Compressor Fundamentals

Fluid Machinery and Displacement

Introduction

- Compressor is used to increase the pressure of air from low pressure to high pressure by using some external energy.

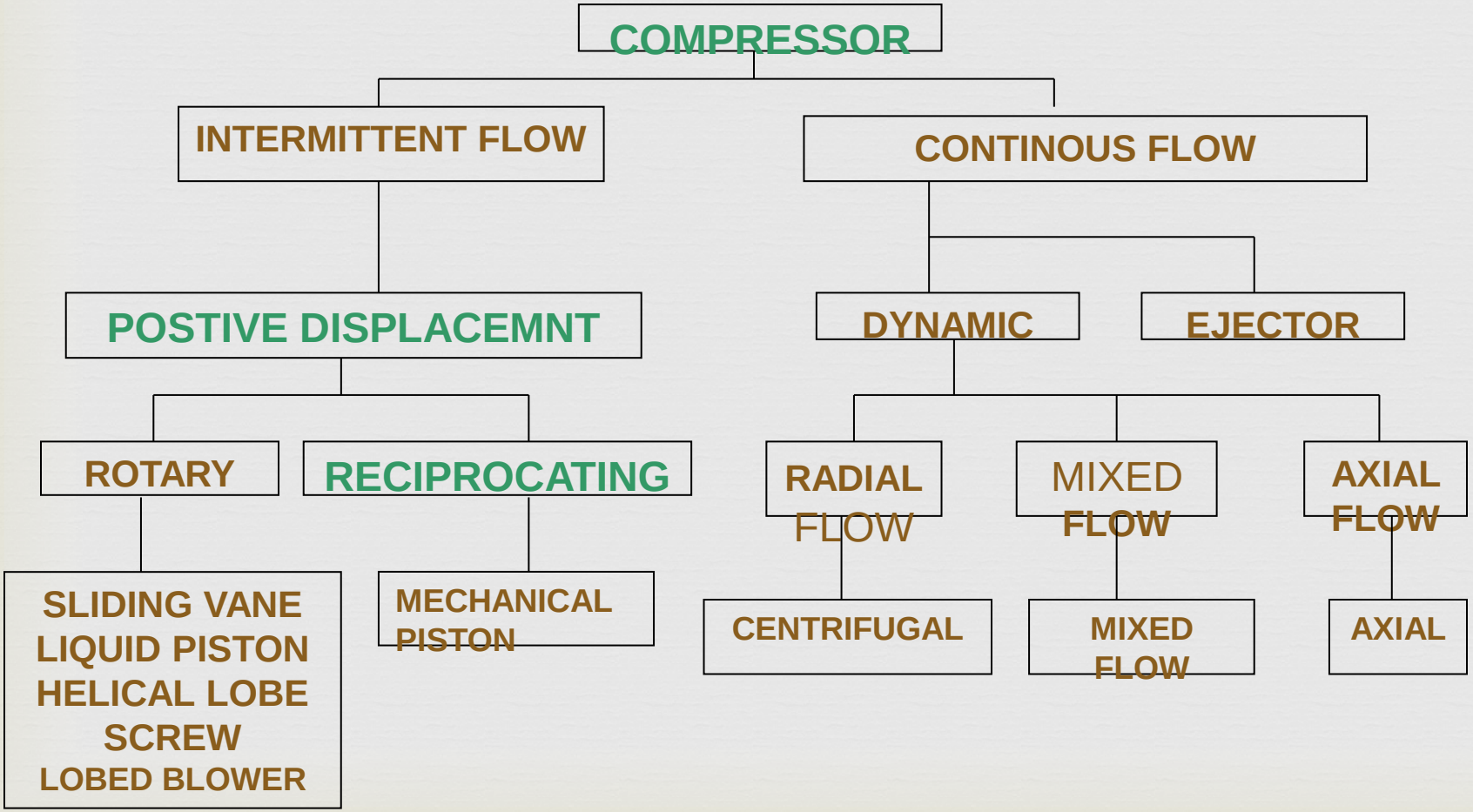
Objectives

- Explain the function of the compressor
- Discuss the concept of compression ratio
- List common compressors found in refrigeration systems
- Describe the component parts of reciprocating compressors

Applications of compressed air

- For filling the air in tube of vehicles
- In automobile service station to clean vehicles.
- For spray painting in paint industries.
- In vehicle to operate air brakes.
- For cleaning workshop machines.
- For supercharging of an IC engines.
- For operation of pneumatic tools i.e. rock drills, vibrators etc.

Classification



Definitions related to compressor

- Compression ratio:-

  It is defined as the ratio of volume of air before compression to the volume of air after compression.

- Compressor capacity:-

  It is the quantity of air actually delivered by a compressor in m^3 per minute.

Definitions related to compressor

- Free air Delivered(FAD):-

  It is the volume of air delivered by compressor under the conditions of temperature and pressure existing at the compressor intake.

- Swept Volume:-

  The volume displaced or swept by piston when it moves between top dead center and bottom dead center.

