Compressors & Compressed Air Systems

Website: www.ttetraining.ltd.uk

Main Components in Compressed Air Systems

- Intake air filters
- Inter-stage coolers
- After coolers
- Air dryers
- Moisture drain traps
- Receivers

Air Quality

Process conditions will dictate the quality of the air required for either the process or the control equipment associated with it.

In general the air needs to be as clean as possible with minimal water content and the use of oil free compressors will be off great benefit. The term normally used to denote the highest quality air is referred to as Instrument Air Quality.

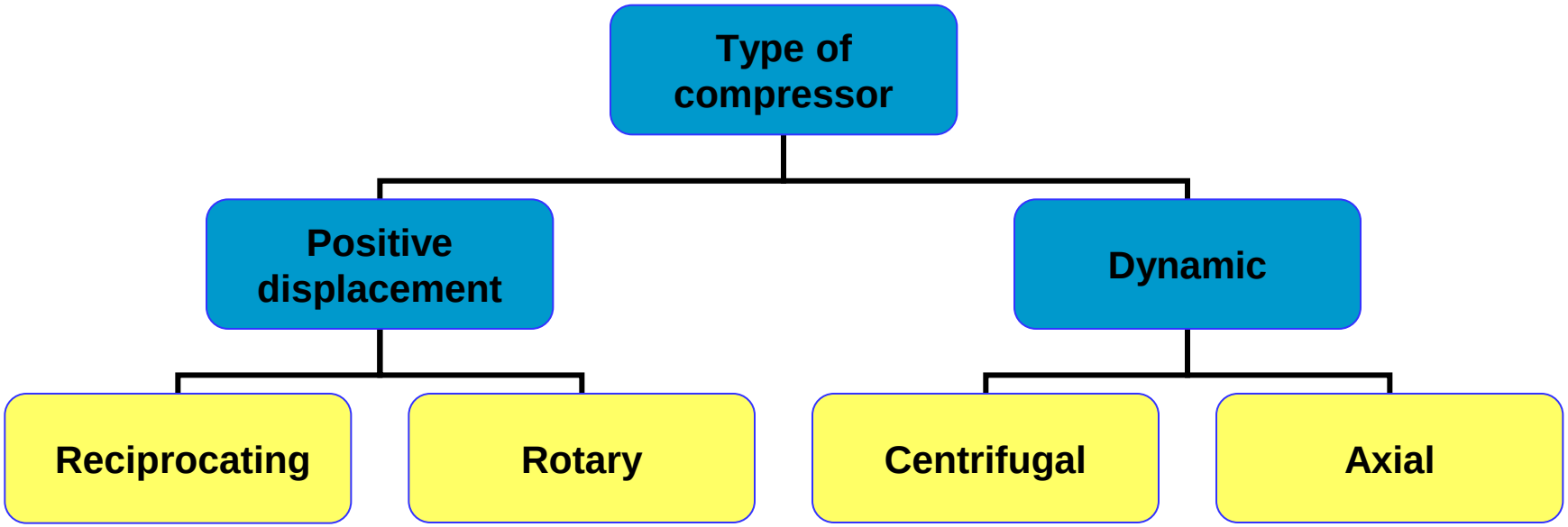
Air Quality

As air it draw into the compressor system it will be filtered, this filtered will normally be monitored with the use of a Dp. cell.

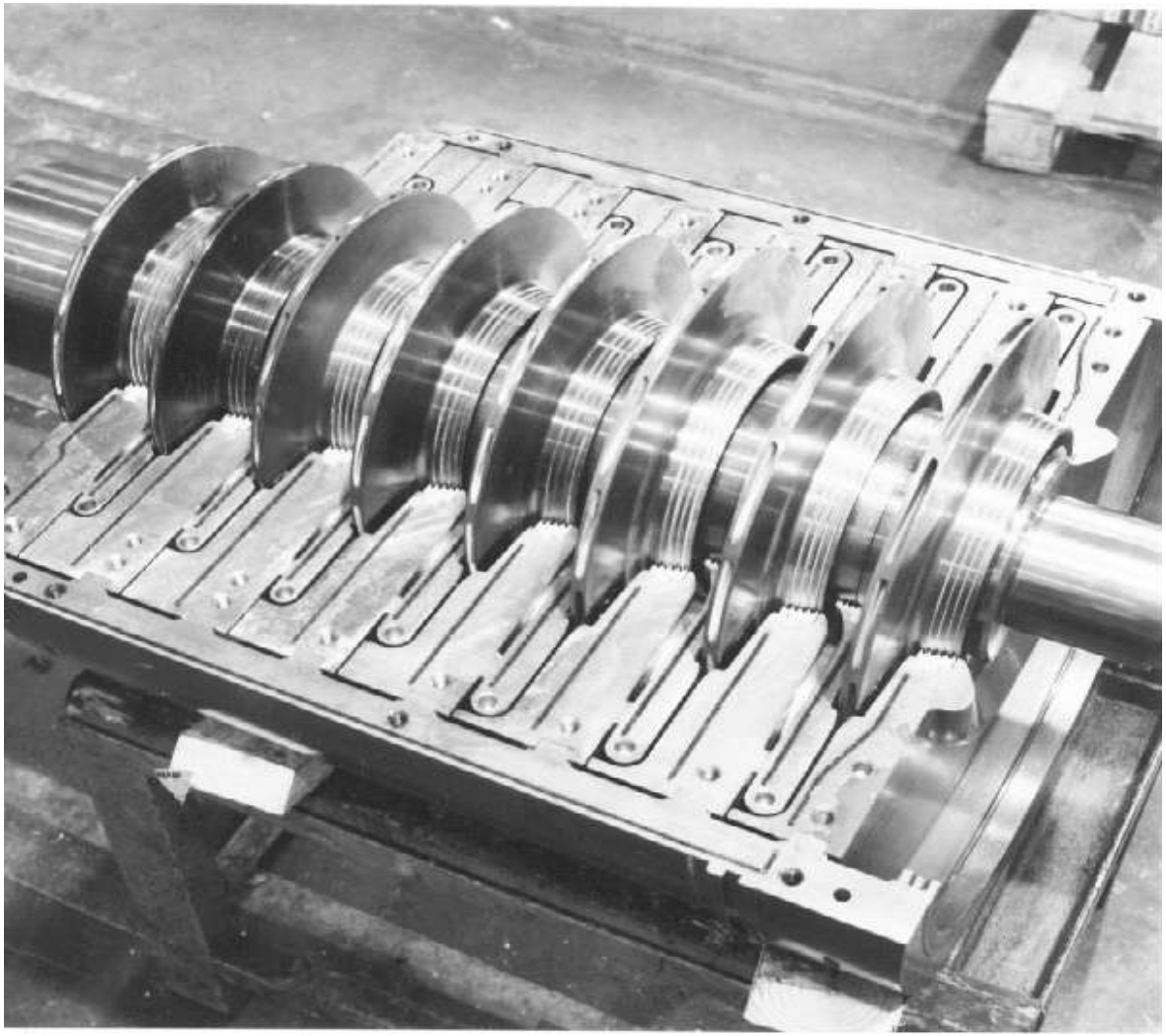
In a multi stage system the use of inter-stage cooling will be used, this will reduce the temperature loading along with reducing the water content.

Finally the system may pass through a chiller unit were the last of the remaining water vapour will be removed

Two Basic Compressor Types



Centrifugal Compressor

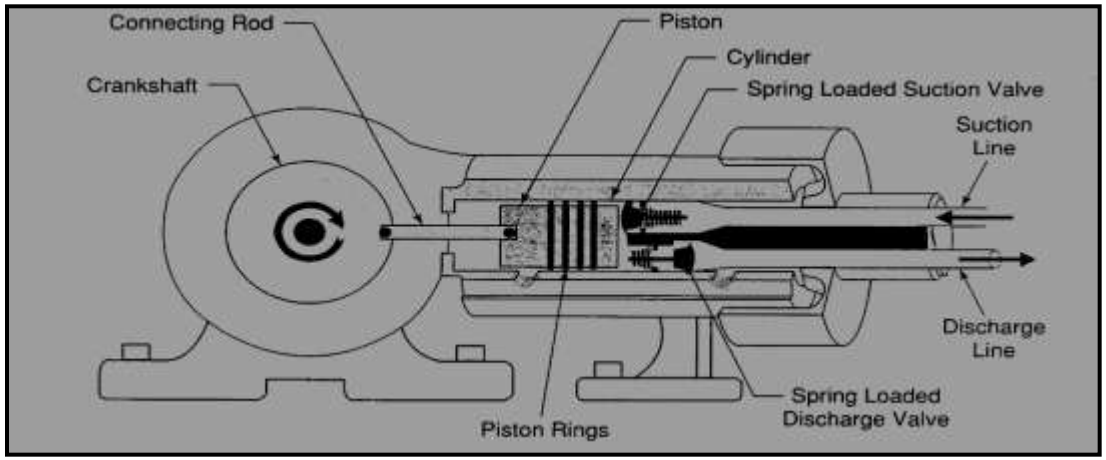


Centrifugal Compressor

- Rotating impeller transfers energy to move air
- Continuous duty
- Designed oil free
- High volume applications
  > 12,000 cfm

Reciprocating Compressor

- Used mainly for air and refrigeration compression
- Works like a bicycle pump: cylinder volume reduces while pressure increases, with pulsating output
- Many configurations available
- Single acting when using one side of the piston, and double acting when using both sides

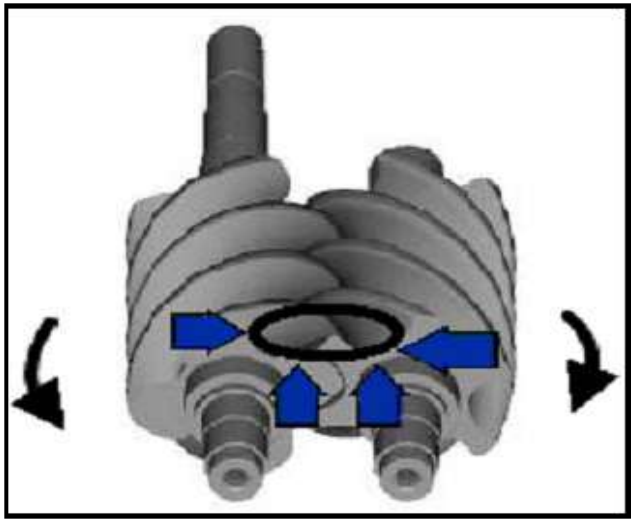


Rotary Compressor

Rotors instead of pistons provide a continuous discharge, main benefits are low cost, compact, low weight, easy to maintain. Sizes range between 30 – 200 hp

Types

- Lobe compressor
- Screw compressor
- Rotary vane / Slide vane



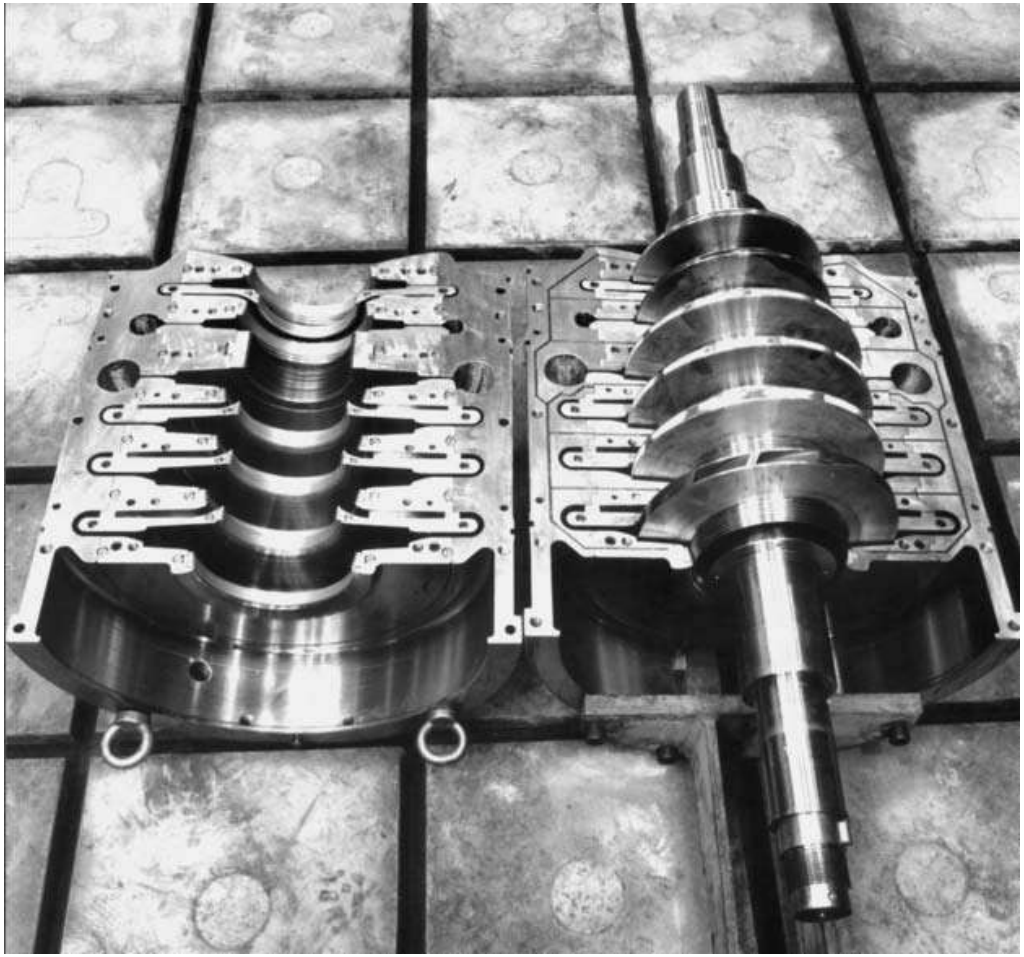
Comparison of Compressors

- **Efficiency at full, partial and no load**
- **Noise level**
- **Size**
- **Oil carry-over**
- **Vibration**
- **Maintenance**
- **Capacity**
- **Pressure**

