COMPRESSORS

- In this chapter, students will learn about
  (1) Compressors.
  (2) Classification of compressors.
  (3) Construction and working of reciprocating and centrifugal types of compressors.

Compressors

- It is one of the equipment to compress/pump the gas.
- According to pressure range, pumping equipment for gas are classified as

Pumping equipment for gas	Pressure Ratio
Fan	1.0 to 1.1
Blower	1.1 to 1.2
Compressor	More than 1.2

- The main difference in compressing liquid and gas is that, under the normal range of operating pressures, the density of a gas is considerably less than that of a liquid. Thus, higher speed of operation is required for gases as compared to liquid for compression.
- Thus, compressor is a device which compresses gas.
- It requires external work to operate a compressor.
- Compressor is generally operated with the help of electric motor, diesel engine etc.

Application of Compressed Air

- The applications of compressed air are classified as (1) industrial application, (2) commercial applications and (3) general application.

Industrial Applications

- To manufacture chemical products.
- To construct dam, road, subway etc.
- To spray insecticides.
- To operate pneumatic tools and equipments.
- To operate blast furnace and sand blasting machine.

Commercial Applications

- To clean automobiles and machine parts.
- To paint a body.
- To drive air motors, water pumps and other equipments.
- To operate air brakes in bus, trains, trucks, etc.
- To operate gates for lifts.
- To fill air in automobile wheels.

General Applications

- To blow glass.
- To operate conveyor in post office.

Classification of Compressor

- Compressor is broadly classified as reciprocating compressor and rotary compressor.

Reciprocating compressor

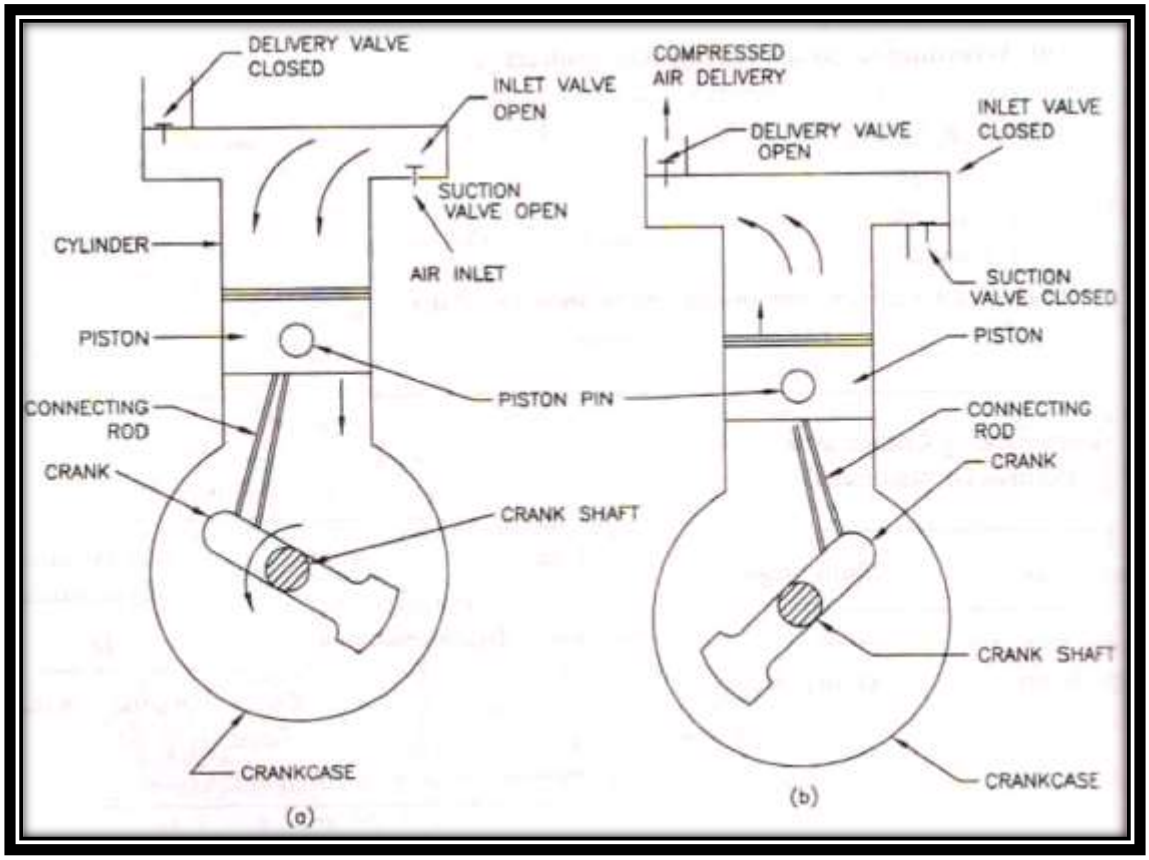
- A compressor, in which gas is compressed using reciprocating motion, is known as reciprocating compressor.
- It is always positive displacement type compressor.
- It further classified as single stage compressor, multi stage compressor, single acting compressor and double acting compressor.

