in the same volume of moist air when it is saturated at the same temperature and pressure. RH is dimensionless, and is usually expressed as a percentage.

Specific humidity - is a ratio of the water vapor content of the mixture to the total air content on a mass basis in the moist air sample (dry air plus the water vapor). Sometimes referred to as the **Humidity ratio**.

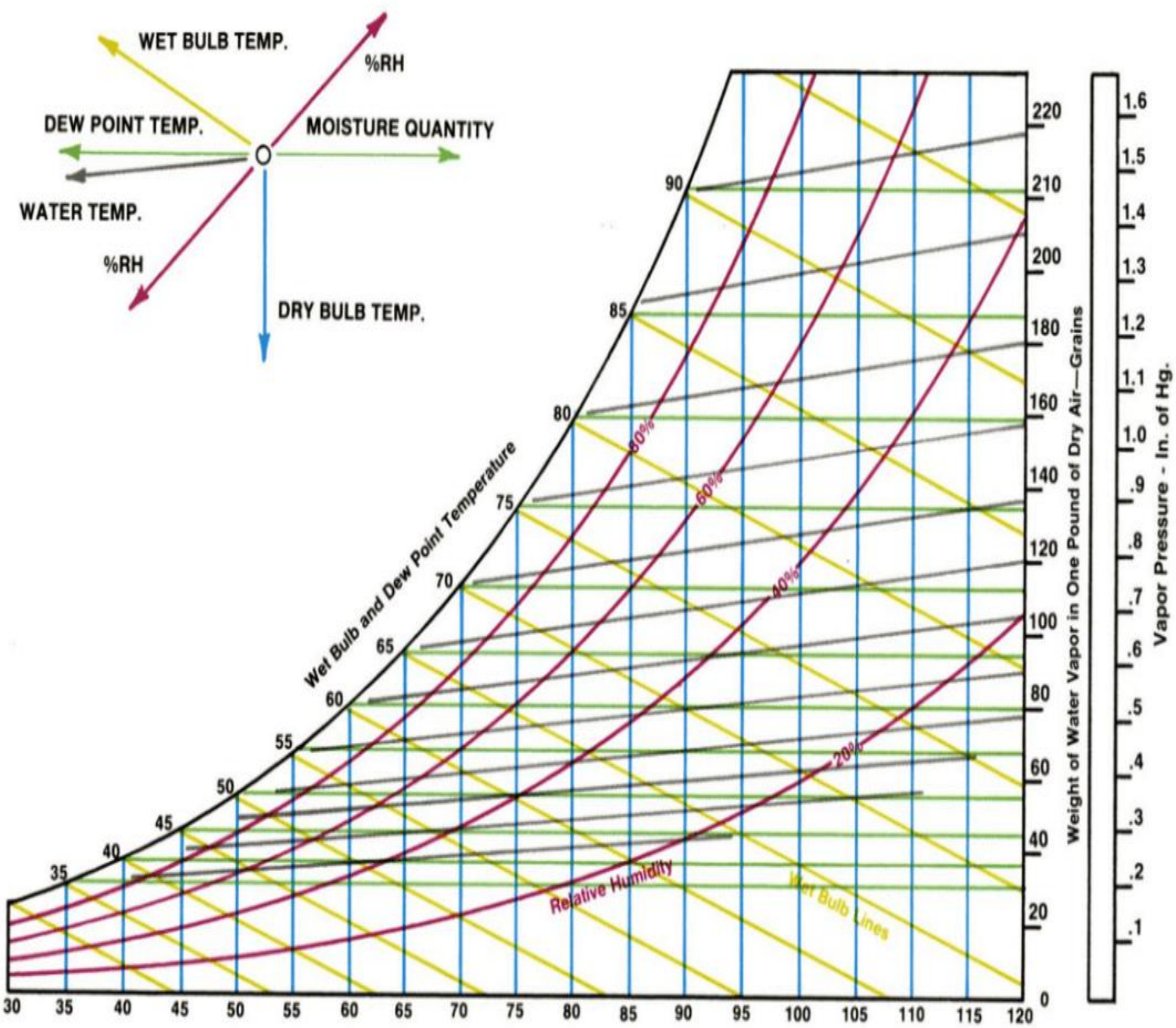
Degree of Saturation (Percentage Humidity). Degree of Saturation is the ratio of the humidity ratio of moist air - to the humidity ratio of saturated moist air at the same temperature and pressure.