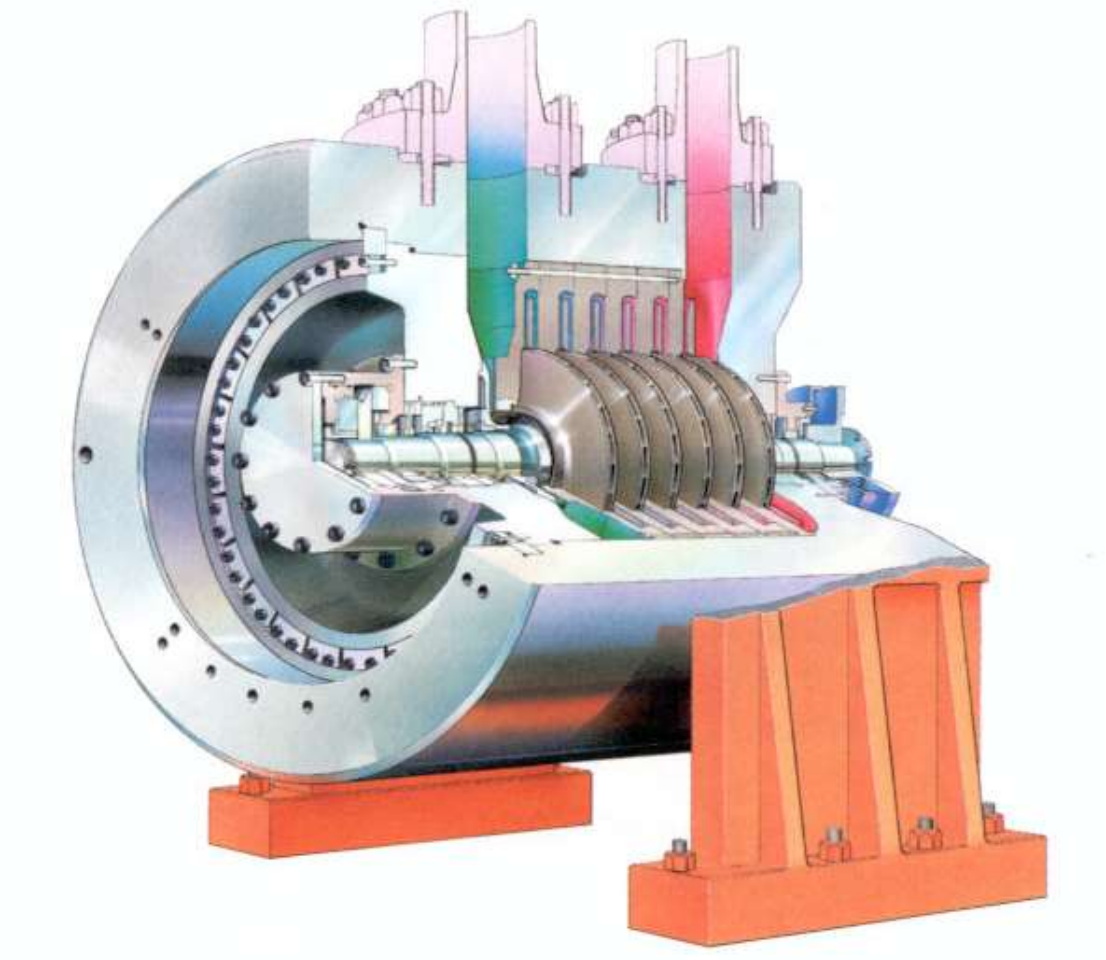
There are two casing designs for centrifugal compressors

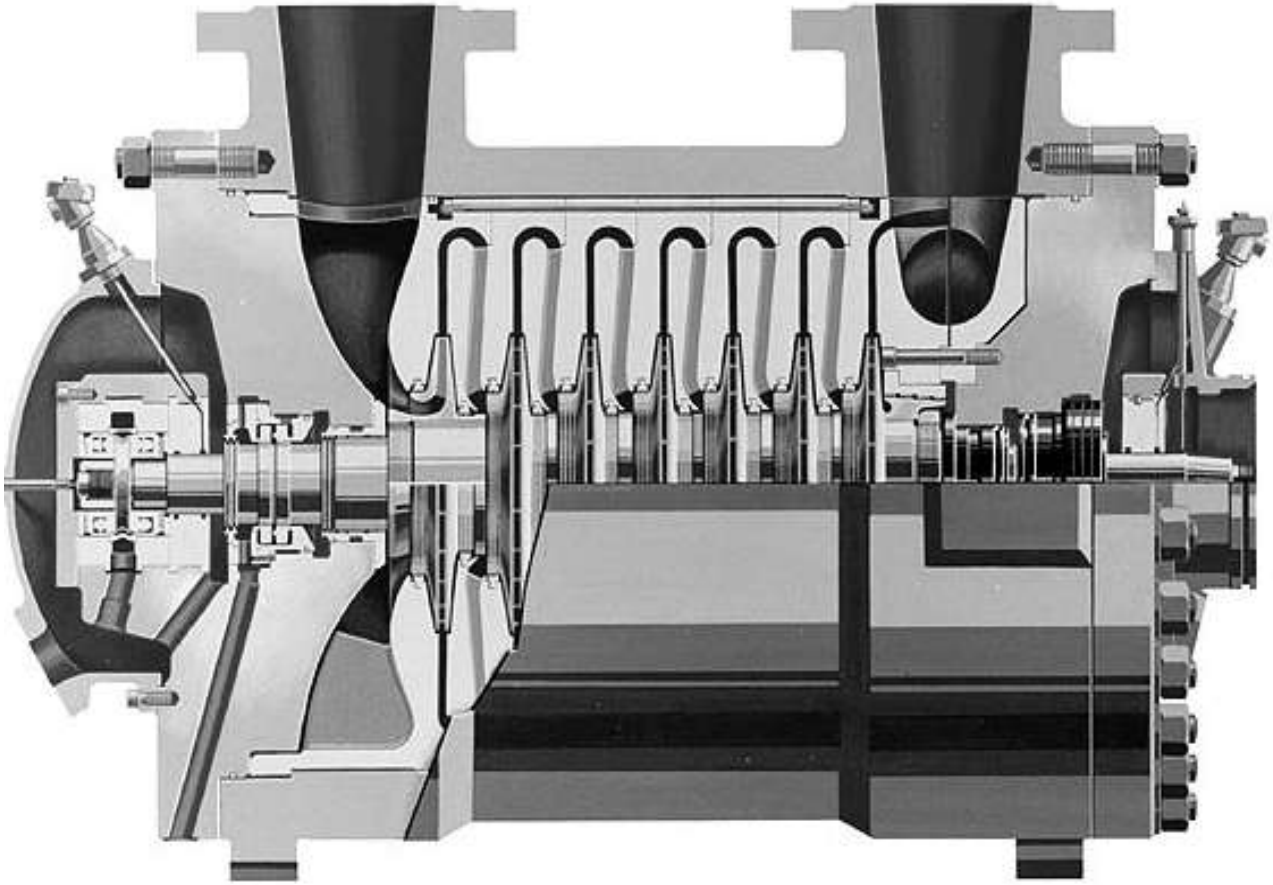
Horizontally split casing

Vertically split casing



Vertically split case or barrel





Note the ice that has formed around the suction end of the compressor.

Why or how would this happen?

There are two basic elements within a centrifugal compressor these are:

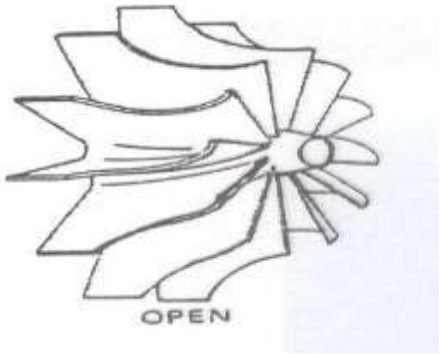
(1) The Rotor
(2) The Stator

These are kept apart by bearings mounted at each end of the compressor rotor. The bearings will comprise of:

(3) Radial contact bearings
(4) Thrust bearings

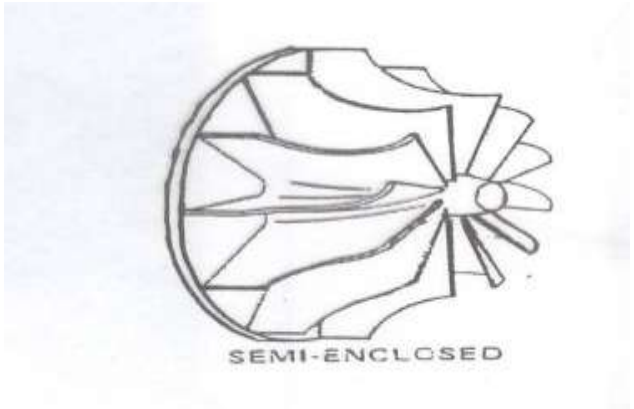
Impellers

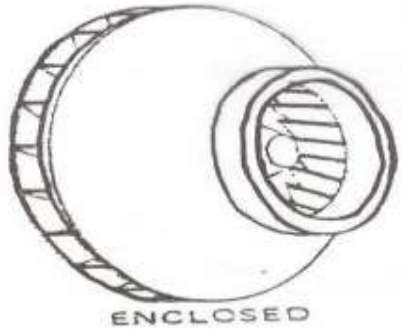
The part of the centrifugal compressor that adds velocity to the gas is the impeller, There are three basic impeller designs:



Used for high heads and small to large flow in single stage compressors only.

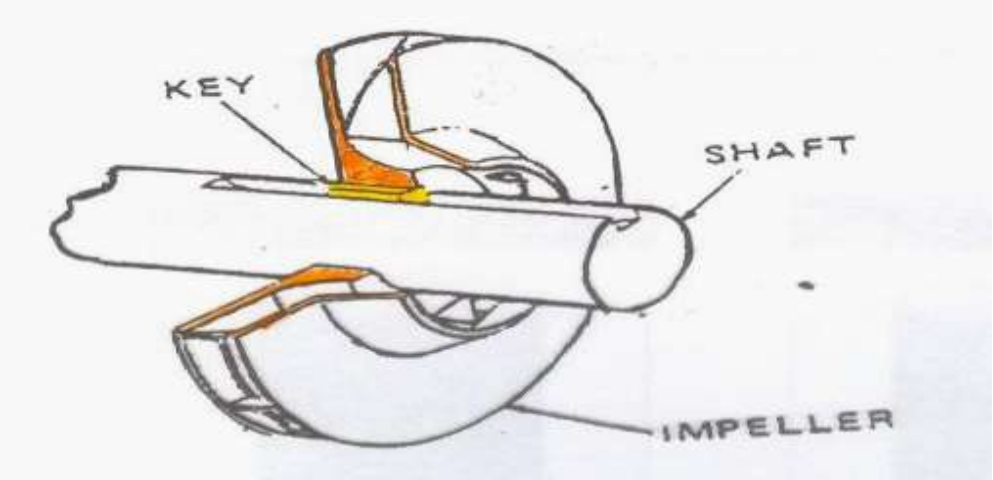
Used for large flow, usually in single stage compressors, or as the first stage in multi-stage compressors.





Used mainly in multi-stage compressors.

Fitting Impellers

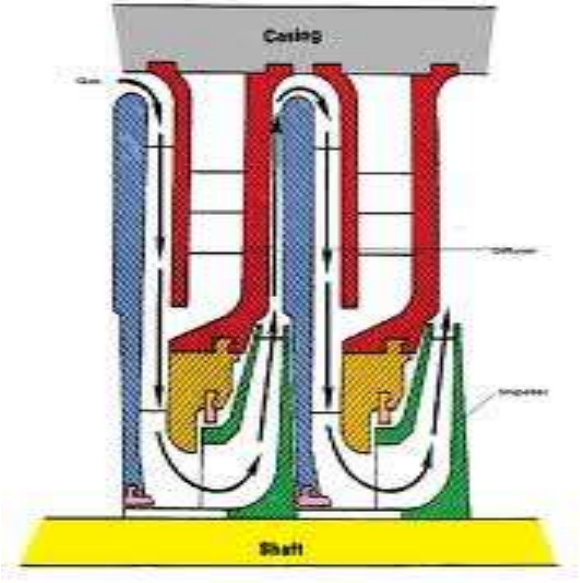


An unbalanced or loose impeller vibrates. To prevent vibration, the impeller must be shrunk onto the shaft and well balanced.