Types of Compressors

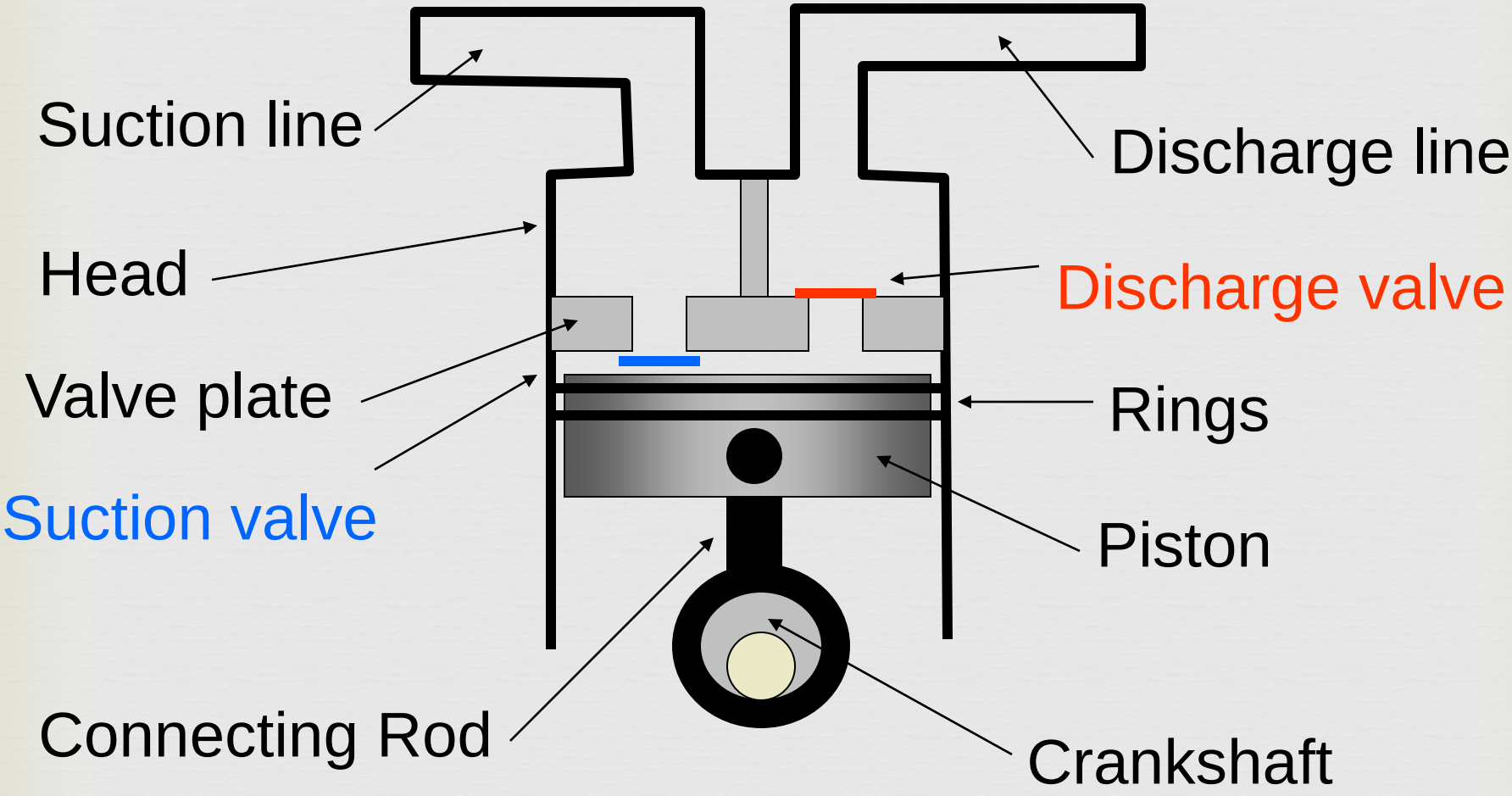
- Positive Displacement (PD) : Operate by trapping a specific volume of air and forcing it into a smaller volume
  - 2 Basic Designs for PD Compressors
    - Rotary
    - Reciprocating
- Centrifugal : Operate by accelerating the air and converting the energy to pressure
  - 2 Basic Designs for Centrifugal Compressors
    - Centrifugal
    - Axial

Reciprocating Compressor

- In a reciprocating compressor, a volume of air is drawn into a cylinder, it is trapped, and compressed by piston and then discharged into the discharge line. The cylinder valves control the flow of air through the cylinder; these valves act as check valves.
- There are two types of reciprocating compressor.

Reciprocating Compressor

- Single – Acting compressor
  - It is a compressor that has one discharge per revolution of crankshaft.
- Double – Acting Compressor
  - It is a compressor that completes two discharge strokes per revolutions of crankshaft. Most heavy-duty compressors are double acting..



Reciprocating Compressor

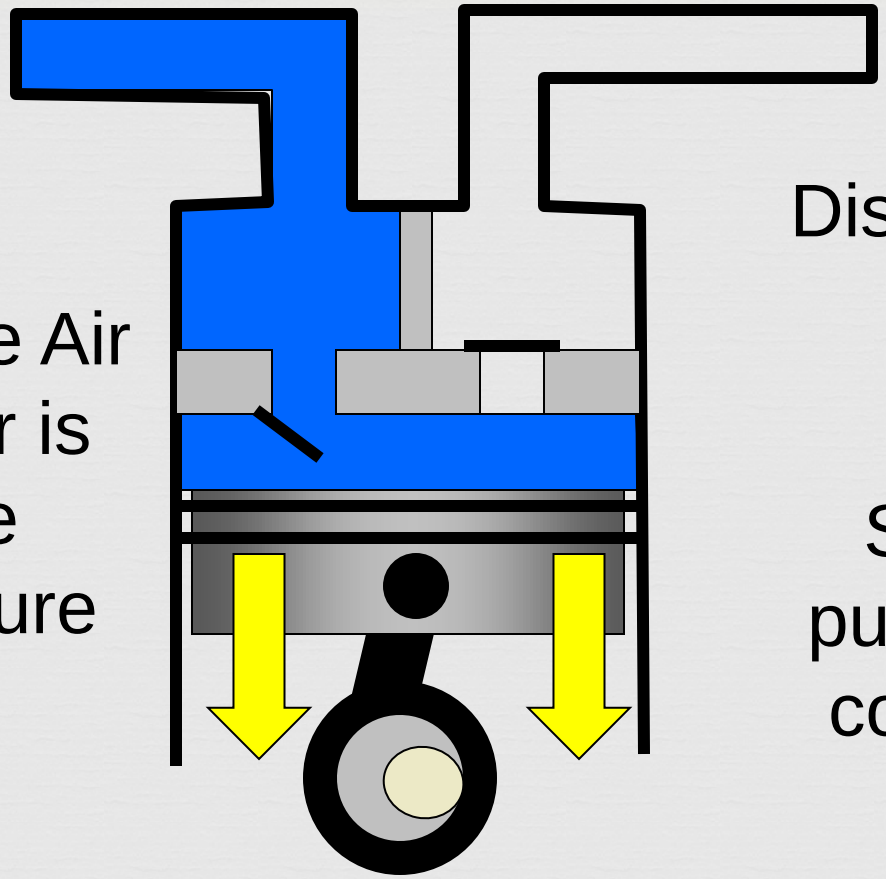
Reciprocating Compressor

- Different parts of double acting compressor are listed below.
  - Suction valve.
  - Suction air jacket.
  - Piston.
  - Cylinder.
  - Discharge valve.
  - Discharge air jacket

Most of the energy that entering the compressor in the suction cylinder is latent heat.