Rotary Compressor

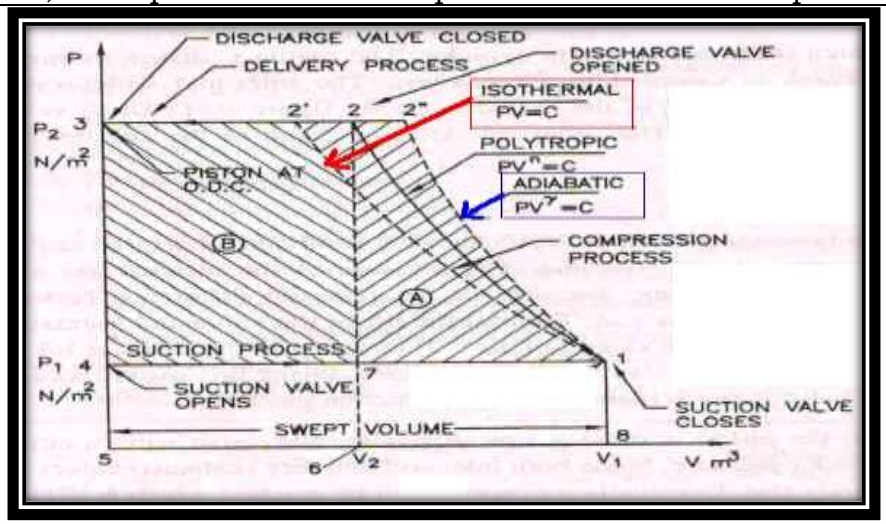
- A compressor, in which gas is compressed using rotary motion, is known as rotary compressor.
- It may be **positive displacement** type compressor or **non positive displacement** type compressor.
- Roots blower, vane compressor, screw compressor and scroll compressor are different types of **positive displacement** type of compressor.
- Centrifugal compressor, radial compressor and axial compressor are different types of **non positive displacement** type of compressor.

Single Stage Reciprocating Compressor without Considering Clearance

Construction and Working of Single Stage Reciprocating Compressor without Considering Clearance	
Construction	• It has a fixed cylinder in which piston reciprocates. • Piston is connected to connecting rod. • Connecting road is connected to crank shaft through crank. • Crank shaft is connected to electric motor. • Inlet and discharge valves are located at the top of the cylinder. • Discharge valve is connected to storage tank. • *Without considering clearance means it is assumed that, when piston is at TDC, there is no gap between piston and cylinder head.* • *As there is only one set of piston and cylinder in which air is compressed, it is known as single stage reciprocating compressor.*

