STUDY MATERIAL

AIR-CONDITIONING & REFRIGERATION (CODE-827)

CLASS -XI

SESSION: 2019-20

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ABOUT THE STUDY MATERIAL

Air-Conditioning and Refrigeration Technology is being widely recognised for the technicians in Skill development. This study material has been curated for use in XI &XII CBSE skill development courses in the field of Air-Conditioning and Refrigeration Technology a full curriculum is developed for the skill development and training programme of Air-Conditioning and Refrigeration Technology in the daily use of domestic and commercial purposes.

The students after successfully completing these two years of study in skill course would have acquired relevant appropriate and adequate technical knowledge in modern technology of Air-Conditioning and Refrigeration Technology. This skill course also full fill the necessary need of human comfort which depends upon physiological and psychological conditions. This material is presently from the view point of the early learners at +2 level in a simplified manner with the help of diagrams wherever required.

Throughout the study material emphasis is placed on the cyclic nature of the refrigeration system and each part of the system is carefully examined is relation to the whole. Most of the national in this study material is based on information's gathered from different renowned publications.

The Air-Conditioning and Refrigeration Technology course is to be offered as a compulsory subject as well as may be offered as an additional subject at Sr. Secondary level to other streams.

The aim is to strive together to make our students ready and help them work on incorporating Air-Conditioning and Refrigeration Technology to improve their practical and learning skills with the modern technology.

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UNIT-1

INTRODUCTION

Thermodynamics

Thermodynamics is the branch of physics that deals with the relationship between heat and other forms of energy. In particular, it describes how thermal energy is converted to and from other forms of energy and how it affects matter.

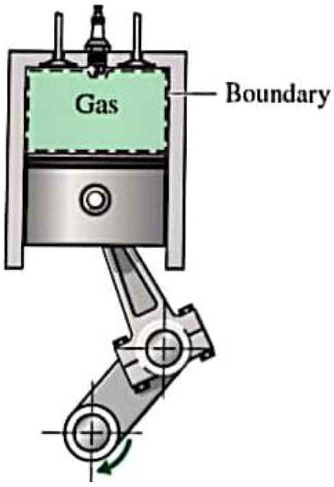
Thermodynamic systems

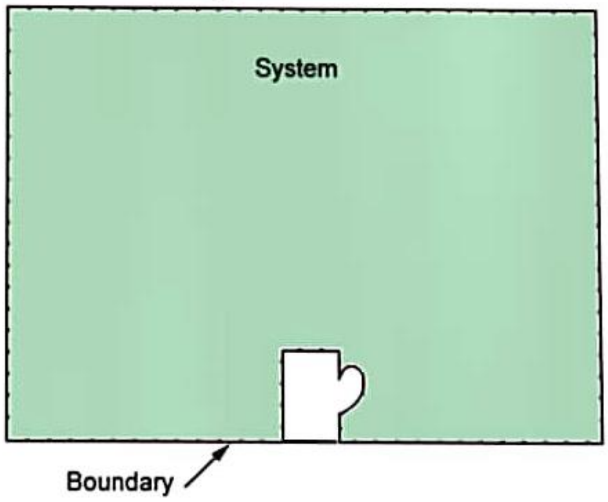
The thermodynamic system may be broadly defined as a definite area or a space where some thermodynamic processes is taking place. It is a region where our attention is focused for studying a thermodynamic process. A little observation will show that a thermodynamic system has its boundaries, and anything outside the boundaries is called its surroundings. These boundaries may be fixed like that of a tank enclosing a certain mass of compressed gas; or movable like boundary of a certain volume of liquid in a pipe line.

A ***system*** is a region containing energy and/or matter that is separated from its surroundings by arbitrarily imposed walls or boundaries. In a thermodynamic analysis, the ***system** is* the subject of the investigation.

A ***boundary*** is a closed surface surrounding a system through which energy and mass may enter or leave the system.

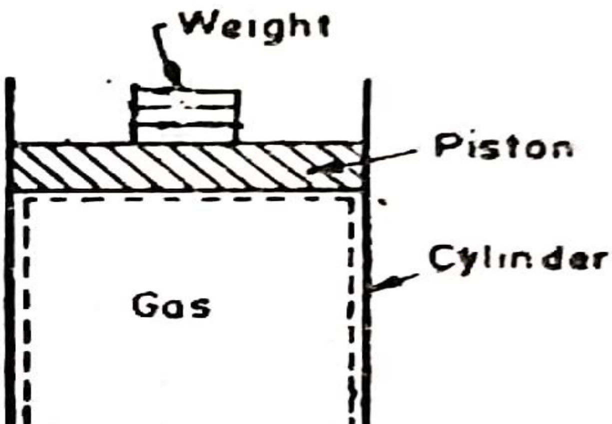
Everything external to the ***system*** is the ***surroundings***.





The thermodynamic systems may be classified into the following three groups:

1. **Closed system**
   This is a system of fixed mass and identity whose boundaries are determined by the space of the matter (working substance) occupied in it.

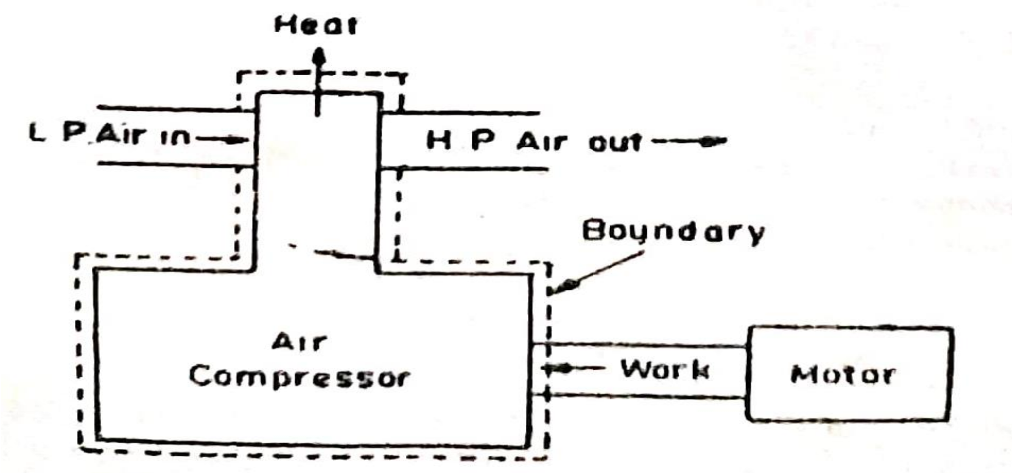


A close system is shown in figure. The gas in the cylinder is considered as a system. The heat and work crosses the boundary of the system during the process, but there is no addition or loss of the original mass of the working substance. It is thus obvious, that the mass of working substance, which comprises the system, is fixed.

2. **Open system**

   In this system, the working substance crosses boundary of the system. Heat and work may also cross the boundary.

   The figure shows the diagram of an air compressor which illustrates an open system.



3. **Isolated system**

   A system which is completely uninfluenced by the surrounding is called an isolated system. It is a system of fixed mass and no heat or work crosses the boundary. An open system with its surroundings (known as a universe) is an example of an isolated system.

Thermal Equilibrium

When there are variations in temperature from point to point of an isolated system, the temperature at every point first changes with time. This rate of change decreases and eventually stops. When no further changes are observed, the system is said to be in thermal equilibrium.

Equality of Temperature

Consider two bodies of the same or different materials, one hot and the other cold. When these bodies are brought in contact, the hot body becomes cooler, and the cold body becomes warmer. If these bodies remain in contact for some time, a state reaches, when there is no further observable change in the properties of the two bodies. This is a state of thermal equilibrium, and at this stage the two bodies have the equal temperatures. It thus follows that when two bodies are in thermal equilibrium with each other, their temperatures are equal.

Laws of thermodynamics

1. **Zeroth Law of Thermodynamics**
   This law states, "When two bodies are in thermal equilibrium with a third body, they are in thermal equilibrium with each other."
2. **First Law of Thermodynamics**
   This law state, "The heat and mechanical work are mutually convertible."
   This law may also be stated as, "The energy can neither be created nor be destroyed though it can be transferred from one form to another."
3. **Second Law of Thermodynamics**
   This law states, "There is a definite limit to the amount of mechanical energy, which can be obtained from a given quantity of heat energy."
   This law has been stated by Claussius in a slightly different form as, "It is impossible for a self-acting machine working in a cyclic process, to transfer heat from a body at a lower temperature, to a body at a higher temperature, without the aid of an external agency."
   This law has also been stated by Kelvin-Planck as, "It is impossible to construct an engine working on a cyclic process, whose sole purpose is to convert heat energy into work."

Meaning of Refrigeration

The term 'REFRIGERATION' may be defined as the process of removing heat from a substance under controlled conditions. It also includes the process of reducing and maintaining the temperature of a body below the general temperature of its surroundings. In other words, the refrigeration means a continued extraction of heat from a body whose temperature is already below the temperature of its surroundings.

Meaning of Air-Conditioning

An air-conditioning system is an execution of an assembly of different parts of the system used to produce a specified condition of air with in a required space or building.

An ideal air-conditioning system should maintain correct temperature, humidity, air purity, air movement, odour and noise level.

Brief history of Air-Conditioning and Refrigeration

The history of air-conditioning and refrigeration started in the early days with the need to preserve foods. Foods that are kept at room temperature spoils easily due to the growth of bacteria. At temperature below 4^0C (40^0F), the growth of bacteria is reduced rapidly. As a result of the development in food refrigeration, other applications that follow include air conditioning, humidity control and manufacturing processes.

Chinese harvested ice from rivers and lakes as early as 1000BC. Herbrews, Greeks, and Romans placed large amounts of snow into storage pits and covered it insulating material like grass, chaff, or branches of trees. They used these pits as well as snow to cool beverages. Egyptians and ancient people of India would moisten the outside of the jars and the resulting evaporation would cool the water that was inside of the jars. The first group of people to use cold storage to preserve food was Persians. They invented Yakhchal, a type of an ice pit.

Harvesting of ice was difficult and dangerous so people tried to invent artificial ways of refrigeration. The first one to make a breakthrough was Scottish professor William Cullen who designed a small refrigerating machine in 1755. He used a pump to create a partial vacuum over a container of diethyl ether. Ether boiled and absorbed the heat from the surrounding air. This resulted in a small amount of ice, but machine was not practical at that time.

The discovery of the principles of the absorption type of refrigeration in 1824 showed that liquefied ammonia could chill air when it is allowed to evaporate. Ice was created using compressor technology in the year 1845 by a physician named John Gorrie.

The commercially available of air conditioning applications started based on the need to cool air for industrial processes than for personal comfort. The first electrical air conditioning was invented by Willis Haviland Carrier in the year 1902. He was also known as the father of Modern Air Conditioning.

His invention was designed to improve the manufacturing of a printing plant. By controlling the temperature and humidity of the plant, the processes were made more efficient as the paper size and the ink alignment were consistently maintained.

The Carrier Air Conditioning Company of America was established by him to meet the demand of better productivity in the workplace. Today, Carrier Corporation is the biggest air conditioner manufacturer and marketing corporation in the world in central air conditioning.

The discovery of Freon in 1928 by Thomas Midgley, Jr., a safer refrigerant to humans compared to the toxic and flammable gases such as ammonia, propane and methyl chloride sparks the invention of air conditioning systems for residential, industrial and commercial applications.

Unfortunately, the use of CFC and HCFC refrigerants are causing the depletion of ozone layer in our atmosphere that is causing harmful rays to penetrate our earth. Newer ozone friendly refrigerants have been developed to replace refrigerants such as R-11, R-12 and R-22 to name a few. Non-ozone depletion refrigerant such as R-410a has been used in newer air-condition systems.

Units of Refrigeration

The practical unit of refrigeration is expressed in terms of 'ton of refrigeration' (briefly written as TR). A ton of refrigeration is defined as, "The amount of refrigeration effect produced by the uniform melting of one American ton of ice from and at 0^{0}C in 24 hours." The American ton equal to 2000 pounds and is popularly used to rate a refrigerating machine instead of a ton equal to 2240 pounds.

In S.I. units, one ton of refrigeration,

$$1 \text{ TR} = 3.5 \text{ kW}$$

Coefficient of Performance of a Refrigerator

The coefficient of performance (briefly written as C.O.P.) is the ratio of heat extracted in the refrigerator to the work done on the refrigerant. It is also known as theoretical coefficient of performance.

Mathematically,

$$\text{Theoretical C.O.P.} = \frac{Q}{W}$$

where, Q = Amount of heat extracted in the refrigerator (or the amount of refrigeration produced, or the capacity of a refrigerator), and

W = Amount of work done.

Heat and Temperature

Heat or thermal energy is the form of energy and this energy possesses when it is being transferred between systems and surroundings. This flow of energy is referred to as heat. The heat flow causes the hotter object to cool down and the colder object to warm up. The foe of heat will continue until they reach the same temperature.

Temperature is the measure of the degree of hotness or coldness of a body. It is measured with the help of thermometers.

Sensible Heat

When a substance is heated and the temperature rises as the heat is added, the increase in heat is called sensible heat. Similarly, when heat is removed from a substance and the temperature falls, the heat removed (or subtracted) is called sensible heat.

Thus the sensible heat may be defined as the heat which causes a change in temperature in a substance. For example, the heat absorbed in heating of water up to the boiling temperature is the sensible heat.

Latent Heat

All pure substances are able to change their state, solids become liquids and liquids become gases. These changes of state occur at the same temperature and pressure combinations for any given substance. It takes the addition of heat or the removal of heat to produce these changes. The heat which brings about a change of state with no change in temperature is called latent (or hidden) heat.

Effects of Heat

On heating any substance the following effects may take place.

1. Rise in temperature of the substance.
2. The substance may melt or vaporise i.e. change in state of substance, solid becomes liquid and liquid becomes gas.
3. Change in colour of a substance.
4. Change in size and shape of a substance.
5. Increase in pressure of the substance.

Comparison of a Heat Engine, Refrigerator and Heat Pump

In a heat engine, as shown in figure, the heat supplied to the engine is converted into useful work. If H_2 is the heat supplied to the engine and H_1 is the heat rejected from the engine, then the net work done by the engine is given by,

$$\mathbf{W_E = H_2 - H_1}$$

The performance of a heat engine is expressed by its efficiency. We know that the efficiency or coefficient of performance of a n engine,

$$\eta_E \text{ or } (C.O.P.)_E = \frac{\text{Work done}}{\text{Heat supplied}} = \frac{W_E}{H_2} = \frac{H_2 - H_1}{H_2}$$

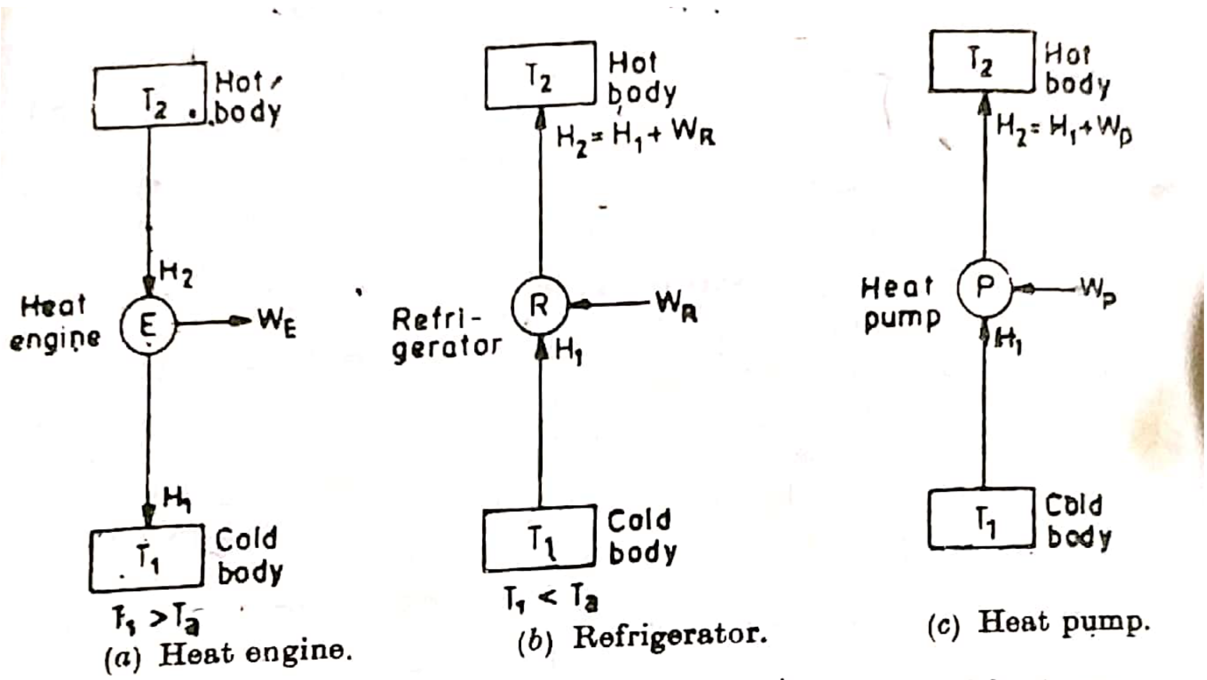


Fig. 2.1. Difference between a heat engine, refrigerator and heat pump.

A refrigerator as shown in figure is a reversed heat engine which either cool or maintain the temperature of a body (T_1) lower than the atmospheric temperature (T_a). This is done by extracting the heat (H_1) from a cold body and delivering it to a hot body (H_2). In doing so, work W_R is required to be done on the system.

$$W_R = H_2 - H_1$$

Mathematically, coefficient of performance of a refrigerator,

$$(C.O.P.)_R = \frac{H_1}{W_R} = \frac{H_1}{H_2 - H_1}$$

Any refrigerating system is a heat pump as shown in figure, which extracts heat (H_1) from a cold body and delivers it to a hot body. Thus there is no difference between the cycle of operations of a heat pump and a refrigerator. The main difference between the two is in their operating temperatures. A refrigerator works between the cold body temperature (T_1) and the atmospheric temperature (T_a), whereas the heat pump operates between the hot body temperature (T_2) and the atmospheric temperature (T_a). A refrigerator used for cooling in summer can be used as a heat pump for heating in winter.

Work done, $$W_P = H_2 - H_1$$

The performance of a heat pump is expressed by the ratio of the amount of heat delivered to the hot body (H_2) to the amount of work required to be done on the system (W_P). This ratio is called coefficient of performance or energy performance ratio (E.P.R.) of a heat pump. Mathematically,

$$(C.O.P.)_H \text{ or } E.P.R. = \frac{H_2}{W_P} = \frac{H_2}{H_2 - H_1}$$

$$= \frac{H_1}{H_2 - H_1} + 1 = (C.O.P.)_R + 1$$

From above we see that the C.O.P. may be less than one or greater than one depending on the type of refrigerating system used. But the C.O.P. of a heat pump is always greater than one.

Basic Refrigeration Tools, Equipment's and Instruments

Refrigeration tools are used in performing preventive maintenance and repair on air conditioners, refrigerators, freezers, and automotive air conditioners. They are as follows:

Tube Cutter

It is a refrigeration tool use to cut copper tubing from sizes 1/8” to 1/2” outside diameter. A large tube cutter is also available for large tube diameters.

Flaring Tool

It is a refrigeration tool used to spread the copper end outwards until a flare is formed.

Swaging Tool

It is a refrigeration tool used to expand the inner diameter of a copper tube so that the resulting diameter is the same as the outside diameter. It is used to join two copper tubes of the same diameter.

Brazing Torch

It is a refrigeration tool used in soldering the joints of two copper tubes together. 800^0F is required to solder copper tubing. Map gas is generally used in these applications, although oxygen-acetylene is also popular except they are bulky and heavy. When brazing copper tube joints, do it in a well-ventilated area. Prolong inhalation can cause cancer.

Copper Tube Bender

It is a copper tube bending refrigeration tool. It has three-size moulded half-round wheels. The most common sizes are from ¼ of an inch diameter, to 5/16, then 3/8. Copper tubes are bent beautifully using this pro fissional bending tool.

Adjustable Wrench

It is a wrench with an adjustable jaw. A six inch adjustable wrench is very useful in the field of refrigeration repair. It can accommodate nuts and bolts of sizes from 1/8 of an inch to 1 inch. It can fit into the tool box easily.

Flat Edge Screw Driver

It is a screw driver with a flat driving end. An 8 inch screw driver with a blade width of 1/4" is the most useful size. It is always a good idea to have a 1/8” blade and a 3/16” blade around with you.

Philip Screw Driver

It is a screw driver with a cross driving end. It is a good idea to have three sizes of this type also. But only good quality Philip screw driver because the teeth easily become blunt very slippery.

Allen Wrench

It is an angular hexagonal driving wrench. They are made of hardened steel.

Long Nose Plier

It is a plier with a long pointed nose. A 7 inch nose plier is very useful and is a good addition to your tool box. You will find the many uses of a long nose plier, from hard to-reach areas like removing a clip from a fan or holding the copper tube when brazing alone.

Electrical Plier

Insulated plier is used by electrician. An 8 inch electrical plier is a must have in your tool box.

Pipe Wrench

It is a wrench for fastening tubes and pipes. A 12 inch pipe wrench must be in the tool box as well. Sometimes we have to remove a rounded hex nut.

Flat File

Flat hardened steel with cutting ridges. Used for filing a newly cut copper tube ends to square it. Or to remove burrs from steel brackets.

Round File

It is round long hardened steel with cutting ridges. Round file is very useful in enlarging a hole by filing. Cleaning a rusty steel tube, removing a clogged from a drain hole. Enlarging a flat washer hole to fit the larger bolt or to shape a certain parts through filing

Half Round File

Half round shaped long hardened steel with cutting ridges. When it is necessary to make a hole larger where the application of a round file is not practical. The half round side can finish a curved surface, and the flat side for the flat surface.

Tape Measure

It is a steel tape measuring device. Either you are going to make measurement for the length of the copper tubing, or measuring the volume of a room.

Hack Saw

It is used for sawing of different types of pipe or metal tubes. It consists of two parts-frame and blade. The frame has three parts- handle, frame and fly nut. The frame is fixed or adjustable. The frame is made of mild steel. The blade is made of high speed steel or tungsten steel. The blade of 6 to 10 teeth per cm is used generally to cut the pipe of cast iron, aluminium, copper etc.

Electric Drill Gun

It is also a good refrigeration tool is operated by electricity and used for heavy work. It is a portable machine used for making holes in wooden boards or metal sheets for allowing the passage of wires. Its capacity depends upon the size of drill bit which is held by chuck. For the refrigeration work, parallel shank type twist drill is used in the drill machine. It is made of high carbon steel or high speed steel

Vice

Bench vice or parallel jaw vice is a tool with two jaws for holding works. It is used for holding the job at the time of filing or sawing the metal plate or copper tube.

Yoke Vice or pipe vice has a V-shaped jaw which is made of common steel and used for sawing the pipe.

Electric Soldering Iron

It is heated by electricity and available in different watts such as 24 watt, 35 watt, 60 watt, 125 watt and 250 watt. It is used for soldering the wires or leakage point in pipe or tube. The front part of it is called bit and made of copper.

Wire Gauge

It is made of steel and in round shape. The slots are made in different sizes on the circumferences. It is marked the number 1 to 36 on one side and diameter in millimeter on other side. It is used to measure the size of wire or metal sheet. The gauge number is more for thin wire or metal sheet and less number of thick wire.

Sling Psychrometer

This instrument is used to measure the percentage of humidity or moisture in a refrigerated or air-conditioned space.

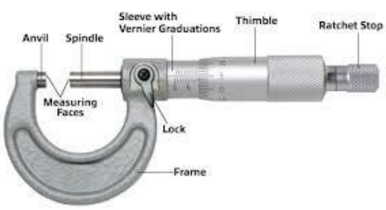
Pressure Gauge

It is used to check the pressure of refrigerant in a refrigeration unit.

Service Manifold

It is made of two types of gauges-pressure gauge and compound gauge. High pressure gauge is used to measure the head pressure of the refrigeration unit and installed in high side. Compound gauge is used to measure the low side pressure of the system.

Micrometer



There are two types of micrometers; outside micrometer or inside micrometer. Outside micrometer is generally used to measure the outside diameter of piston, shaft and piston pin in refrigeration system. Inside micrometer is used to measure the inside diameter of a cylinder, connecting rod and big end bearing.

Thermometer

It is used to measure the temperature of various parts of the refrigeration system.

Halide Torch

It is used for finding the refrigerant leakage in the system so it is known as leak detector. It indicates green flame where leak is possible.

Vacuum Pump

It is a device that removes unwanted air and water vapour from the air conditioning system when it is under service in order to leave behind a partial vacuum.

Air Flow Meter

It measures air velocity, air speed and air pressure.

Capacitor Tester

These are designed to identify internal problems with a capacitor. The testers will identify capacitors that may be damaged or faulty.

Charging Hose: A rubber hose used for charging refrigerants to a system.

Clamp Meter

The Clamp Meter is an electrical meter with an integral AC current clamp. This allows properties of the electric current in the conductor to be measured.

Fin Comb

The Fin Comb is designed to straighten evaporator and condenser fins. The tool also cleans dirt and dust to help prevent overflows.

Hygrometer

It is an instrument used to measure relative humidity.

Manometer

A manometer is a device to measure pressures.

Multi Tester

A Multi Tester is a device which can be used to gather data about electrical circuits. It can measure resistance, voltage, and continuity, while more advanced versions may be able to provide additional data.

Oil Pump Charger

Oil Charging Pumps are valuable tools for adding or removing oil in refrigeration and air conditioning systems.

<u>Safety Pre-cautions</u>

General safety precautions

1. Always put on proper recommended uniform and do not wear loose clothes.
2. Do not wear a ring or watch while working.
3. Use goggles while welding or brazing to protect your eyes.
4. Never try out or use the machines, tools and equipment without having complete knowledge about them.
5. There should be proper light while working.
6. Never stand under a suspended load.
7. Keep the workshop table and floor clean.
8. Keep the tools at proper place after use.
9. Only tools needed for the job should be kept on the working table.
10. Check everything of machine before switching it on operation.
11. Don't oil / lubricate machine while it is moving.
12. Don't throw chips, nails and wire pieces on the floor.
13. Never use blunt edged tools.

Precautions while handling refrigerant cylinder

1. Store the refrigerant cylinder in an airy room.
2. Don't over fill cylinder.
3. Keep full and empty cylinder separately.
4. Never tamper the safety devices fitted on refrigerant cylinder.
5. Use line valve and pressure guage while working for pressure leak test.
6. Use gas masks while working on refrigerant cylinder.
7. Never mix different gases in a cylinder.
8. Always charge refrigerant into the low side of the system to avoid damaging the compressor, or causing the system to rupture.
9. Inspect refrigerant cylinders regularly. Do not use the cylinders if they show signs of rust, distortion, denting, or corrosion.
10. Keep first aid box in workshop.