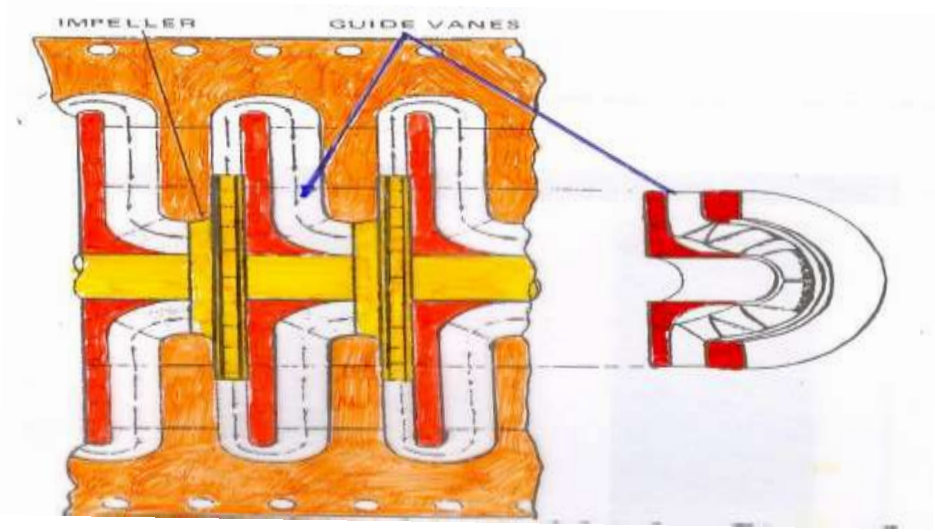
Diaphragms

A Multi-stage centrifugal compressor contains diaphragms or diffusers that convert the kinetic energy (high velocity) of the gas into pressure by gradually slowing (diffusing) the gas velocity.

The diaphragms are located between the impellers.



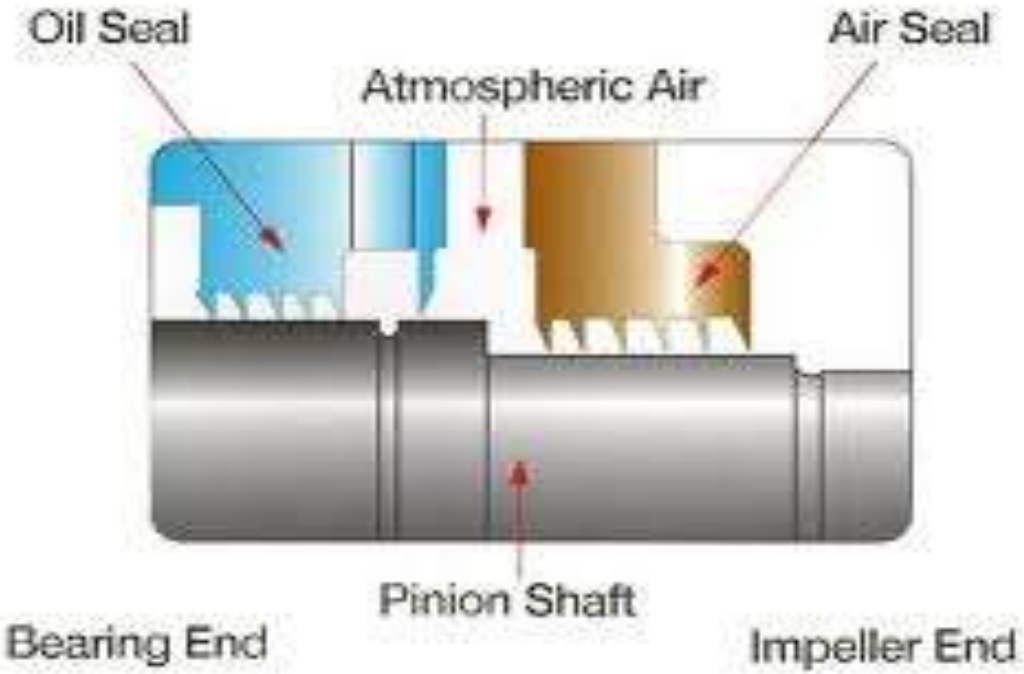
Guide Vanes



These vanes are designed to guide the flow of gas efficiently into the eye of the impeller. The guide vanes in multi-stage centrifugal compressors are placed at the end of the return passage of the diaphragm. The gas that leaves an impeller passes through the diffuser passage and in the return passage is guided by guide vanes into the next impeller.

Labyrinth Seals

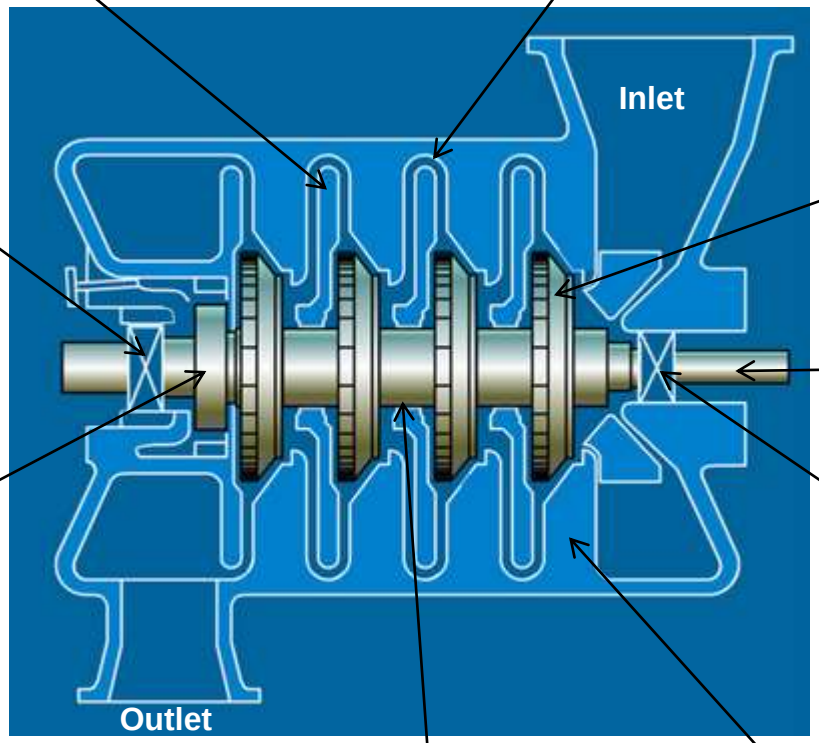
The rings or teeth are made of soft metal so that the shaft will not be damaged in case of accidental contact. The rings or teeth are also sharp so that any friction generated by contact would be small. The spaces between the teeth form a labyrinth passage.



The labyrinth seal is a set of metal rings or teeth that encircle the shaft. The teeth do not contact or touch the shaft.

Diaphragms, separate each stage and maybe water cooled

Diffuser



Impellor

Thrust bearing (4)

Rotor (1)

Balance Piston

Radial bearing (3)

Labyrinth seal

Stator (2)

Tilting Pad Thrust Bearing

Compression Ratio

$$\text{Compression Ratio} = \frac{Po}{Pi} = \frac{\text{Output Pressure}}{\text{Input Pressure}}$$

If a compressor had an output pressure of 5 bar and an inlet pressure of 2 bar the compression ratio would equal:

$$R = \frac{Po}{Pi} = \frac{5}{2} = 2.5$$

SURGE CONDITION

As the flow through a centrifugal compressor is progressively reduced by either the discharge valve or a restriction the discharge pressure increases.

With this flow reduction, a recirculation pattern develops in the impeller.

At some minimum flow, the recirculation flow pattern collapses. The impeller can no longer develop the discharge pressure required to maintain flow through the compressor.

Since the pressure developed is less than that in the downstream system, a flow reversal occurs. The delivered flow from the compressor then immediately drops to zero.

SURGE CONDITION

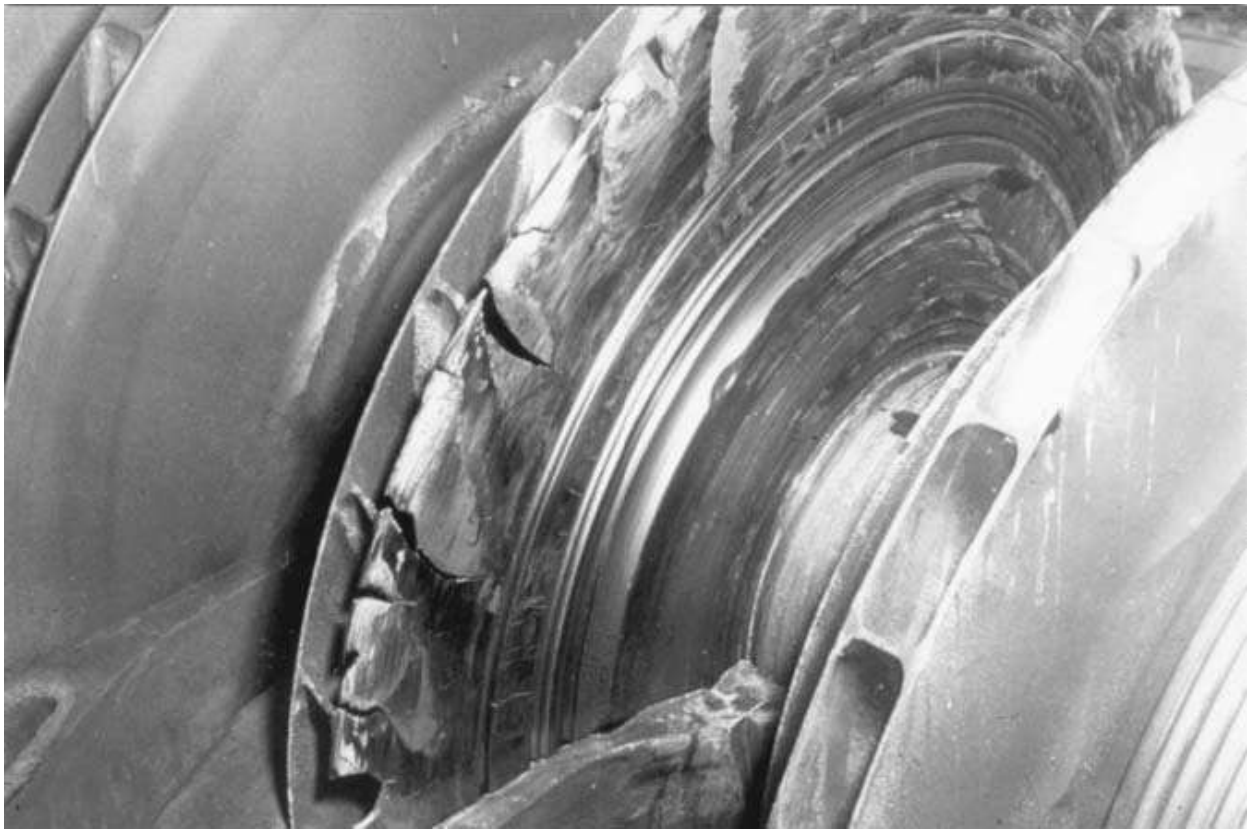
When the flow drops to zero, the pressure of the downstream system has dropped.
Compressor flow will once again develop head and move toward maximum head. If the position or status of the discharge valve or restriction has not been altered, the flow and discharge pressure will change along the compressor characteristic curve until the surge point is again reached.
If the downstream system cannot accept, or, utilize the compressed gas delivered by the compressor, or, if the required flow from the compressor for a given speed is not maintained, the compressor could, and, probably will, surge if not properly protected.

SURGE CONDITION

Surge protection is normally incorporated into the overall flow control of the compressor system. It can be setup in several ways from controlling the flow of incoming air by choking or using the off-loading start-up system, or by recirculation from the discharge end but only after the air has been cooled by the intercooler, or venting to atmosphere if this is appropriate depending on the type of gas being handled.

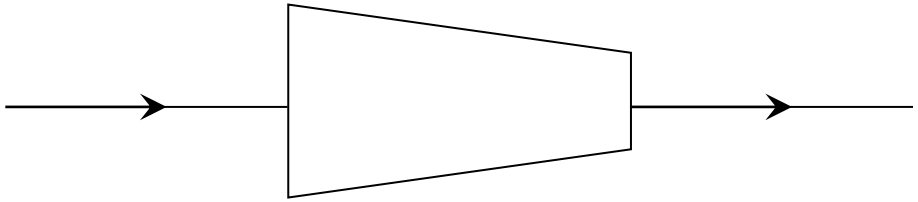
Never the less the surge condition situation has to be monitored and controlled to a very high degree and the control systems have to act extremely quickly as serious damage can and very often occurs inside the compressor.