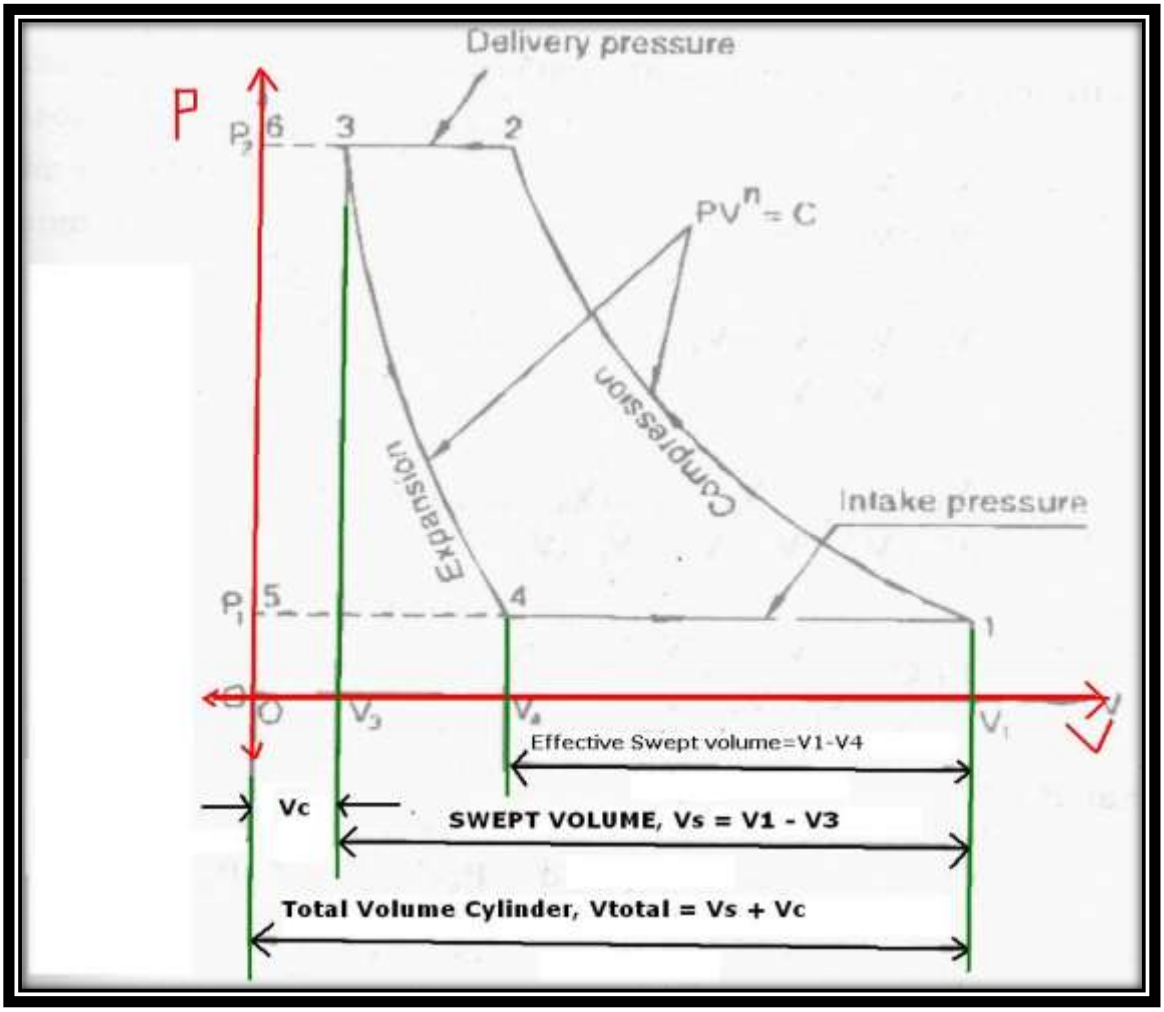


Working	***First Stroke***
	• Initially electric motor is switched on. • As electric motor starts, crank shaft rotates and piston reciprocates. • *Piston moves from TDC to BDC.* • *Due to movement of piston, partial vacuum is generated inside the cylinder.* • *Thus, inlet valve opens and air from atmosphere enters inside the cylinder.*
	Second Stroke
	• During second stroke, piston moves from BDC to TDC. • Due to movement of piston, gap between piston and cylinder head decreases. • Thus, the pressure of air inside the cylinder increases. • As the pressure of air increases, discharge valve opens and compressed air enters into storage tank. • In storage tank, compressed air is stored and whenever necessary it is used. • *The air can be compressed at any one of the ideal gas processes, viz., (1) isothermal process, (2) adiabatic process and (3) polytropic process.* • *The P-V diagram of the air compression process is also shown in which all three processes are shown.* • *As we know that, area under P-V curve, indicates work done/ supplied.* • *Therefore, work required to compress the air for isothermal process is less, work required for adiabatic process is medium and work required for polytropic process is high.* • Thus, ideal process of air compression is Isothermal process.