UNIT-2
REFRIGERATION CYCLE AND APPLICATIONS

A. vapour compression refrigeration system:

Introduction: - In the vapour compression system, the refrigerant vapour is sucked into the compressor and is compressed adding the energy in the form of work to increase its thermal level above atmosphere. A flow diagram of a simple vapour compression system is shown in the given figure

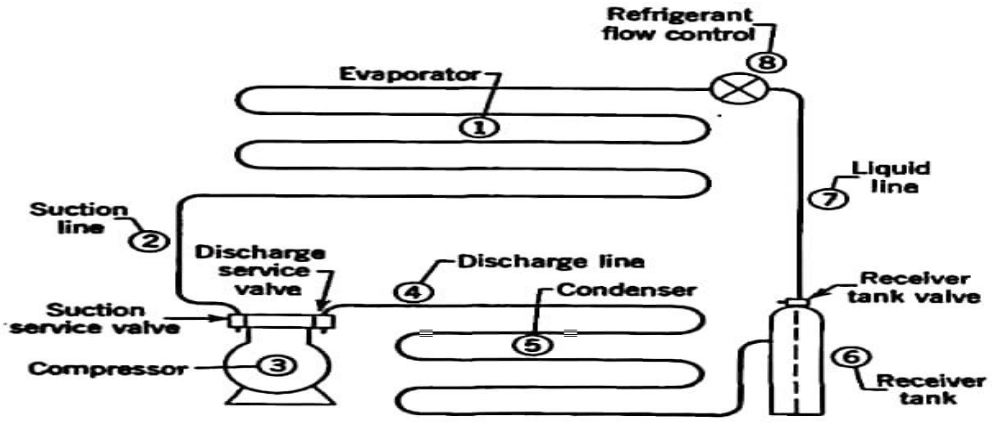


FIG: VAPOUR COMPRESSION REFRIGERATION SYSTEM

The principal parts of the system are (1) an evaporator, whose function is to provide a heat transfer surface through which heat can pass from the refrigerated space or product into the vaporizing refrigerant ; (2) a suction line , which conveys the low pressure vapour from the evaporator to the suction inlet of the compressor ; (3)a vapour compressor , whose function is to remove vapour from the evaporator, and to raise the temperature and pressure of the vapour to a point such that the vapour can be condensed with normally available condensing media; (4) a “hot-gas” or discharge line which delivers the high-pressure, high- temperature vapour from the discharge of the compressor to the condenser ;(5)a condenser , whose purpose is to provide a heat transfer surface through which heat passes from the hot refrigerant vapour to the condensing medium;(6) a receiver tank, which provides storage for the condensed liquid so that a constant supply of liquid is available to the evaporator as needed;(7) a liquid line, which carries the liquid refrigerant from the receiver tank to the refrigerant flow control; and (8) a refrigerant flow control, whose function is to meter the proper amount of refrigerant to the evaporator and to reduce the pressure of the liquid entering the evaporator so that the liquid will vaporize in the evaporator at the desired low temperature.

DEFINITION OF A CYCLE: - As the refrigerant circulates through the system, it passes through a number of changes in state or condition, each of which is called a process. The refrigerant starts at some initial state or condition, passes through a series of processes in a definite sequence, and returns to the initial-condition. This series of processes is called a cycle. The simple vapour- compression, refrigeration cycle is made up of four fundamental processes: (1) expansion, (2) vaporization, (3) compression, and (4) condensation. To under-stand properly the refrigeration cycle it is necessary to consider each process in the cycle both separately and in relation to the complete cycle. Any changes in any one process in the cycle will bring about changes in all the other processes in the cycle.

VAPOUR COMPRESSION CYCLE: - A vapour compression cycle is shown in the given figure:-

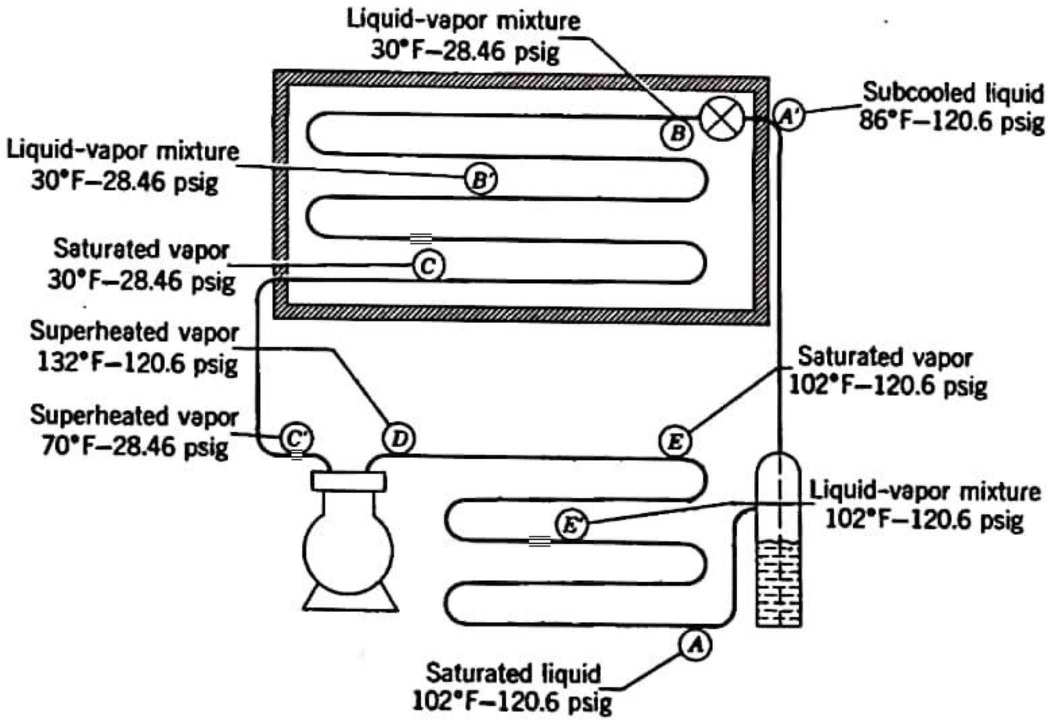


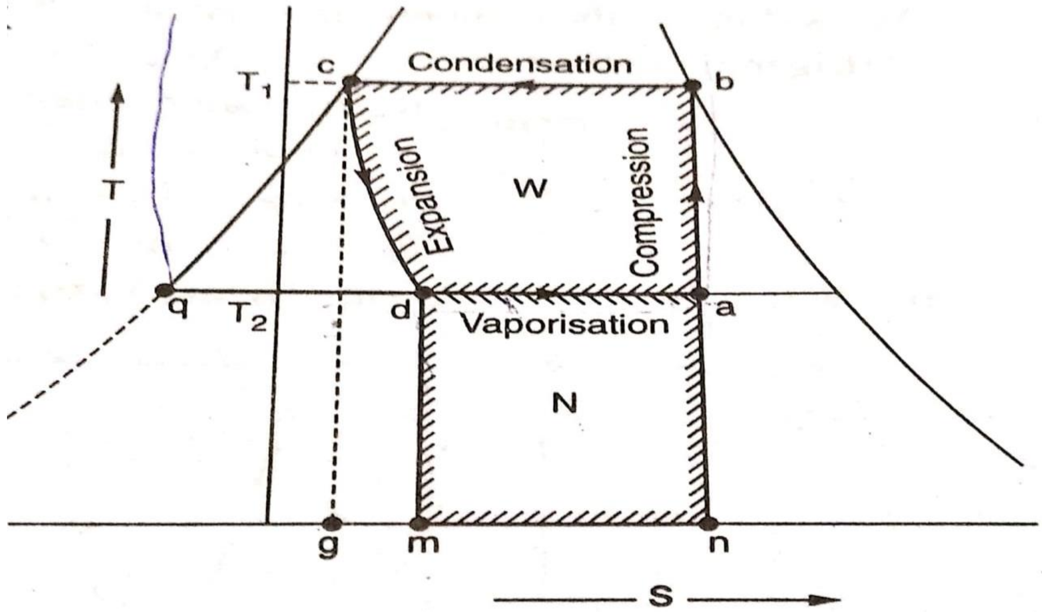
FIG: VAPOUR COMPRESSION CYCLE

Starting at the receiver tank, high-temperature, high-pressure liquid refrigerant flows from the receiver tank through the liquid line to the refrigerant flow control. The pressure of the liquid is reduced to the evaporator pressure as the liquid passes through the refrigerant flow control so that the saturation temperature of the refrigerant entering the evaporator will be below the temperature of the refrigerated space. It will be shown later that a part of the liquid vaporizes as it passes through the refrigerant control in order to reduce the temperature of the remaining liquid to the evaporating temperature. In the evaporator, the liquid vaporizes at a constant pressure and temperature as heat to supply the latent heat of vaporization passes from the refrigerated space through the walls of the evaporator to the vaporizing liquid. By the action of the compressor, the vapour resulting from the vaporization is drawn from the evaporator through the suction line into the suction inlet of the compressor. The vapour leaving the evaporator is saturated and its temperature and pressure are the same as those of the vaporizing liquid. While flowing through the suction line from the evaporator to the compressor, the vapour usually absorbs heat from the air surrounding the suction line and becomes superheated. Although the temperature of the vapour increases somewhat in the suction line as the result of superheating, the pressure of the vapour does not change, so that the pressure of the vapour entering the compressor is the same as the vaporizing pressure. In the compressor the temperature and pressure of the vapour are raised by compression and the high-temperature, high-pressure vapour is discharged from the compressor into the hot-gas line. The vapour flows through the hot-gas line to the condenser, where it gives up heat to the relatively cool air being drawn across the condenser by the condenser fan. As the hot vapour gives off heat to the cooler air, its temperature is reduced to the saturation temperature corresponding to its new higher pressure and the vapour condenses back into the liquid state as additional heat is removed. By the time the refrigerant reaches the bottom of the condenser, all the vapour is condensed and the liquid passes into the receiver tank, ready to be circulated.

REPRESENTATION OF VAPOUR COMPRESSION CYCLE ON TEMPERATURE-ENTROPY (T-s) DIAGRAM:-

(a) When the vapour is dry and saturated at the end of compression.

The vapour compression cycle is shown on T-s diagram in the given figure;



The points a, b, c and d represents the different state points of the vapour compression cycle. At state a, low pressure and low temperature (T2) vapour enters the cylinder of the compressor, where it is compressed isentropically to state b thereby rising its temperature to T1. It is then condensed in the condenser along the line b-c and in doing so, it gives its latent heat to the condensing medium. c-d represents the throttling expansion of the liquid refrigerant through the expansion valve to the low temperature T2. It will be noticed from the T-s diagram that a part of the liquid refrigerant vaporizes as it passes through the expansion device and its dryness fraction at stated is represented by the ratio q d /q a. At stated, the refrigerant enters the evaporator where it further vaporizes at constant pressure and temperature and takes its latent heat from the refrigerated space through walls of the evaporator. The process of vaporization continues up to state which was the starting point and thus the cycle is completed.

Now, work done by compressor = W =Area a-b-c-q

Refrigerating effect =Heat extracted during process d-a

= Area under d-a= d-a-n-m

C.O.P. = refrigerating effect/ Work done

=Area d-a-n-m /Area a-b-c-q

Process c-d is throttling expansion.

So, total heat at state c = total heat at state d

Or, $h_c = h_d$

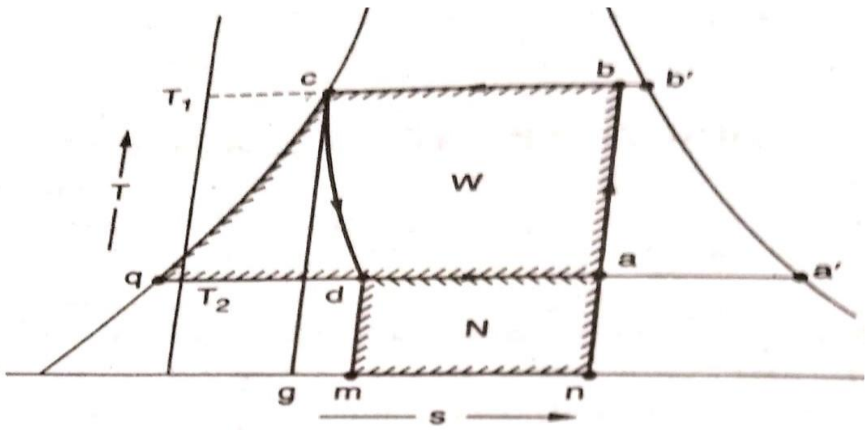
Then, COP can be expressed as:

$$COP = h_a - h_d / h_b - h_a = h_a - h_c / h_b - h_a$$

(b) When the vapour is wet at the end of compression.

Work done by compressor = W = Area a-b-c-q

Refrigerating effect = Area d-a-n-m

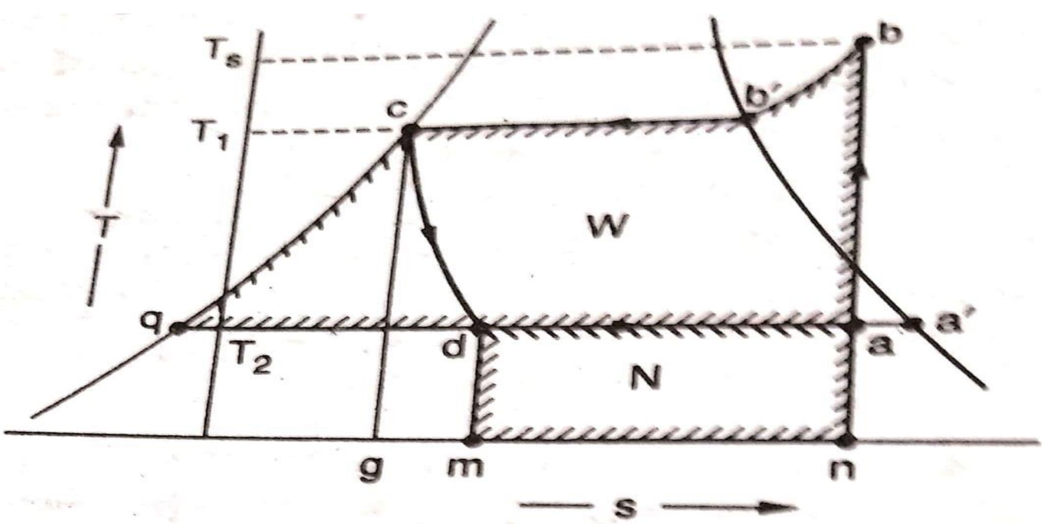


C.O.P. = refrigerating effect/ Work done

= Area d-a-n-m /Area a-b-c-q

$$= h_a - h_d / h_b - h_a = h_a - h_c / h_b - h_a$$

(c)When the vapour is super-heated after compression.



Work done by compressor = h b-h a

Refrigerating effect = h a-h d

C.O.P. = h a-h d / h b-h a = h a-h c / h b-h a

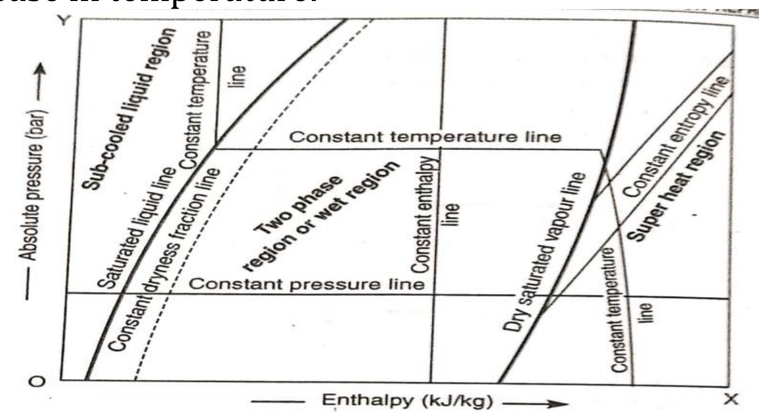
In this case, h b = h b' + Cp (Ts – T1)

h b'=Total heat of dry saturated vapour at temperature T1.

REPRESENTATION OF VAPOUR COMPRESSION CYCLE ON PRESSURE-ENTHALPY (P-H) CHART:-

The pressure enthalpy charts are commonly used in refrigeration practice for studying the performance of the machines. In a pressure-enthalpy chart as shown in the given figure:

The pressure is represented on the ordinate and the enthalpy on the abscissa. The whole diagram is divided into three marked regions; sub cooled liquid region, region of saturated liquid-vapour mixture and superheated vapour region. The saturated liquid line and saturated vapour line are the two main lines which demarcate the three regions. In the sub-cooled liquid region, the sub cooling of the liquid refrigerant is shown to take place at constant pressure with the decrease in temperature.



THEPRESSURE-ENTHALPY (P-H) CHART

In the middle region, pressure and temperature are not independent variables. The superheated region indicates the properties of superheated vapour produced due to heating of saturated vapour with increase in temperature and specific volume. In this region, lines of constant temperature and constant specific volume are drawn. Lines of constant entropy are also drawn to facilitate plotting of isentropic compression.

Such a chart gives directly the changes in enthalpy and pressure during a process for thermodynamic analysis.

The simple vapour compression cycle is shown on pressure-enthalpy chart in the given figure:

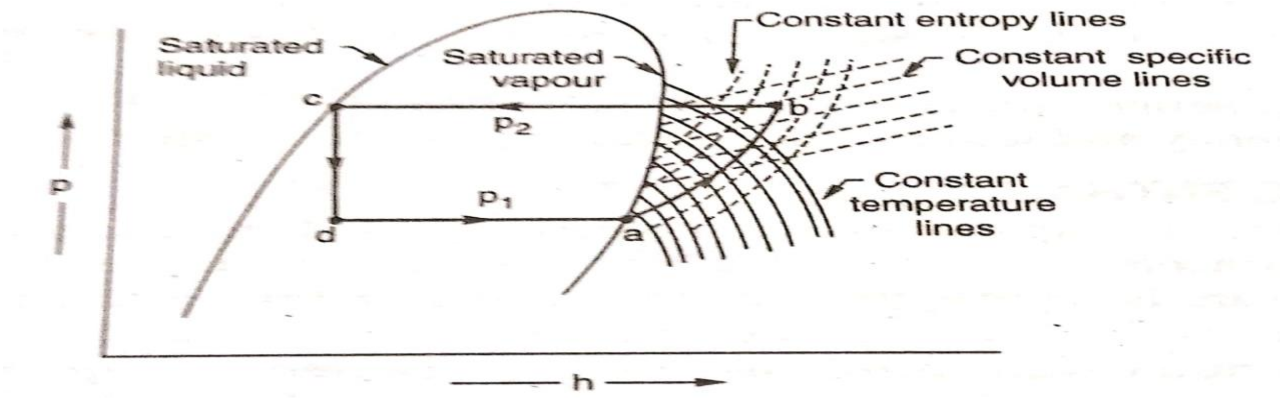


FIG: VAPOUR COMPRESSION CYCLE ON PRESSURE-ENTHALPY (P-H) CHART

The points a, b, c and d corresponds to different processes. The compressor draws dry and saturated vapour from the evaporator at lower pressure p1 and compresses it isentropically to the upper pressure p2. The isentropic compression is shown by the line a—b. Since the vapour is dry and saturated at the start of compression so it becomes superheated at the end of compression as given by point b. The process of condensation which takes place at constant pressure is given by the line b—c. The vapour now reduced to saturated liquid is throttled through the expansion device and the process is shown by the line c—d. At point d, a mixture of vapour and liquid is supplied to the evaporator where it takes its latent heat and gets dry and saturated as shown by the point a. The cycle is thus completed.

Heat extracted N = h a-h d

Work done W = h b-h a

C O P = h a-h d / h b-h a

The values of h a, h b, h d can be directly read from the p-h chart.

EFFECT OF SUB COOLING :- The process of cooling the refrigerant below the condensing temperature for a given pressure is known as sub cooling. In the given figure:

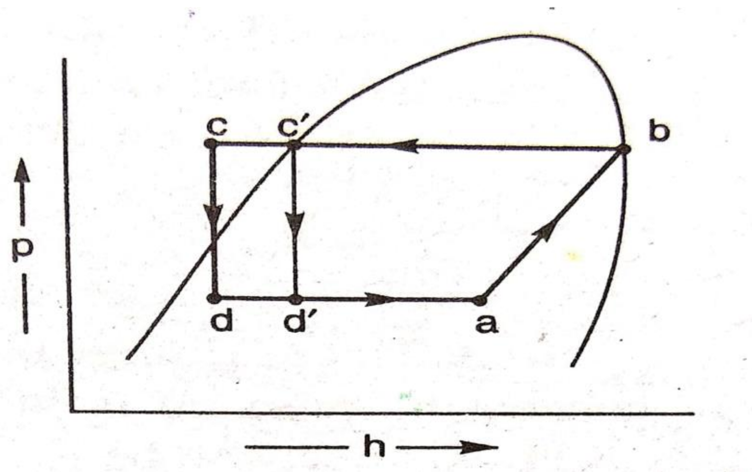


FIG: EFFECT OF SUB COOLING

The process of sub cooling is shown by c’-c. The effect of sub cooling as may be seen from the p-h diagram is to increase the refrigerating- effect. Therefore, sub cooling results in increase of COP provided that no further energy has to be spent to obtain the extra cold coolant required. The process of sub-cooling may be achieved by any of the following two methods:

(i) By passing the liquid refrigerant through a heat exchanger in which the cold vapour from the evaporator is allowed to flow in the reverse direction before it goes to the suction of the compressor. This process sub cools the liquid but superheats the vapour going into the compressor which means compressor will have to do more works as the superheated vapour will have more volume. As a result, refrigerating effect is increased but COP will not be improved.

(ii) By using enough quantity of cooling water so that the liquid is further cooled below the saturation temperature. In some cases, a temperature sub cooler is also employed for this purpose.

EFFECT OF SUPERHEATING: The effect of superheating as may be seen from the given fig:

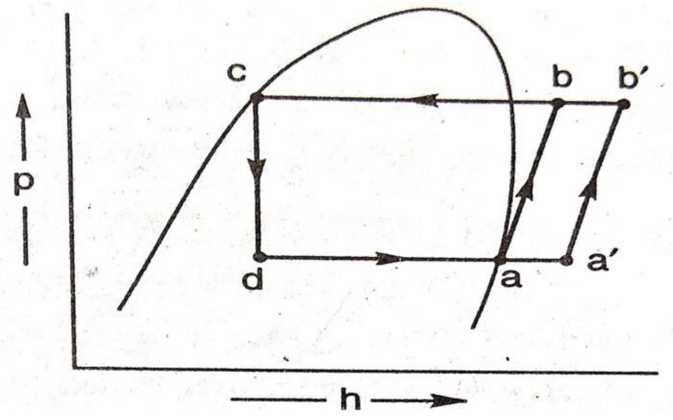


FIG: EFFECT OF SUPERHEATING

Is to increase the refrigerating effect but this increase in refrigerating is at the cost of increase in amount of work spent to reach the upper pressure limit. As compared to the increase in refrigerating effect, the increase in work is more. Hence, the overall effect of superheating is to have a low value of COP.

EFFECT OF CHANGE IN SUCTION PRESSURE (P_S): Let the suction pressure is reduced from P_S to P_s’ as shown on p-h diagram in the given figure:

Its effect will be:

(1) To increase the refrigerating effect as, h_a’-h_d’< h_a-h_d.

(2) To increase work of compression as, h_b’-h_a’> h_b-h_a.

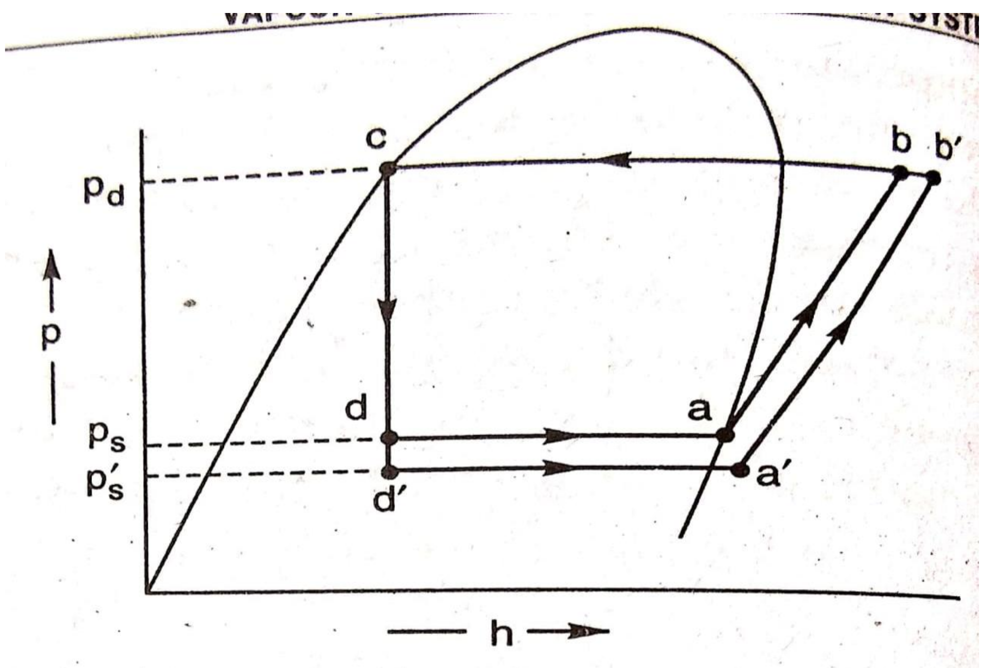


FIG: EFFECT OF CHANGE IN SUCTION PRESSURE

Here, the increase in refrigerating effect is very less as compared to increase in work. The net effect is the decrease in COP.

Hence the decrease in suction pressure leads to the decrease of COP. Therefore, it is desired to have highest suction pressure in consistent with the requirement of temperature and load at evaporator.

EFFECT OF CHANGE IN DISCHARGE PRESSURE ON COP (Pd):

Let the discharge pressure or condensing pressure is increased from Pd to Pd' as shown on p-h diagram in the given figure:
Its effect will be:
(i) To increase compressor work as $h_{b'} - h_a > h_b - h_a$.

(ii) To decrease refrigerating effect as $h_a - h_{d'} < h_a - h_d$.