SURGE DAMAGE

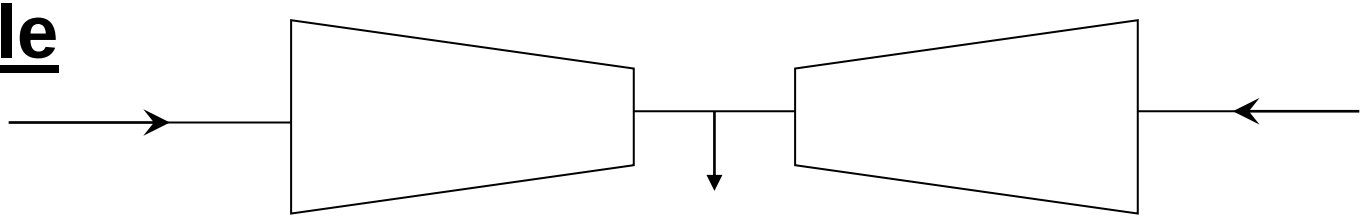


Types of Flow

Single Flow

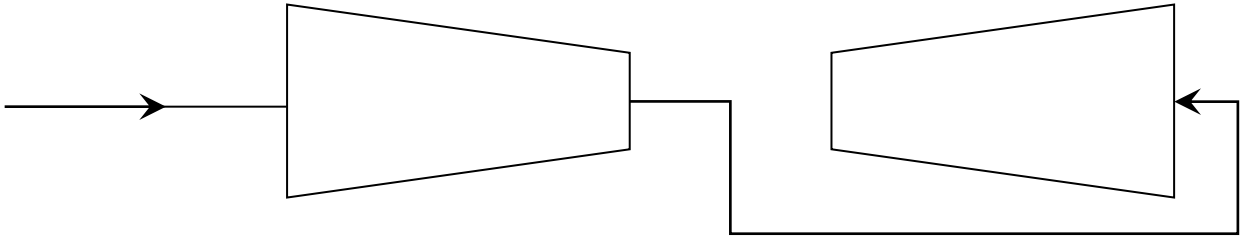


Double Flow



This has a double suction with a common discharge, minimising axial thrust

Multi-Stage

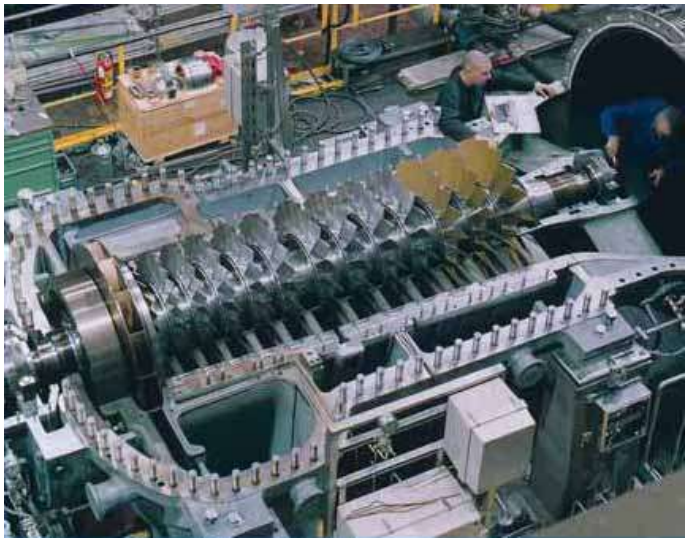


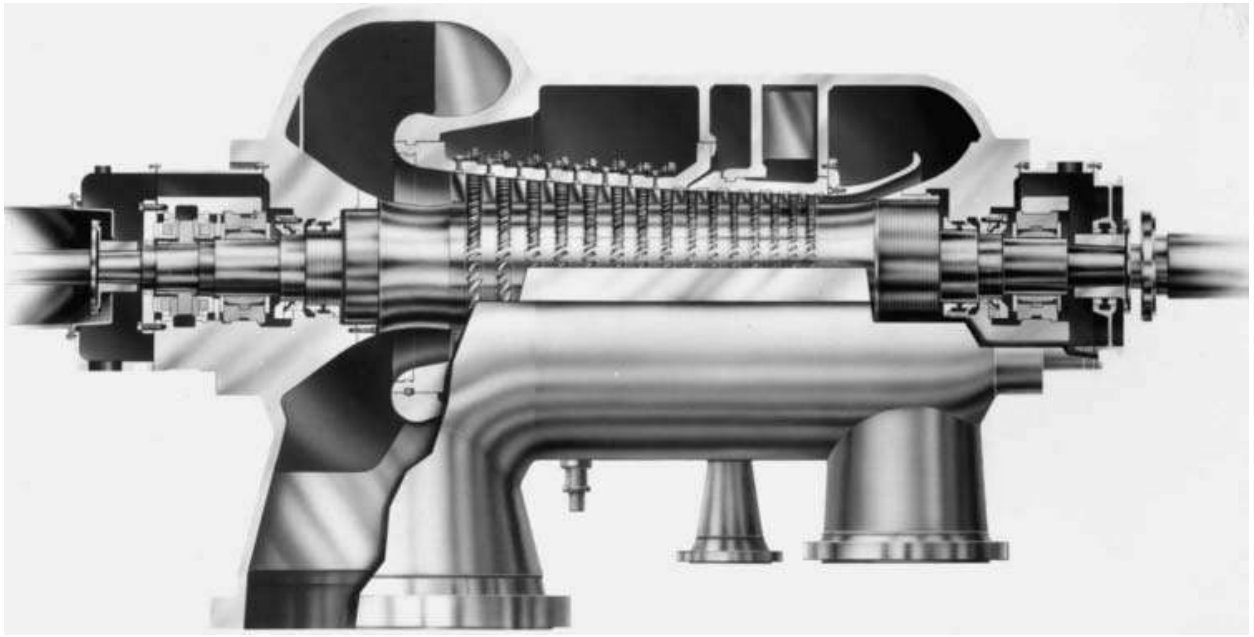
The discharge of one impeller feeds the suction of the next impeller.

Axial thrust can be a problem with this design.