Single Stage Reciprocating Compressor Considering Clearance

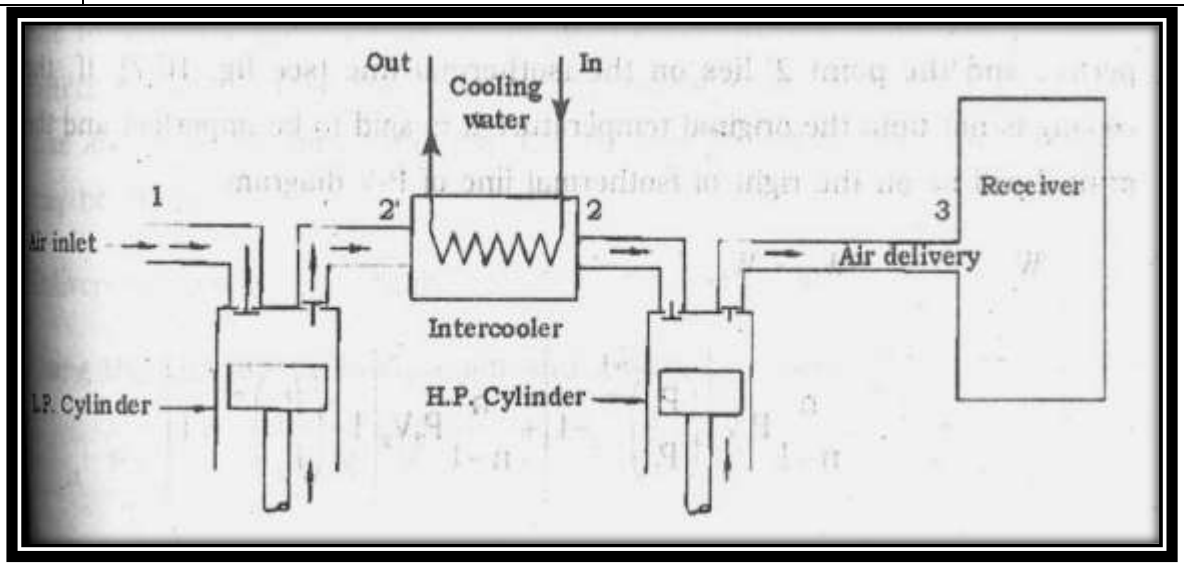
Construction and Working of Single Stage Reciprocating Compressor Considering Clearance	
Construction	• Construction of single stage reciprocating compressor considering clearance is exactly same as the same of single stage reciprocating compressor without considering clearance except that there is a gap between piston and cylinder head when piston is at TDC. • As there is only one set of piston and cylinder in which air is compressed, it is known as single stage reciprocating compressor.



Working	***First Stroke***
	• Initially electric motor is switched on. • As electric motor starts, crank shaft rotates and piston reciprocates. • Due to the gap, when piston is at TDC, gap is filled with some air. • Now, piston moves from TDC to BDC. • Due to movement of piston, air present inside the cylinder expands first and then low vacuum is generated inside the cylinder. • Thus, inlet valve opens and air from atmosphere enters inside the cylinder. • The less quantity of air enters inside the cylinder as compared to the case of without considering the clearance.
	Second Stroke
	• During second stroke, piston moves from BDC to TDC. • Due to movement of piston, gap between piston and cylinder head decreases. • Thus, the pressure of air inside the cylinder increases. • As the pressure of air increases, discharge valve opens and compressed air enters into storage tank. • When piston reaches at TDC, due to the gap, some air remains inside the cylinder. • In storage tank, compressed air is stored and whenever necessary it is used. • For this case also, ideal process of air compression is Isothermal process.