So, with increase in discharge pressure, compressor work increases while the refrigerating effect is decreased. The net effect is decrease in COP. So, increase in discharge pressure results in the decrease of COP. Hence, the discharge pressure should be kept as low as possible depending upon the temperature of cooling medium available

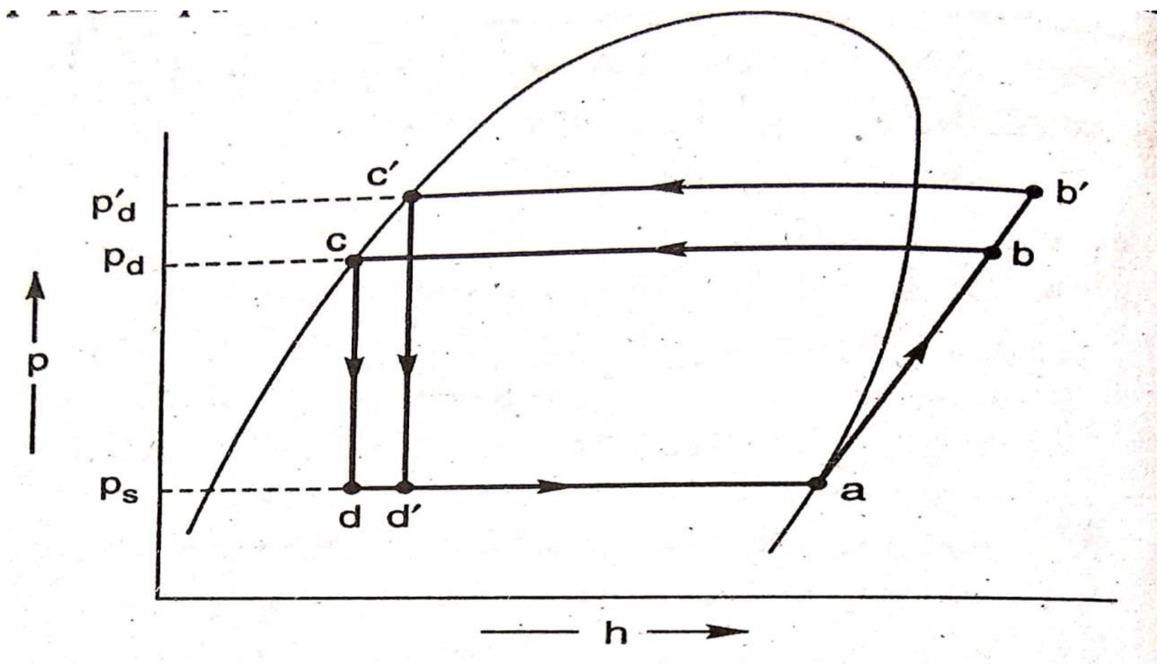


FIG: EFFECT OF CHANGE IN DISCHARGE PRESSURE

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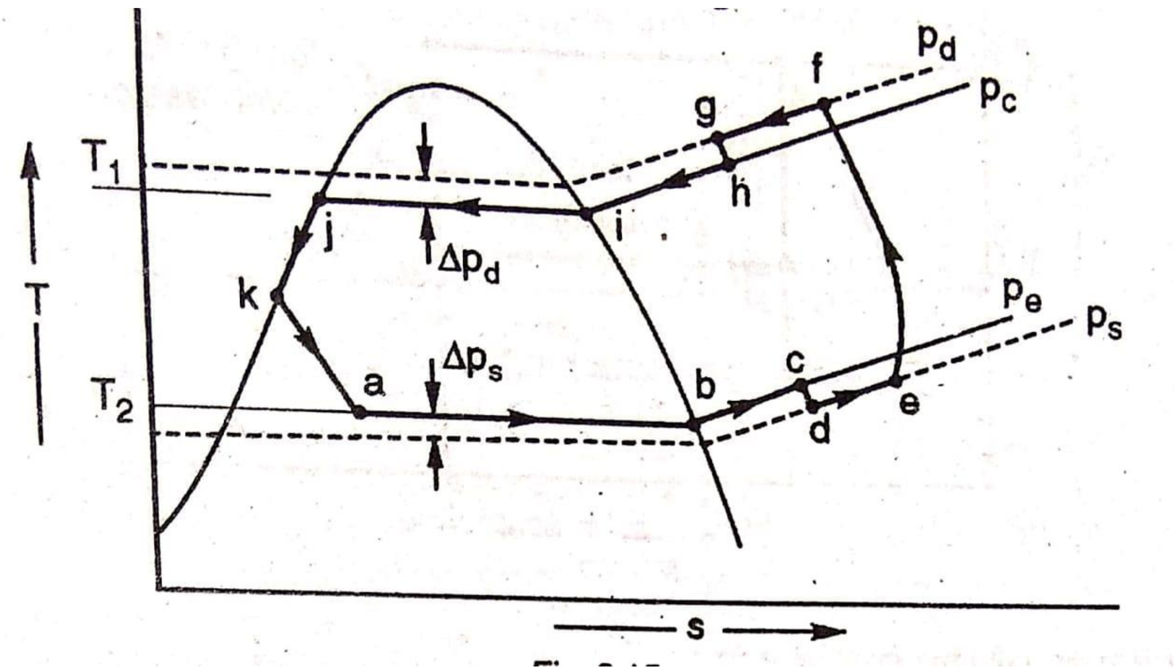
<u>DEVIATION OF ACTUAL CYCLE FROM THE THEORETICAL CYCLE:</u> The actual vapour compression cycle suffers some inefficiency compared with the standard vapour compression cycle. There are other changes from standard cycle also which either intentionally or unavoidably occurs. Some of the reason of this deviation between the theoretical cycle and the actual cycle are discussed below:-

(i) The liquid refrigerant in the compressor may be sub-cooled, i. e., its temperature may be reduced below the saturated temperature corresponding to the pressure in the condenser. Sub-cooling of the liquid in the condenser is a normal occurrence and serves the desirable function of ensuring 100% liquid entering the expansion valve.

(ii) The vapour refrigerant usually leaves the evaporator in a superheated state, which is recommended as a precaution against droplets of liquid being carried over in to the compressor.

(iii) In a standard vapour compression cycle, compression is assumed to be isentropic which actually is not there due to friction and other losses.

(iv) The standard vapour compression cycle assumes no drop in pressure in the evaporator and condenser. However, due to friction, the pressure of the refrigerant drops in these components in actual cycle. The given figure shows the actual cycle on T-s diagram.



<u>FIG: DEVIATION OF ACTUAL CYCLE FROM THE THEORETICAL CYCLE</u>

(1) **Process a-b-c**. This process shows the flow of refrigerant through the evaporator at pressure p e and temperature T2. Point c shows the entry of vapour refrigerant to the compressor in a superheated state. Superheating of vapour refrigerant to state c may either be due to its absorption of larger amount of heat from the evaporator (an advantage) or due to its picking up of heat from the suction pipe (disadvantage).

(2) **Process c-d-e-f-g-h**. This process represents the passage of refrigerant through the compressor. As the vapour refrigerant enters the compressor at point c, due to suction valve resistance, pressure drops to the value given by point d. Hence, the actual suction pressure of the compressor is lower than the evaporator pressure. During suction, the refrigerant takes heat from the cylinder walls and its temperature rises to the value given by point e. Process e-f shows the actual compression of refrigerant which may neither be isentropic nor polytropic. It may be assumed that heat absorbed by the gas during first part of compression is equal to heat rejected during the latter part. Like heating effect at suction given by process d-e, there is a cooling effect at the discharge which is given by the process f-g. The process g-h shows the drop in pressure due to discharge valve resistance which means that the discharge pressure is higher than the condenser pressure p c.

(3) **Process h-i-j-k.** This process shows the flow of refrigerant in the condenser at a pressure pc and temperature T1. Process h-i shows the de-superheating of superheated vapour from superheated state to dry and saturated state. Process i-j represents removal of latent heat and process j-k shows the sub-cooling of liquid refrigerant.

(4) **Process k-a.** This process represents the throttling of sub-cooled liquid refrigerant from condenser pressure to the evaporator pressure.

WORKING OF A DOMESTIC REFRIGERATOR: A domestic refrigerator consists of the following two major parts:

(1) Insulated Cabinet, (2) Refrigerating System.

The typical mechanism of a simple domestic refrigerator consists of a hermetically sealed compressor placed in the cabinet base. The condenser is installed at the back and the evaporator is placed inside the cabinet at the top. A typical mechanism is illustrated in the given figure.

The cycle of operation is as follows:

(1) The liquid refrigerant enters the evaporator (A) at a low pressure where it evaporates by absorbing its latent heat and thus producing refrigerating effect in the evaporator.

(2) The refrigerant vapour is drawn through the suction line (C) back to the compressor (D). The accumulator (B) provided between the suction line and the evaporator collects liquid refrigerant coming out of the evaporator due to incomplete evaporation, if any, and prevents it from entering the compressor.

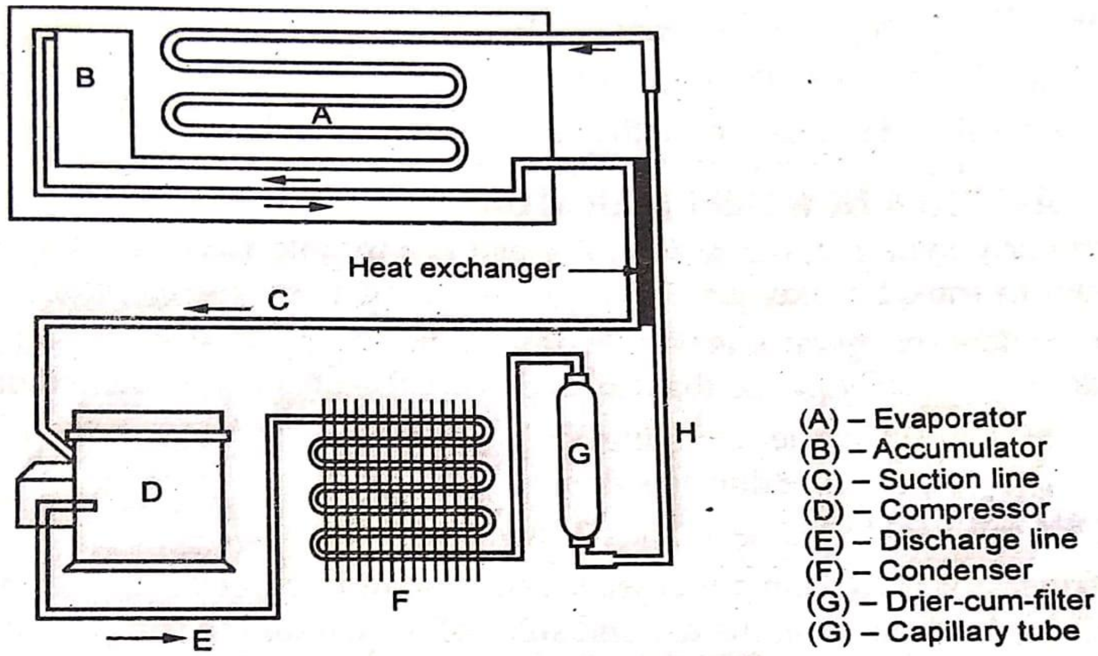


FIG: WORKING OF A DOMESTIC REFRIGERATOR

(3) The compressor compresses the refrigerant vapour to a high pressure and temperature. The compressed vapour flows through discharge line (E), into the condenser (F). The condenser in this case, is vertical natural draft, wire tube type.

(4) In the condenser, the high pressure high temperature vapour gives up its heat to the surrounding air and the vapour is condensed back to liquid.

(5) The high pressure liquid refrigerant flows through the drier cum filter (G) and then enters the capillary tube (H). The capillary tube is attached to the suction line at the heat exchanger as shown in the figure.

(6) The warm refrigerant passing through the capillary tube gives some of its heat to the cold suction line vapour. This increases the heat absorbing ability of the liquid refrigerant slightly and increases the superheat of vapour entering the compressor.

(7) The refrigerant leaves the capillary as a low pressure liquid which now enters the evaporator (A) and the cycle is repeated over and over again.

The electric circuit diagram of a refrigerator is shown in the given figure:-

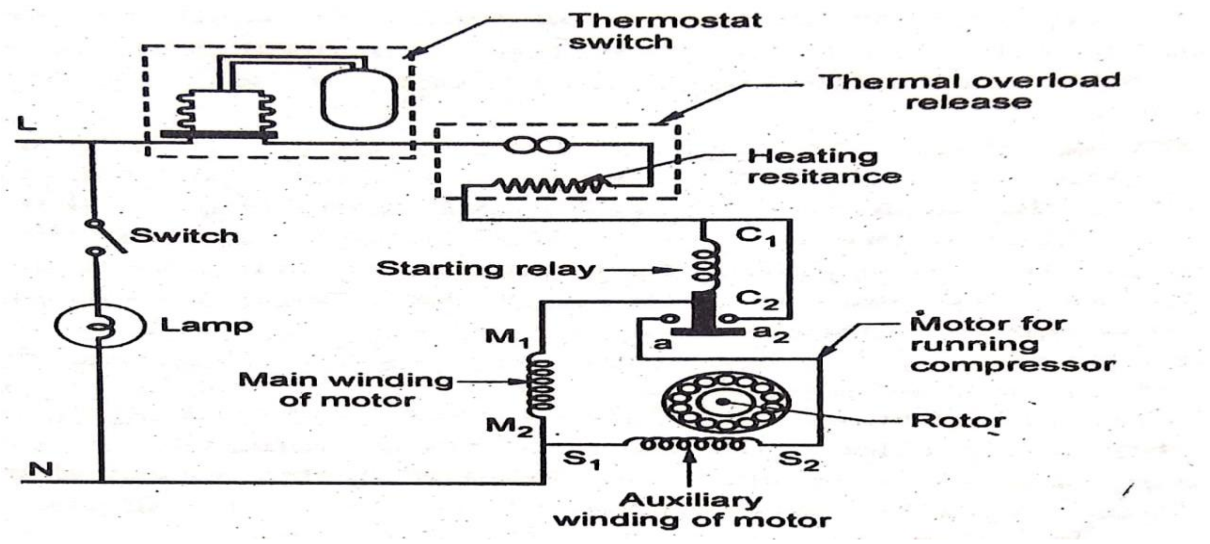


FIG: ELECTRIC CIRCUIT DIAGRAM OF A REFRIGERATOR

The various components involved in the electric circuit are:

(1) Lamp and Switch,
(2) Thermostat Switch,
(3) Thermal Overload Protector,
(4) Starting Relay,
(5) Electric Motor.

When refrigerator is connected across the supply as shown in figure, current passes through the thermostat switch, thermal overload protector, coil C1C2 of starting relay, the main winding M1M2 of the motor. Since to start with the motor is at rest, it draws a very heavy current. This heavy current flows through coil C1C2 of the starting relay. This coil gets energized and it pulls up the plunger, short circuiting the contacts a1a2 and putting auxiliary windings S1S2 also in the circuit. Now since both the main winding and auxiliary windings are energized, motor starts running. As soon as the motor picks up the normal speed, the current drawn by the main winding of motor becomes normal. At normal current, plunger in the coil C1C2 cannot remain pulled and it is released down, opening the contacts a1a2 thus auxiliary windings get out of circuit. Therefore, the purpose of the starting relay is to put auxiliary winding in the circuit at the time of starting the motor and to disconnect it as soon as the motor starts working at normal speed. In case starting relay fails to close, motor will not start as explained above. But once it closes and it fails to open, then auxiliary winding shall also keep on drawing the current, resulting in increased current drawn by the motor. In that case, either the fuse shall be blown off or thermal overload shall trip out.

WATER COOLERS: Water is more essential to man than anything else. In summer, cold water is life giving to a thirsty man. At a medium temperature of 10 degree Celsius, water is most refreshing. So cooling of warm water becomes necessary in summer.

There are two types of water coolers:

(i) Pressure or tap water coolers (instantaneous type),

(ii) Storage type coolers.

(i) Pressure type water coolers: In this type of water cooler, the coils of the evaporator and the tubes containing water to be cooled run side by side. The refrigerant flowing through the coils takes heat from the water flowing through the tubes and cools it. The fresh quality of water comes from the bottom and is discharged at the top after getting cooled. Whereas the flow of the refrigerant in the liquid form is in the reverse direction. It comes from the top and discharges at the bottom and through the coil the opposite flow of water to that of refrigerant in liquid form is required in order to have the maximum heat taken out from the water thus quickly cooling the water.

(ii) Storage type water cooler: In such type of coolers, the water is filled in a tank. The level of this water is kept same by providing float valve in it. The coils of the evaporator are fitted around the water tank. The heat of the water is taken by the low pressure liquid refrigerant flowing in the coils of the evaporator. Such types of coolers are used where the continuity of water supply is not there. The diagram of water cooler is self-explanatory. The evaporator tubes surrounding the water tank cool the water in the tank and when the desired temperature of the water is attained, the thermostat switch opens out thus disconnecting the power supply to the motor.

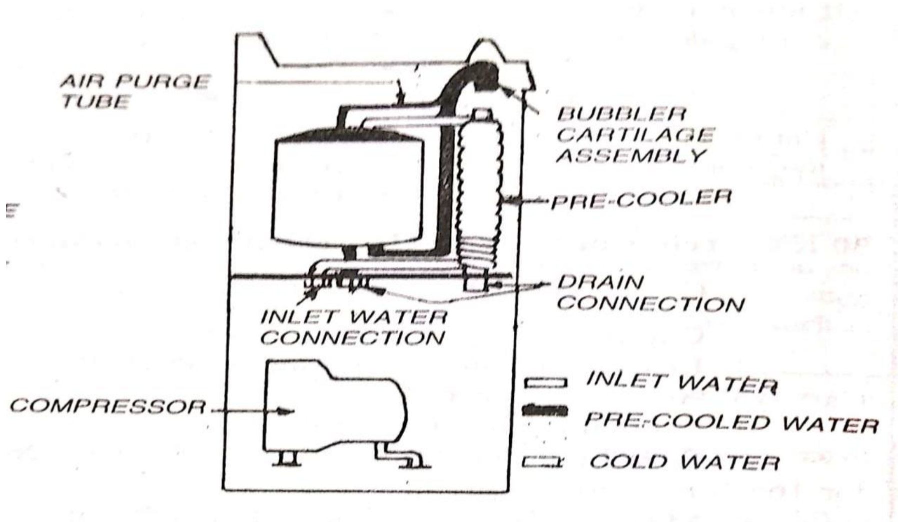


FIG: PRESSURE TYPE WATER COOLER

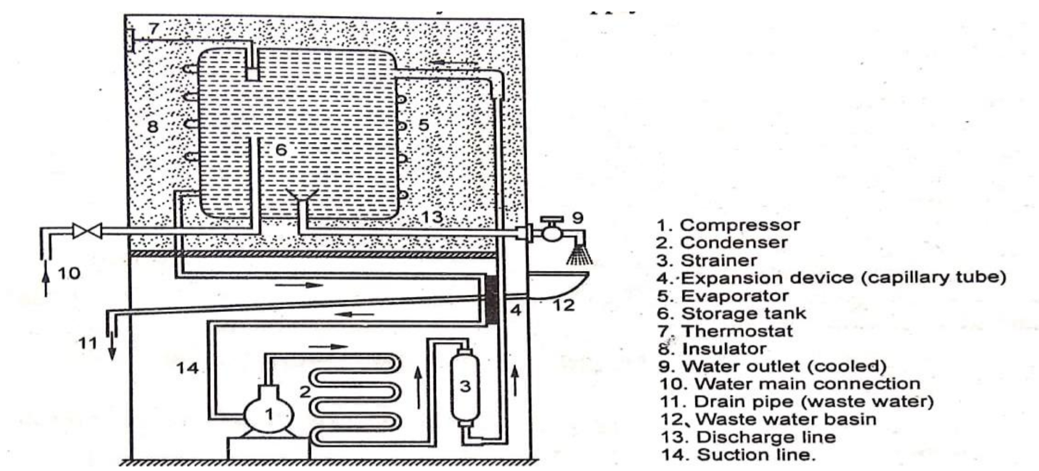


FIG: STORAGE TYPE WATER COOLER

The motor used is capacitor start capacitor run single-phase induction motor. Starting capacitor helps in producing more starting torque whereas running capacitor helps in improving the power factor which in turn reduces the current drawn by the motor.

REFRIGERATION TOOLS AND MATERIALS: A list of essential tools and equipments used in refrigeration is given herewith:-

(1) Wrenches, (2) Screw drivers, (3) Hacksaw, (4) Calipers, (5) Snip, (6) Feeler gauge, (7) Hammer, (8) File, (9) Dies, (10) Taps, (11) Chipping chisels, (12) Vices, (13) Pliers, (14) Punches, (15) Tube cutter, (16) Tube bender, (17) Flaring tool, (18) Swaging tool,(19) Ratchet type flat nut wrench, (20) Pinch off tool, (21) Re-facing tool, (22) Vacuum pump, (23) Oil can, (24) Micrometer, (25) Pressure gauges, (26) Gauge manifold set, (27) Halide torch leak detector, (28) Electronic leak detector, Etc.

A brief description of the above mentioned tools and equipments is given in the previous chapter on *introduction*.

TUBING: Most tubing used is made of copper. However, aluminium, steel, stainless steel and plastic tubing are also used in certain places.

ACR TUBING – Most copper tubing used in air conditioning and refrigeration is known as Air conditioning and Refrigeration (ACR) tubing.

TYPES OF COPPER TUBING: There are two types of copper tubing:

(i) Soft copper tubing, and

(ii) Hard drawn copper tubing.

(i) *Soft copper tubing*: Soft copper tubing is used in domestic work and in some commercial refrigeration and air conditioning applications. It is annealed (First heated and then cooled) in order to make it flexible so that it may be easily bent and flared.

(ii) *Hard drawn copper tubing*: Hard drawn copper tubing is used in commercial refrigeration and air conditioning applications. Hard tubing is used in straight length as these cannot be bent. These are available in 20 ft. lengths.

USE OF STEEL TUBING: Since copper or brass tubing cannot be used with refrigerant ammonia, as there is a chance of chemical reaction between ammonia and copper, so steel tubing is used with ammonia. Connections on steel tubing may be made either with flared joints or silver brazed joints.

IMPORTANT APPLICATIONS OF STAINLESS STEEL TUBING: Stainless steel is strong, corrosion restraint and may be used connected to fittings by either flaring or brazing. It is often used in food processing, ice cream manufacture, milk handling systems and similar applications.

FLARE FITTINGS USED IN REFRIGERATION AND AIR CONDITIONING INSTALLATIONS: Flare fittings are used to connect tubes in desired directions. There are many types and sizes of flare fittings as shown in the given figure-

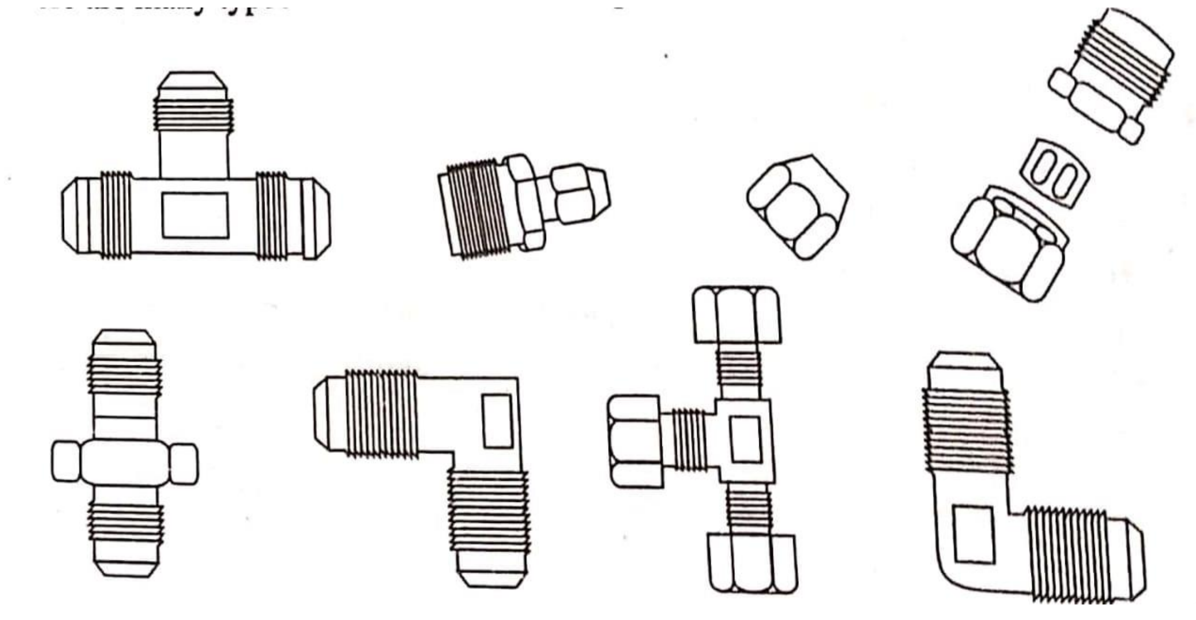


FIG: FLARED AND COMPRESSION TUBE FITTINGS

CUTTING: In order to cut copper tubing to be used in refrigeration and air conditioning system accurately and smoothly, the best way is to use a tube cutter. The tube to be cut is held in between the roller and the cutter wheel and high pressure is put on the lead screw. Revolve the cutter slowly around the tubing, so that the sharp cutting wheel feeds gradually into the tubing, making a clean right angle cut. The tube cutter is widely used for annealed copper tubing.

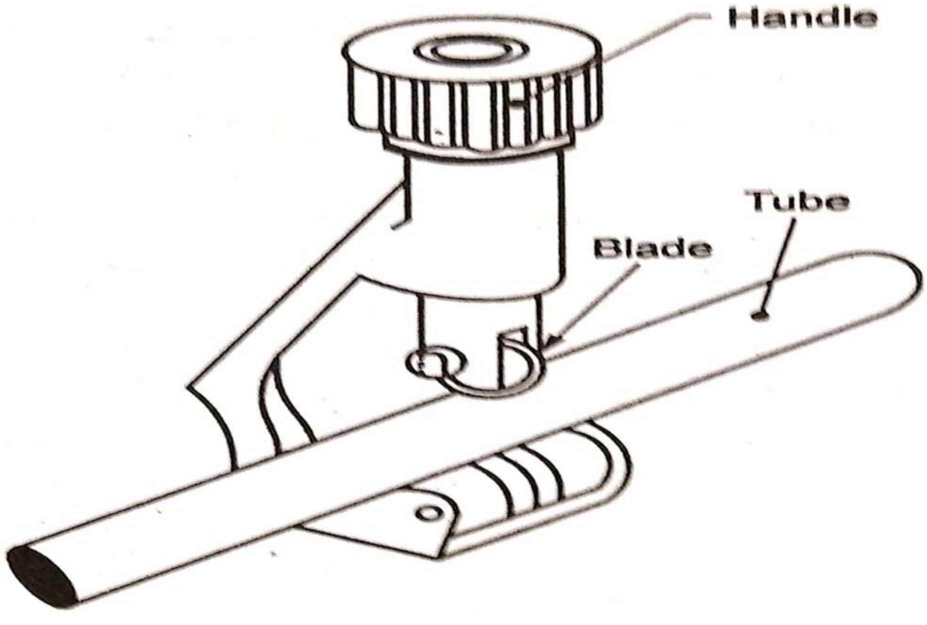


FIG: CUTTING COPPER TUBING

BENDING: A number of special tools are available for bending operation. While using spring type bender as shown in figure, it should be kept in mind that the tubing should be bent somewhat farther than it is required and then bend up to the proper angle. Thus the spring is loosened and can be easily removed.