Specific enthalpy . It is the sum of the internal (heat) energy of the moist air in question. In psychrometrics, the term quantifies the total energy of both the dry air and water vapour per kilogram of dry air.

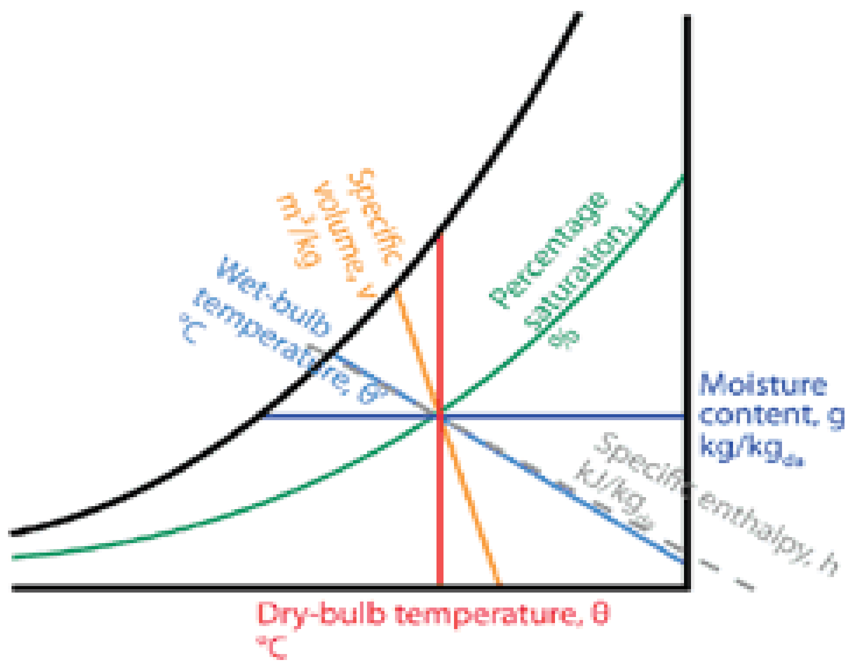
Specific volume - is the volume of the mixture (dry air plus the water vapor) containing one unit of mass of "dry air". The SI units are cubic meters per kilogram of dry air.

Adiabatic Saturation Temperature. Also called The thermodynamic wet-bulb temperature. It is the lowest temperature which may be achieved by evaporative cooling of a water-wetted (or even ice-covered), ventilated surface.

Psychrometric chart



A psychrometric chart is a graph of the thermodynamic parameters of moist air at a constant pressure, often equated to an elevation relative to sea level.