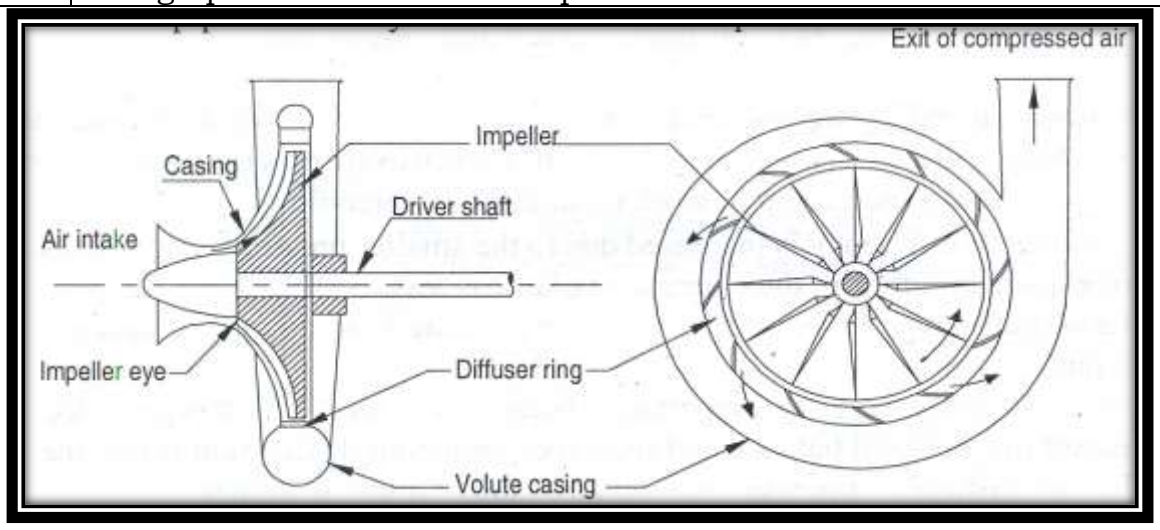
Multi Stage Reciprocating Compressor

Construction and Working of Multi Stage Reciprocating Compressor	
Construction	• It has more than one single stage reciprocating air compressors in which air is compressed. • The compressed air from first air compressor is cooled in intercooler and then cooled compressed air enters the next air compressor, and so on. • For example, in three stage reciprocating air compressor, initially air is compressed in first air compressor (known as Low Pressure compressor, LP Compressor), cooled in intercooler, again compressed in second compressor (known as Medium Pressure Compressor, MP Compressor), again cooled in intercooler and finally compressed in third air compressor (known as High Pressure Compressor, HP Compressor). For HP compressor, air enters the storage tank.
Working	• In this type of compressor, is compressed in number of compressors one after another and it is cooled in intercooler located between two compressors. • Due to intercooler, the compression process is nearer to the Isothermal process. • If intercooler is not provided, the compression process will be polytropic process which requires more work.



