

## Parts of refrigeration systems (Compressor)

### Expected Learning Outcome

- Types of compressor and their working principles
- Types of evaporators and their working principles
- Types of condensers and their working principles
- Types of expansion devices and their working principles

### Parts of refrigeration systems

#### 3.1.Compressor

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

##### 3.1.1.Necessity of compressor in a vapour compression system

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

##### 3.1.2.Classification of compressor

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

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

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

Three main groups of compressor,

- Reciprocating compressor
- Rotary compressor
- Centrifugal compressor

### 3.1.2.1. Reciprocating compressors

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

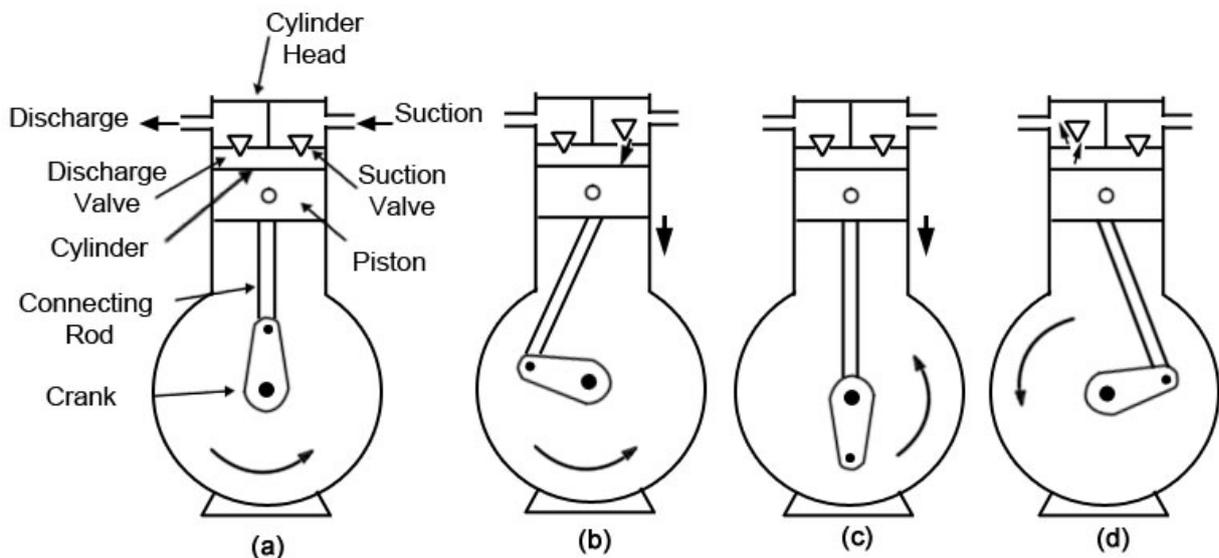
The functions of reciprocating compressor in vapor compression refrigeration system are as follows.

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

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

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

#### 3.1.2.1.1. Working principle of Reciprocating compressor



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

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

### **3.1.2.1.2.Different parts of the Reciprocating compressor**

#### **Piston**

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

#### **Piston rings**

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

#### **Crank shaft**

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

#### **Connecting rod**

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

#### **Rings**

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

#### **Suction and discharge valve**

The valve that controls the flow of refrigerant from the suction line into cylinder head is

known as suction valve. The valve that discharges the compressed gas towards the discharged line is called discharged valve. These valves are named according to the function they perform.