PSYCHROMETRIC PROCESS

Sensible heating

Sensible cooling

Humidification & dehumidification

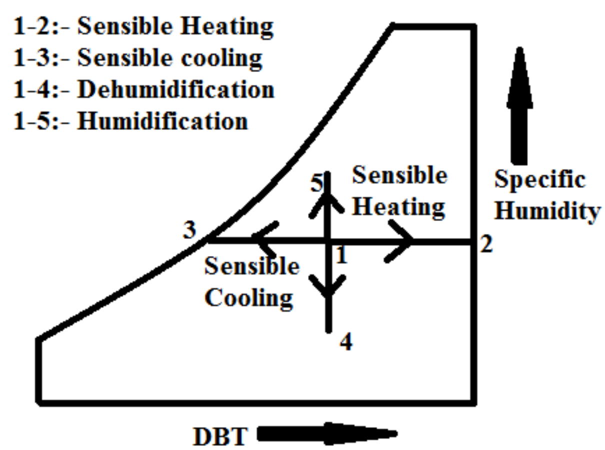
Cooling and adiabatic humidification

Cooling and humidification by water injection

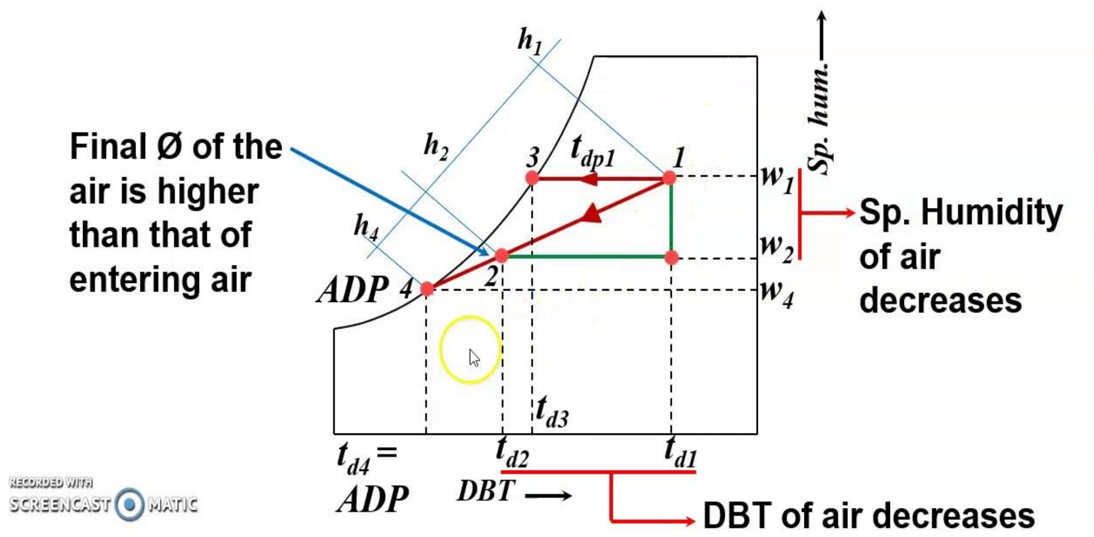
Heating and humidification

Humidification by steam injection

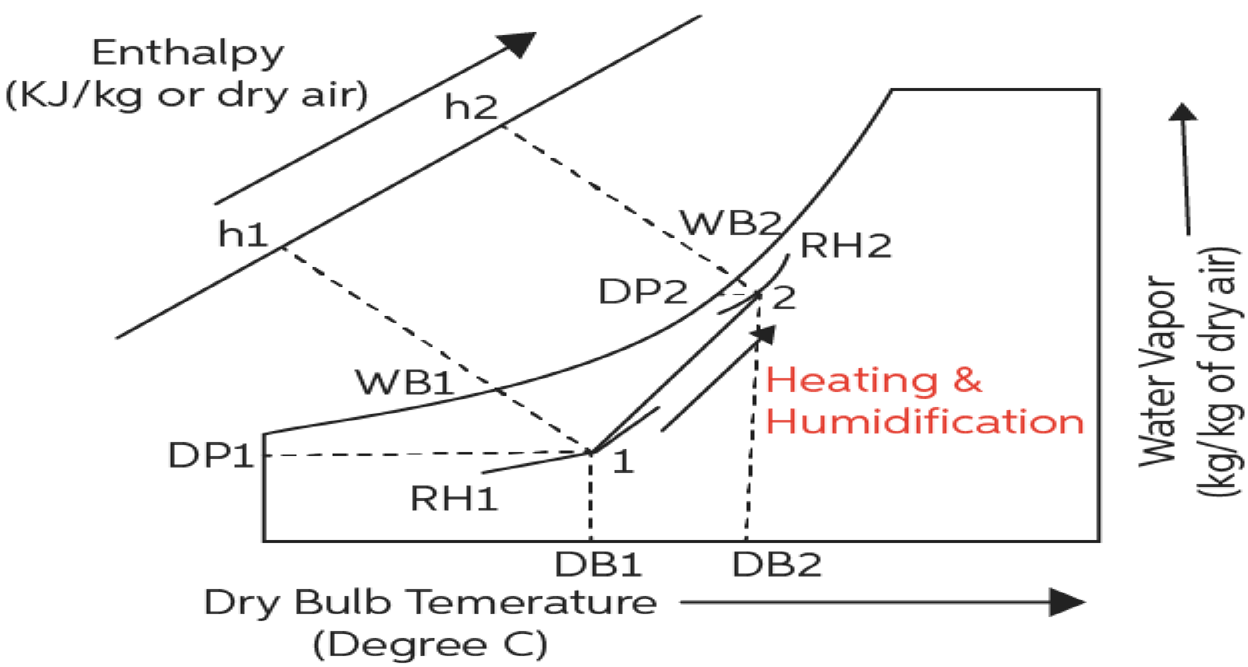
Adiabatic mixing of air streams



Cooling and Dehumidification



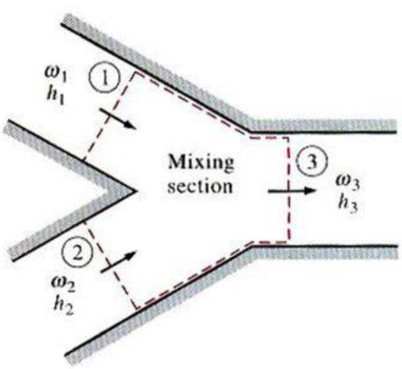
Heating & humidification

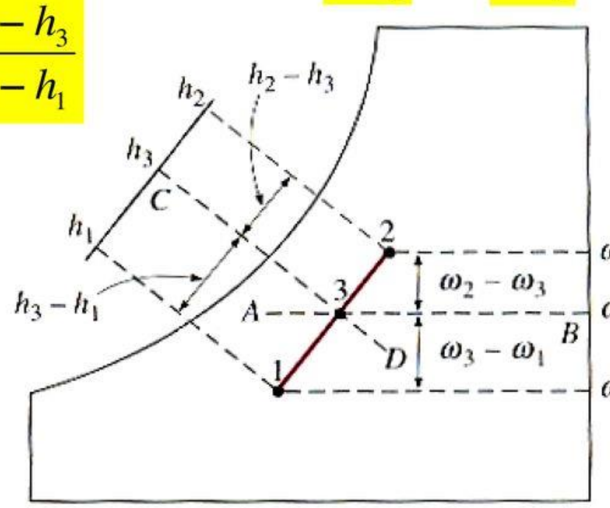


Adiabatic Mixing of Air streams

- **When two airstreams at two different states (states 1 and 2) are mixed adiabatically, the state of the mixture (state 3) will lie on the straight line connecting states 1 and 2 on the psychrometric chart, and the ratio of the distances 2-3 and 3-1 is equal to the ratio of flow rates** and $\dot{m}_{a_1}$ $\dot{m}_{a_2}$

$$\frac{\dot{m}_{a_1}}{\dot{m}_{a_2}} = \frac{\omega_2 - \omega_3}{\omega_3 - \omega_1} = \frac{h_2 - h_3}{h_3 - h_1}$$





AIR CONDITIONING SYSTEM

HUMAN COMFORT

The human comfort depends upon physiological and psychological condition. The most acceptable definition, from the subject point of view, is given by the American Society of Heating, Refrigeration and air Conditioning Engineers (ASHRAE) which states : human comfort is that conditions of mind, which expressed satisfaction with the thermal environment. Factors Affecting Human Comfort

1. Effective temperature
2. Heat production and regulation in human body
3. Heat and moisture losses from the human body
4. Moisture content of air
5. Quality and quantity of air
6. Air motion
7. Hot and cold surfaces
8. Air stratification Effective Temperature