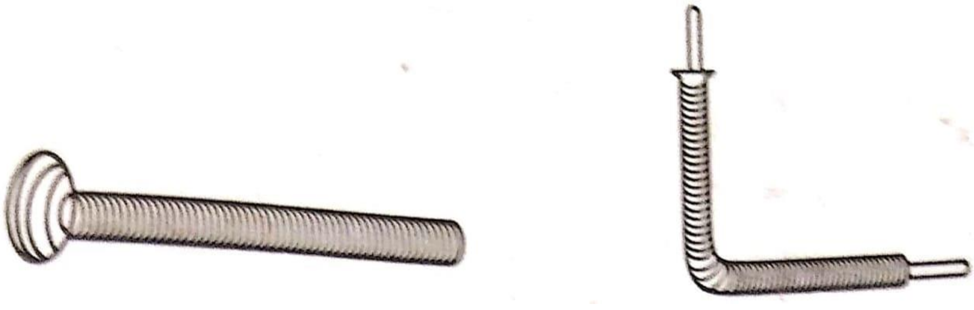


FIG: SPRING TYPE TUBE BENDER

A lever type tube bender as shown in given figure is used to form bends neatly and accurately with buckling the tubing. These tools form bends up to 180 degree in one continuous operation. The forming wheel is calibrated to show the degrees of bend attend. Manufacturers also furnish information for making bends to predetermined dimensions. Each of these tools is used with one size of tubing. Combination lever type tube benders are also available which are used for bending several sizes of tubing changing the forming wheel and block.

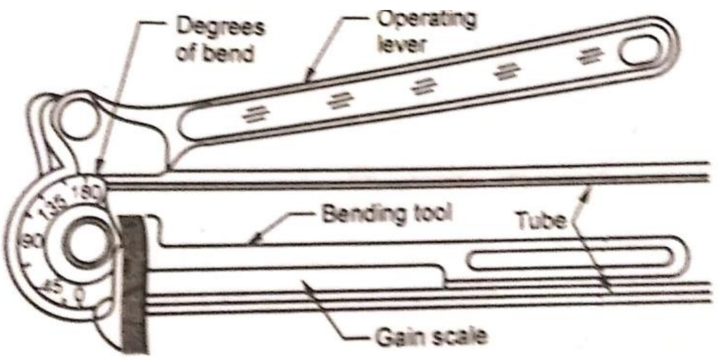


FIG: LEVER TYPE TUBE BENDER

FLARING: A flare is obtained on a copper tubing with the help of a flaring tool, it contains a series of blocks to accommodate tubing of different sizes. The tubing previously cut with the tube cutter is placed in the flare block in correct position.

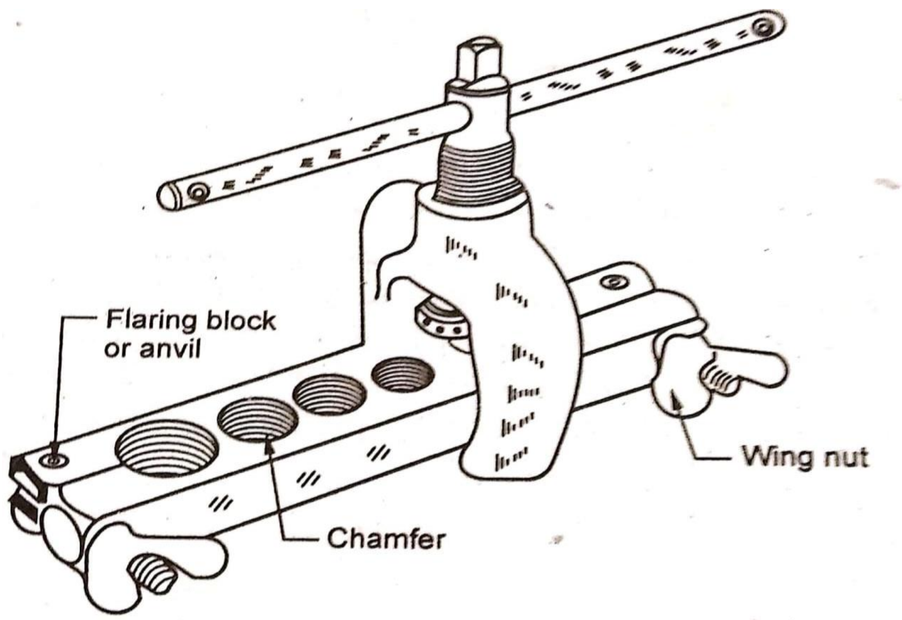


FIG: FLARING OPERATION

The tubing should extend about 40mm above the block. Then tighten the clamp. Select the proper yoke for the size of tubing to be flared and attach it to the flare block. The cone should be tapered at an angle of 45 degrees. Now place a drop of oil on the cone and with a slow turning effect, screw the cone firmly into the end of the tubing. When the flare is completed, unscrew the cone and remove the flared tubing from the flare block.

SWAGING: Swaging is the process of shaping copper tubing so that two pieces may be joined without the use of a fitting. The tool used for this is known as swaging tool.

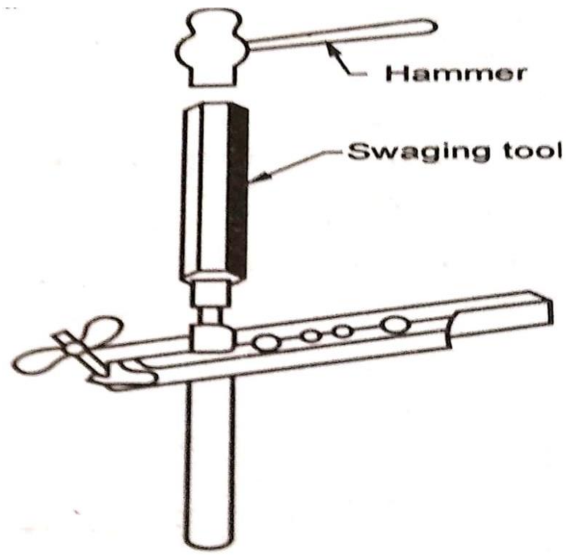


FIG: SWAGING OPERATION

The swaging tool can be of punch type or screw type, hold the tube in the flaring block tool and set bar in vice, the tubing to be extended above bar a distance of its diameter plus 3mm and clamp. Now a specially designed punch is hammered into the tubing to a depth equal to its original diameter. Now remove the punch and insert other piece of tubing in this swaged portion. Apply heat to the joint and add solder for making a substantial joint.

UNIT 3

COMPRESSOR AND IT'S CLASSIFICATION'S

1.1. INTRODUCTION

In a refrigeration cycle, the refrigerant has to undergo a number of changes in its state or condition to produce the necessary refrigerating effect. Each such change in the state of refrigerant is called a process. In order to carry out these processes, the refrigeration system is provided with a number of components which form an essential part of the system. In addition to this, certain control devices are also provided with every 'refrigeration system for its economical, efficient and safe working. A brief description of the various components and control devices is given as below:

1.2 COMPRESSOR

A compressor is considered to be the heart of the compression refrigeration system. It pumps the refrigerant the train the system and circulates it again and again in cycles. It produces high pressure and hence high temperature to enable the refrigerants to reject its heat in the condenser. It also helps to produce low pressure (suction pressure) in the evaporator to make the refrigerant to pick up maximum amount of heat from the space to be refrigerated.

The compressors used in the modern vapour compression systems can be either of positive displacement or non-positive displacement type (centrifugal type).

The positive displacement compressors are classified as:

(1) Reciprocating compressors

(2) Rotary compressors

These are used for all types of installations from fractional hp large tonnage air-conditioning and commercial applications.

The centrifugal type compressors are best suited for refrigerants having high molecular weights and high specific volume. These are essentially high speed and large tonnage compressors which are commonly applied to water or brine chilling applications:

The compressor's capacity is influenced by its operating pressures. If the discharge pressure increases above conditions, the compressor capacity will decrease. If the suction pressure increases, the compressor capacity increases and the power requirement also increases; however, the power required per ton of refrigeration will decrease. This indicates, in general, the desirability of carrying suction pressures as high as possible and the discharge pressure as low as possible regardless of the refrigerant being used.

1.3 RECIPROCATING COMPRESSORS

The principle of working of a single acting reciprocating compressor is illustrated in Fig. 1.1).

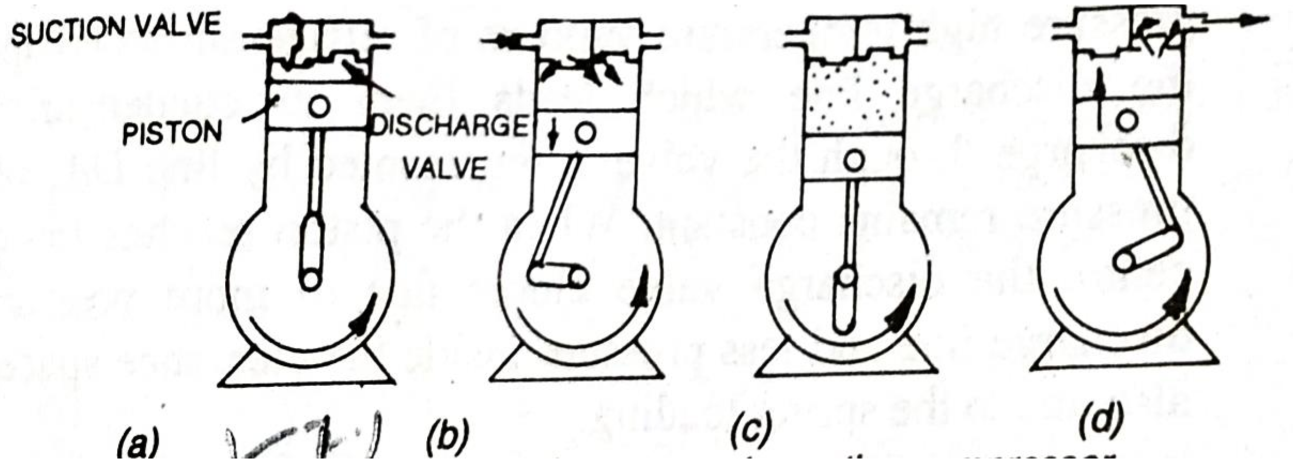


Fig. 1.1. Working of a single acting reciprocating compressor.

(i) As shown in Fig. 1.1. (a) The piston is at the top dead center. The suction and discharge valves are closed. The suction valve remains closed due to high pressure of vapour entrapped in the clearance space above the piston and the discharge valve does not open due to its own weight or spring loading. The position of piston is shown by point A on p-v diagram given in Fig. 1.2.

(ii) As the piston moves downwards as shown in Fig. 1.1 (b), the pressure of the entrapped vapour decreases, even below than the suction line pressure or evaporator pressure, and the suction valve opens. The vapour refrigerant enters the cylinder through suction valve. The stroke of the piston is known as the suction stroke. The reduction of pressure by expansion of entrapped vapour in the clearance space is given by curve A-B and intake of fresh vapours from the suction line by line BC on p-v diagram (Fig. 1.2). The suction valve opens at point 'B'. The piston reaches at 'C' at the end of the suction stroke. Now the suction valve closes usually by spring action. The discharge valve remains closed as before.

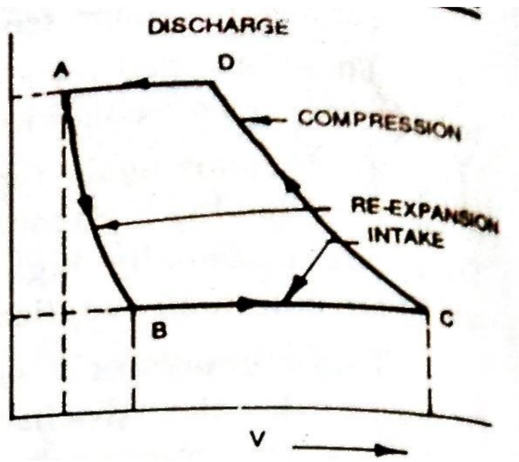


Fig. 1.2

(iii) The piston starts moving upward, compressing the vapour refrigerant decreasing its volume, thereby increasing its pressure and temperature. The compression is shown in Fig. 1.2., by the curve CD. At point 'D', due to increase in pressure the discharge valve opens and permits the high pressure high temperature vapours of refrigerant to escape in the discharge line which leads them to condenser. The discharge through the valve is represented by line DA where pressure remains constant. When the piston reaches top dead center the discharge valve closes due to more pressure in discharge line and less pressure inside the clearance space and also due to the spring loading. This cycle is repeated again and again.

The uses of this type of compressor are given below:

(1) It is used with refrigerants requiring small displacement an high pressure condensing. Such refrigerants have low specie volume.

(2) It may be employed for refrigerating plants from small capacity of 1/4 ton to a large capacity of 1000 ton.

(3) Such compressors are available in sizes ranging from 1/8 hp in small domestic units to 100 hp or more in large air-conditioning and industrial installations.

(4) The common refrigerants which generally demand the use of these compressors are Freon-12, Freon-22, sulphur dioxide and ammonia.

In the reciprocating compressors, the pressure of the refrigerant vapour is increased by the co-ordinated action of pistons and valves.

The reciprocating compressors are classified in the following manner:

1. According to construction:

(i) Vertical reciprocating compressors.

(ii) Horizontal reciprocating compressors.

2. According to working:

(i) Single acting reciprocating compressors

(ii) Double acting reciprocating compressors.

3. According to the assembly with motor:

(i) Open compressor.

(ii) Hermetically sealed compressors.

(iii) Semi-Hermetic compressor.

1.4. VERTICAL AND HORIZONTAL RECIPROCATING COMPRESSORS

Vertical reciprocating compressors are single acting, the piston of which is driven directly by connecting rod and crankshaft enclosed in crankcase which is pressure tight. These are almost enclosed type and take less floor space for their installation.

Horizontal reciprocating compressors are always made to work on double acting principle. Pistons of these compressors are driven with the help of a crankshaft, connecting rod, cross head and piston rod. The horizontal reciprocating compressors are not suitable for small size applications as they require more floor space for their installation.

1.5. SINGLE ACTING AND DOUBLE ACTING RECIPROCATING COMPRESSORS

In a single acting compressor, compression of the vapour occurs only on one side of the piston and once during each revolution of the crankshaft. These are usually vertical in construction and are used for small size application. Piston rings are only fitted in these compressors when the diameter of piston exceeds 5 cm.

In a double acting reciprocating compressor, the compression of vapour occurs on both sides of the piston and so twice in each revolution of the crankshaft.

1.6 OPEN. SEMI-HERMETIC AND HERMETICALLY SEALED RECIPROCATING COMPRESSORS

An Open type compressor is driven with electric motor, the help of pulley and belt system. The compressor and motor mounted on the same base plate on which is also mounted the receiver tank and condenser. This combination of components put together is known as a condensing unit. In the open type condensing unit, maintenance is easy and evacuation and charging of refrigerant is done with the help of the same compressor and motor. The cooling of motor is done by atmospheric air with the help of fan which also cools the condenser.

A Hermetic sealed compressor is mounted directly on the shaft of the motor. The compressor and motor assembly are hermetically sealed in a welded steel shell. Such units are known as hermetic condensing units. These are employed in small domestic refrigerators, home freezers and window air conditioners. Such compressors have many advantages over the open type.

(a) Leakage of refrigerants is completely prevented.

(b) It is more compact and requires small space.

(c) It is less noisy.

(d) The motor is cooled more efficiently as it is housed in low pressure area.

It has some disadvantages too, which are:

(a) Maintenance is not easy. The welded joint has to be broken open for repairs.

(b) The presence of moisture in the refrigerant may harm winding of the motor.

(c) A separate vacuum pump is required, for evacuation charging the refrigerant.

The cooling of motor is done by the refrigerant itself in this case and if evacuation is done by this compressor, the refrigerant will e the system while motor runs to create vacuum. So motor will wed and its winding will burn away. So a separate vacuum so is employed to evacuate the system. T

The Semi-hermetic type compressors are the modification of hermetically sealed compressors. They are made accessible by bolting cover with the shell. The bolted construction permits the assemblies to be opened as and when some repair or servicing is required to be done.

1.7. ROTARY COMPRESSORS

In a rotary compressor, the refrigerant vapour is handled by mating members and not reciprocating members as in reciprocating compressors, so the rotary compressors are suitable for high speeds. The rotary compressors operate on a positive displacement principle similar to that of reciprocating type. These are used where capacity needed in small. The rotary compressors are made in two different types:

(i) Roller type rotary compressor.

(ii) Vane type rotary compressor.

(1) Roller type rotary compressor. A roller type rotary compressor is shown in Fig. 1.3. The main parts of it are: cylinder,

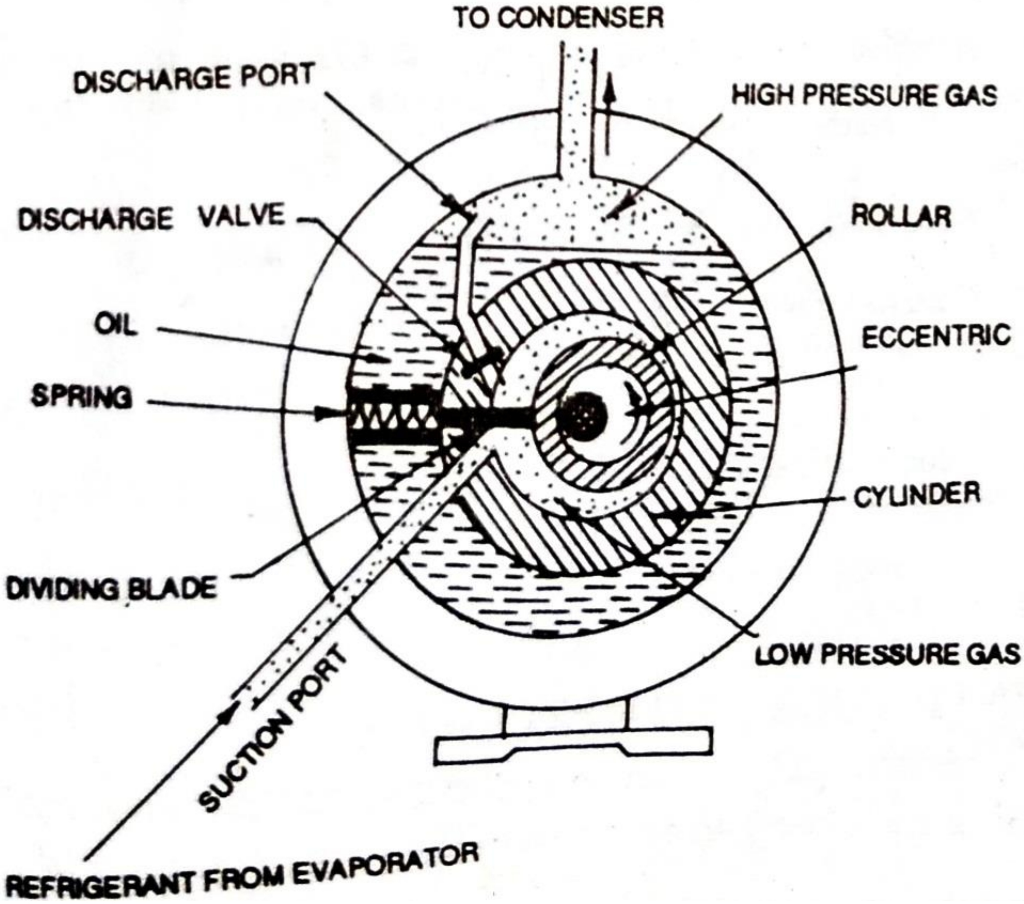


Fig. 1.3

roller mounted eccentric on motor shaft and a spring loaded blade. The centre of shaft coincides with the centre of cylinder. The whole assembly is placed in an air tight housing shown in Fig. 1.3. The upper portion of the housing is kept vacant oil to accommodate the compressed vapour.

When the roller is revolved by the shaft of the motor, one point makes continuous contact with the cylinder wall. The refrigerant which enters the open space to the lower side of the spring loaded blade is pushed out through the discharge valve at the upper side of blade.

(ü) Vane type rotary compressor. In vane type rotary compressor, a rotor is arranged co-axially with the motor shaft which itself is not centred with the cylinder. The rotor has several vanes (usually four in number) which maintain contact with the cylinder. These vanes move in and out of slots in the rotor to make sliding contact with cylinder. The constructional details of a vane type rotary compressor are shown in Fig. 1.4. The advantages of a rotary compressor over a reciprocating type are:

1. It is less noisy in operation.

2. It is suitable for refrigerants with low specific volume at low suction pressure.

3. It is preferable for low temperature applications.

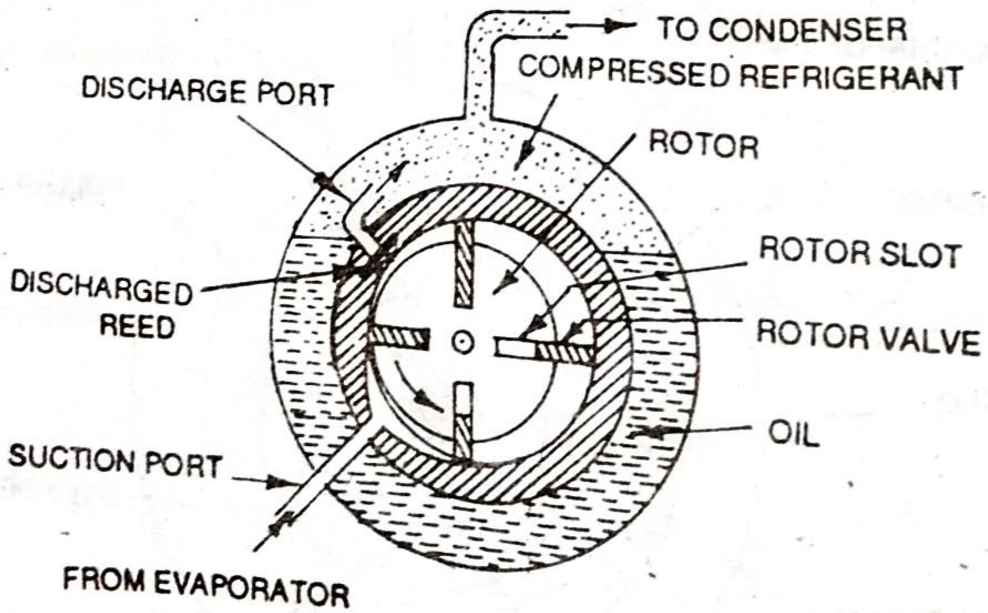


Fig. 1.4

1.8 CENTRIFUGAL COMPRESSORS

In a centrifugal compressor, the refrigerant vapour is ha by a rotating member known as impeller. This compressor increases the pressure of the first creating a very high velocity and then converting a part of the kinetic energy of the moving refrigerant such as Freon-11 and Freon-113 where the volume passing through the compressor is large and the required increase in pressure is small.

At present, the centrifugal compressors are available to work units in sizes ranging from 35 ton to 2000 ton capacity.

The centrifugal compressor consists essentially of a series of impeller wheels mounted on a shaft and enclosed in a casing. Main advantages of this type of compressors are:

1. These are high speed machines and are directly coupled with electric motors or steam turbines.

2. Due to absence of reciprocating parts, lubrication is simple and maintenance cost is less.

3. There is saving of space for large sizes as compared with reciprocating machines.

4. Throttling to suite load gives corresponding power reduction.

5. These are free from vibrations.

1.9. SCREW COMPRESSOR

It is a positive displacement compressor available in capacities from 15 hp to 800 hp. It is gaining rapid popularity due to its simplicity and capability of handling both ammonia and halocarbon refrigerants. The main parts of this type of compressor are:

1. Outer casing	2. Main bearing
3. Thrust bearing	4. Mechanical seal
5. Balance piston	6. Female rotor
7. Male rotor.	

The female rotor has six concave lobes and the male rotor has Tour convex lobes as shown in Fig. 1.5.

The male rotor is driven by the motor. The female rotor meshes 1 male rotor and is driven by it. The refrigerant vapour (low sure vapour) enters at one end of the compressor and is urged (compressed vapour) at the opposite end as shown in

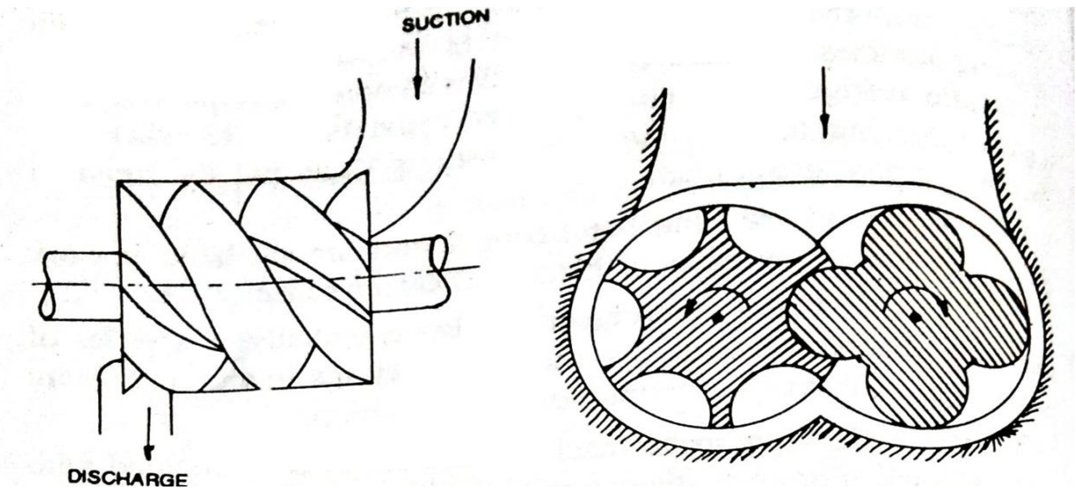


Fig. 1.5.

This type of compressor has many advantages over other types as discussed below:

1. Less vibrations
2. High volumetric efficiency
3. Less frictional parts and therefore, less wear and tear.

1.10. COMPRESSOR VALVE ASSEMBLY

The usual valve assembly consists of a valve plate, an intake valve; an exhaust valve and the valve retainer (refer Fig. 1.6).