### **3.1.2.1.3. Important terms used in reciprocating compressor**

#### **B.D.C**

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

#### **T.D.C**

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

#### **Piston stroke**

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

#### **Suction stroke**

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

#### **Compression stroke**

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

#### **Piston displacement volume**

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

#### **Compression ratio**

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

#### **Volumetric efficiency**

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

### **3.1.2.2. Rotary Compressors**

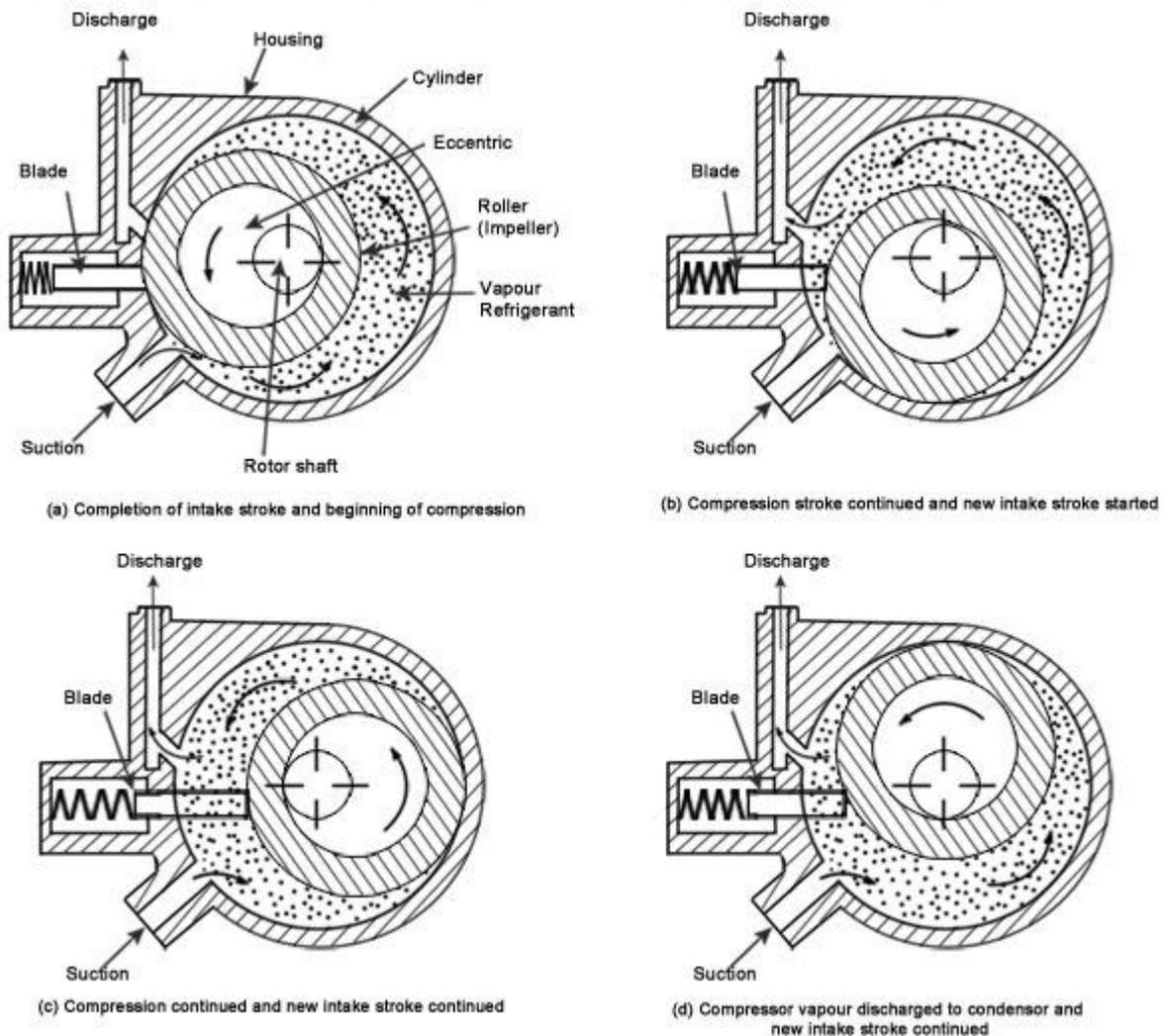
In rotary compressors, the vapour refrigerant from the evaporator is compressed due to the movement of blades. The rotary compressors are positive displacement type compressors. Since the clearance in rotary compressors is negligible, therefore they have high volumetric efficiency. These compressors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

#### **3.1.2.2.1. Single stationary blade type rotary compressor**

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

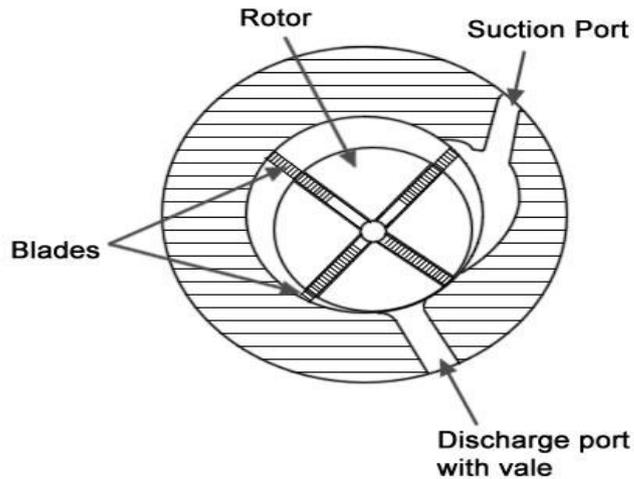
In figure (a) to (d) shows the various positions of roller as the vapour refrigerant is compressed. Figure (a) shows the completion of intake stroke (i.e. the cylinder is full of low

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



### 3.1.2.2. Rotating blade type rotary compressor

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

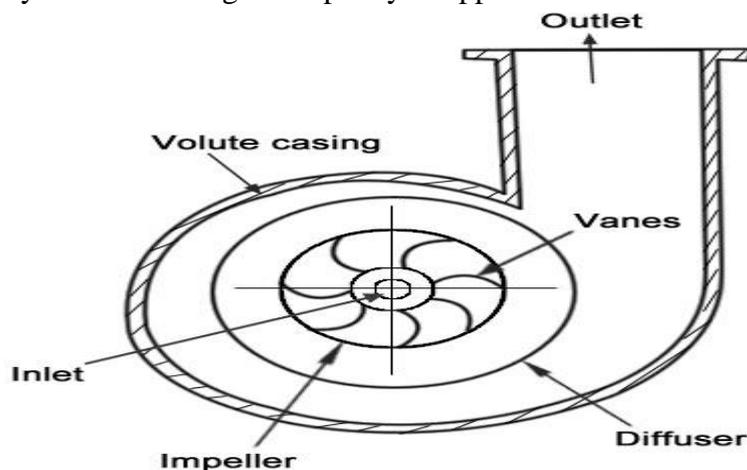


Rotating Blade type rotary Compressor

### 3.1.2.3. Centrifugal Compressors

#### Working principle

The centrifugal compressor for refrigeration systems was designed and developed by Dr. Willis H. Carrier in 1922. This compressor increases the pressure of low pressure vapour refrigerant to a high pressure vapour refrigerant by means of centrifugal force. The centrifugal compressor is generally used for refrigerant that require large displacement and low condensing pressure, such as R-II and R-113. However, the refrigerant R-12 is also employed for large capacity applications and low-temperature applications.



Centrifugal compressor

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

before it leaves the refrigerant to the evaporator.

Note :

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

### **3.1.2.3.1. Advantages and disadvantages of Centrifugal Compressors**

#### **Advantages**

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

#### **Disadvantages**

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