Effectice Temperature

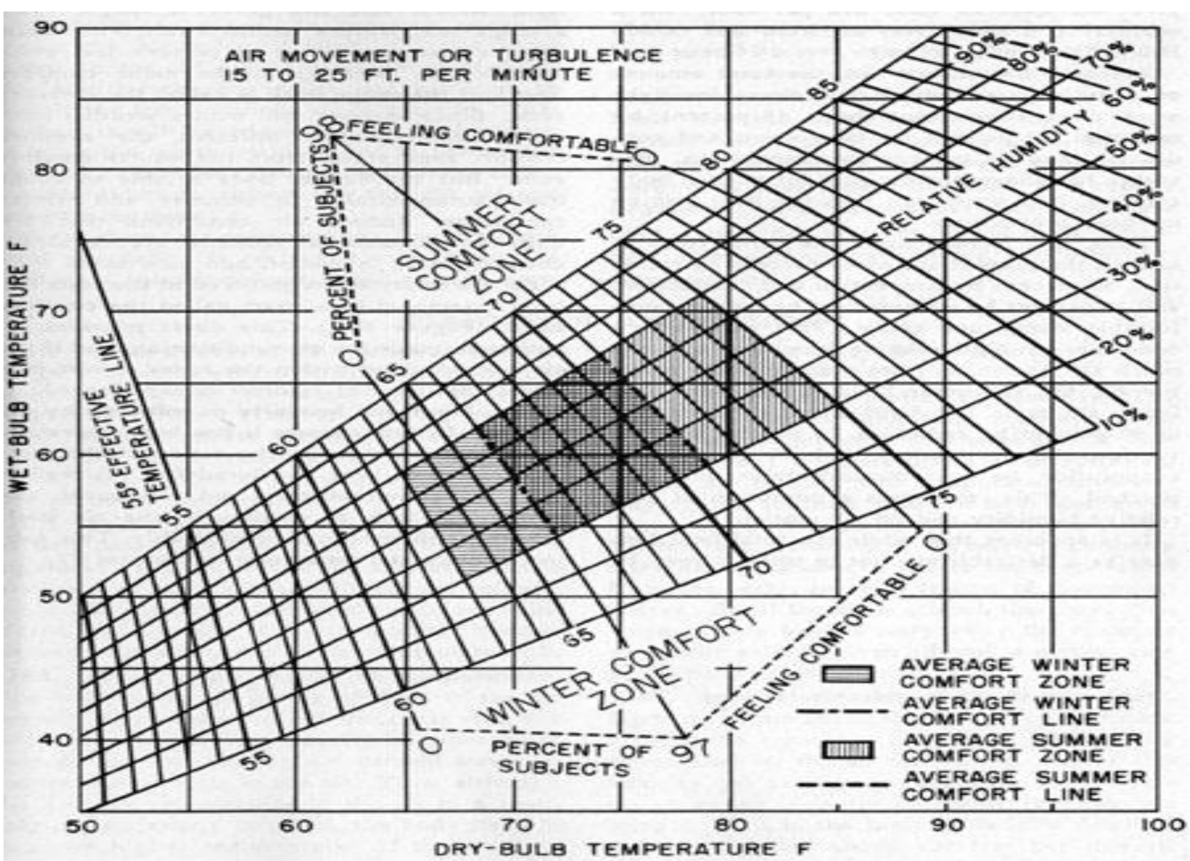
The degree of warmth or cold felt by a human body depends mainly on the following three factors:

1. Dry bulb temperature,
2. Relative humidity and
3. Air velocity.

In order to evaluate the combined effect of these factors, the effective temperature is employed. It is defined as that index which collates the com binned effects of air temperature, relative humidity and air velocity on the human body. The numerical value of effective temperate is made equal to the temperature of stills (i.e 5 to 8 m/min air velocity) saturated air,

which produces the same sensation of warmth or clones as produced under the given conditions. The practical application of the concept of effective temperature is presented by the comfort chart. 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 the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE). In the comfort chart, the dry bulb temperature is taken as abscissa and the wet bulb temperature of ordinates.

COMFORT CHART



Heat Production and Regulation in Human Body

The rate of heat production depends upon the individual's health, his physical activity and his environment. The rate at which the body produces heat is metabolic rate. The heat production from a normal healthy person when a sleep (called based metabolic rate) is about 60 wtts and it is about ten times more for a person carrying out sustained very hard work.

Heat and Moisture Losses from the Human Body

The heat is given off from the human body as either sensible or latent heat or both. In order to design any air-conditioning system for spaces which human bodies are to occupy, it is necessary to know the rates at which these two forms of heat are given off under different conditions of air temperature and bodily activity.

Moisture Content of Air

The moisture content of outside air during winter is generally low and it is above the average during simmer, because the capacity of the air to carry moisture is dependent upon its dry bulb temperature. This means that in winter, if the cold outside air having a low mist rue content leaks into the conditioned space, it will cause a low relative humidity unless minster is assed to the air by the processes of humidification. In summer, the reveres will take place unless moisture is removed from the inside air by the dehumidification process.

Quality and Quantity of Air

The air in an occupied space should, at all times, be free room toxic, unhealthful ordisagreeable fumes such as carbon dioxide. It should also be free from dust and odour.

Air Motion

The air motion which included the distribution of air is very important to maintain uniform temperate in the conditioned space. The air velocity in the occupied zone should not exceed 8 to 12m/min. Cold and Hot Surfaces: The cold or hot objects in a conditioned space may cause discomfort to the occupants.

Air Stratification

The movement of the air to produce the temperature gradient from floor to ceiling is termed as air stratification. In order to achieve comfortable conditions in the occupied space, the air conditioning system must be designed to reduce the air stratification to a minimum.

What is an air conditioning system ?

An air conditioning system is an electrical device that is purposely installed for the removal of heat and moisture from the interior of an occupied space. It is a process that is commonly used to achieve a more comfortable environment, basically for human and other animals.