Centrifugal Compressors

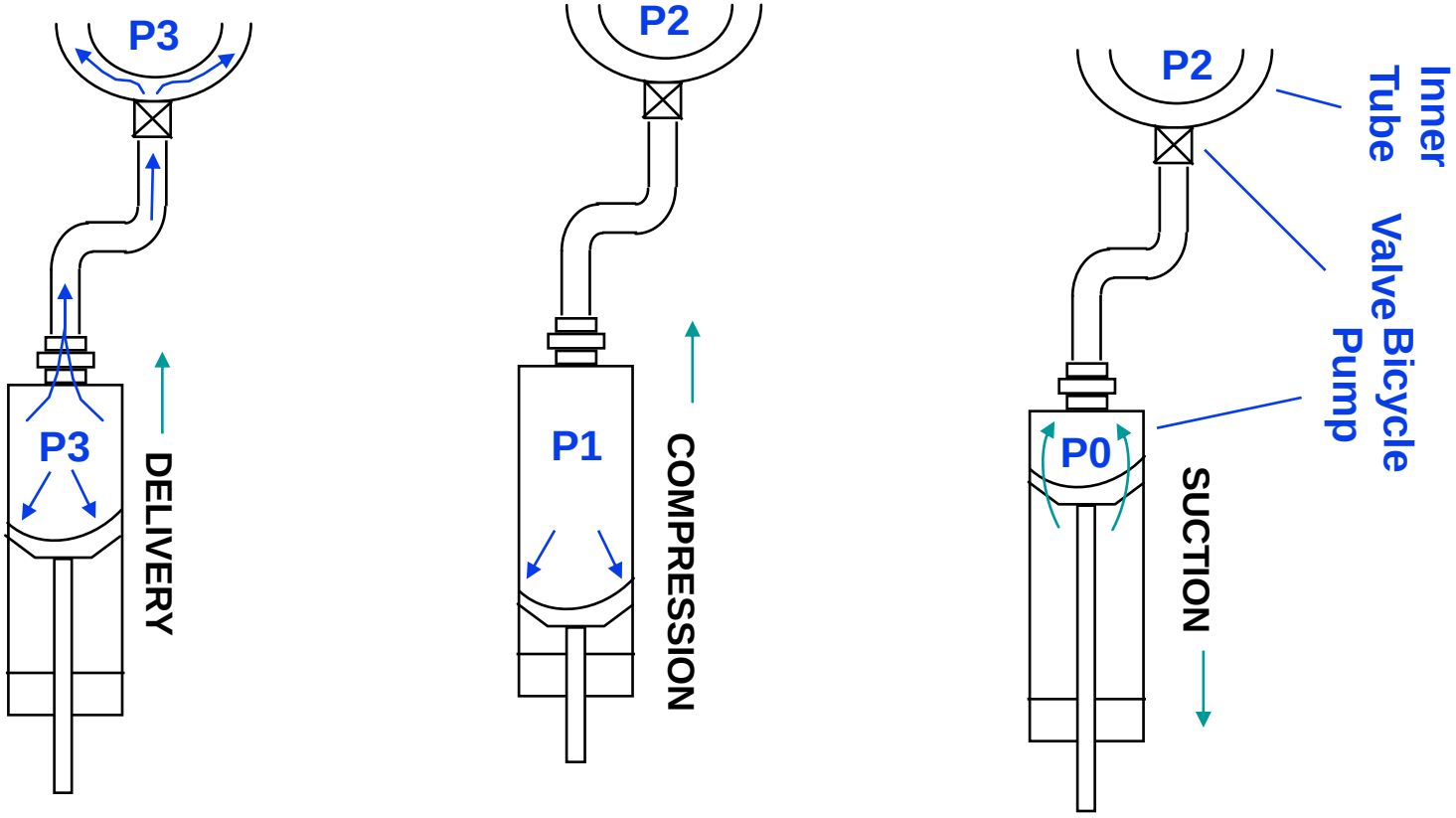
Axial Flow





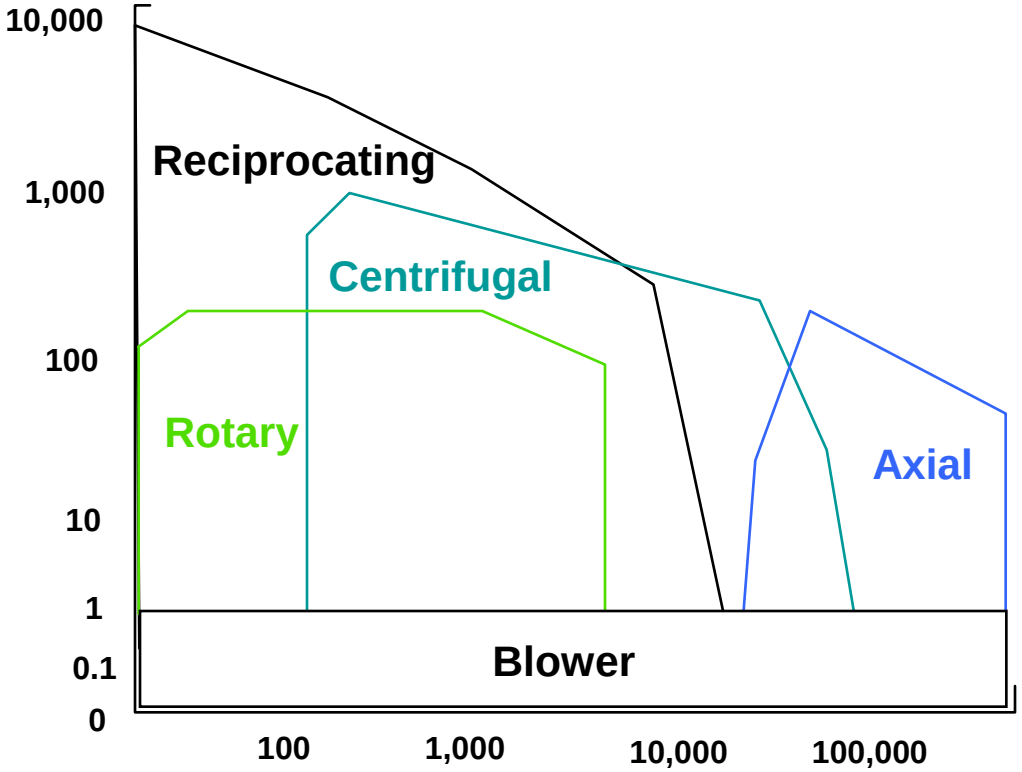
Reciprocating Compressors

The Simplest Type of Compressor - A Cycle Pump



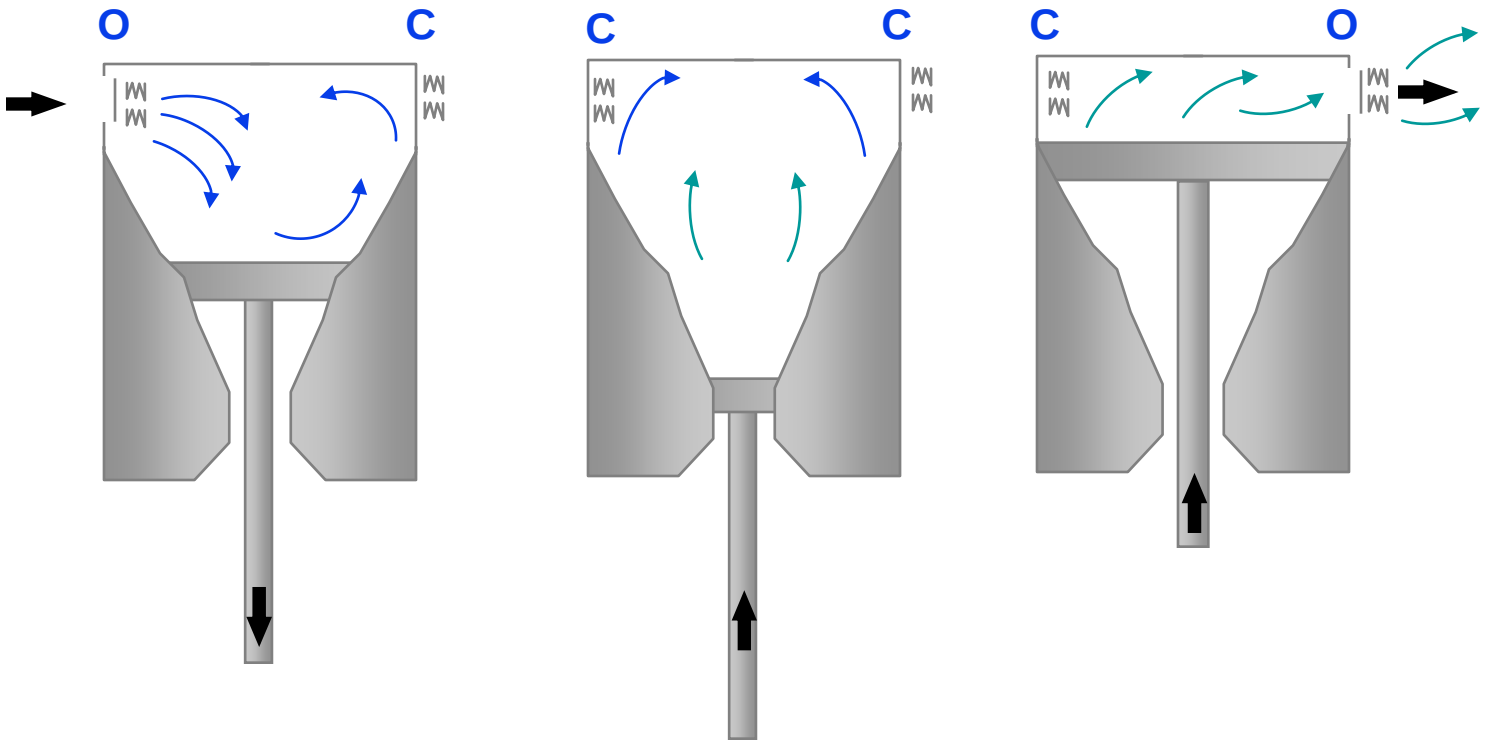
Operating Ranges of Various Types of Compressors

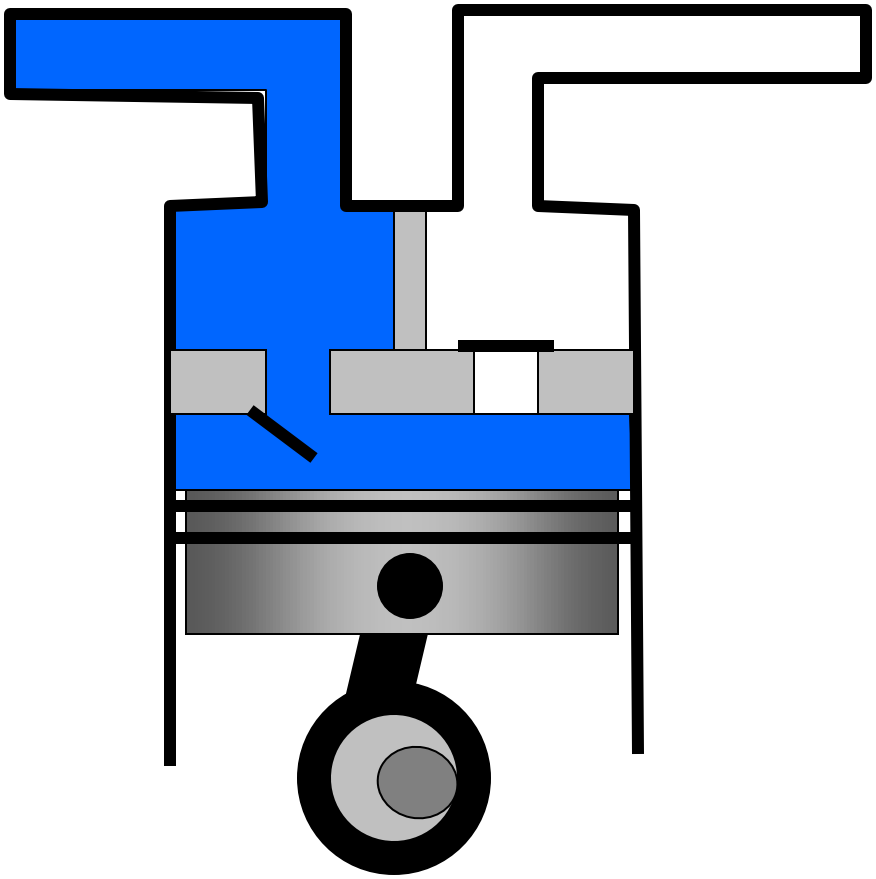
Discharge Pressure P.S.I.

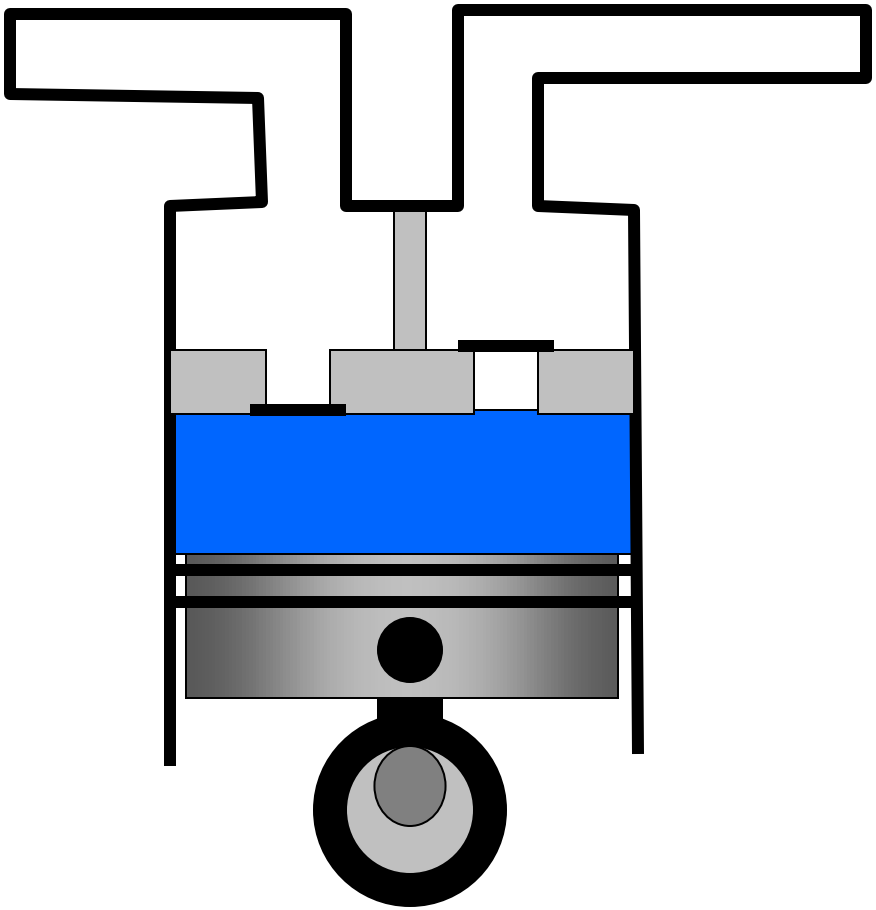


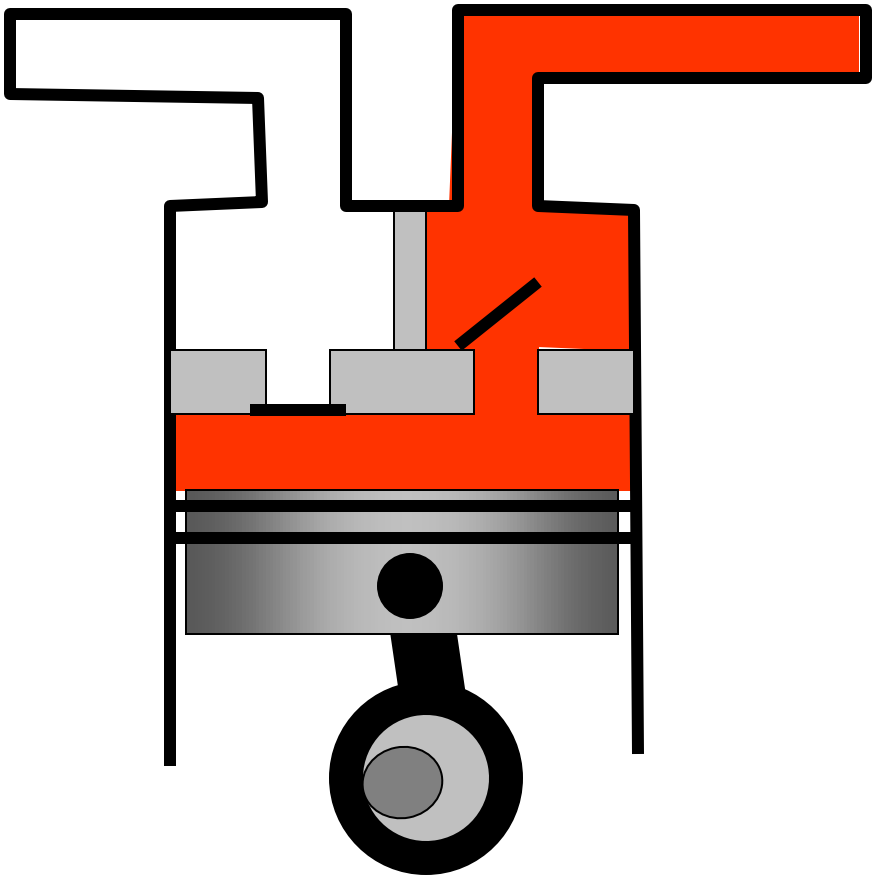
Volume Throughput C.F.M.