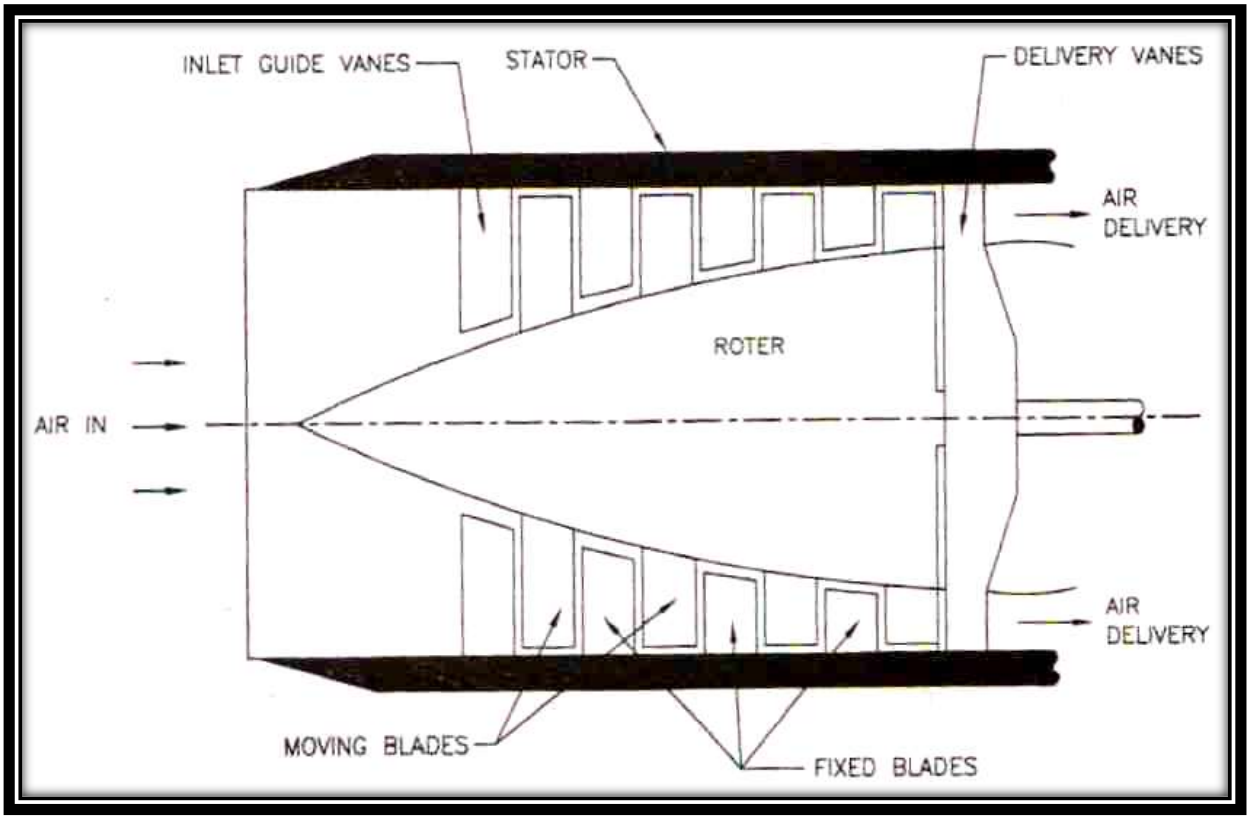
Centrifugal Compressor

Construction and Working of Centrifugal Compressor	
Construction	• It has an air tight casing which encloses other parts of a centrifugal compressor. • At the centre of the pump, a shaft is provided which is connected to the electric motor. • Impeller vanes are attached to the shaft. • Air enters from one end of the impeller vane. • At the periphery of the impeller vane (At the other end of the impeller vane), diffuser rings (diffuser vanes, guide vanes) are located. • Shaft, impeller vanes and diffuser rings are placed in the casing. • The gap between diffuser ring and casing is not uniform; it increases continuously from inlet to outlet section. • It is known as volute casing.
Working	• Electric motor is switched on. • As electric motor rotates, shaft also rotates which rotates the impeller vanes. • Thus, air inside the impeller rotates and centrifugal force is generated. • Thus, pressure and velocity of air in the impeller increases. • Thus, air comes out from the impeller vanes at high velocity. • High velocity air then enters the diffuser vanes where velocity of air is converted into pressure. • Thus, at high pressure air comes out from the diffuser vanes. Then air enters the volute casing. In volute casing also, velocity of air is converted into pressure and air at high pressure exits the compressor.