Suction valve open

Pressure of the Air in the cylinder is equal to the suction pressure

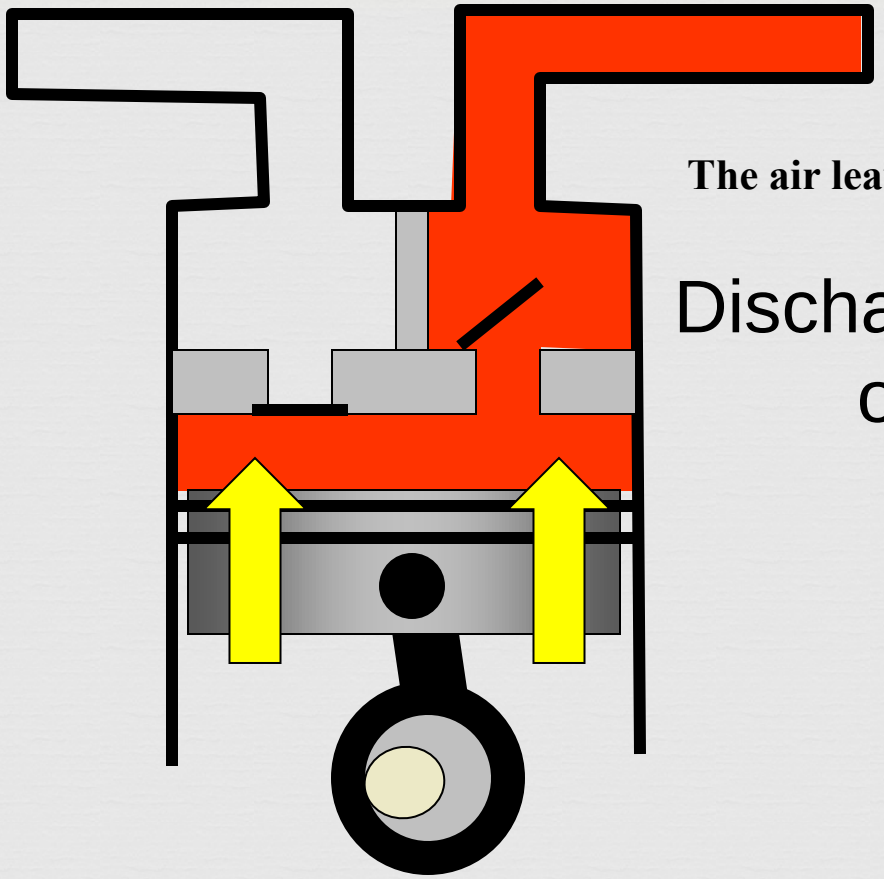


Discharge valve closed

Suction air pulled into the compression cylinder

Piston moving downward in the cylinder

Suction valve closed

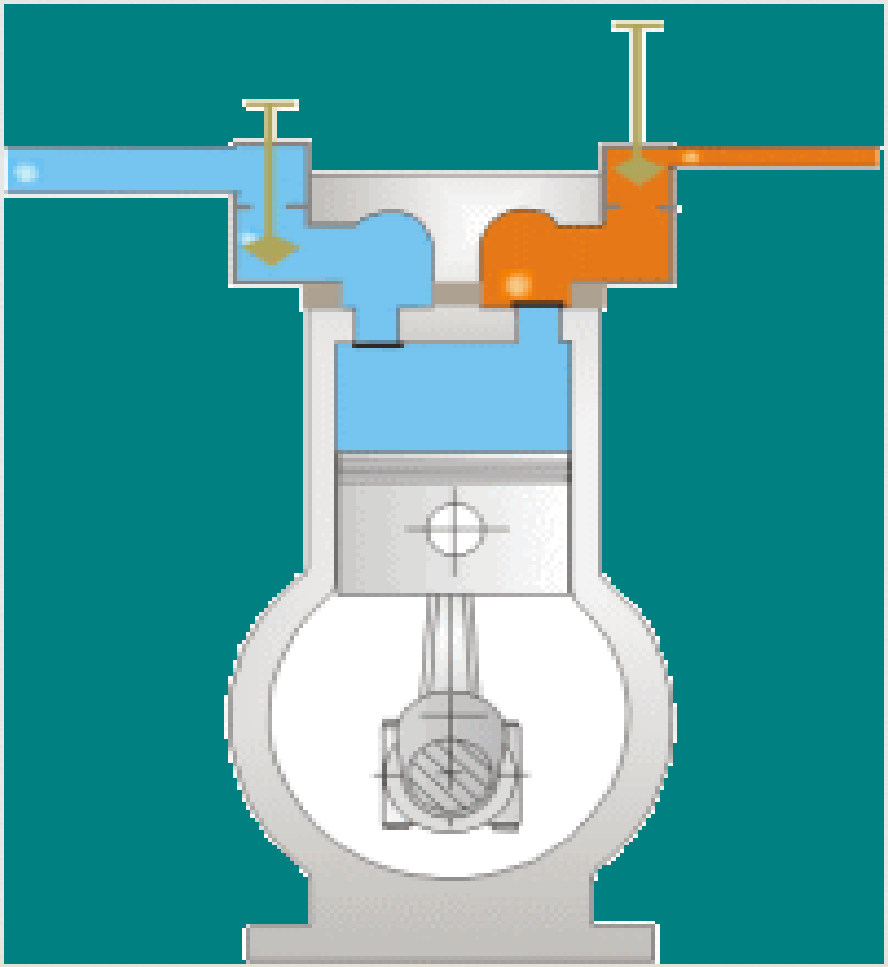


The air leaving the compressor is very warm.