Air conditioning system is also used to cool and dehumidify rooms that contain heat-producing electronic devices, such as computer server, power amplifiers. It also used in space that contains delicate products like artwo

Functions of the air conditioning system

Below are the major functions of an air conditioning system in modern houses:

- The primary purpose of air conditioning is to create a room climate comfortable for humans.
- Some special type of conditioning system is used to cool the temperature of electric devices.
- It controls the humidity of a room as 30 to 65% is permitted while the temperature should be between 20 and 26 degrees Celsius.
- Air conditioning system affects the room air to comfort people and their productivity is not impeded.
- The condition of the air is characterized by temperature, pressure and humidity. The air pressure is not changed.
- Air conditioning system can be for heating, dehumidifying, cooling, and humidifying.

Equipment Used in an Air Conditioning System

Following are the main equipment or parts used in an air conditioning system:

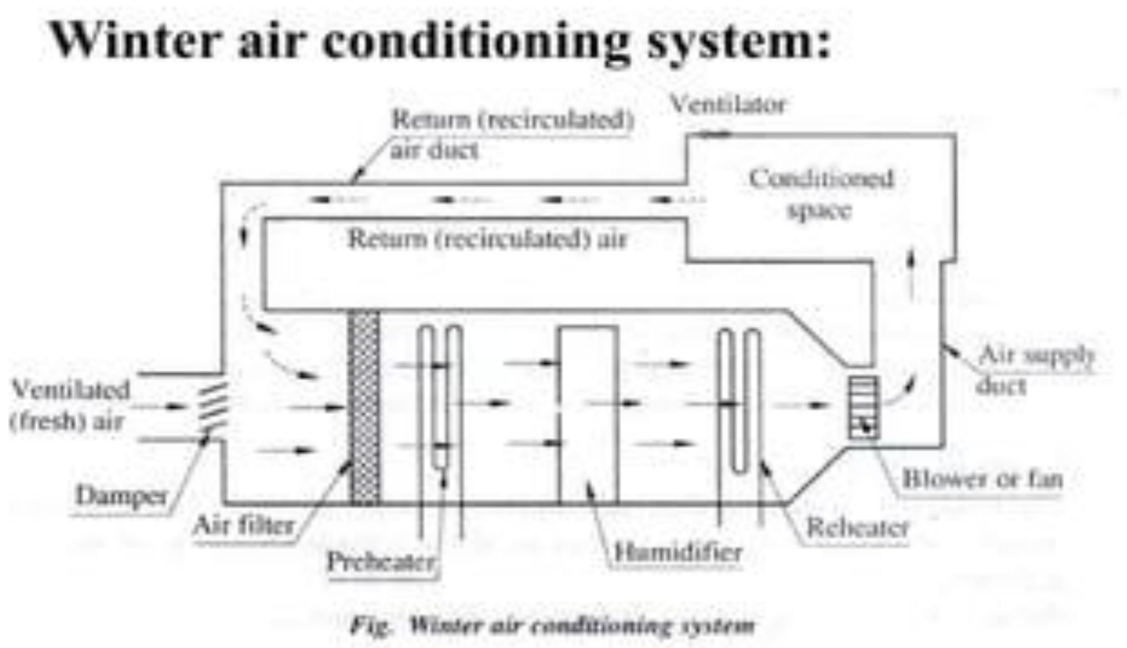
1. **Circulation fan:** The main function of this fan is to move air to and from the room.
2. **Air conditioning unit**: It is a unit, which consists of cooling and dehumidifying processes for summer air conditioning or heating and humidification processes for winter air conditioning.
3. **Supply duct**: It directs the conditioned air from the circulating fan to the space to be air-conditioned at the proper point.
4. **Supply outlets**: These are the grills, which distribute the conditioned air evenly in the room.
5. **Return outlets:** These are the openings in a room surface which allow the room air to enter the return duct.
6. **Filters:** The main function of the filters is to remove dust, “dirt and other harmful bacteria”s form the air.

Classification based on the season in the year

- A summer air conditioner which controls all four atmospheric condition for summer comfort.
- Winter air conditioner is designed for comfort in the winter.
- A year-round air conditioner which consists of heating and cooling tools with an automatic control that could serve in any weather condition in the year.

WINTER AIR CONDITIONING SYSTEM

The Winter Air Conditioning Diagram is shown below.



Working of Winter Air Conditioning System

In winter air conditioning, the air is heated and is accompanied by humidification.