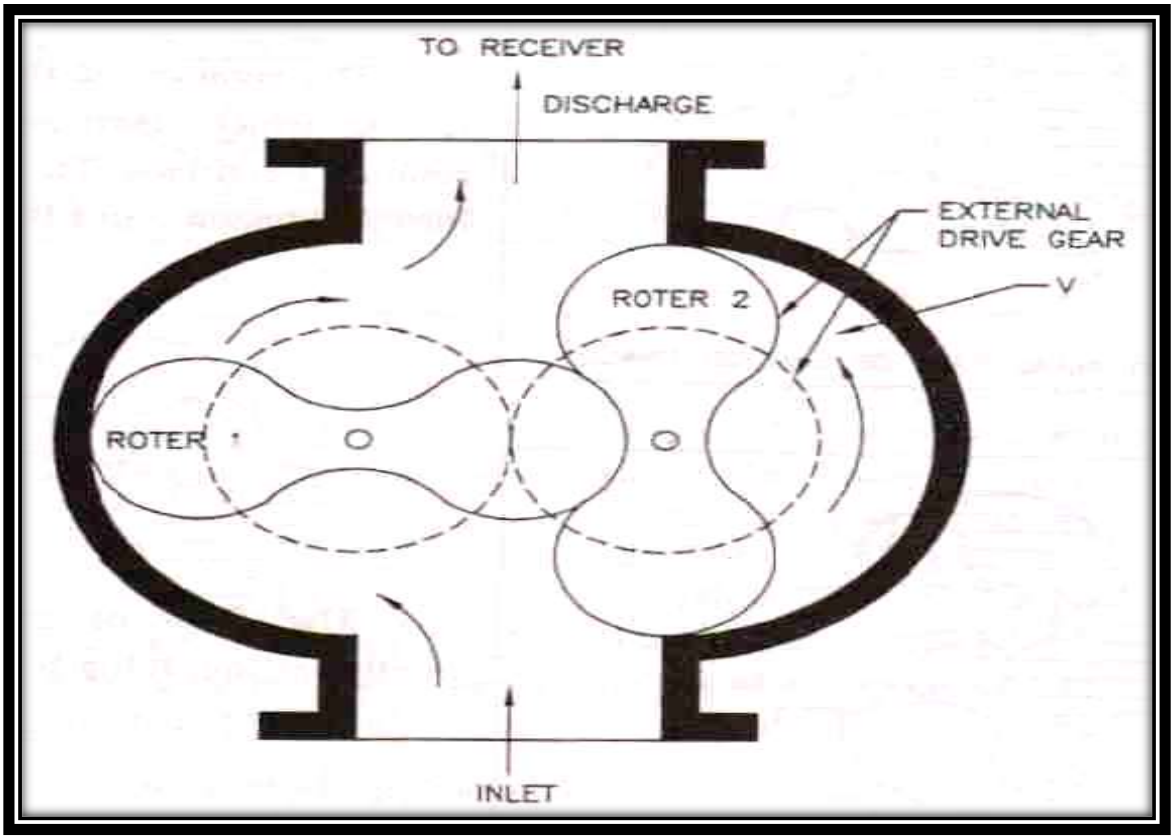
Axial Compressor

Construction and Working of Axial Compressor	
Construction	• It has a rotor mounted on an electric motor shaft. • Rotor is placed in an air tight casing having continuously decreasing area from suction to discharge side. • Moving blades are attached to the rotor and fixed blades are attached to the casing. • Moving blades and fixed blades are arranged one by one. • In this type of compressor, air moves parallel to the axis of the motor shaft. Thus, it is known as axial compressor.
Working	• As electric motor is switched on, rotor rotates at high speed. • Thus, air in contact with moving blades also rotates with high speed, i.e. kinetic energy of air increases. • Then air enters the fixed blade. In fixed blade, kinetic energy of air is converted into pressure energy. • Again air enters the next set of moving blade and fixed blade up to the discharge section. • Then high pressure is discharged from discharge section.