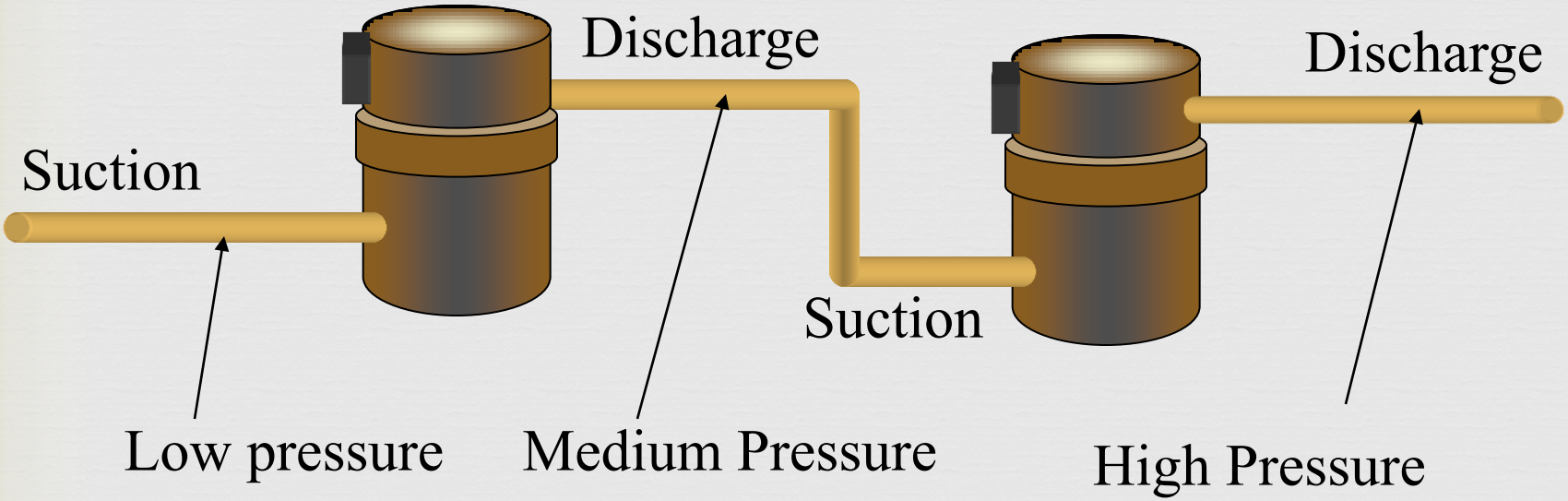
Discharge valve open

Piston moving up in the cylinder

Reciprocating Compressor



Two stage compressor



FIRST STAGE SECOND STAGE

Advantages of multi-staging

- Reduction in power required to drive the compressor.
- Better mechanical balance of the whole unit and uniform torque.
- Increase in volumetric efficiency.
- Reduced leakage loss.
- Less difficulty in lubrication due to low working temperature.
- Lighter cylinders can be used.
- Cheaper materials can be used for construction as the operating temperature is lower.

Intercooling

- Perfect intercooling.
- Imperfect intercooling.

Efficiencies for compressor

- Volumetric efficiency:-

  It is the ratio of actual volume of the free air delivered at standard atmospheric condition in one delivery stroke to the swept volume by the piston during the stroke.

- Isothermal efficiency:-

  It is defined as the ratio of isothermal power to the indicated power.

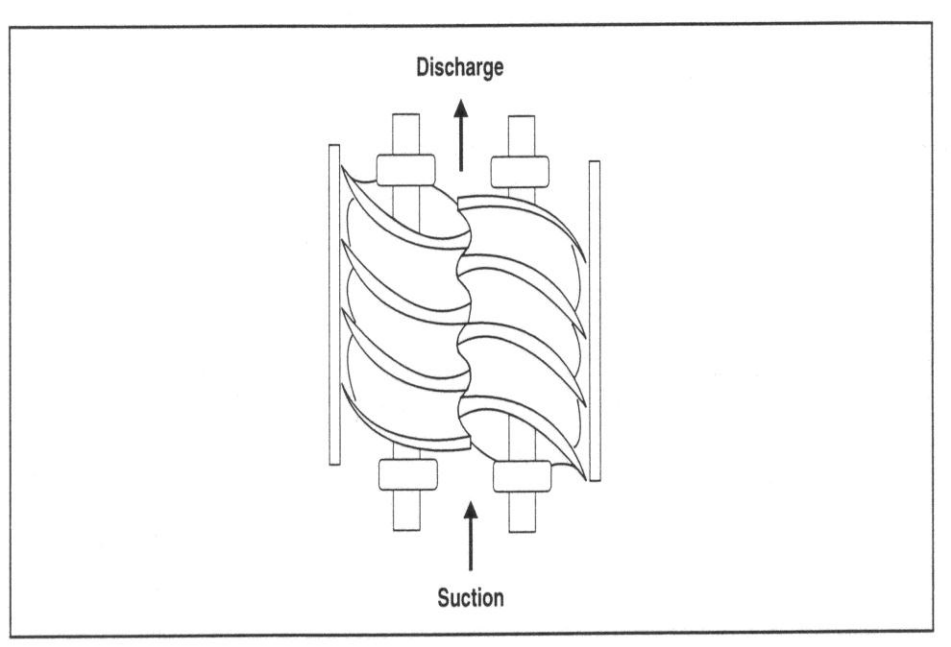
- Mechanical efficiency:-

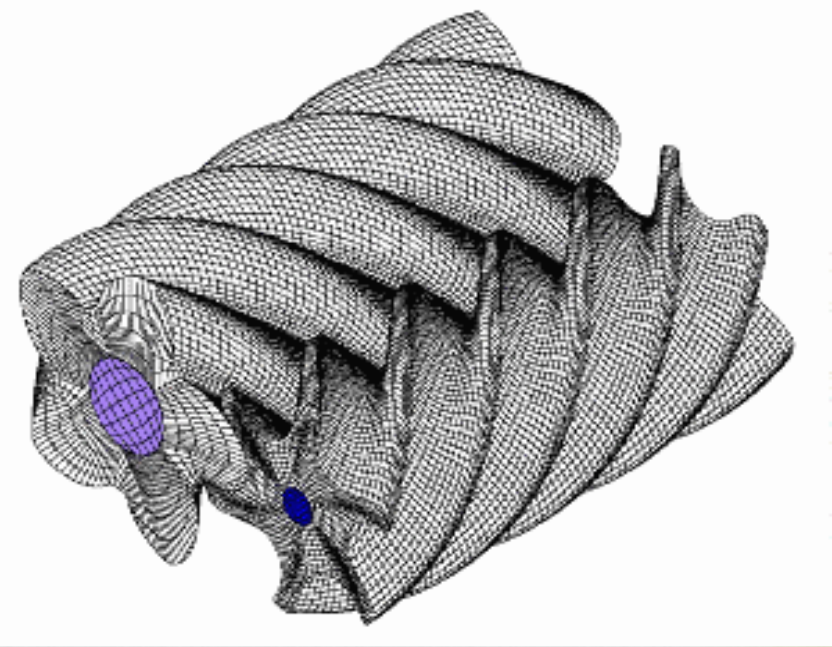
It is the ratio of indicated power to the shaft(Brake) Power.