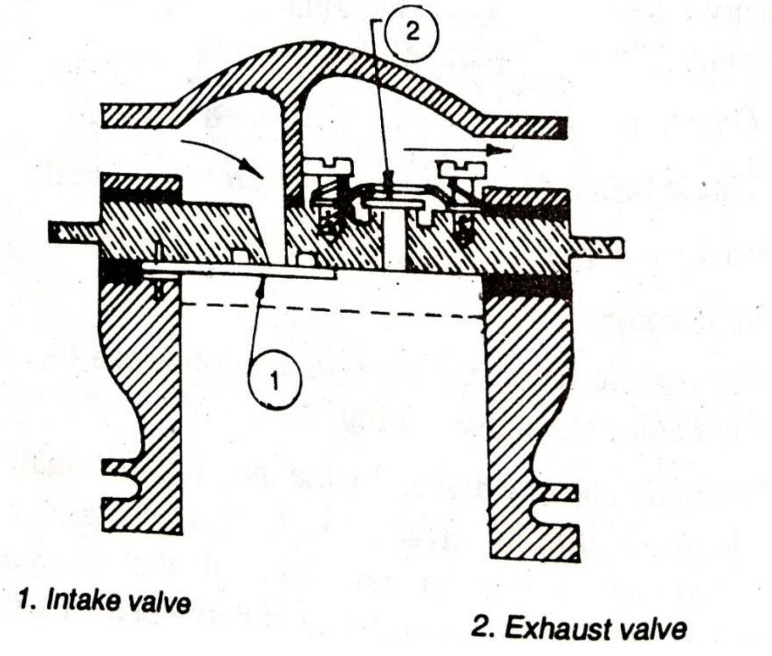


Fig. 1.6. Typical compressor valve plate.

1.11. VARIOUS DESIGNS OF COMPRESSOR VALVES

Some designs of compressor valves are shown in Fig. 1.7.

1. Deed valve, spring closed refer Fig. 1.7 (a)

2. Poppet valve, spring closed refer Fig. 1.7 (b). It is used on large compressors.

3. Reed valve refer Fig. 1.7. (c). Pressure difference keeps valve closed.

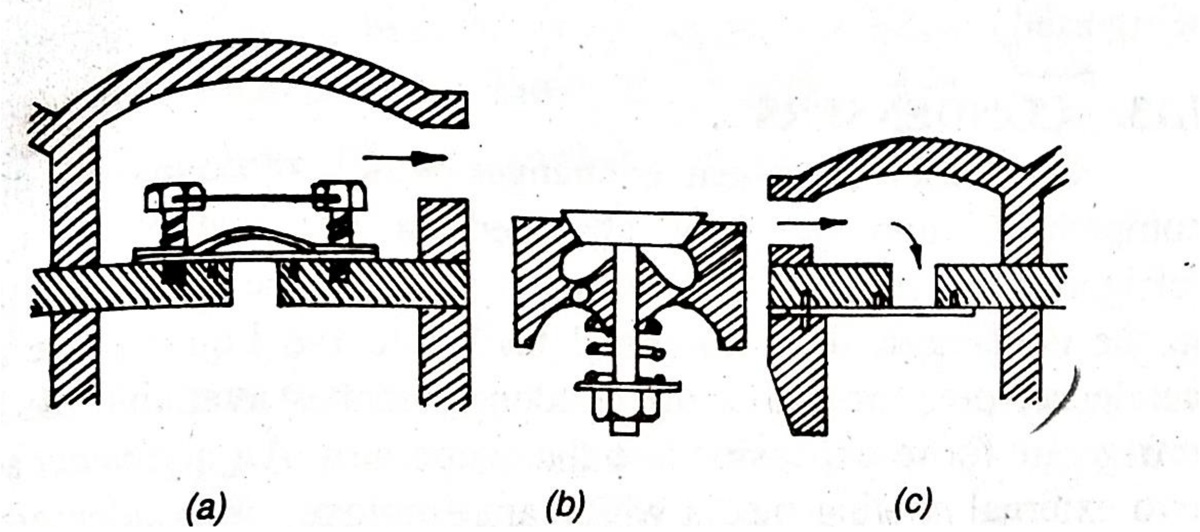


Fig. 1.7

1.12. CONSTRUCTION AND WORKING OF A COMPRESSOR SERVICE VALVE

Conventional compressors are provided with suction and discharge service valves to connect gauges to the system, check pressures and add or take out refrigerant or oil. A typical compressor service valve is shown in Fig. 1.8 which has three openings i.e.

1. Connection to compressor

2. Suction or discharge connection

3. Opening for gauge connection to permit charging or purging of the line and to check pressures.

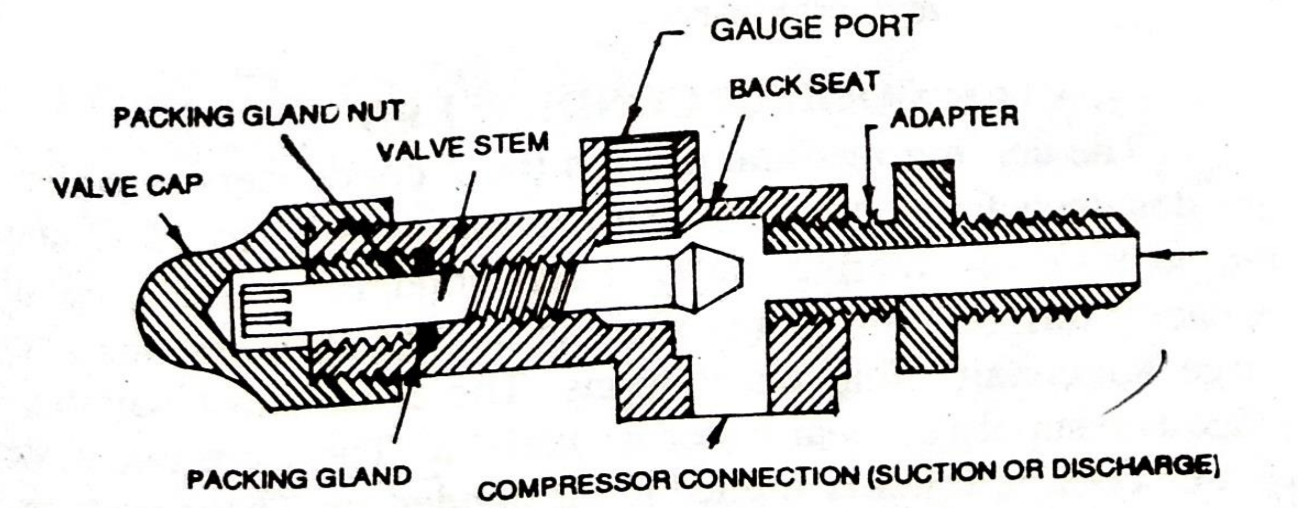


Fig. 1.8

This valve is of back seating type which means that w stem is turned all the way back, the gauge port is closed. In this position of the valve, the line connection is open to the compressor. When the valve stem is turned in as far as it can go, the suction or discharge line is closed while the gauge port is open to the pressure. At mid-point, the stem is so located that the compressor is open to the line connection, the gauge port or both. Due to this design the gauge connection must be plugged is being used.

Cylinder In small compressors, the cylinder (Fig. 1.9) is formed by precision boring the main body which is usually constructed of closed-grained cast iron. In large-sized compressors, the cylinder is made separately and fitted into the main body. Such a cylinder is called a cylinder sleeve or liner. With a removable cylinder sleeve, it becomes easier and cheaper to replace a sleeve than the complete compressor body, when the cylinder-bore has worn out.

Piston A piston (Fig. 1.9) is a cylindrical metal plug that moves up and down in the cylinder Pistons are made of cast iron or aluminum. The piston must be just loose enough to move freely in the cylinder.

At the same time it should not be so loose as to allow leak-back of the discharge gas from top of the piston to the crankcase. The clearance between the cylinder and piston (the difference bet the diameter of the cylinder bore and outside diameter of the piston) is filled with an oil film provide lubrication. This oil film also prevents leak-back of the discharge gas to the crankcase. It is obvious that this clearance should be low enough to retain this oil film.

Straight pistons (pistons without rings) are used in small-sized compressors. For bigger compressors, pistons are fitted with piston rings, so that when they get worn out, only the rings have to the changed. When the piston moves inside the cylinder, heat is generated due to friction. A continuously flowing oil film cools and thus prevents an excessively high temperature developing in the cylinder and the piston. The oil reduces friction and also prevents leak-back of the discharge gas. When piston rings are used, the area of contact between the cylinder wall and rings is comparatively

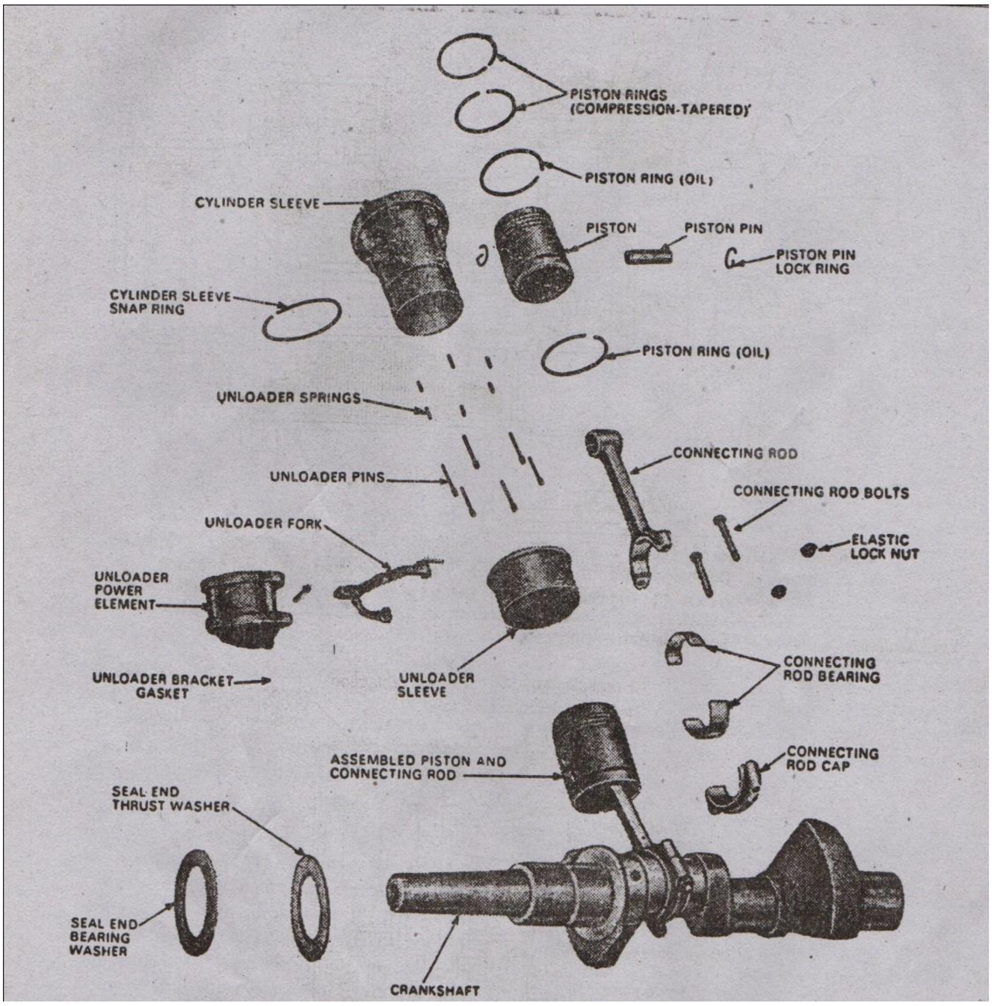


Fig. 1.9

very much less, and so the frictional heat generated is also less. Rings are installed in grooves on the piston.

Piston rings (Fig. 1.10) are metallic (cast iron) rings with a split at one point. Due to the split, the rings can be slightly enlarged and slipped over the piston and moved into the ring grooves in the piston. When the piston with the rings is inserted into the cylinder wall and against the sides of the piston grooves. The tight fitting of the piston rings in the cylinder along with the oil film forms a good seal against the leak-back of the discharge gas.

The oil throw-off or splash from the compressor crankcase by the rotating crankshaft lubricates the cylinder, piston, rings, etc. Usually there is far more oil splashed than required, and to prevent the carry-over of the excess oil and at the same time to retain enough oil for lubrication, special rings are used. These are called 'oil rings' or 'scraper rings’.

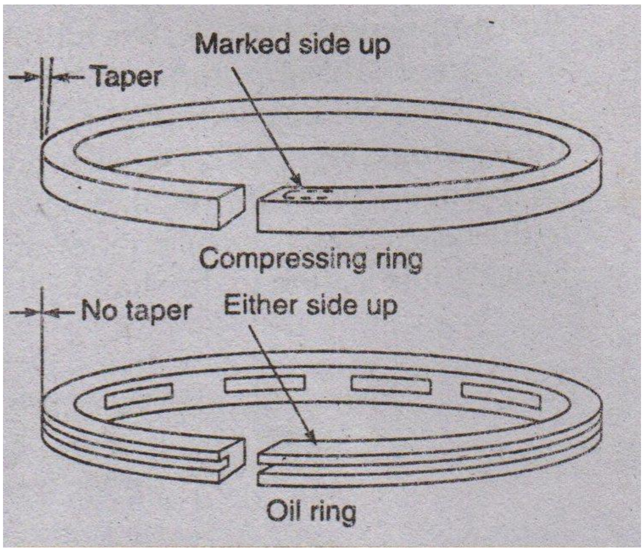


Fig. 1.10

Crankshaft The reciprocating (or straight line) motion of the piston 'is made possible by the 'crank' of the crankshaft. The crank or Crank Pin being offset from the centre line of the shaft, it swings round in a circle as the shaft rotates. The connecting rod connects the crank pin to the piston. The crank-end of the connecting rod (called the 'big end') has a bearing which permits the crank pin to move freely within the big end. The piston-end of the connecting rod is attached to the piston by the 'piston pin'. The piston pin is tightly fitted in the piston. A bearing in the piston-end of the connecting rod permits the connecting rod to swing back and forth on the piston pin as the crank rotates.

The crankshaft is made of either forged alloy steel of considerable strength or out of spheroidal grey (SG) iron casting. The SG iron shaft can be Position of piston pin retaining clips used only for direct-drive and not for belt-drive applications. The crank-shaft should be strong enough to take the thrust of the piston during compression, without getting distorted. It should be well-balanced to eliminate undue vibrations. Crankshafts are provided with counter weights opposite the crank pin, to provide balance.

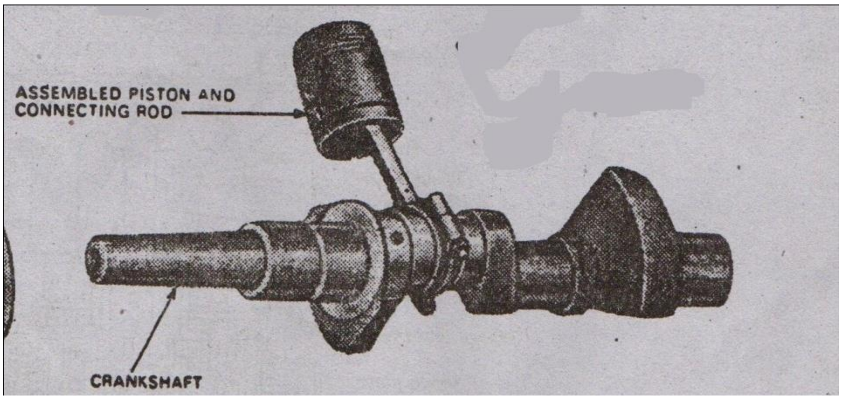


Fig. 1.11

The portions of the shaft which work inside the bearings are called 'journals' thus we have main bearing journals-seal-end and rear-end or pump-end, big-end or connecting rod journal, etc. In large compressors a bearing between the two end-bearings, called the centre-bearing is provided.

Refrigeration compressors are lubricated by one of the following two methods-For slow-speed compressors, splash lubrication is used. Oil scoops are fitted at various points on the crankshaft which, as the shaft rotates, pick up oil from the oil sump and pour it into the bearings and splash on to the cylinder walls.

Modern compressors are designed to run at high speeds--thus achieving reduced physical size of the compressors. For effective lubrication of such high-speed compressors, 'forced-feed' lubrication is adopted. An oil pump, attached to one end of the crankshaft, supplies (or forces) oil, under pressure to the bearings (Fig. 1.12) through drilled passages in the crankshaft to supply oil to all the bearings. The oil pump will have more capacity than what is needed. At the end of the oil passage, a pressure-regulating valve is usually provided to maintain a fairly constant oil pressure to the bearings. Excess oil is relieved by the pressure-regulating valve, usually to the seal chamber to provide lubrication to the shaft-seal assembly.

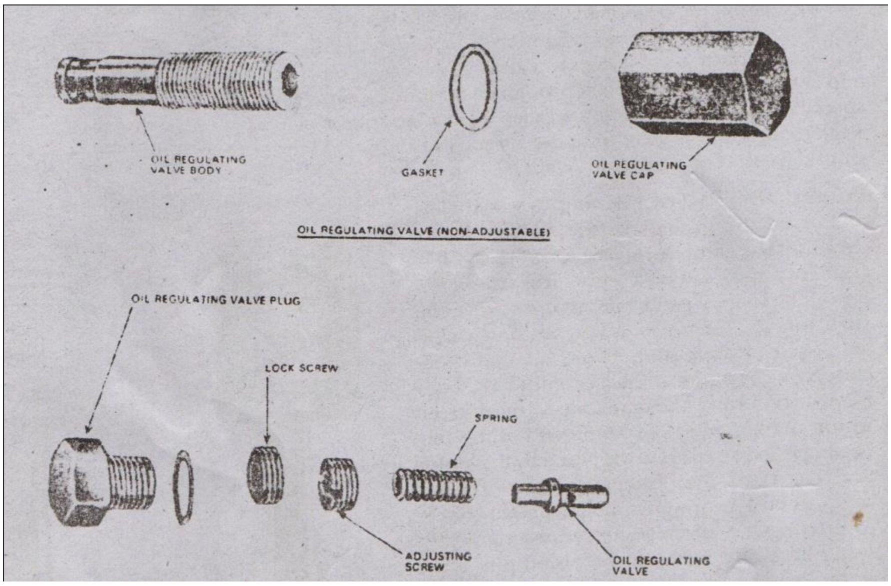


Fig. 1.12

Connecting Rods The connecting rod must be very strong and rigid. It should also be as light as possible. It is usually made of high carbon steel forgings. The piston end of the connecting rod is attached to the piston by the piston pin. Piston pins can be fitted in several ways. One way is to lock the pins to the piston by means of lock rings or lock bolts. The bearing in the small-end of the connecting rod permits free back and forth motion of the connecting rod in the pin. In another way, the pin is locked to the connecting rod and the pin moves in the bearings provided on the piston. A third way allows movement in bearings, both on the piston and connecting rod. In multi-cylinder compressors, the weight of each connecting rod used should be the same, otherwise vibrations can result.

ASSIGNMENT

MULTIPLE CHOICE QUESTIONS

1. The compressor used in a domestic refrigerator is
   (A) Reciprocating compressor (B) Horizontal compressor
   (C) Vertical compressor (D) None of the above.
2. The commonly used reciprocating compressors are
   (A) Single stage (B) Multi-stage
   (C) Double stage (D) None of the above.

3. The compressor used in domestic refrigerator is

(A) Open type compressor

(B) Hermetically sealed compressor

(C) Semi-hermetically sealed compressor

(D) None of the above.

4. The condenser used in a conventional domestic refrigerator is

(A) Natural type air cooled condenser

(B) Forced draft type air cooled condenser

(C) Water cooled condenser

(D) None of the above.

5. For cooling of circulating water in a water cooled condenser, the device used is

(A) Fan (B) Cooling tower

(C) Geyser (D) None of the above.

6. The expansion device used in domestic refrigerator is

(A) Expansion valve (B) Thermostatic expansion valve

(C) Open type expansion valve (D) Capillary tube.

7. The function of a compressor, in a refrigeration system is to

(A) Increase pressure of refrigerant

(B) Increase temperature of refrigerant

(C) Circulate the refrigerant with system

(D) All of the above

8. The desirable condition of the refrigerant at entry to the compressor is

(A) wet refrigerant

(B) liquid refrigerant

(C) dry and saturated vapour refrigerant

(D) none of the above

9. The evaporator in a refrigeration system is also known as

(A) heating coil (B) cooling coil

(C) electric coil (D) magnetic coil

Answer

1. (A)	2. (A)	3. (B)	4. (A)	5. (B)
6. (D)	7. (D)	8. (C)	9. (B)	

TRUE/FALSE

1. The compressor, in a refrigeration system helps in maintaining desired pressure differential.

2. The refrigerant at the entry to compressor must be saturated liquid.

3. For domestic refrigerator, the hermetically sealed compressor is used.

4. In cold storages, condensers are generally water cooled.

5. For domestic refrigerator, the device used for expansion is automatic expansion valve.

6. In a refrigeration system, heat is rejected in condenser.

7. Ammonia is used in domestic refrigerator as refrigerant.

8. For domestic refrigerator, condenser is natural air cooled type.

9. For ice plants and cold storages, ammonia is used as refrigerant

10. For domestic refrigerator, open type compressor is used

Answer

1. True	2. False	3. True	4. True	5. False
6. True	7. False	8. True	9. True	10. False

FILL IN THE BLANKS

1. The principal types of compressors are:

(1) …………………………

(ii) ....……………………....

2. In a semi-hermetically sealed unit, the .... be detached from the compressor for field repair.

3. In a hermetically sealed unit, the motor remains ……………... the shell.

4. The evaporators are divided into the following two classes with reference to
circulation of refrigerant:
(i) ………………………
(ii) ……………………..

5. In a capillary tube regulator, the necessary pressure drop is provided by
……………………

Answers

1. (i) Reciprocating compressors
   (ii) Rotary compressors
2. motor
3. inside
4. (i) Flooded type evaporator
   (ii) Dry expansion evaporator
5. Throttling expansion.

SHORT ANSWER TYPE QUESTIONS

1 (i) Which type of compressor is used in
  (a) Window type air-conditioner
  (b) Domestic refrigerator
  (ii) What is the function of solenoid valve?
  (iii) What type of evaporator is used in domestic refrigerators?
  (iv) Name various devices used for expansion of liquid refrigerants.
  (v) Why receiver is not used on a system provided with capillary tube?
2. What is the function of a compressor in a refrigeration system?
3. How compressors are classified?
4. Give some advantages of a hermetically sealed unit over an open unit.
5. Discuss the merits of a centrifugal compressor over a reciprocating compressor.
6. Explain the working of a rotary compressor by drawing a neat sketch.
7. What is the function of a condenser in refrigeration system? Give the main types of condensers in use with specific application of each type.
8. Describe briefly how a spray pond works?
9. Give two advantages of forced draft towers over induced draft towers.
10. Explain the difference between a flooded evaporator and a dry expansion evaporator.
11. Give the important types of evaporators with specific application of each type.
12. Explain the working of a thermostat valve by drawing a neat sketch.
13. What is the function of a capillary tube? Why a receiver is not used on the system provided with a capillary tube?
14. Give a few safety devices provided on a refrigeration system.
15. State the merits of hermetically sealed compressor over open compressor units.

UNIT-4

BASIC ELECTRICITY

Electromotive Force (EMF)

It is the maximum potential difference across the terminals of a source of an electric current which causes to flow the electrons in any closed circuit. The unit of electromotive force is 'VOLT'.

Potential Difference

The potential difference (V) between two points in any circuit is an electrical pressure or voltage required to drive the current between them. It is measured in 'volts'.

Electric Current

An electric current is a flow of particles (electrons) flowing through wires and components. It is the rate of flow of charge. In the circuits using metallic wires, electrons constitute a flow of charges. It is represented by 'I'. The unit of current is 'Ampere (A)'.

Resistance

The resistance may be defined as the property of a substance which opposes the flow of electric current through it. It is represented by 'R'. The unit of resistance is ohm 'Ω'. Resistances are said to dissipate electric energy as heat.

Volt

It is defined as the potential difference across a resistance of one ohm carrying a current of one ampere.

Power

Power is the rate of doing work.

$$P = \frac{W}{t}$$

'P' denotes the power, 'w' denotes work and 't' denotes the time.

The electrical unit of power is 'Joule/second', called 'Watt (w)'. The bigger unit of power is kilowatt (kW).

Energy

Energy is defined as the capacity of doing work.

Energy may exist in several forms and may be changed from one form to another. For example, Lead acid battery changes chemical energy into electrical energy on discharge and vice-versa. A generator changes mechanical energy into electrical energy. The unit of energy under electrical consumption is watt hour or kilowatt hour (kWh).

OHM'S LAW

This law is related to current, voltage and resistance. Ohm's law states that the current is directly proportional to voltage and inversely proportional to resistance, provided the physical conditions namely temperature etc remain constant thus,

$$I \propto V$$

$$I \propto \frac{1}{R}$$

So that

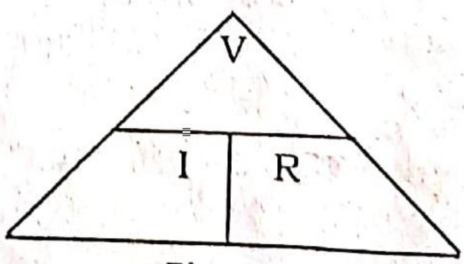


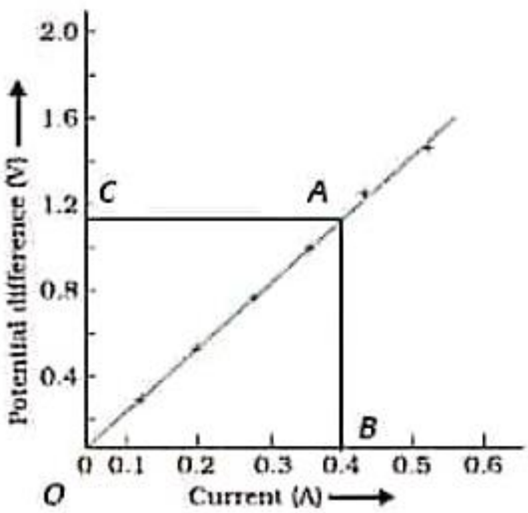
Fig. 2.1 :

$$I = \frac{V}{R} \quad \text{(i)}$$

$$V = I \times R \quad \text{(ii)}$$

$$R = \frac{V}{I} \quad \text{(iii)}$$

Representation on V-I graph



Alternating Current (A.C.)

An electric current which changes in direction after every half cycle is called an alternating current. It varies sinusoidal as shown in figure. In our domestic electric supply alternating current is used for various electrical appliances like T.V., heater, refrigerator etc.