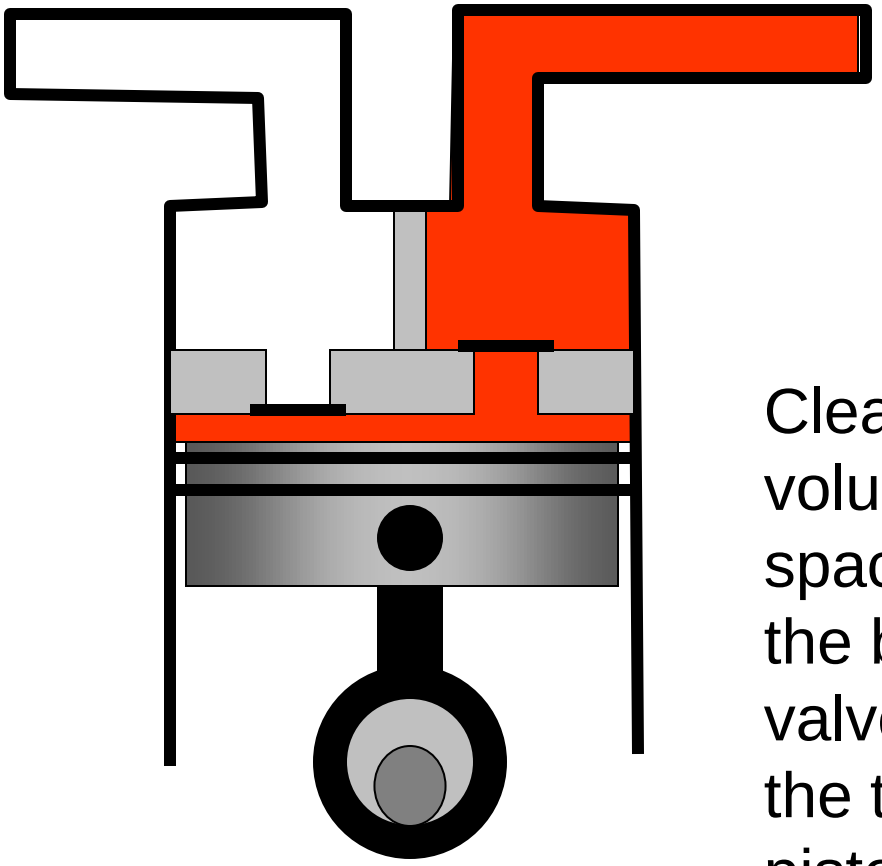
Reciprocating Compressor



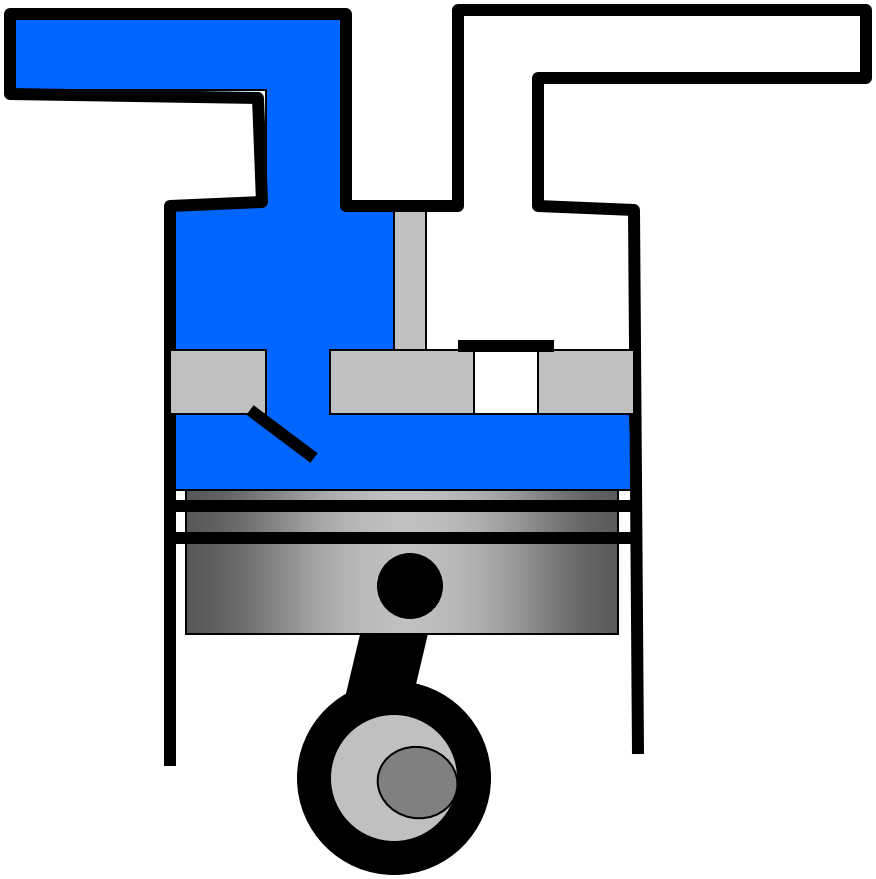


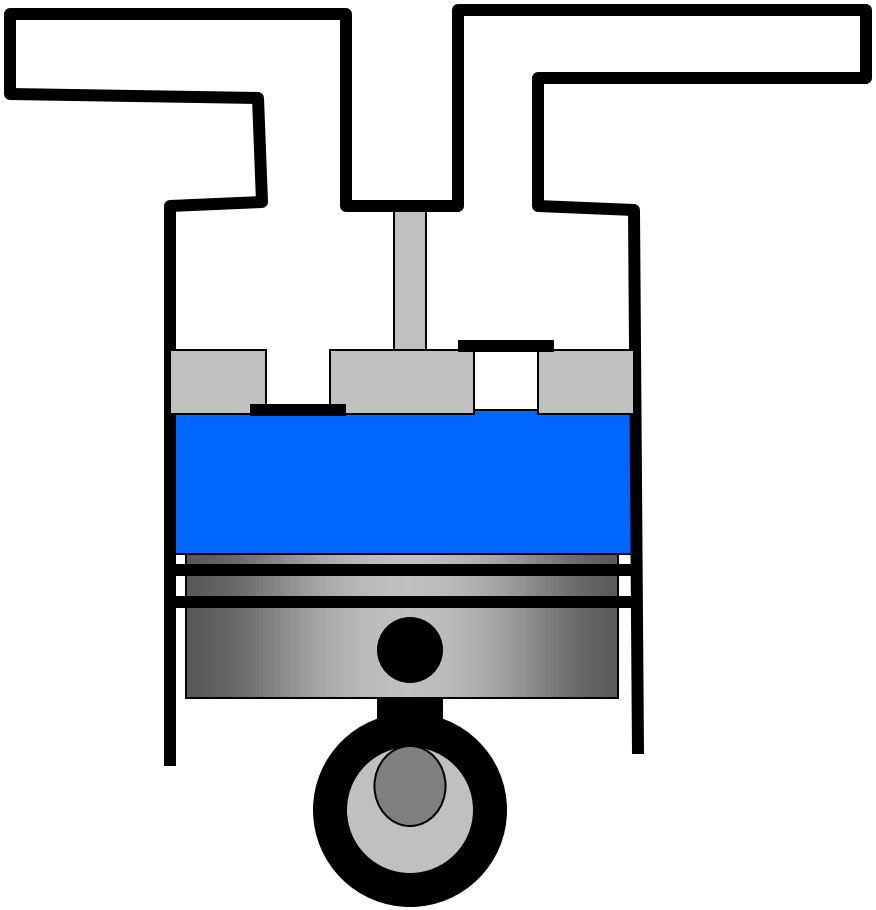


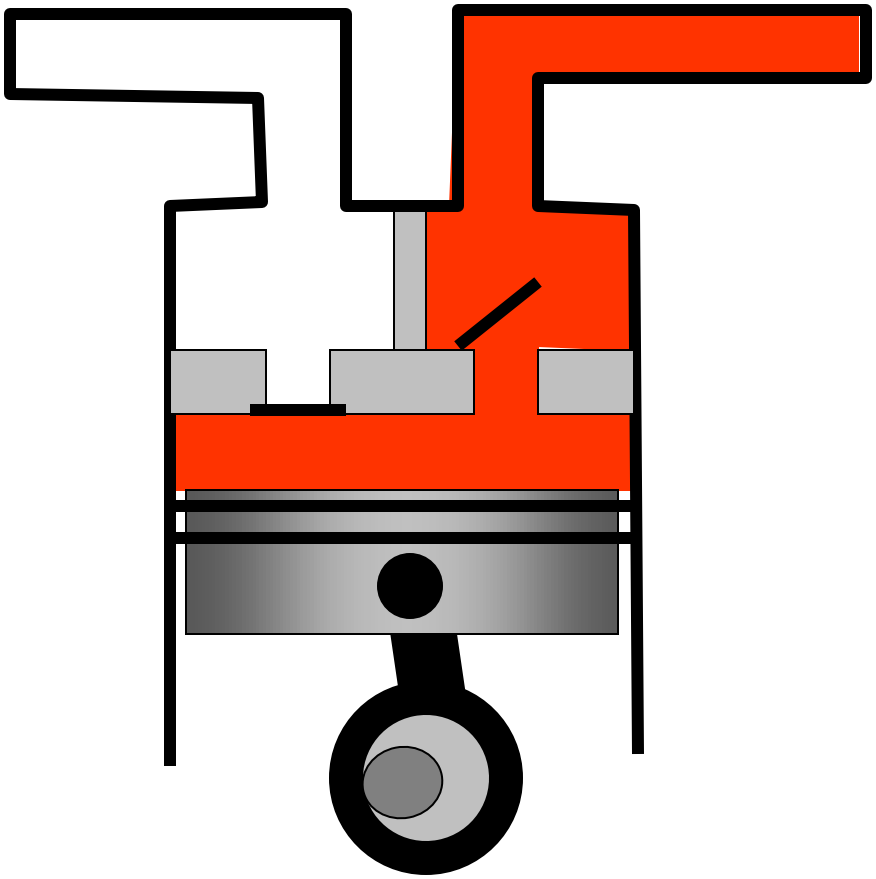




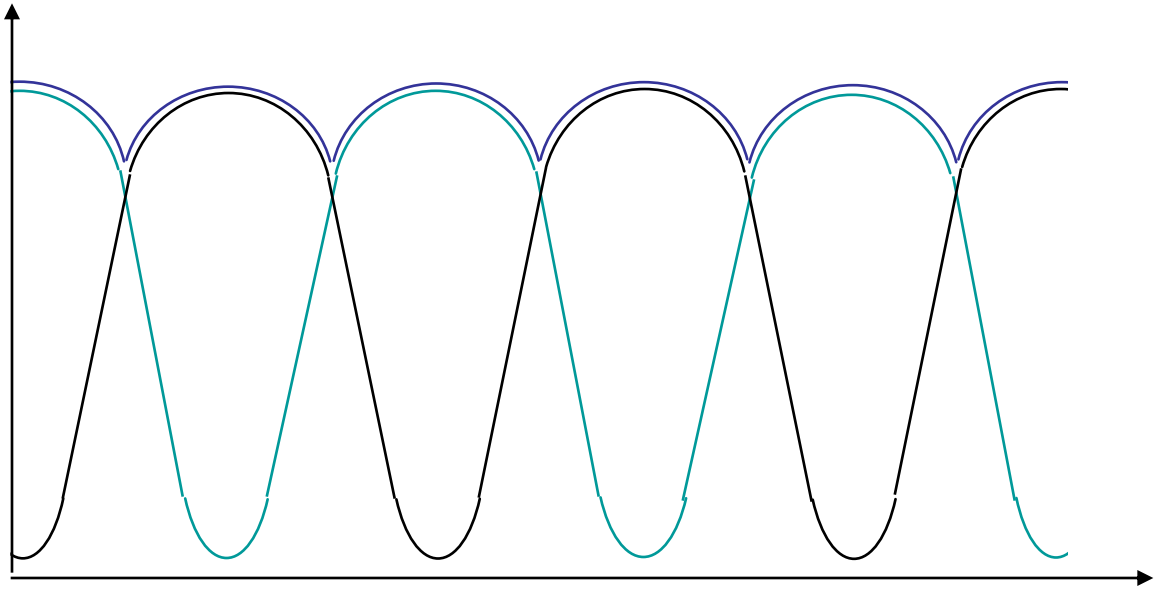
Clearance volume of the space between the bottom of the valve plate and the top of the piston at top dead center?