Rotary air compressor

- Rotary compressors (get their name from the rotating motion of the transfer element) compress gases with lobes, screws, and vanes into smaller volumes.
- 4 Primary Types of Rotary Compressors:
  - Rotary Screw
  - Sliding Vane
  - Lobe
  - Centrifugal
  - Axial flow

Screw Compressors

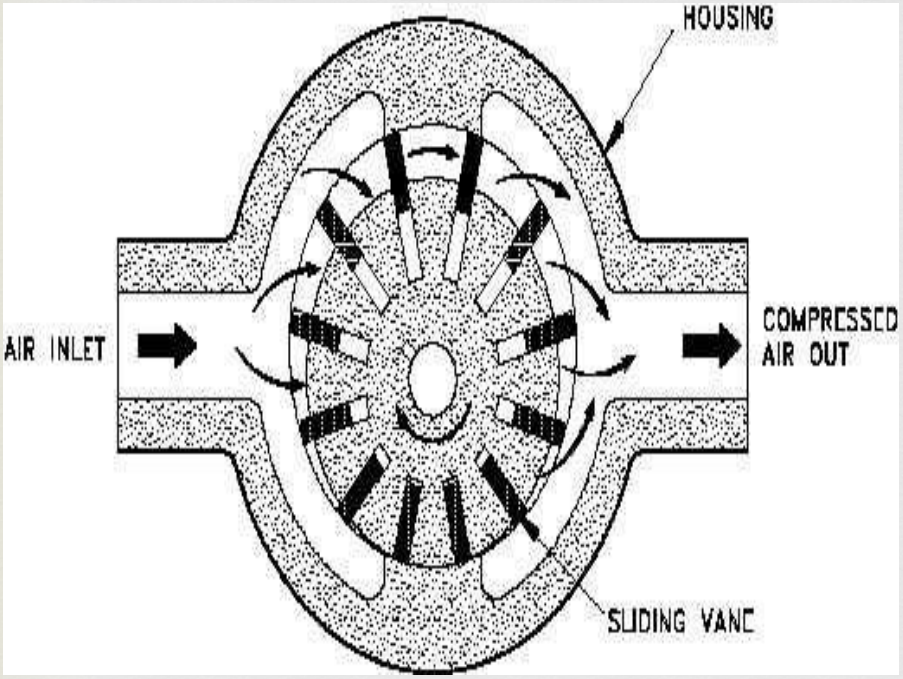


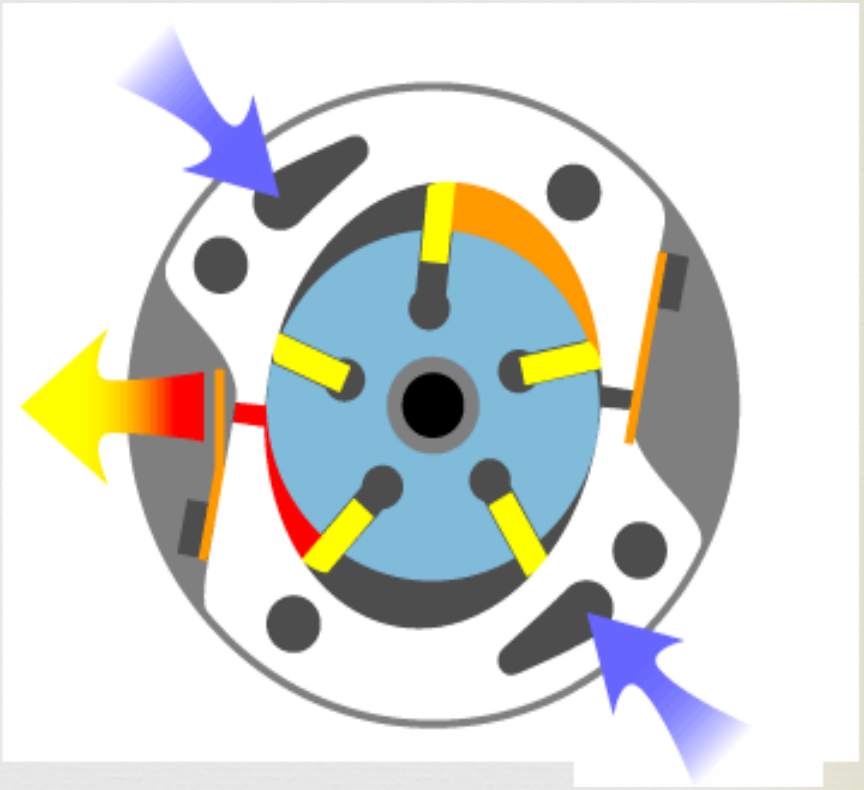


Screw Compressors

- Commonly used in industry.
- It operates with 2 helical rotors that rotate toward each other, causing the teeth to mesh.
- As the left rotor turns clockwise, the right rotor rotates counterclockwise. This forces the gases to become trapped in the central cavity.
- The 2 rotors are attached to a drive shaft and drive that provide energy to operate the compressor.
- Have an inlet suction line and outlet discharge port.