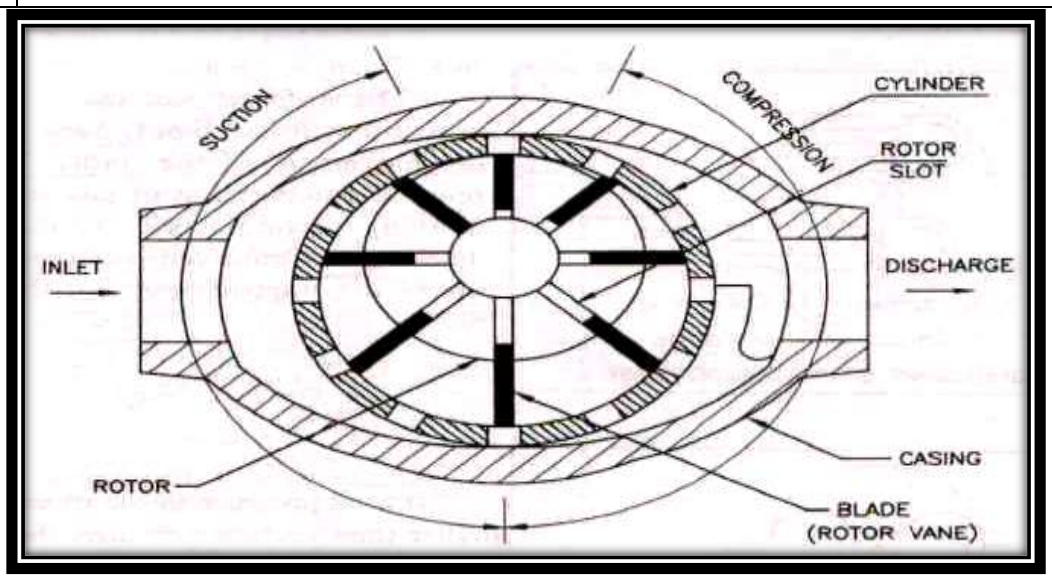
Roots Blower

Construction and Working of Roots Compressor	
Construction	• It contains two inter-connected dumbbell shaped rotors. • One rotor is connected to electric motor. • These rotors are placed in an air tight casing. • At one end, there is suction and other end there is discharge section.
Working	• Electric motor is switched on. • As electric motor rotates, one rotor rotates which in turn rotates another rotor and air enters the blower. • Air is entrapped between rotor and casing. • Thus, entrapped air has to move along with the rotor from suction to discharge section. • Thus, air comes out from the discharge section.



Vane type Compressor/Blower

Construction and Working of Vane type Compressor/Blower	
Construction	• The construction is similar to the vane type pump. • It contains a rotor mounted on shaft of electric motor. • On the periphery of rotor, grooves are prepared. • Sliding vanes are arranged in each groove with springs. Thus, when we press the sliding vane, it moves inside the groove and comes out when we release the pressure on it. • The rotor is placed in the casing eccentrically, i.e. centre of rotor and center of casing are not same. • Due to this arrangement, there is non-uniform gap between rotor and casing. • Sliding vanes are always in contact with casing. • At one side there is suction and another side discharge.
Working	• As electric motor rotates, rotor also rotates and air enters the compressor/blower. • Air is entrapped between two vanes and casing. • Thus, entrapped air has to rotate along with the rotor from suction to discharge section. • When air moves from suction to discharge section, gap between rotor and casing also decreases. Thus, air is compressed. • Compressed air comes out from the discharge section.



Difference between reciprocating compressor and centrifugal compressor

Reciprocating Compressor	Centrifugal Compressor
In this type of compressor, air is compressed due to reciprocating motion.	In this type of compressor, air compressed due to centrifugal force generated.
It is positive displacement type compressor.	It is non-positive displacement type compressor.
It does not discharge continuously.	It discharges air continuously.
It is suitable for less discharge at very high pressure.	It is suitable for very high discharge at low pressure.
Maximum discharge pressure can be 1000 bar.	Maximum discharge pressure can be 40 bar.
It is working at low speed.	It is working as high speed.
This type of compressor is larger in size.	This type of compressor is smaller in size.
Running cost and maintenance cost are more.	Running cost and maintenance cost are less.

Reference Books:

(1). Elements of Mechanical Engineering – MCQ and Numerical as per GTU, By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-3-330-07021-9)

(2). Elements of Mechanical Engineering – Laboratory Manual (as per GTU), By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-620-2-05650-2)

(3). Elements of Mechanical Engineering – Tutorial (as per GTU), By Neeraj Chavda, Lap Lambert Academic Publishing, Germany (ISBN : 978-613-9-82424-3)

(4). Basic Mechanical Engineering (Elements of Mechanical Engineering), By J. P. Hadiya, H. G. Katariya and S. M. Bhatt, Books India Publications.

(5). Thermodynamics: An Engineering Approach Seventh Edition in SI Units, Yunus A. Cengel, Michael A. Boles, McGraw-Hill, 2011.

(6). Basic Mechanical Engineering, By Pravin Kumar, Pearson Publications.

(7). Engineering Thermodynamics, By Rayner Joel.

(8). Thermal Science and Engineering, By Dr. D. S. Kumar, S. K. Kataria & sons Publications.

(9). Fundamental of Mechanical Engineering, By G. S. Sawhney, PHI Publications.

(10). Elements of Mechanical Engineering, By Sadhu Singh, S. Chand Publication.

(11). Elements of Mechanical Engineering, By P. S.Desai and S. B.Soni.