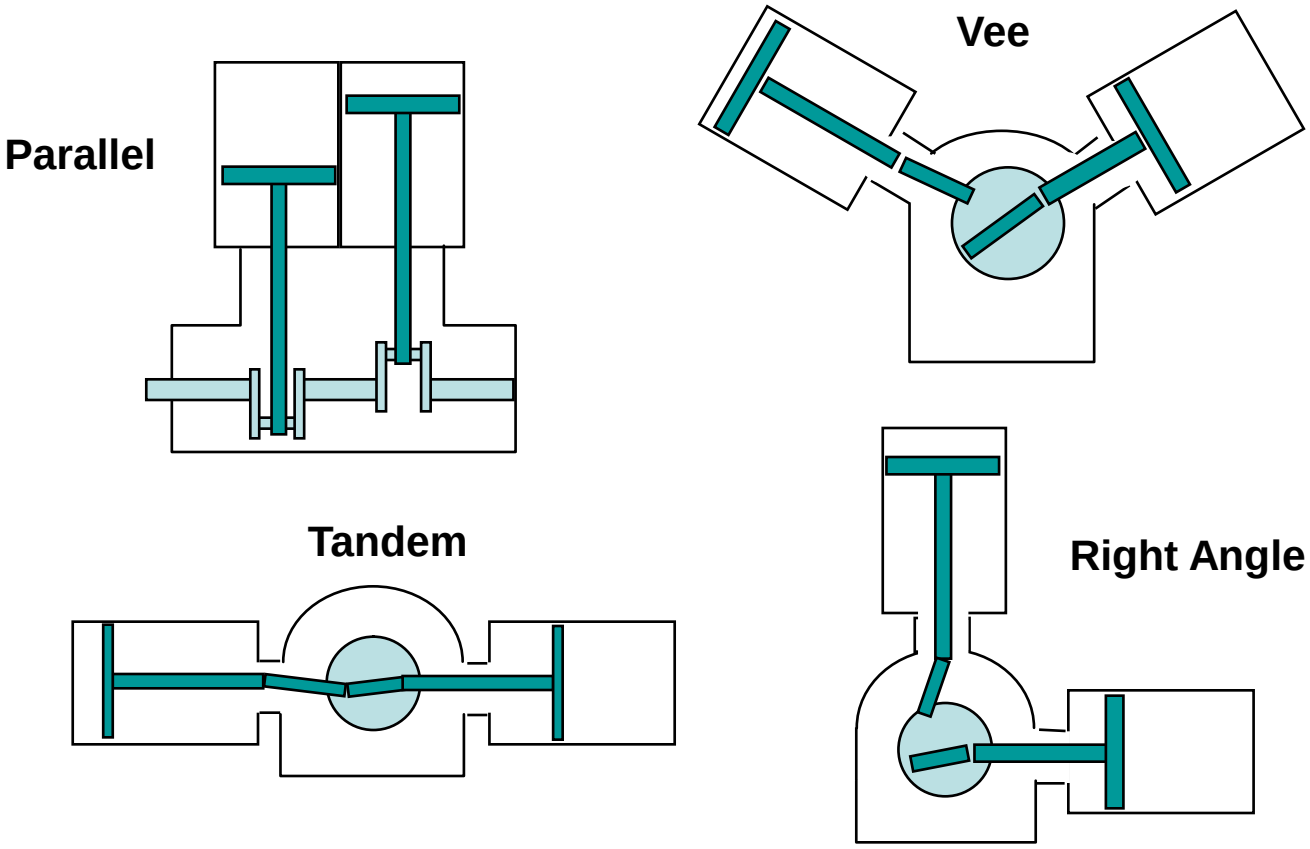


Pulsed Flow

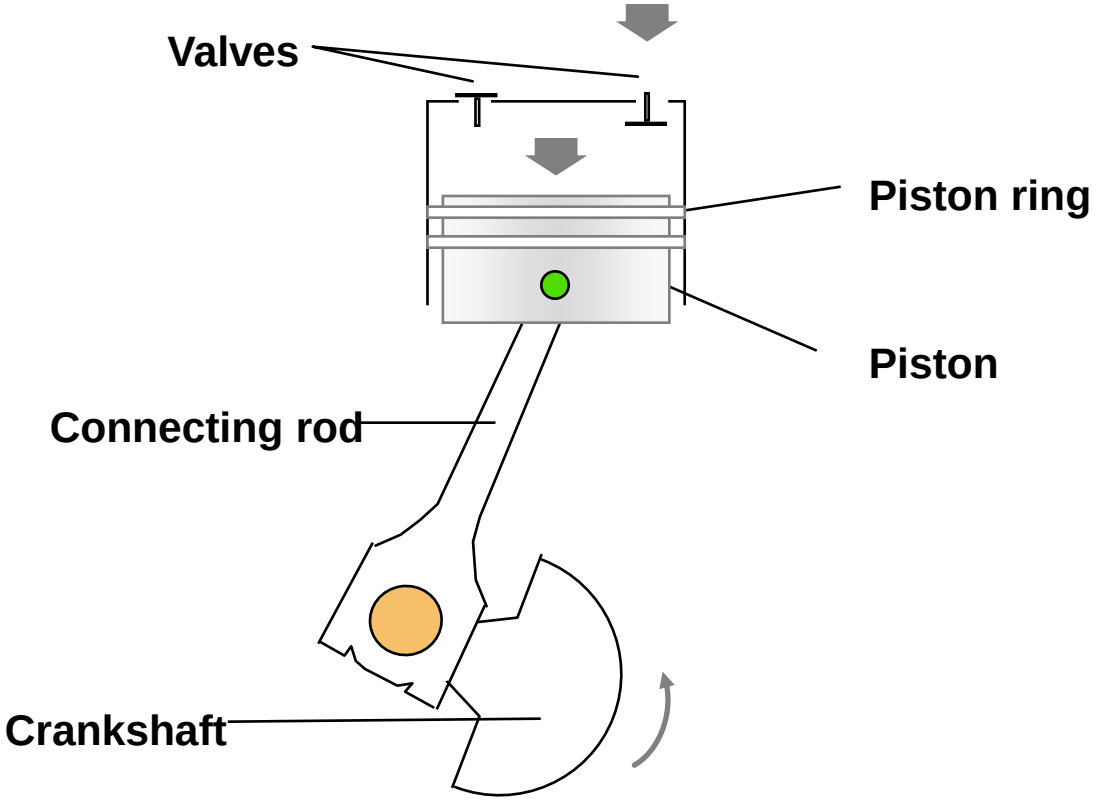


Pulsed flow is undesirable so with double acting piston, peaks and troughs are evened out

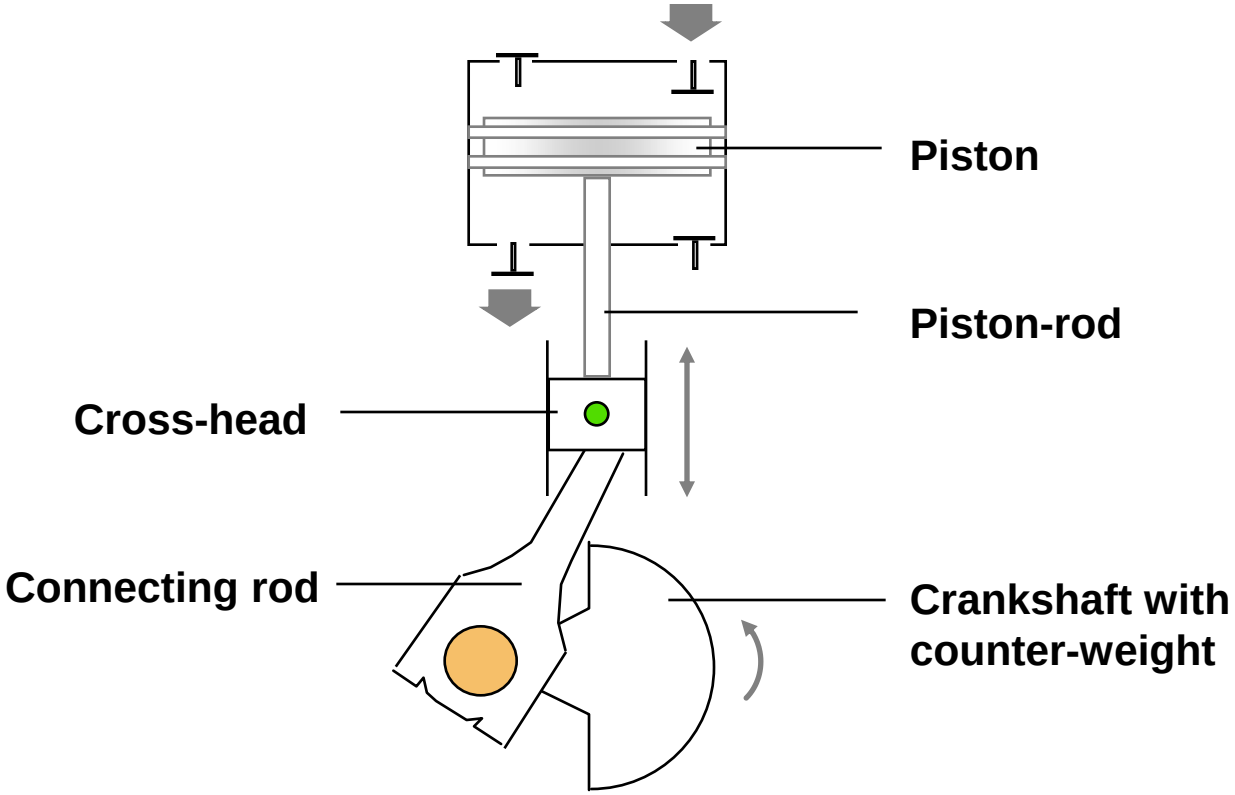
Cylinder Arrangements



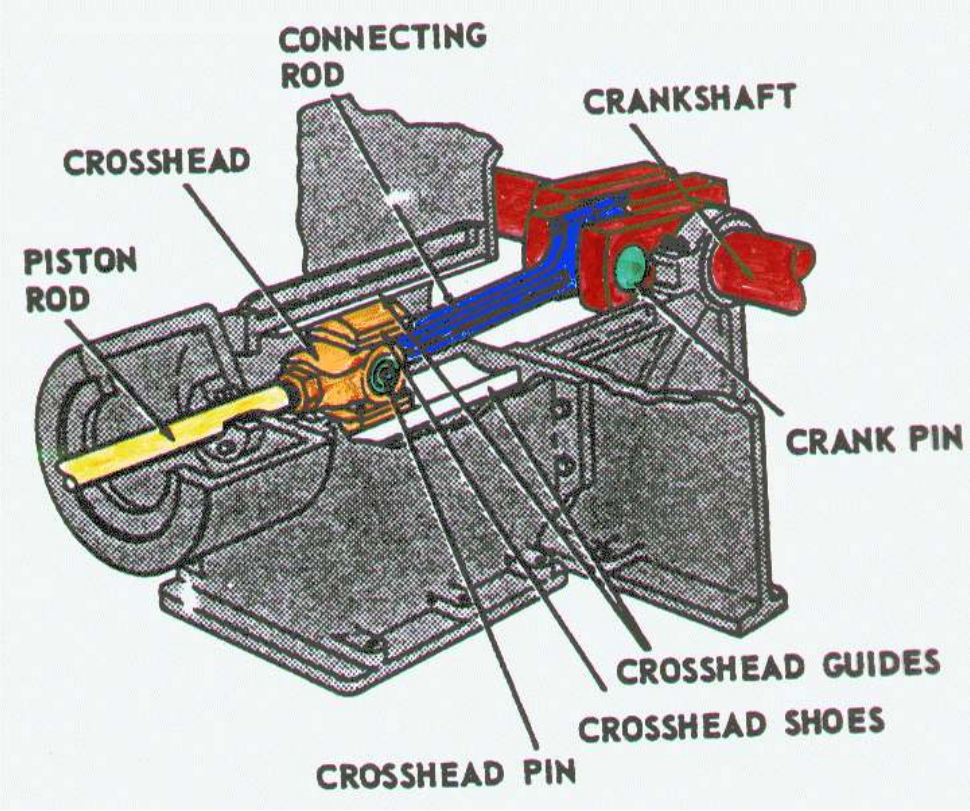
A Single-acting Reciprocating Compressor