Vane Compressor

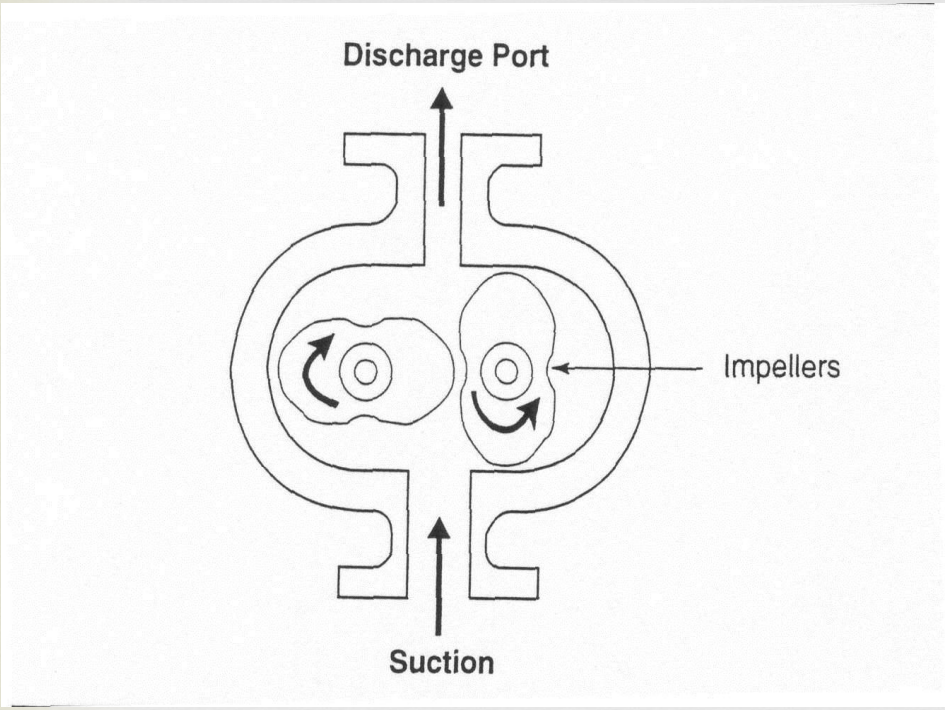


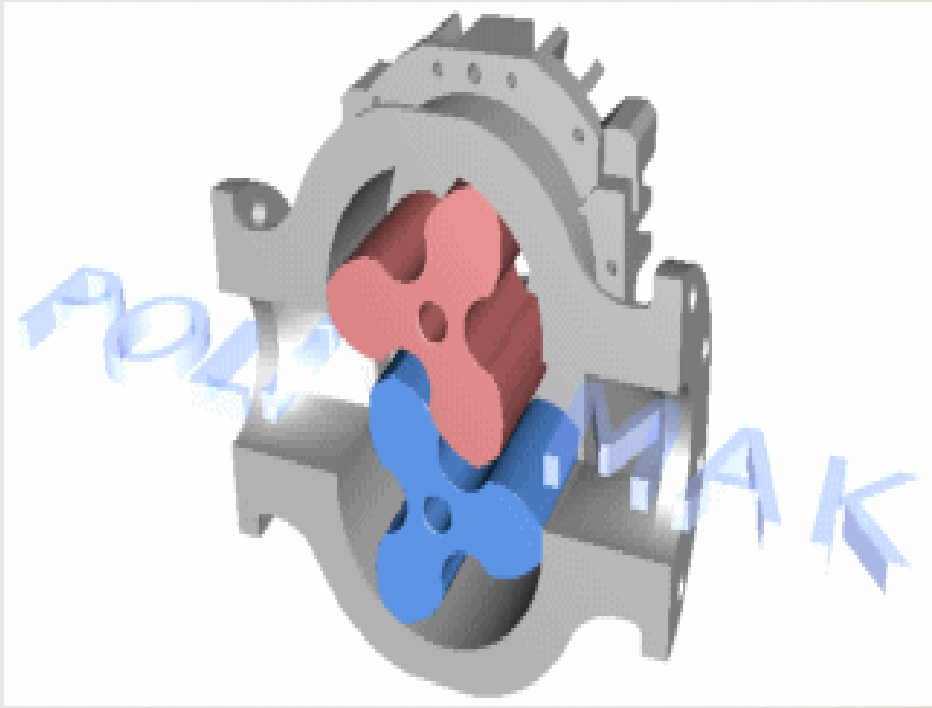


Vane Compressor

- Uses a slightly off-center rotor with sliding vanes to compress air.
- Inlet air flows into the vanes when they are fully extended and form the largest pocket. As the vanes turn toward the discharge port, the gases are compressed.
- As the volume decreases, the pressure increases until maximum compression is achieved. Then the air is discharged out the compressor.