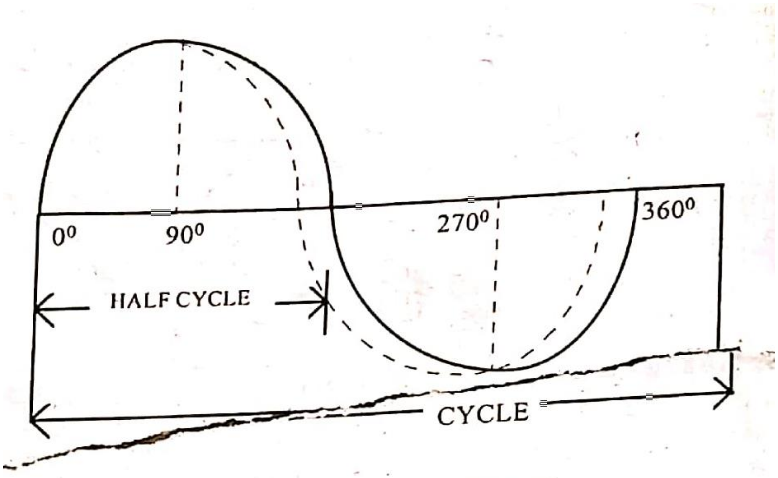


Fig 2.6 : AC Current

Frequency: A.C. has certain frequency and it is defined as the number of cycles per second.

Direct Current (D.C.)

It is another form of current which does not changes its direction and magnitude and is steady at all the times. The cells and dynamos or generators give pure D.C.

Advantages of A.C. over D.C.

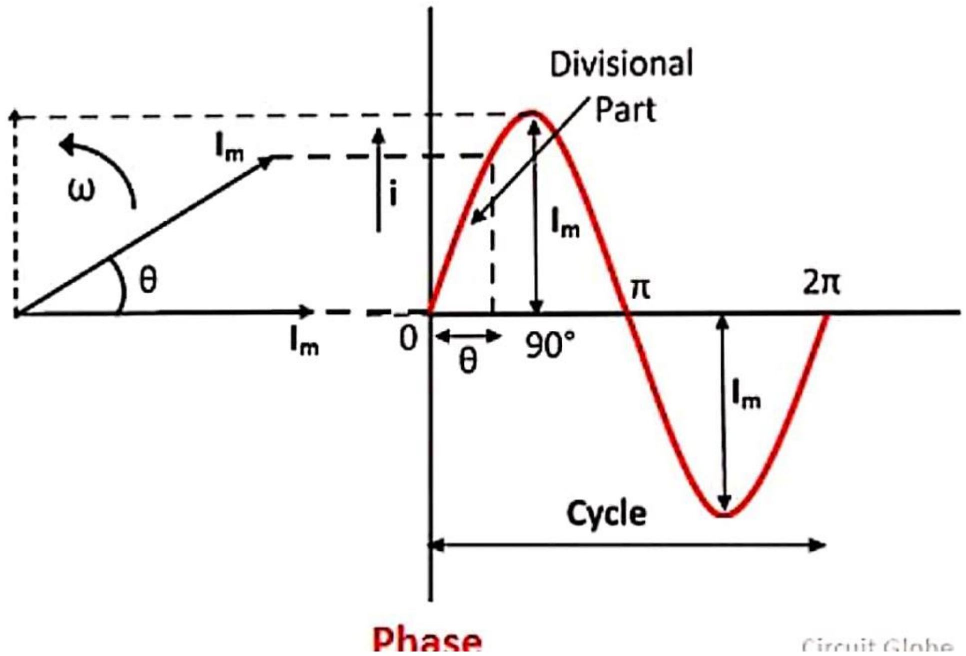
- A.C. can generate more voltage than D.C. (for example A.C. can generate up to 33,000 volts whereas D.C. can generate 650 V only)
- A.C. voltage can be increased and decreased with the help of transformer. Whereas D.C. cannot be changed.
- A.C. can be converted into D.C. easily when and where required but D.C. cannot be converted to A.C. so easily. It will not be so economical too.

Difference between dc current and ac current

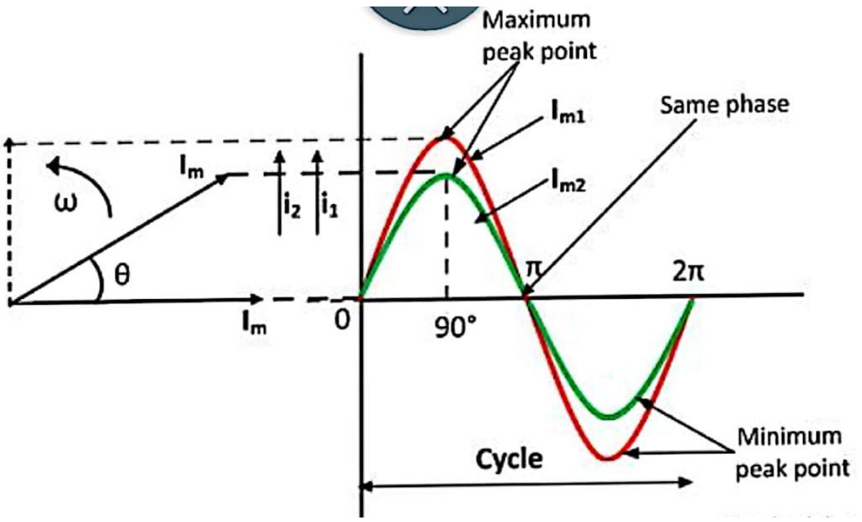
===DC current	===AC current
IN DC current, electric charge flow only in ıe direction.	≥ IN ac current, electric charge changes its direction periodicly.
DC current can not transfer at long distance ɜcause of very large energy loss.	≥ Ac current safe travel at long distance.
The frequencies of dc current is zero.	≥ The generating frequencies is 50 hz to 60 hz in ac current.
: The current of ɲagnitude verying with ime is constant.	≥ The current of magnitude verying with time.
: The source of availability is battery or cell.	≥ The source of availability is generator or mains.
≥ IN dc circuit have only resistance.	≥ IN Ac circuit have resistance with capacitor and inductor.
≥ Power factor is always 1.	≥ IN ac power factor laies between o to 1.
≥ Its wave form are pure and pulsating.	≥ Its wave are sinusoidal, tringular, square, quasi square wave.

Phase

The phase of an alternating quantity is defined as the divisional part of a cycle through which the quantity moves forward from a selected origin. When the two quantities have the same frequency, and their maximum and minimum point achieve at the same point, then the quantities are said to have in the same phase.

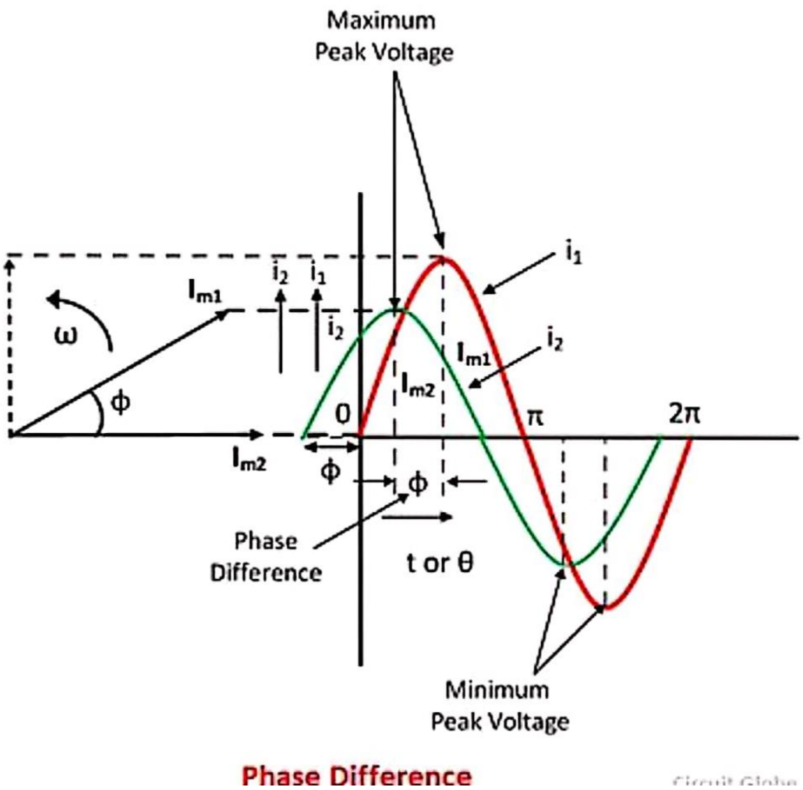


Consider the two alternating currents Im1 and Im2 as shown in figure below. Both the quantity attains their maximum and minimum peak point at the same time. And the zero value of both the quantities establishes at the same instant.



Phase difference

The phase difference between the two electrical quantities is defined as the angular phase difference between the maximum possible values of the two alternating quantities having the same frequency.



In other words, the two alternating quantities have phase difference when they have the same frequency, but attain their zero value at the different instant. The angle between zero points of two alternating quantities is called angle of phase differences. As shown in the figure, the phase difference angle is Ø.

Polyphase system

When a system has more than one phase, it is called polyphase system. For example there can be 2 phase, 3 phase etc.

(i) 2 Phase System

The alternator producing two phase supply has two windings, kept in such a way that phase difference between them is 90^0 as shown in figure.

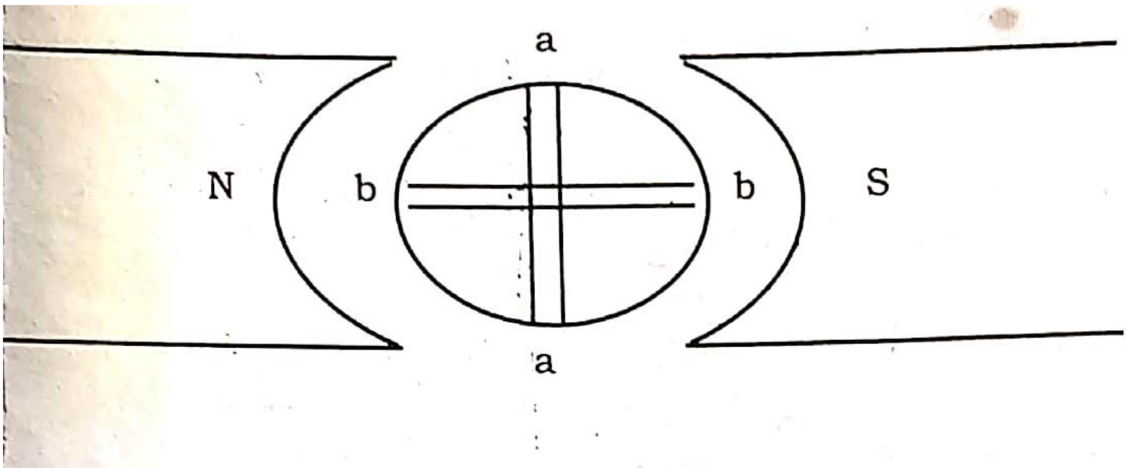


Fig 2.7 : 2[1] phase system

In such a supply the voltage between phase and neutral is 220 volts. (Single Phase)

(ii) 3 Phase System

3 phase alternator consists of 3 windings placed in such a way that the phase difference between them is 120^0.

Figure shows, in such supply the voltage between any two phase will be 440V.

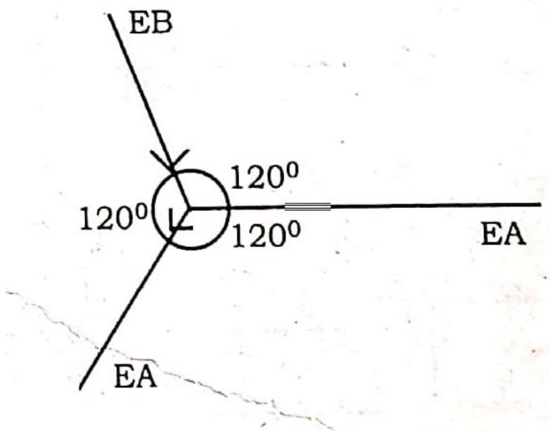


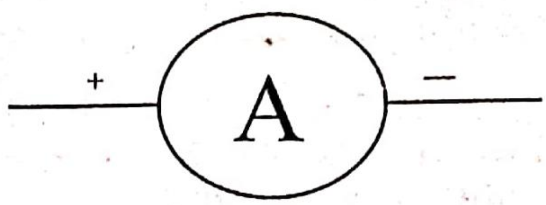
Fig 2.8 : 3 Phase System

Testing Instruments

There are number of testing instruments in the field of electricity. But some important of them are described here.

(i) Ampere meter

Ampere meter is used for measuring the current in a circuit drawn by any load of circuit. These are also called Ammeter. It is always connected in series circuit in supply as shown in figure.

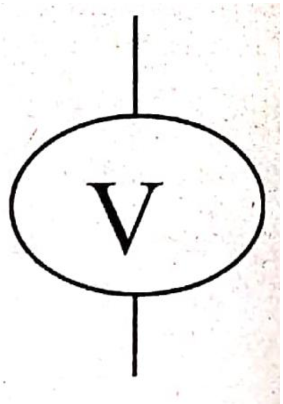


Ampere meters are available in the range of 0 to 5 Ampere, 0 to 15 Ampere, 0 to 30 Ampere, and above scales.

(ii) Voltmeter

Voltmeter is used for measuring the voltage of main supply and/or electricity circuit. It is always connected in parallel circuit in main supply as shown in figure.

Voltmeters are available in the range of 0 to 300 V for single phase line and 0 to 440 volts for three phase line in different shapes like square and round.



(iii) Multimeter (AVO Meter)

It is also known as Ampere-volt and ohm meter (AVO meter). By using multimeter A.C. voltage, D.C. voltage, D.C. current and resistance in ohms can be checked. Now-a-days mostly Digital or Analog multimeters are used.

Connection of Ammeter and Voltmeter

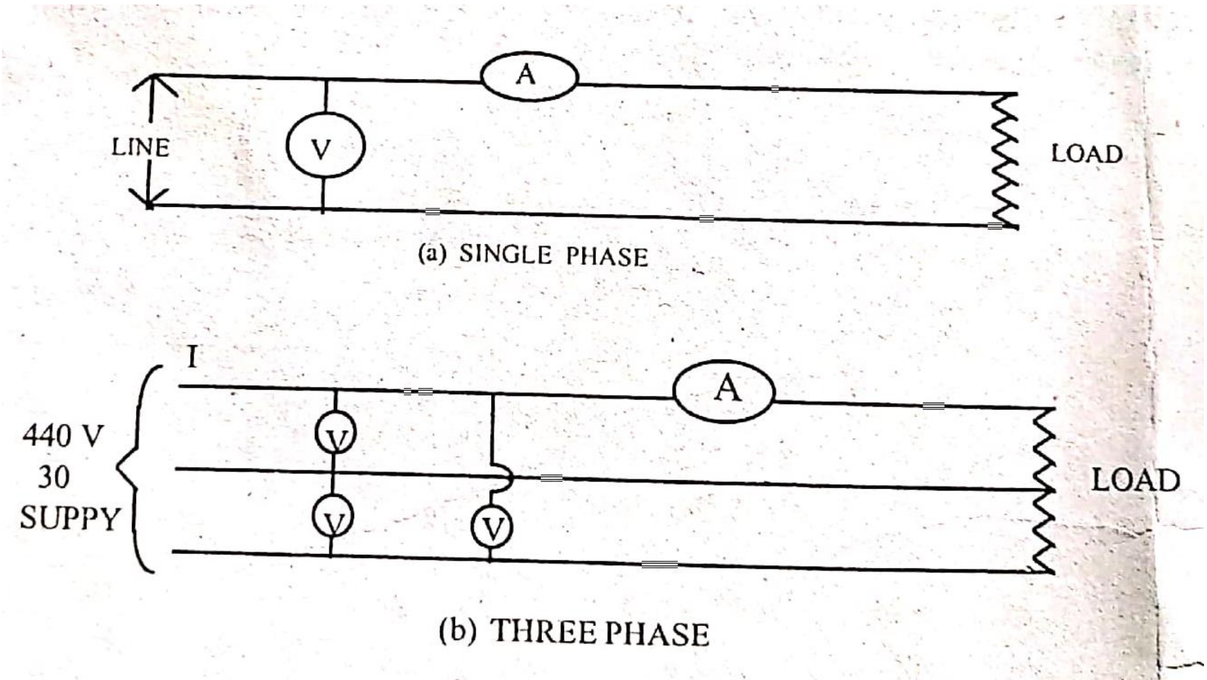
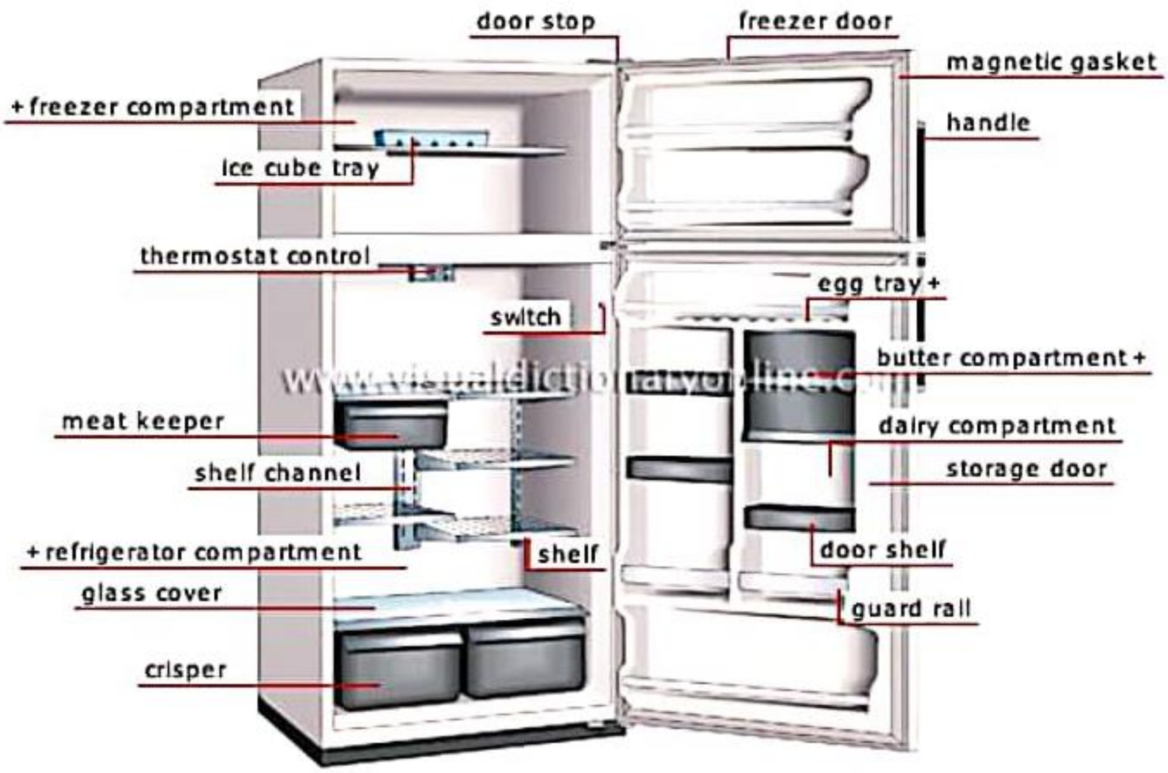


Fig 2.9 : Connections of ammeter and voltmeter

Wiring Circuit Diagram of Refrigerators



Name of the Electrical Parts of a Refrigerator

The following parts are fitted in refrigerator.

1. Compressor motor
2. Starting Relay
3. Thermostat
4. Thermal Overload Protector or Release
5. Cabinet Light
6. Door Switch

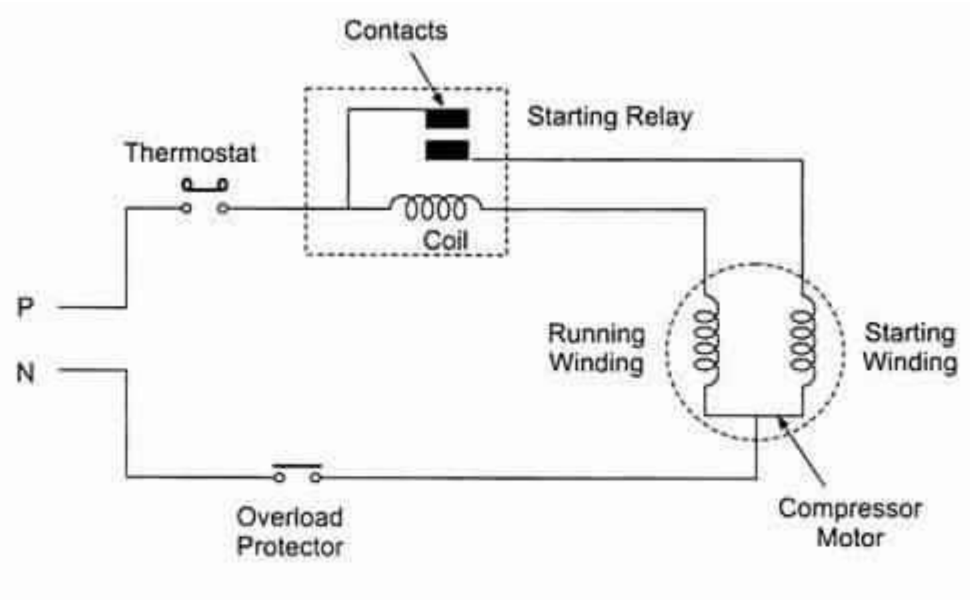


Fig. 6.6 *Electrical Circuit of Domestic Refrigerator*

A brief description of each part, along with its function, is as follows:

1. **Compressor Motor**

   It may be a DC motor. Since we have mostly AC supply sp AC motor is used which work on 220 volts 50 Hz supply. These are usually fractional horse power (F.H.P.) motors of about 1/8 H.P. The Induction type motors commonly used are single phase split phase type and they are not rated for continuous rating but for intermittent rating as the refrigerator motor works for some time and then stops and remain stopped for some time again.

   The size of the motor depends upon the capacity of the refrigerator.

   As shown in the figure above both starting and running windings are in parallel. The high resistance winding of a split phase motor and a capacitor is connected to give the necessary phase shift in order to make the motor self-starting. As the motor pick up the speed, the starting relay cut-out the starting winding. Thereafter, the motor continues to run only on running winding. Each time the motor starts, the sequence is repeated. Mostly the motor and compressor are in one unit, known as a sealed unit.

2. **Starting Relay**

   The relay is of electro-magnetic type and used for making or breaking the contact of starting winding with the supply. It essentially consists of two N.C. contacts in series with the starting winding. Relay coil is placed in series with running winding.

In the start both windings are in parallel with the supply and motor starts. As it picks up speed, the sufficient voltage is induced in starting winding and attracts the armature. This opens N.C. contacts and starting winding cut-off. Now the motor will run only with running winding.

3. Thermostat

It is a thermal switch. As soon as the temperature reaches -7^{0}C in the freezer and 10^{0}C in other parts of the fridge (domestic fridge), the thermostat automatically cuts off the supply to the machine. After some time, when the temperature rises in the refrigerator, it again receives the supply to the machine automatically.

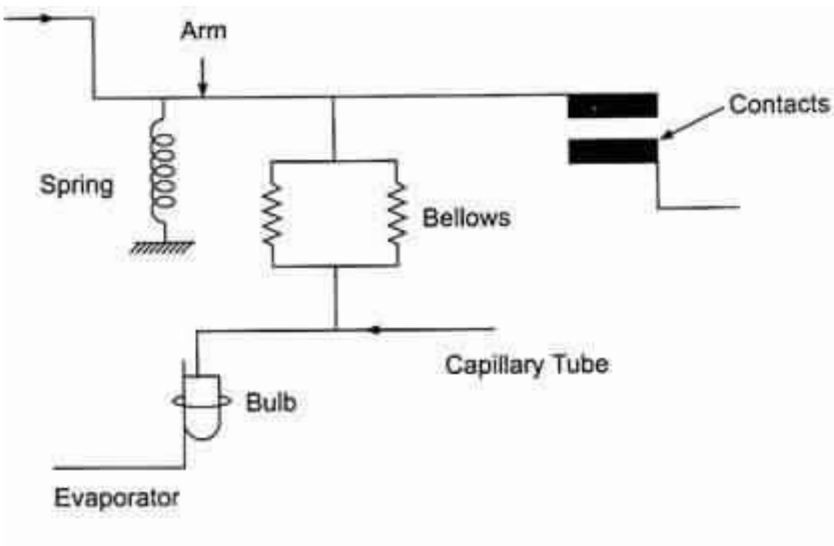


Fig. 6.8

The thermostat has setting from 0 to 10. But as precautions, it should not be set beyond 3 as it overloads the refrigerator, which ultimately reduces its efficiency and life. The two mechanisms, bimetal control and sensing bulb control, used in thermostats.

4. Thermal Overload Relay (OLR)

The thermal OLR is a protective device for the protection of the compressor motor unit of the refrigerator. It has bimetals and a heating resistance. As soon as the temperature of the compressor, due to any reason, rises beyond safe limits, the OLR automatically trips and disconnects the supply to the motor.

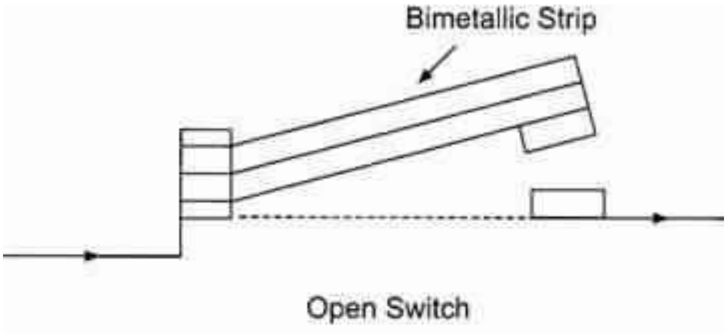


Fig. 6.9(b) *Open Switch*

It is connected in series with the motor circuit. Whenever excess current flows through the motor, due to any reason, the bimetals are heated. This interrupts the supply, thus motor is protected.