The outside air flows through a damper and mixes up with the recirculated air which is obtained from the conditioned space.

The mixture here passes through a filter to remove dirt, dust, and other impurities.

The air now passes through a preheat coil to prevent possible freezing of water due to which dry bulb temperature increases to a very high value and the relative humidity drops to a low value.

This air is being pumped into the humidifier.

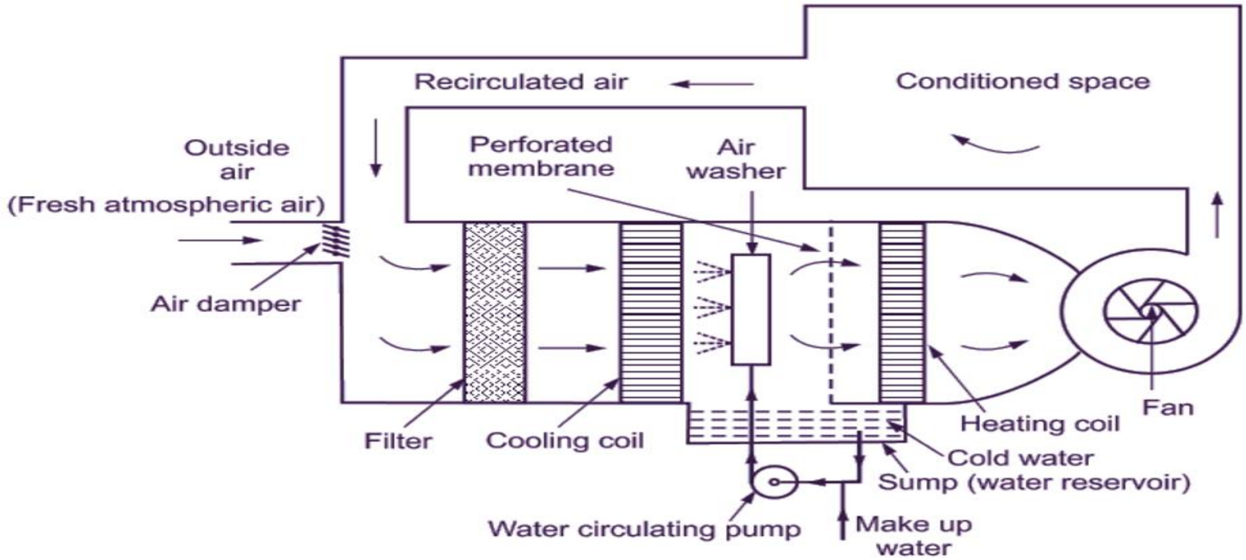
So, humidification of air (addition of moisture) is done and then the air is made to pass through a reheat coil to bring the air to the designed dry bulb temperature.Now the conditioned air is supplied to the conditioned space by means of a fan. From the conditioned space, a part of the used air is exhausted into the atmosphere by the exhaust fans or ventilators.The remaining part of the air known as recirculated air is again conditioned as shown in the figure.

Initially, the relative humidity is 60% in the winter season, so to reduce it, a process of reheating is done where it is reduced to 20%.So it is again humidified due to which it reaches a point of 80% or 100% RH where the DBT is very low.

So in order to get the desired dry bulb temperature, again the process of reheating is done where the desired percentage of 40% RH is also obtained.A damper is used in order to control the area and have an intake of the required amount of air.

SUMMER AIR CONDITIONING SYSTEM

The diagram of the summer air conditioning system is shown below.



Working of Summer air conditioning system

The outside air(atmospheric air) flows through the air filter to remove impurities or dust particles present in the air. The air now passes through a cooling coil.The coil has a temperature much below the required dry bulb temperature of the air and very high relative humidity in the conditioned space.So the cooled air is pumped into a dehumidifier, where it loses its moisture in the conditioned space.After that, the air is made to pass through a heating coil which heats the air slightly.This is done to bring the air to the designed DBT and relative humidity(RH).Now the conditioned air is supplied to the conditioned space by a fan.From the conditioned space, a part of the used air is exhausted to the atmosphere by the exhaust fans or ventilators.The remaining part of the used air is again conditioned.The outside air is sucked and it is made to mix with the recirculated air to make up for the loss of conditioned air through exhaust fans or ventilation from the conditioned space.

YEAR ROUND AIR CONDITIONING SYSTEM

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