Lobe Compressor

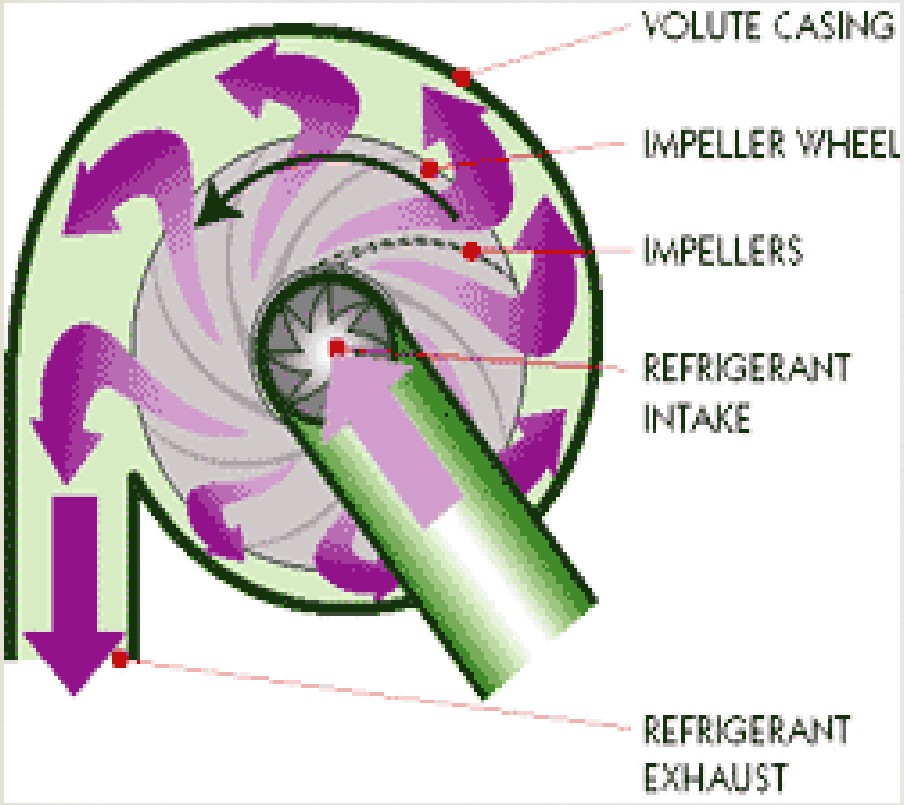


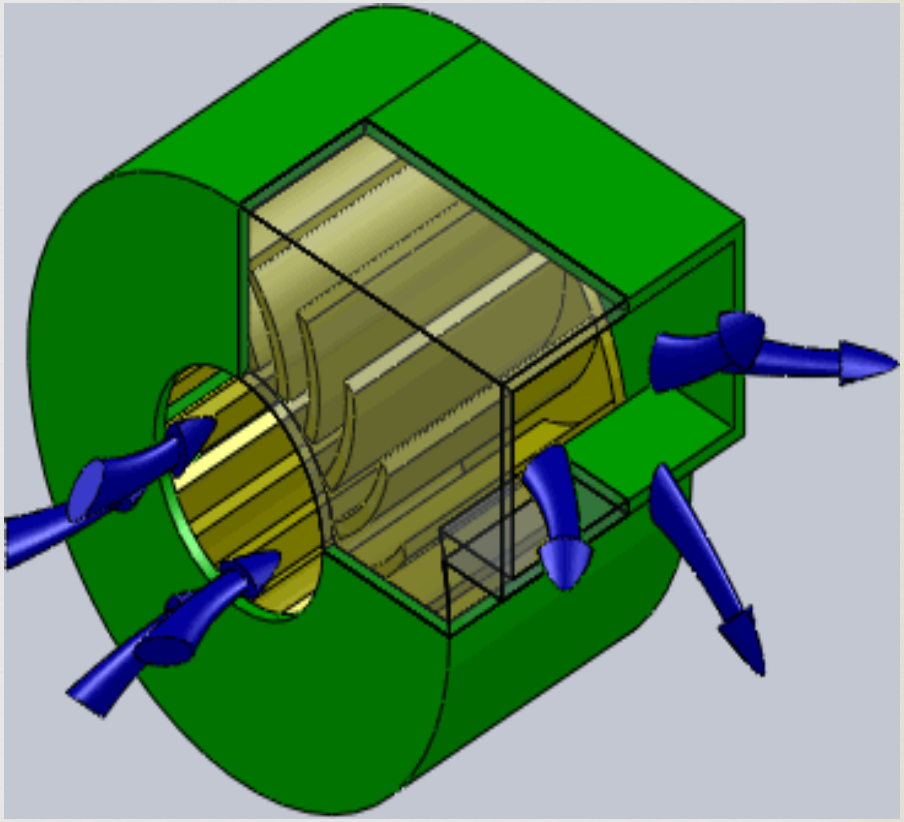


Lobe Compressor

- Characterized by 2 kidney-bean shaped impellers used to trap and transfer air.
- The 2 impellers move in opposite directions on parallel mounted shafts as the lobes sweep across the suction port.
- Compressed gases are released into the discharge line.
- The lobes do not touch each other. A few clearing exists between the casing and lobes.