5. Lamp and Switch Circuit

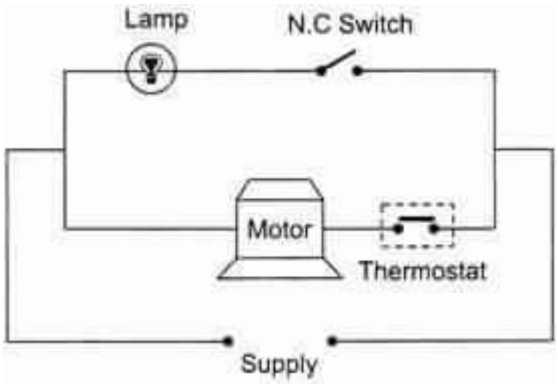


Fig. 6.7

The switch is fitted in the door of the cabinet. So long as the door of the refrigerator is closed, the switch remains open and the lamp remains off. As soon as the door is opened, the circuit is completed and the lamp is switched on. The user can trace and place commodities in the refrigerator. The lamp is automatically switched off as the door is closed. This saves consumption of electrical energy.

6. Body

The whole body of the refrigerator is made of double walled cabinet which is packed with high thermal insulation material like fibre glass, cork, expanded rubber etc. so that the heat from outside atmosphere does not leak into the refrigerator. The cabinet is made air-tight by providing a soft rubber seal all around the inside of the door.

Air Conditioner

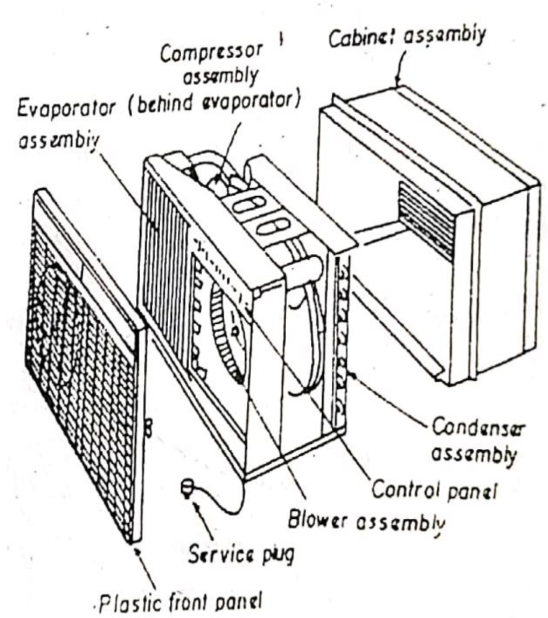


Fig 19.3 : Parts of Window Type Air Conditioner

The main parts of a window type air-conditioner are as given below:

1. Chassis or outer cover.
2. Air-conditioning machine part:
   (a) Base plate
   (b) Compressor
   (c) Condenser coil
   (d) Cooling coil
   (e) Blower motor (Double shaft)
   (f) Blower
   (g) Condenser fan
   (h) Exhaust Air damper
   (i) Fresh Air damper
   (j) Front grill or
   (k) Front grill with auto swing motor
   (l) Air filters

3. Electrical parts

(a) Overload protector
(b) Voltage type relay
(c) Starting capacitor
(d) Running capacitor
(e) Selector switch
(f) Thermostatic switch
(g) Blower motor.

Electrical parts

The description of various electrical parts in an air conditioner is given below:

(a) Over load protector:

It is used to protect an electric motor against drawing excess current. It is always connected in series with compressor motor.

(b) Voltage Type Relay:

The purpose of this relay is to start a sealed compressor. When it reaches around 75% of its rated speed it disconnects starting capacitor from the circuit.

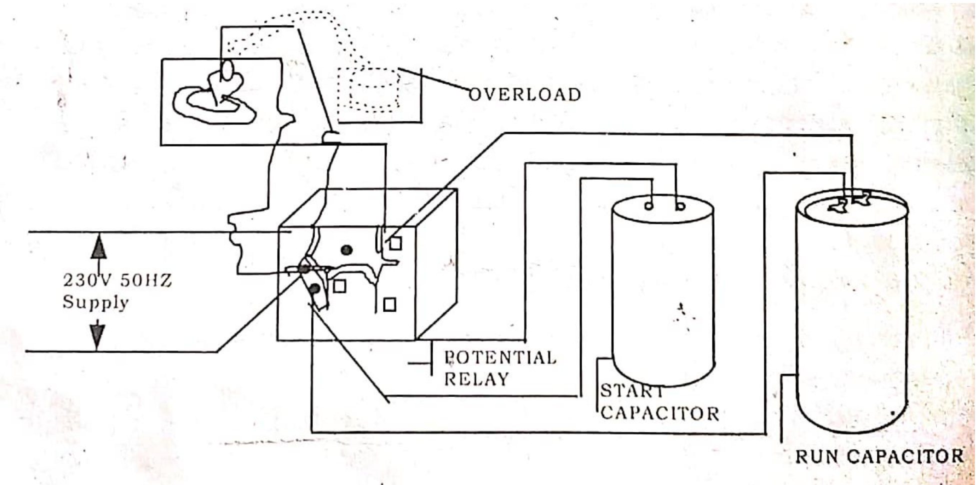


Fig 19.4 : wiring diagram of an Air Conditioner

(c) Starting Capacitor:

It is used to give an extra torque to a sealed compressor motor at the time of start, and the motor then starts easily. These capacitors are manufactured in the range i.e. 80-100µF, 100-120µF etc.

(d) Running Capacitor:

It is used to give extra torque to the sealed compressor motor at the time of start and to eliminate the back E.M.F. (Back electromotive force).

(e) Selector switch:

It is fitted on an air conditioner. It is used to switch on and off the air conditioner. There are two types of selector switch:

(1) Rotary type (2) Piano type or push button type

(f) Thermostatic Switch:

It is used to control the temperature of the air conditioned space. The terminal bulb of the thermostatic switch is kept in front of the cooling coil in the circulating air. When the temperature of the circulating air in the air-conditioned room reaches the desired temperature for which the switch is adjusted the compressor takes stops. In this way the compressor takes the rest for some time. And when the temperature of the circulating air increases this switch again starts the compressor. Thus, with the help of this switch the desired temperature is maintained in an air-conditioned room and during this the compressor also takes some rest.

UNIT-5

Psychrometry and Human Comfort

Psychrometry

The psychrometry 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 behaviour of dry air and water vapour mixture under various sets of conditions.

Psychrometric Terms

Though there are many psychrometric terms, yet the following are important from the subject point of view:

1. **Dry air.**
   The pure dry air is a mixture of a number of gases such as nitrogen, oxygen, carbon-dioxide, hydrogen, argon, neon, helium etc. But the nitrogen and oxygen have the major portion of the combination.
   The dry air is considered to have the composition as given in the following table.

Table 15·1. Composition of dry air.

S. No.	Constituent	By volume	By weight
1.	Nitrogen (N_2)	78·03%	75·47%
2.	Oxygen (O_2)	20·99%	23·19%
3.	Argon (Ar)	0·94%	1·29%
4.	Carbon-dioxide (CO_2)	0·03%	0·05%
5.	Hydrogen (H_2)	0·01%	—

2. **Moist air.**

It is a mixture of dry air and water vapour. The amount of water vapour, present in the air, depends upon the absolute pressure and temperature of the mixture.

3. **Vapours and gases.**

Differences between a vapour and a gas are as follows:

(i) A gas has one defined state at room temperature whereas a vapour is a substance that is in gaseous and liquid equilibrium at room temperature, at a given pressure. For example, air has oxygen, nitrogen, neon etc. as gases and also has water vapours.

(ii) Because vapour is actually the gaseous state of an element, vapour particles will be of a single element and may have a definite shape whereas gas particles when observed under microscopic view do not have a definite shape and will be a collection of atoms, ions, electrons and molecules.

4. **Saturated air.**

It is a mixture of dry air and water vapour, when the air has diffused the maximum amount of water vapour into it. The water vapour, usually, occur in the form of superheated steam as an invisible gas. However, when the saturated air is cooled, the water vapour in the air starts condensing, and the same may be visible in the form of mist, fog or condensation on cold surfaces.

5. **Degree of saturation.**

It is the ratio of actual mass of water vapour in a unit mass of dry air to the mass of water vapour in the same mass and pressure of dry air when it is saturated at the same temperature.

6. **Humidity.**

It is the mass of water vapour present in 1 kg of dry air, and is generally expressed in terms of gm per kg of dry air. It is also called specific humidity or humidity ratio.

7. **Absolute humidity.**

   It is the mass of water vapour present in 1 m^3 of dry air, and is generally expressed in terms of gm per cubic meter of dry air. It is also expressed in terms of grains per cubic meter of dry air. Mathematically, one kg of water vapour is equal to 15,430 grains.

8. **Relative humidity.**

   It is the ratio of actual mass of water vapour in a given volume of moist air to the mass of water vapour in the same volume of saturated air at the same temperature and pressure.

9. **Dry bulb temperature.**

   It is the temperature of air recorded by a thermometer, when it is not affected by the moisture present in the air. The dry bulb temperature is generally denoted by td or tdb.

10. **Wet bulb temperature.**

    It is the temperature of air recorded by a thermometer, when its bulb is surrounded by a wet cloth exposed to the air. Such a thermometer is called wet bulb thermometer. The wet bulb temperature is generally denoted by tw or twb.

11. **Wet bulb depression**.

    It is the difference between dry bulb temperature and wet bulb temperature at any point. The wet bulb depression indicates relative humidity of the air.

12. **Dew point temperature.**

    It is the temperature of air recorded by a thermometer, when the moisture (water vapour) present in it begins to condense. It is, usually, denoted by tdp. For saturated air, the dry bulb temperature, wet bulb temperature and dew point temperature is same.

13. **Dew point depression**.

    It is the difference between the dry bulb temperature and dew point temperature of air.

Psychrometric chart

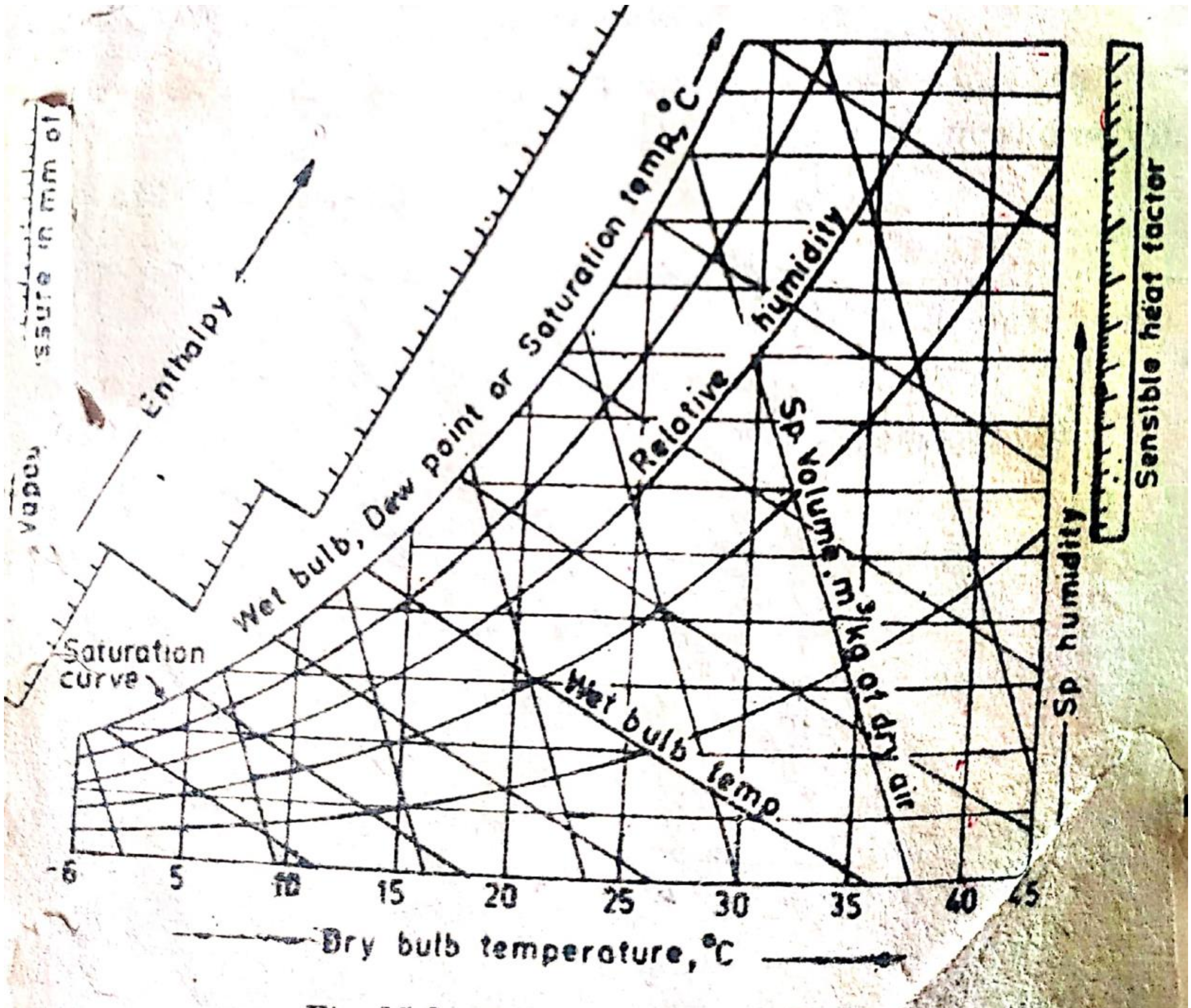


Fig. 15·6. Psychrometric chart.

It is a graphical representation of the various thermodynamic properties of moist air. The psychrometric chart is very useful for finding out the properties of air (which are required in the field of air conditioning) and eliminate lot of calculations. There is a slight variation in the charts prepared by different air-conditioning manufactures but basically they are all alike.

In a psychrometric chart dry bulb temperature is taken as abscissa and specific humidity i.e. moisture contents as ordinate as shown in figure. Though the psychrometric chart has a number of details yet the following lines are important from the subject point of view:

1. Dry bulb temperature lines.

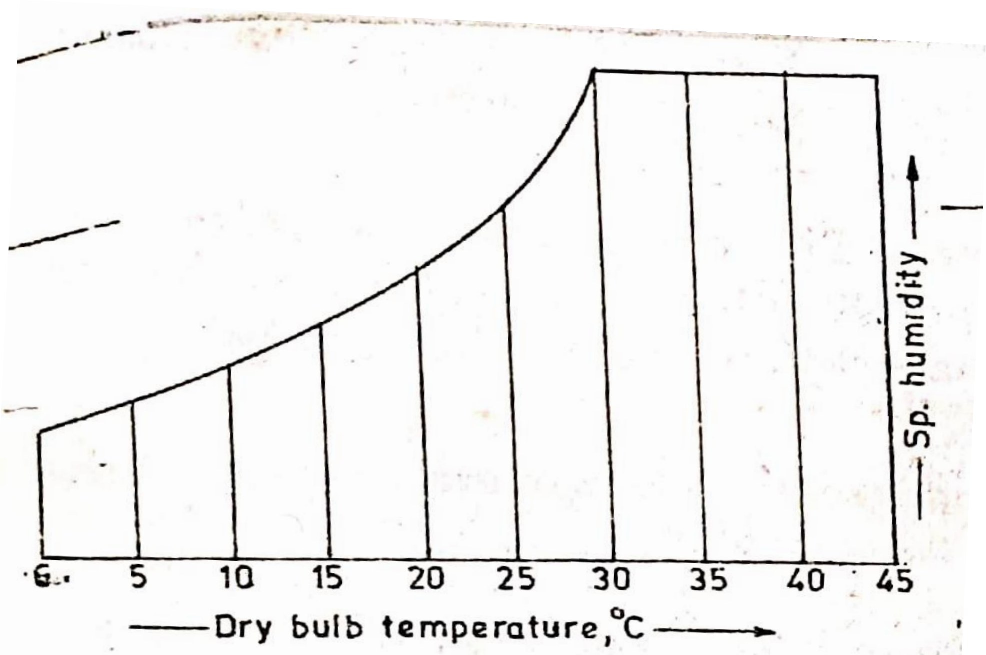
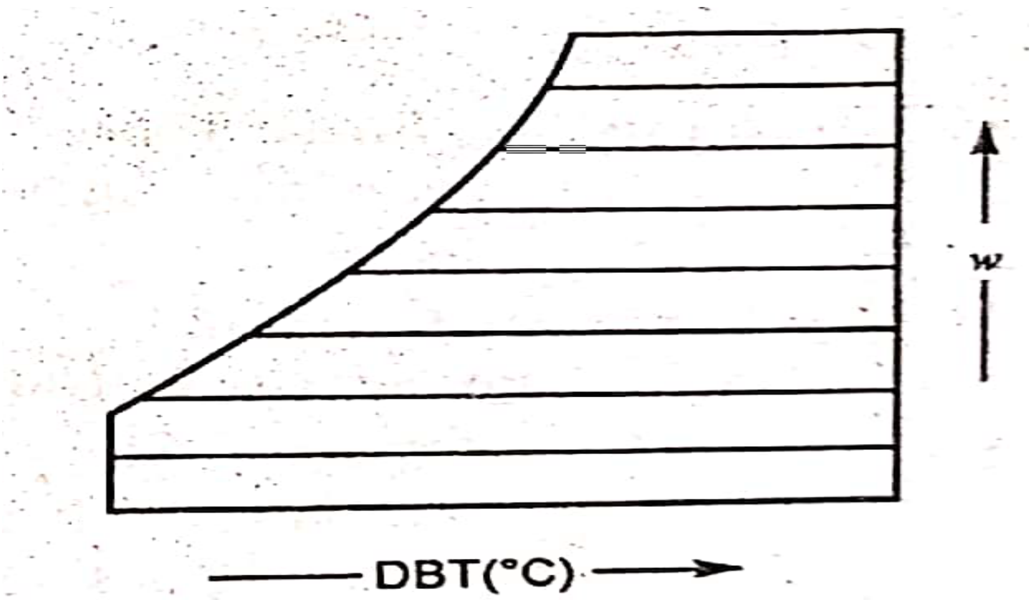


Fig. 15·7 Dry bulb temperature lines.

The dry bulb temperature lines are vertical i.e. parallel to the ordinate and uniformly spaced as shown in figure. Generally, the temperature range of these lines on psychrometric chart is from -6^{0}C to 45^{0}C. The dry bulb temperature lines are drawn with difference of every 5^{0}C and upto the saturation curve as shown in figure. The values of dry bulb temperatures are also shown on the saturation curve.

2. <u>Specific humidity or moisture content lines.</u>



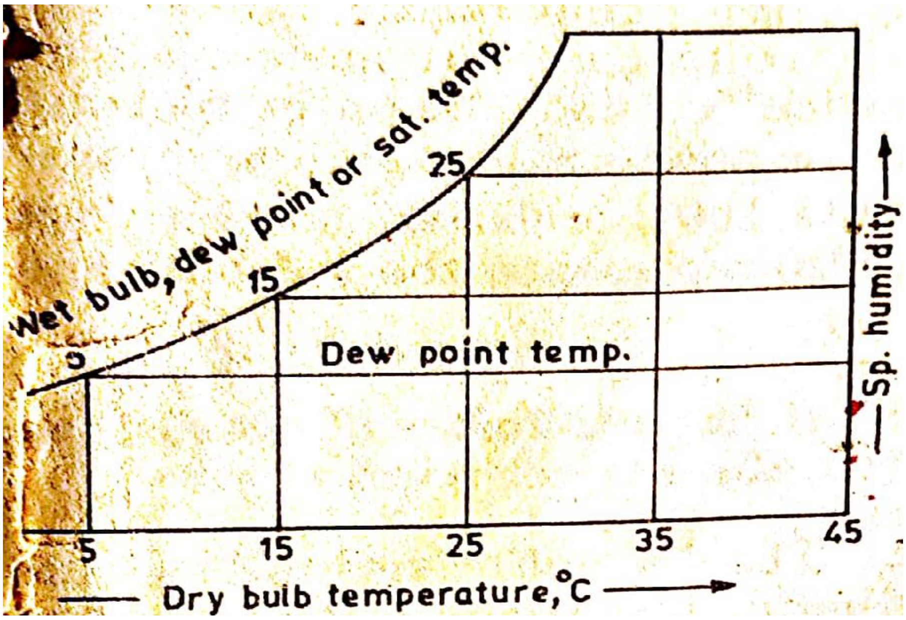
(iii) Humidity ratio lines

The specific humidity (moisture content) lines are horizontal i.e. parallel to the abscissa and are also uniformly spaced as shown in figure. Generally, moisture content range of these lines on psychrometric chart is from 0 to 30 gm/kg of dry air. These lines are drawn with a difference of every 1gm (or o.oo1kg) and up to the saturation curve as shown in figure.

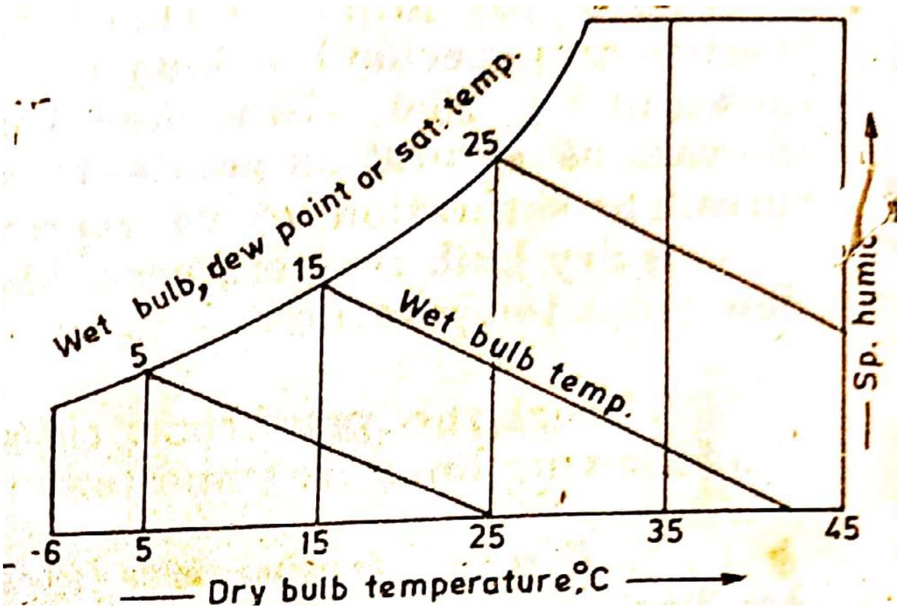
3. Dew point temperature.

The dew point temperature lines are horizontal i.e. parallel to the abscissa and non-uniformly spaced as shown in figure. At any point on the saturation curve, the dry bulb temperatures and the dew point temperatures are equal.

The values of dew point temperatures are generally given along the saturation curve of the chart as shown in the figure.



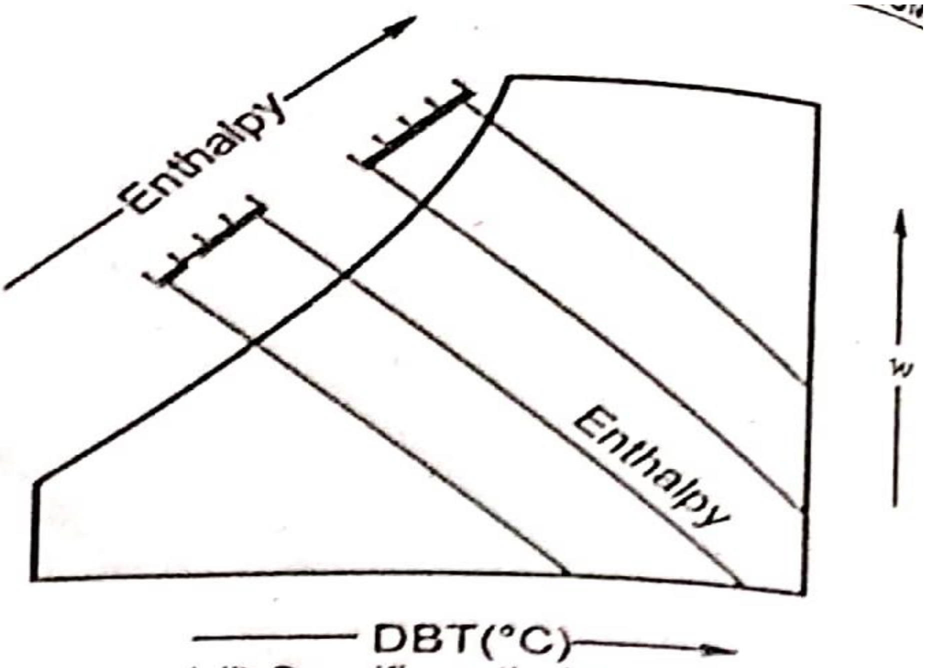
4. Wet bulb temperature lines.



The wet bulb temperature lines are inclined straight lines and non-uniformly spaced as shown in figure. At any point on the saturation curve, the dry bulb temperatures and the wet bulb temperatures are equal.

The values of wet bulb temperatures are generally given along the saturation curve of the chart as shown in figure.

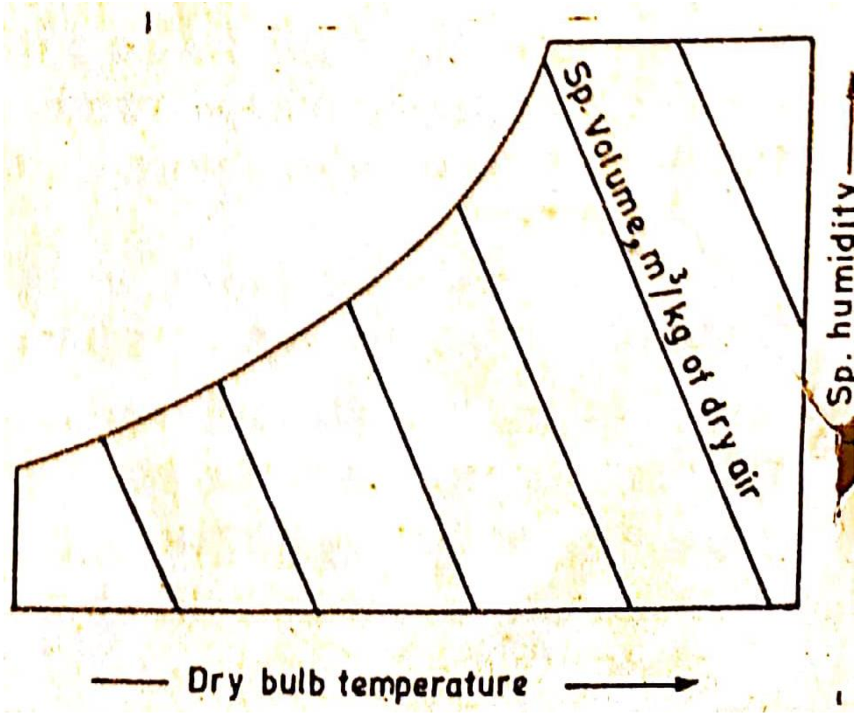
5. **Enthalpy (total heat) lines.**



(vii) Specific enthalpy lines

The enthalpy (or total heat) lines are inclined straight lines and uniformly spaced as shown in figure. These lines are parallel to the wet bulb temperature lines, which are drawn up to the saturation curve. Some of these lines coincide with the wet bulb temperature lines also.