Centrifugal Compressor





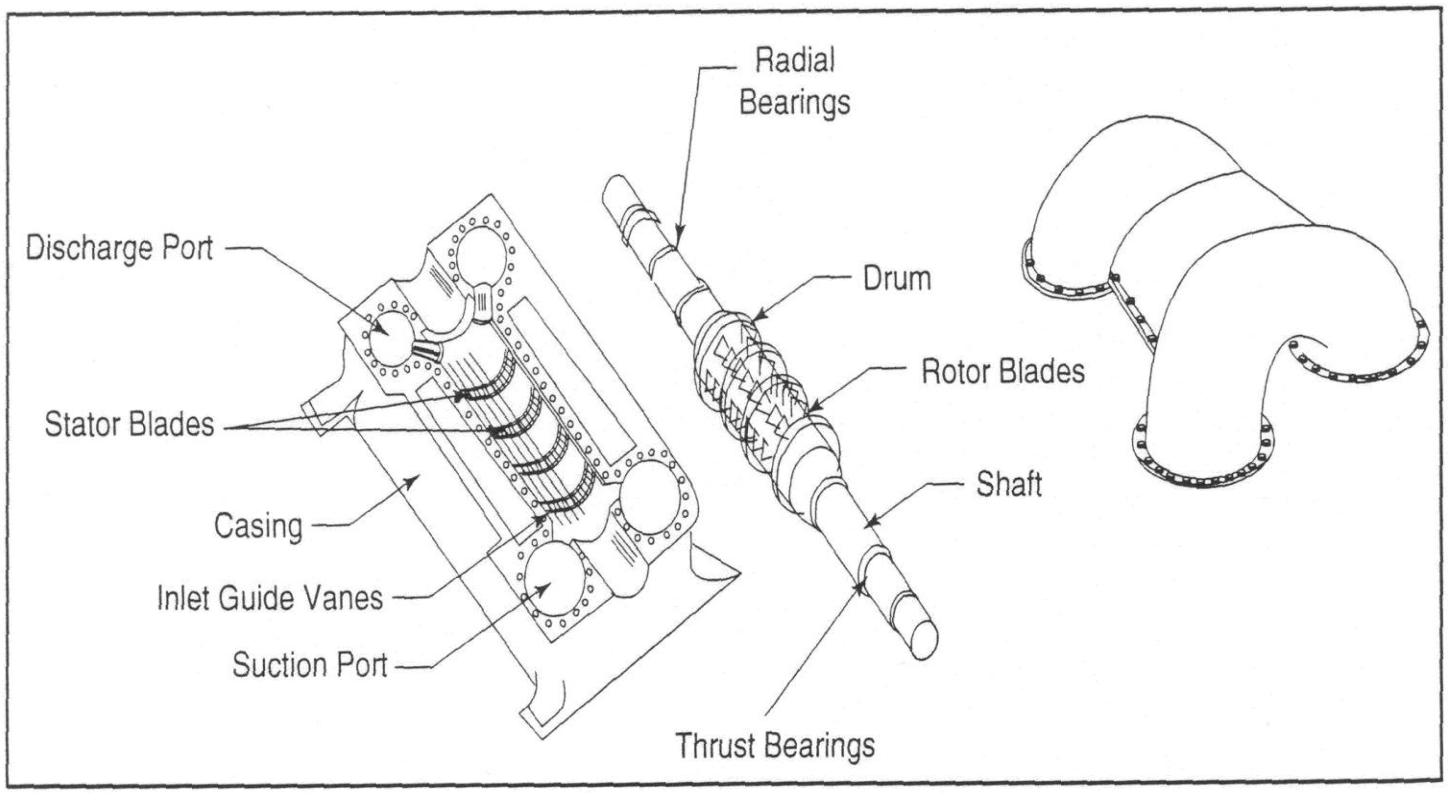
Centrifugal Compressor

- Centrifugal compressors accelerates the velocity of the gases (increases kinetic energy) which is then converted into pressure as the air flow leaves the volute and enters the discharge pipe.
- Usually operate at speeds > 3,000 rpm.
- Deliver much higher flow rates than positive displacement compressors

Centrifugal Compressor

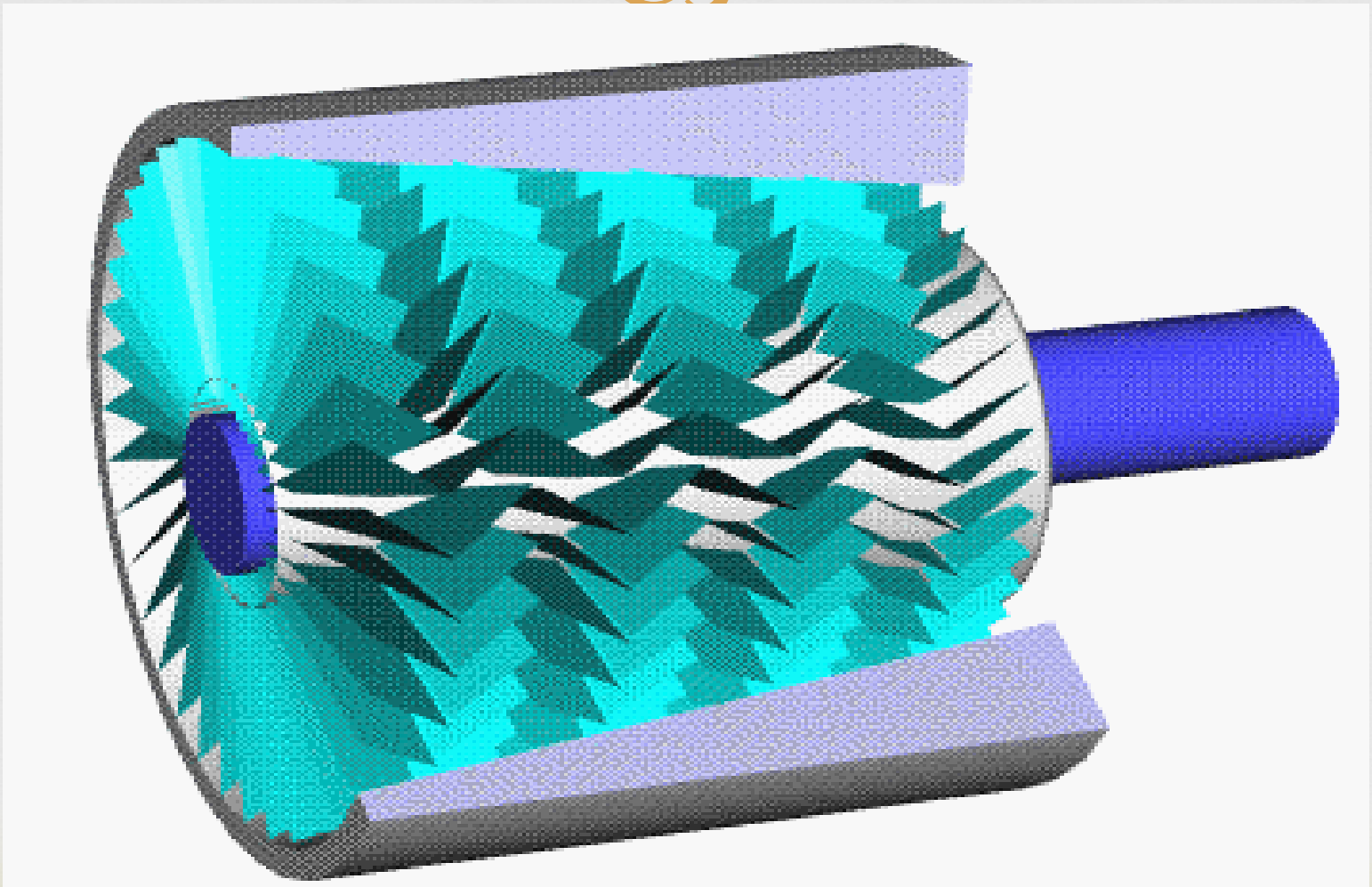
- Basic Components
  - Impellers, Vanes, Volutes, Suction Eyes, Discharge lines, Diffuser Plates, Seals, Shaft, Casing
  - Suction Vane Tips = Part of the impeller vane that comes into contact with air first.
  - Discharge Vane Tips = Part of the impeller vane that comes into contact with air last

Axial flow compressor



Axial Compressor

Axial flow compressor



Axial flow compressor

- Composed of a rotor that has rows of fanlike blades.
- In industry, axial compressors are used a lot high flows and pressures are needed.
- Air flow is moves along the shaft.
- Rotating blades attached to a shaft push air over stationary blades called stators.
- Stator blades are attached to the casing.

Axial flow compressor

- As the air velocity is increased by the rotating blades, the stator blades slow it down. As the air slows, kinetic energy is converted into pressure.
- air velocity increases as it moves from stage to stage until it reaches the discharge.
- Multi-Stage axial compressors can generate very high flow rates and discharge pressures.
- Axial compressors are usually limited to 16 stages (due to temperature/material limitations)
- Pound for pound, axial compressors are lighter, more efficient, and smaller than centrifugal compressors.