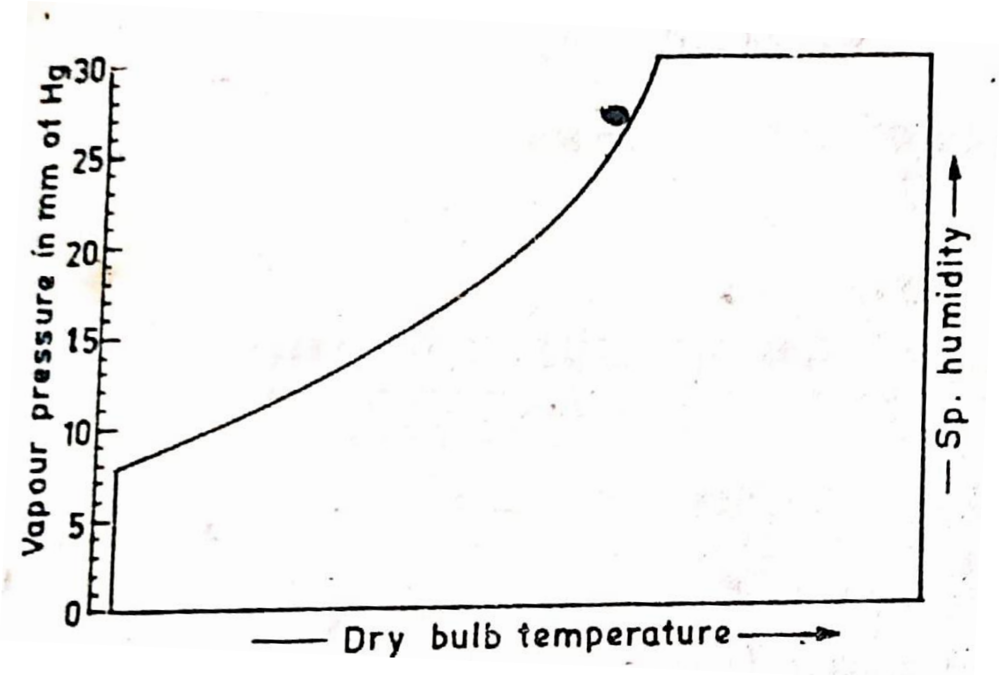
6. **Specific volume lines.**



The specific volume lines are obliquely inclined straight line and uniformly spaced as shown in figure. These lines are drawn up to the saturation curve.

The values of volume lines are generally given at the base of the chart.

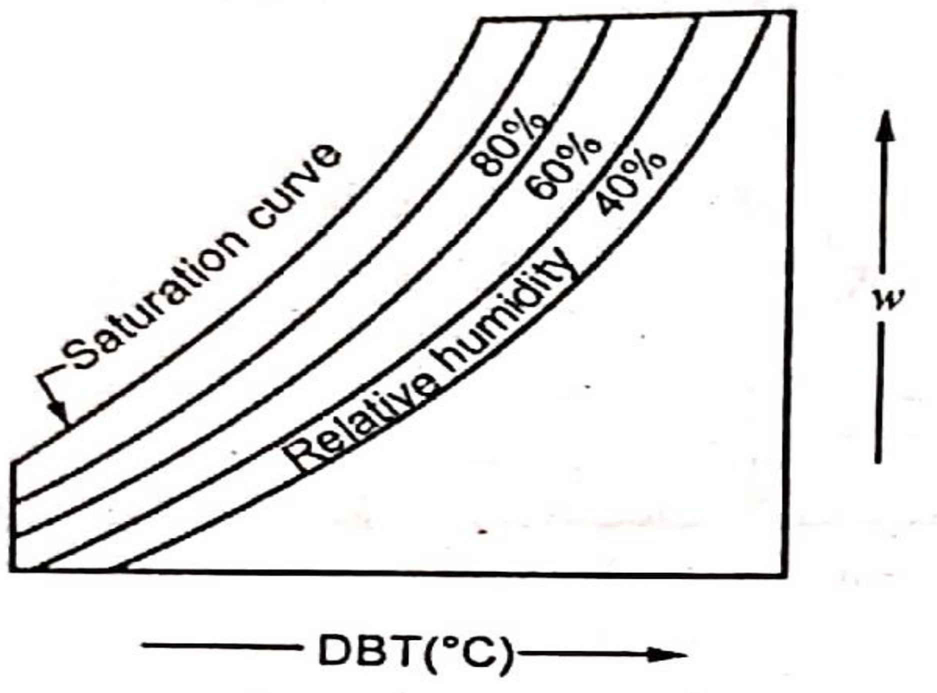
7. **Vapour pressure lines**.



The vapour pressure lines are horizontal and uniformly spaced. Generally, the vapour pressure lines are not drawn in the main chart. But a scale showing vapour pressure in mm of Hg is given on the extreme left side of the chart as shown in figure.

8. Relative humidity lines.

The relative humidity lines are curved lines and follow the saturation curve. Generally, these lines are drawn with values 10%, 20%, 30% etc, and upto 100%. The saturation curve represents 100% relative humidity.



(viii) Relative humdiity lines

The values of relative humidity lines are generally given along the lines themselves as shown in figure.

Human Comfort

There are many definitions given for this term 'human comfort' by different bodies. But the most accepted 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 condition of mind, which expresses satisfaction with the thermal environment.

Factors Affecting Human Comfort

In designing winter and summer air conditioning system, the designer should be well conversant with a number of factors which physiologically affect human comfort. The important factors include,

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, and
8. Air stratification.

Effective temperature

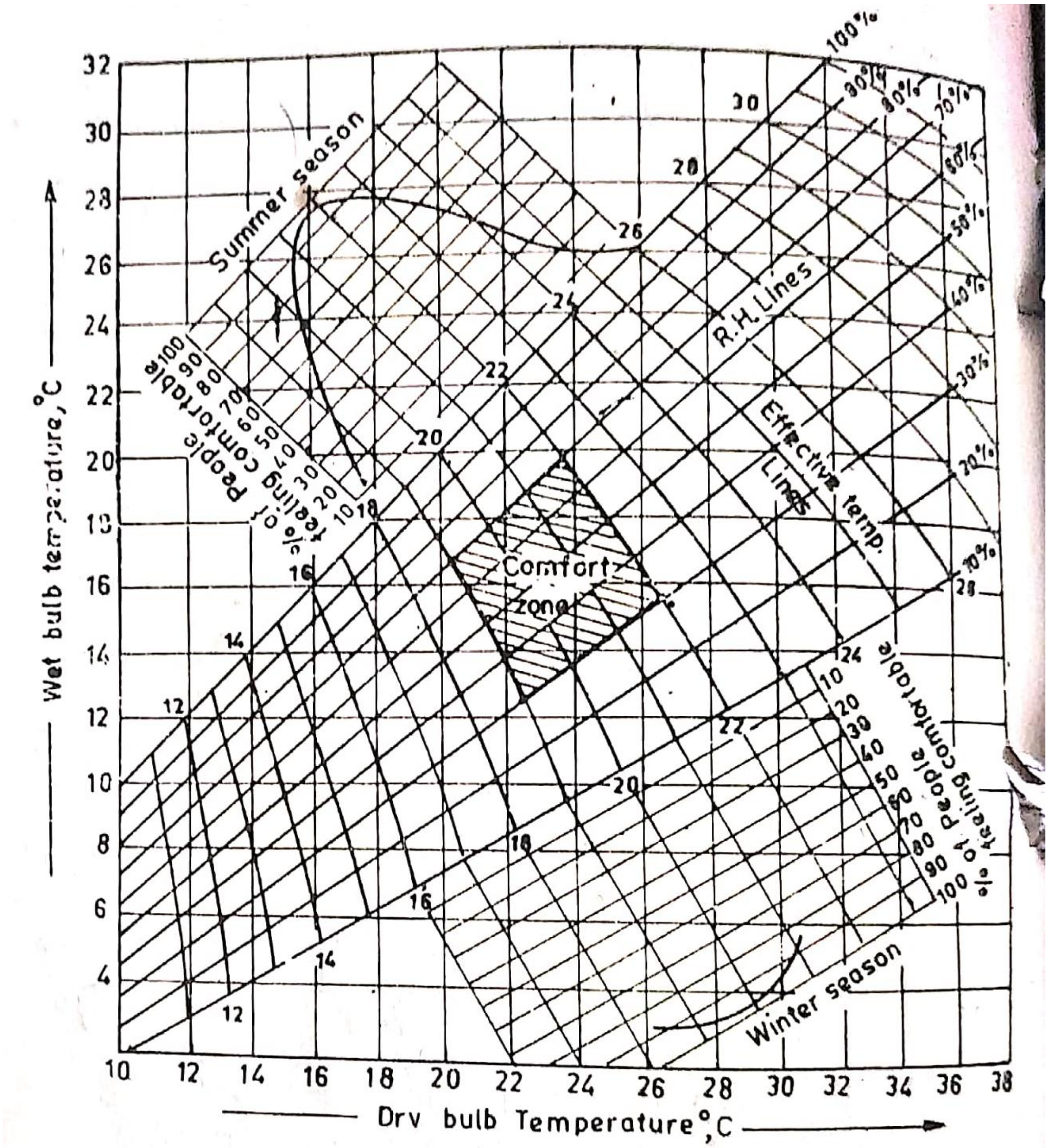
The degree of warmth or cold felt by a human body depends mainly on the following three factors.

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

In order to evaluate the combined effect of these factors, the term effective temperature is employed. It is defined as that index which correlates the combined effects of air temperature, relative humidity and air velocity on the human body.

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). It is applicable to reasonably still air (5 to 8 m/min air velocity) to situations where occupants are seated at rest or doing light work and to spaces whose enclosing surfaces are at a mean temperature equal to the air dry bulb temperature.

Comfort chart



The comfort chart shows the range for both summer and winter condition within which a condition of comfort exists for most people. For summer conditions, the chart indicates that a maximum of 98% people felt comfortable for an effective temperature of 21.6^{0}C. For winter conditions, chart indicates that an effective temperature of 20^{0}C was desired by 97.7 percent. It has been found that for comfort, women require 0.5^{0}C higher effective temperature than men. All men and women above 40 years of age prefer 0.5^0C higher temperature than the persons below 40 years of age.

The comfort conditions for persons at work vary with the rate of work and the amount of clothing worn. In general, the greater the degree of activity, the lower the effective temperature necessary for comfort.

Factors Affecting Optimum Effective Temperature

The important factors which affect the optimum effective temperature are as follows:

1. Climatic and seasonal differences.
   It is known fact that the people living in colder climates feel comfortable at lower effective temperatures than those living in warmer regions.
2. Clothing.
   It may be noted that the person with light clothing need less optimum temperature than a person with heavy clothing.
3. Age and Sex.
   We have already discussed that the women of all ages require higher effective temperature (about 0.5^0C) than men. Similar is the case with young and old people. The children also need higher effective temperature than adults. Thus, the maternity halls are always kept at an effective temperature of 2 to 3^0C higher than the effective temperature used for adults.
4. Duration of stay.
   It has been established that if the stay in a room is shorter (as in the case of persons going to banks), then higher effective temperature is required than that needed for long stay (as in the case of persons working in an office).
5. Kind of activity.
   When the activity of the person is heavy such as people working in a factory, dancing hall, then low effective temperature is needed than for the people sitting in cinema hall or auditorium.

6. Density of occupants.
   The effect of body radiant heat from person to person particularly in a densely occupied space like auditorium is large enough which require a slight lower effective temperature.

UNIT 6

APPLICATIONS OF AIR CONDITIONING

1.1. DEFINITION

Air Conditioning may be defined as the process by which the temperature of a given space or a substance is lowered below that of the atmosphere or surroundings. The system maintained at the lower temperature is known as refrigerated system while the equipment used to maintain this lower temperature is known as the refrigerating equipment. In order to maintain a temperature below the surrounding atmosphere, it is essential that whatever amount of heat gets into air conditioned space, must be extracted out to maintain the desired temperature

The cooling effect may be obtained by any of the following principles:

(i) By chemical means in which case a chemical reaction is carried out which absorbs heat for its completion. The heat required for the purpose is taken from the substance or space to be cooled.

(ii) (ii) By bringing the substance to be cooled directly or indirectly in contact with some cooling medium such as chilled water or ice from which heat has already been removed either naturally or otherwise.

(iii) (iii) By using mechanical or heat energy to operate a "heat pump" by which heat may be abstracted from a low temperature region and rejected, together with the energy required to sustain the process, to a region of high temperature.

1.2. APPLICATIONS OF REFRIGERATION / AIR CONDITIONING

The applications of refrigeration are numerous in our daily life. Some of them are given as below:

1. Comfort air conditioning of auditoriums, hospitals, residences, hotels,
Showrooms, dancing halls, offices etc.

2. Manufacture and preservation of medicines. Surgery has found a wide
application because preservation of blood and human tissues (eyes etc.) has become possible by refrigeration only.

3. Storage and transportation of food stuffs such as meat, ice cream, dairy product, fish, fruit, vegetables and fruit juices etc.

4. Processing of textiles, printing work and photographic material etc.

5. Cooling of concrete for dams.

6. Treatment of air for blast furnaces.
7. Processing of tobacco, petroleum and other chemical products.
8. Production of rocket fuels.
10. Computer functioning.

1.3 LAWS OF AIR CONDITIONING

All refrigeration systems are designed to work on the following laws:

1. Fluids absorb heat while changing from a liquid state to a vapour state and give up heat in changing from a vapour to a liquid. This law applies in both condenser and evaporator.
2. The temperature at which a change of state occurs, remains constant during the change provided the pressure remains constant. This law also applies in both condenser and evaporator.
3. Heat by itself flows only from a body which is at a higher temperature to a body which is at a lower temperature. This law also applies in both condenser and evaporator.
4. Metallic parts of the evaporating and condensing units use metals which have a high heat conductivity, (copper, brass, aluminum).
5. Heat energy and other forms of energy are mutually convertible. For example, electrical energy may be converted into heat energy and heat energy may be converted into electrical energy. Similarly, heat energy may be converted into mechanical energy and mechanical energy into heat energy. This law applies to both electric motor and compressor.

1.4 Comfort Air Conditioning System

In comfort air conditioning, the air is brought to the required dry bulb temperature and relative humidity for the human health, comfort and efficiency. If sufficient data of the required condition is not given, then it is assumed to be 21°C dry bulb temperature and 50% relative humidity. The sensible heat factor is, generally, kept as following:

For residence or private office = 0.9

For restaurant or busy office =0.8

Auditorium or cinema hall = 0.7

Ball room dance hall etc. = 0.6

The comfort air conditioning may be adopted for homes, offices, shops, restaurants, theatres, hospitals, schools etc.

1.5 Industrial Air Conditioning System

It is an important system of air conditioning these days in which the inside dry bulb temperature and relative humidity of the air is kept constant for proper working of the machines and for the proper research and manufacturing processes. Some of the sophisticated electronic and other machines need a particular dry bulb temperature and relative humidity. Sometimes, these machines also require a particular method of psychometric processes. This type of air conditioning system is used in textile mills, paper mills, machine-parts manufacturing plants, tool rooms, photo-processing plants etc.

Industrial air-conditioning system.

1.6 Winter Air Conditioning System

In winter air conditioning, the air is heated, which is generally accompanied by humidification. The schematic arrangement of the system is shown in Fig. 1.1

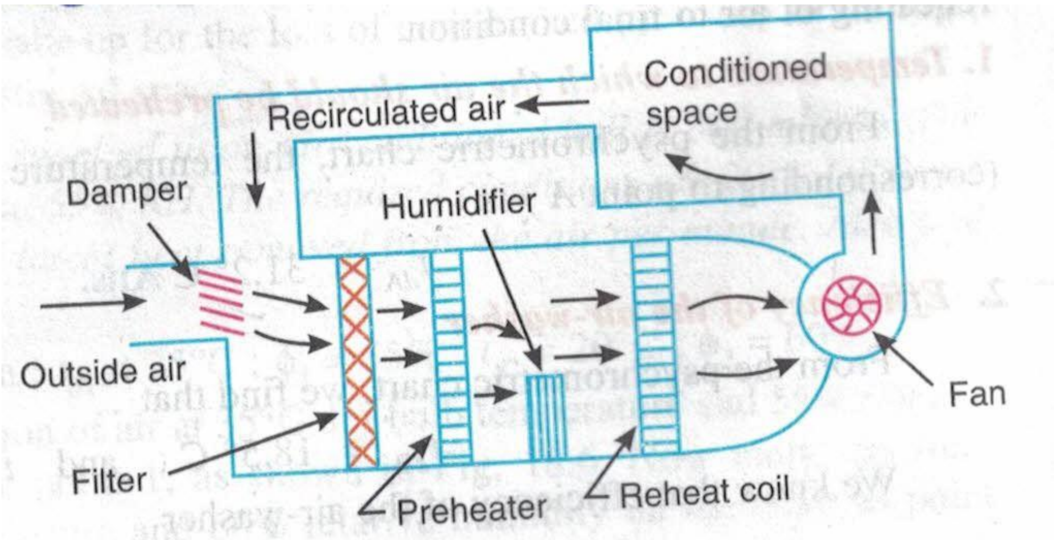
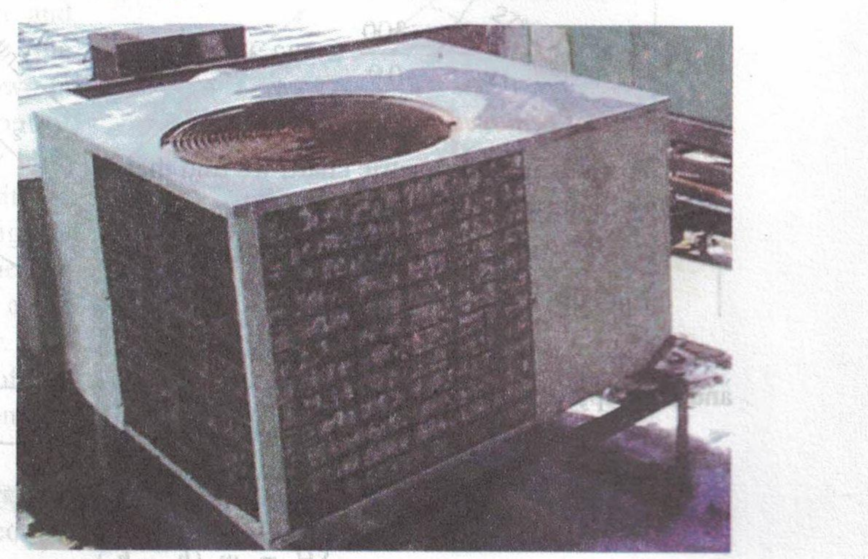


Fig 1.1

The outside air flows through a tamper and mixes up with the recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove dirt, dust and other impurities. The air now passes through a preheat coil in order 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

1.7 Summer Air Conditioning System

It is the most important type of air conditioning, in which the air is cooled and generally dehumidified. The schematic arrangement of a typical summer air conditioning system is shown in Fig. 1.2



Summer air-conditioning system.

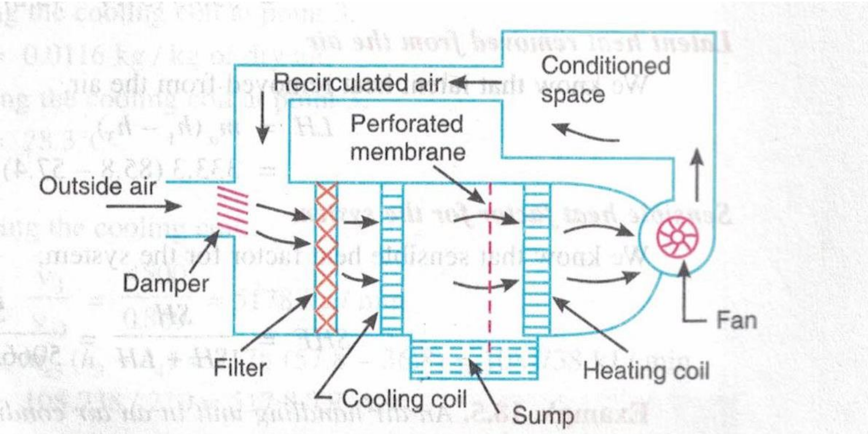


Fig 1.2

The outside air flows through the damper, and mixes up with recirculated air (which is obtained from the conditioned space). The mixed air passes through a filter to remove dirt, dust and other 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 form which is in a sump. After that, the air is made to pass through a heating coil which heats up the air slightly. 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 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 (known as recirculated air) is again conditioned as shown in Fig. 1.4. The outside air is sucked and made to mix with the recirculated air in order to make up for the loss of conditioned (or used) air through exhaust fans or ventilation from the conditioned space.

1.8 Packaged air conditioners. These are factory assembled units having a complete system mounted in a cabinet. The system is usually water cooled and is used in small commercial or other establishments such as restaurants, stores, banks and laboratories, etc. In early days, the capacities of such units ranged from 2 to 10 ton with 2, 3 and 5 ton sizes predominating. Now the units are available in capacities up to 100 ton. The equipment may be located in the conditioned space or outside the conditioned space, with or without ducts. In the conditioned space, they may be floor mounted, ceiling mounted or window mounted. Outside the conditioned space, they may be located in the basement, garage or attic.

These units are divided into two groups depending upon the location of components as: (i) Remote type (ii) Console type.

Remote type: In this type of system, the air handling unit is separated from the condensing unit. They may be of horizontal or vertical type depending the position of drain pan and filter.

Console type: The console is placed in the room below the window sill and has suitable fresh air inlet opening, provided in the walls. Fig. 1.3. shows the working principle of a water cooled console unit. The condensing unit is mounted in the bottom of the console, air blower in the middle and the evaporator coil at the top of the cabinet. The return air enters the lower grill while the cooled air is discharged at the upper grill.

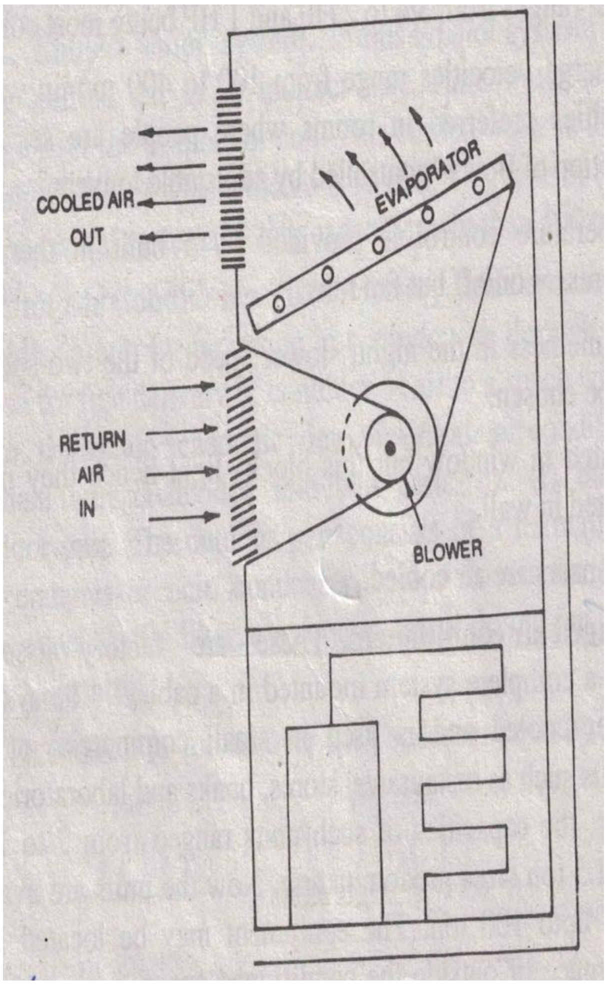


Fig. 1.3

1.9 Central air conditioning plants: In this type of system, the various components of equipment such as fans, coils and filters etc., are designed for assembly in the field rather than in a factory as a unit. A central system is required to serve several rooms requiring individual control of each room. Such installations are quite flexible in operation as they are not factory assembled. They are also more durable than unit machines.

Since central plants are used for large cooling capacities, so the condensers used for them are water cooled. The heat carried by water during its circulation through the condenser, is rejected in the cooling tower. However, the heat exchange at the evaporator coil may be achieved by either of the following two ways:

(a) Direct expansion system (Dx): In this system, the air is cooled directly by passing it over the coil surface as is done in unit machines.

(**b) Chilled water system:** In this system, water is chilled by passing it over the coil surface. This chilled water may then be used in water coils for cooling the air.

The important features of a central system are:

1. One apparatus serving many rooms may involve a lower investment cost than that for a number of self-contained plants.
2. A central system may occupy a basement that is relatively unimportant,

   whereas individual factory assembled apparatus placed in each room may occupy otherwise valuable space.
3. A central system is easily accessible for servicing. It is possible to provide doors in the encasement for cleaning and inspecting all of the component parts in a manner usually superior to that practicable with compact units. Also service is concentrated in one or just a few places.
4. Central air conditioning systems usually are connected by ducts with the various rooms served and preferably have exhaust fans that may affect complete return-air fan may return air to the supply system for recirculation, as a measure of economy of fuel or refrigeration.
5. Central systems are served by heating and refrigerating equipment which may be located at some distances from the air supply apparatus and which may serve one or more central air supply system.
6. For small requirement they are uneconomical and unit systems are preferable. General trend is to use these units in residential air conditioning. However, for large buildings, central system will be economical.
7. Most of the central systems have year the round control.

ASSIGNMENT

1. Fill in the blanks or delete which is not applicable.

(a) The four important factors involved in a complete air conditioning installation are

(i)................................ (ii)................................

(iii).............................. (iv)...............................

(b) A fan used to discharge air against pressure at its outlet is known as.

(c) A fan used to remove air or gases from a space by suction is known as………………..

(d) A grill provided with a damper is known as..................................

(e) Unit air conditioner has capacity from..................... to………….. ton.

2. What is the meaning of air conditioning?

3. How the air conditioning systems are classified?

4. Give a brief description of the various components of an air conditioning system.

5. Explain the working of a window type air conditioner by drawing a line sketch.

6. Give the layout of a modern air conditioning system.

7. Describe with a neat sketch the working of a year the round air conditioning system.

8. Explain briefly how the following foods are processed/preserved.

   (i) Milk and butter

   (ii) Meat products

   (iii) Poultry products

   (iv) Fishery products

9. State the main advantages which accrue by cold storage of fruits, food stuffs and vegetables.

10. Explain briefly the following with neat sketches:

   (i) All the year round air conditioner.

   (ii) Year-round absorption air conditioner.

11. Explain briefly the 'air conditioning of theatres'.