A Double-acting Reciprocating Compressor



Reciprocating Motion with Crosshead Bearing



Two Stage Compression

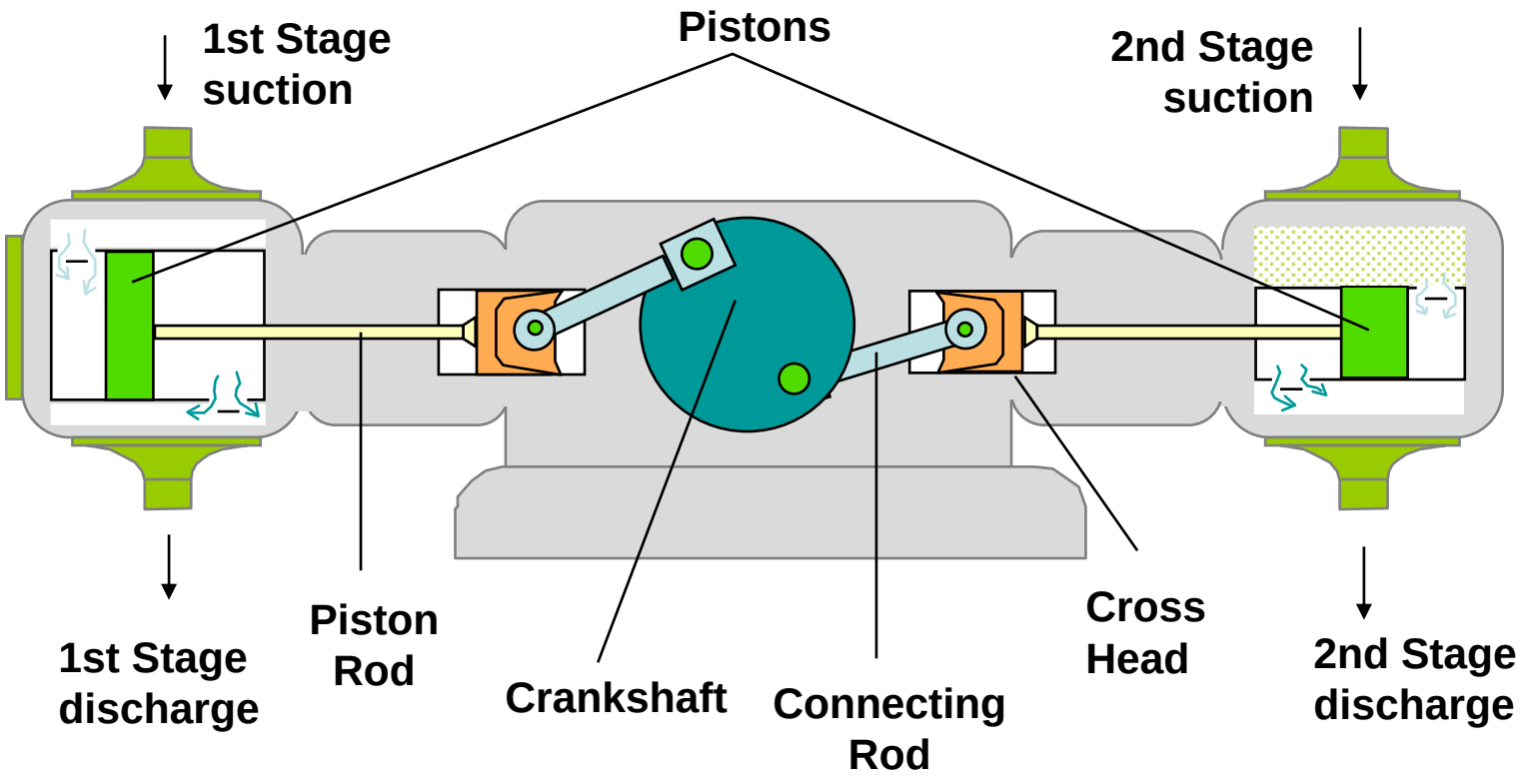
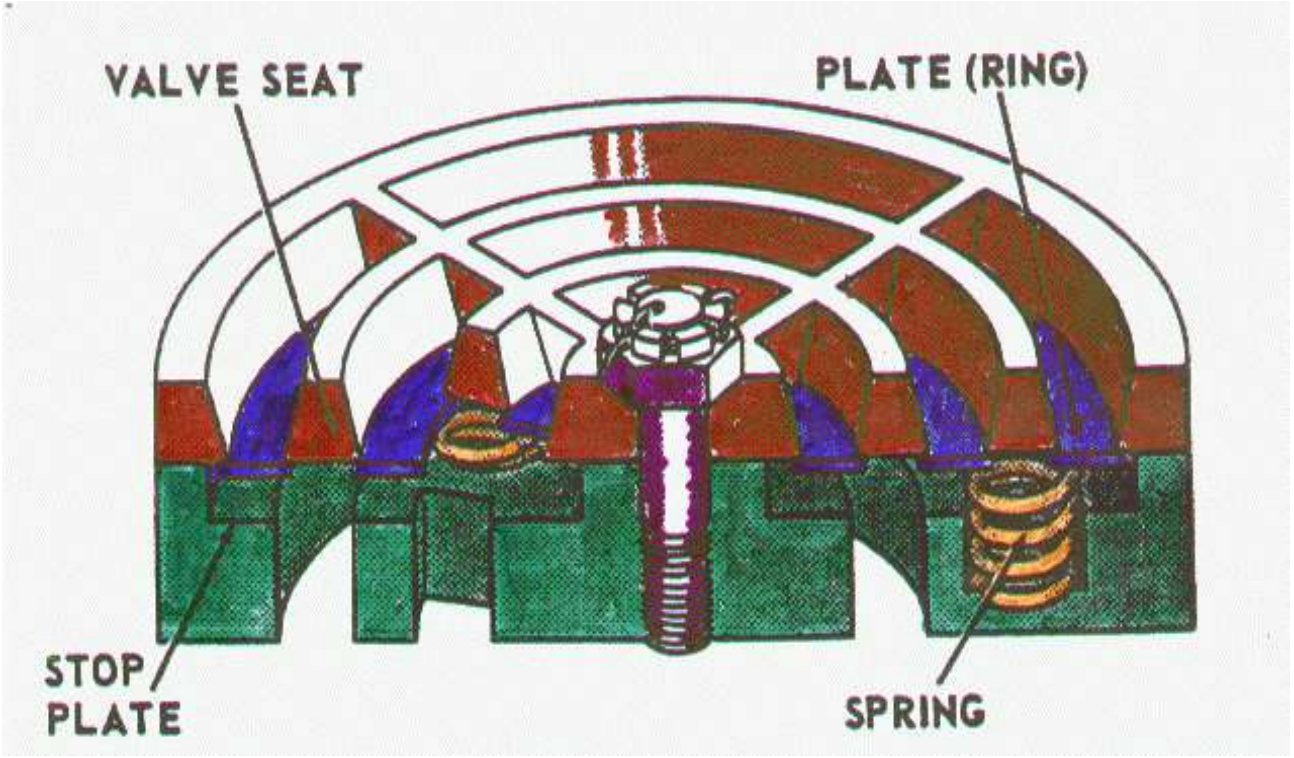
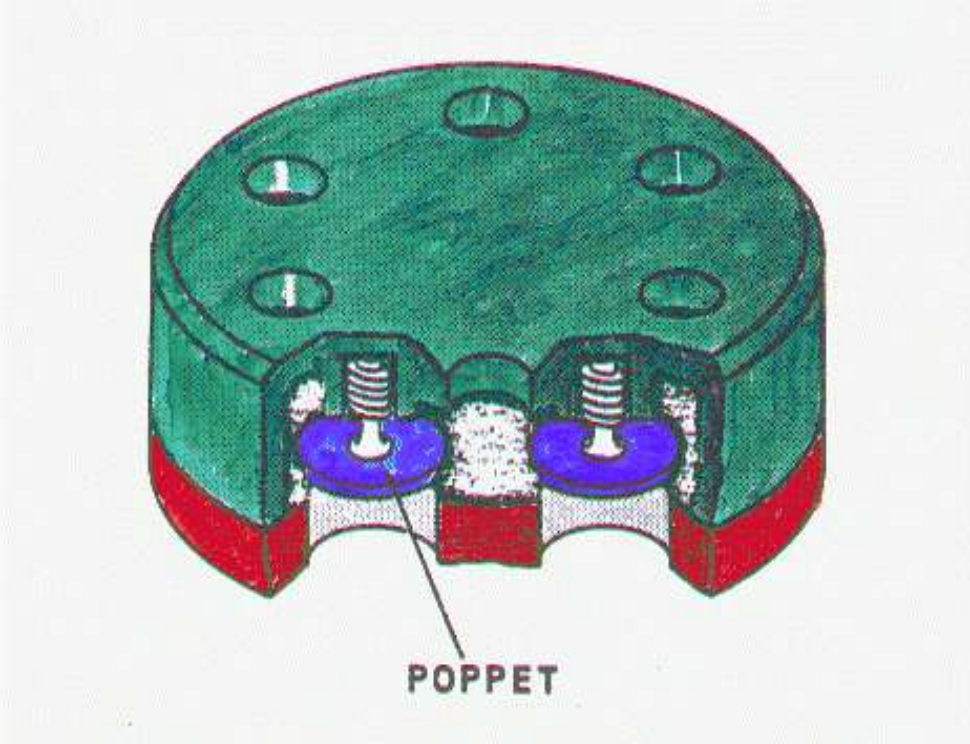


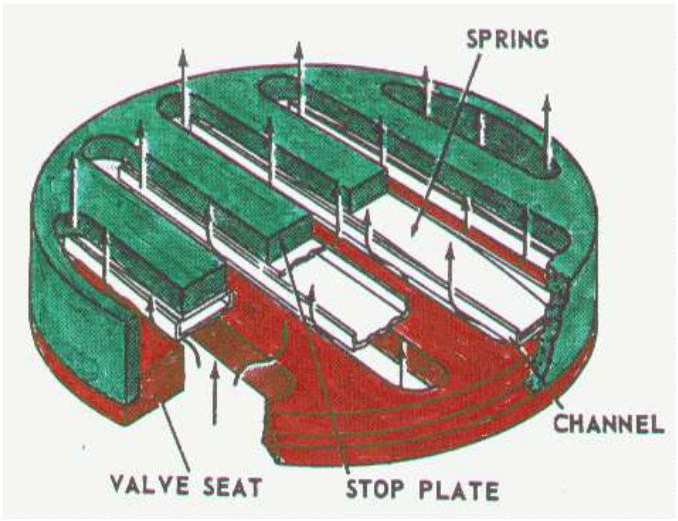
Plate Valve

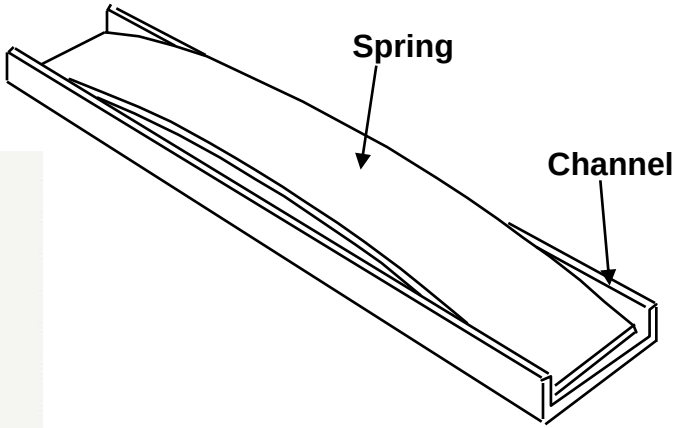


Poppet Valve



Feather Valve or Reed Valve





Piston Ring Material

- **PTFE - Polytetra Fluoroethylene**
- Ideal for use in non lubricated service - it has a low co-efficient of friction

- **BRONZE**
- Offers great wear resistance
- Preferential for high temperatures and pressures
- Requires marginal lubrication

- **CARBON**
- Is unaffected by sour or wet gases
- For temperatures up to 275^{o}F

- **CAST IRON**
- Provides good sealing over a wide temperature range but needs lubrication.

PACKING

•The purpose of packing is to prevent the leakage of gas through the clearance between the cylinder head and the piston rod.

•The packing must operate over a long period of time with little or no leakage and a minimum of friction.

•A packing unit is made up of two elements :

•1. The packing case

•2. The packing rings

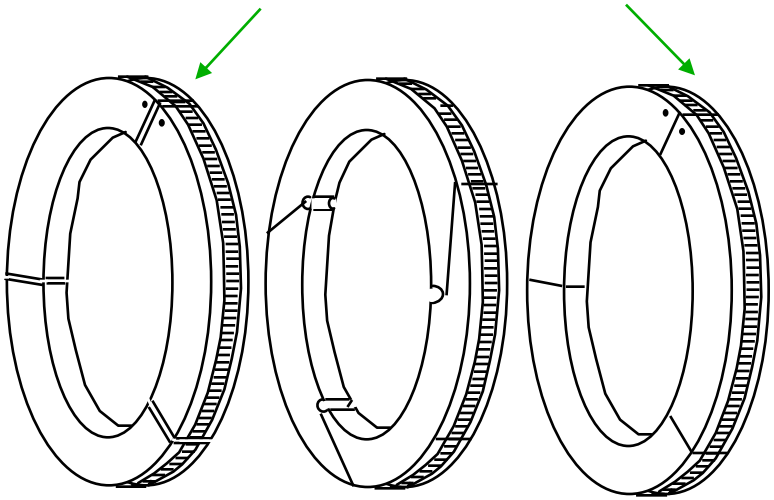
PACKING

The number of packing rings contained within the packing case is determined by the operating conditions of the compressor.

- Packing rings are fitted as a set with 2 or 3 to a set.
- These sets comprise :
- Radial cut rings
- Tangential cut rings
- The sets are located in retainers within the packing case.

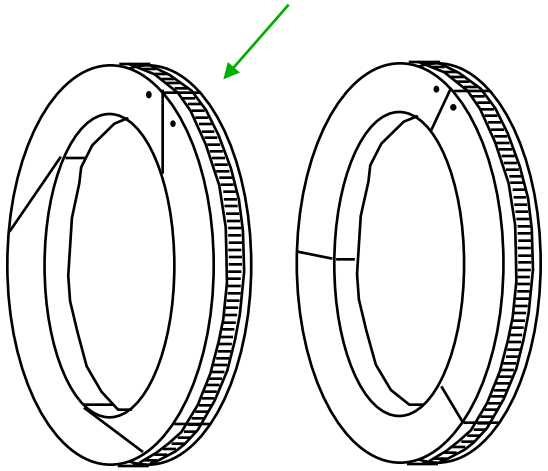
Basic Sealing Elements

Radial Element



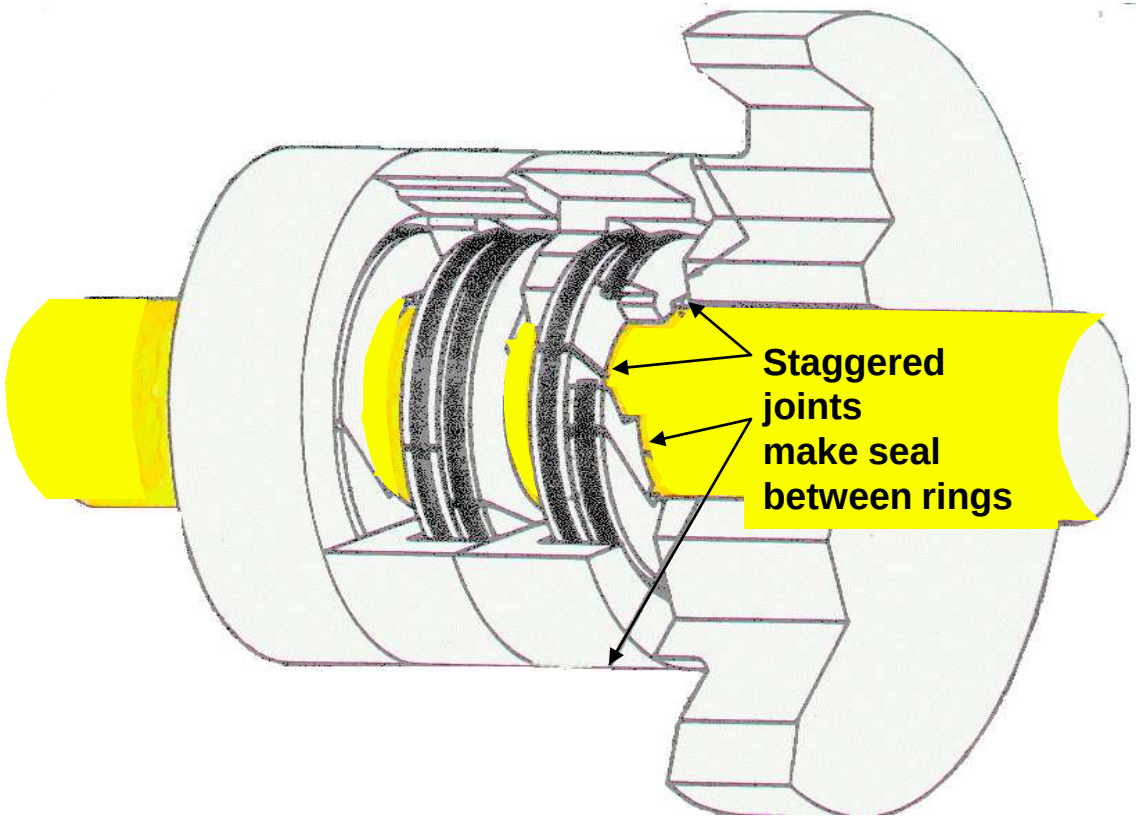
- The three radial cuts in the ring permit compensation for wear.

Tangential Element

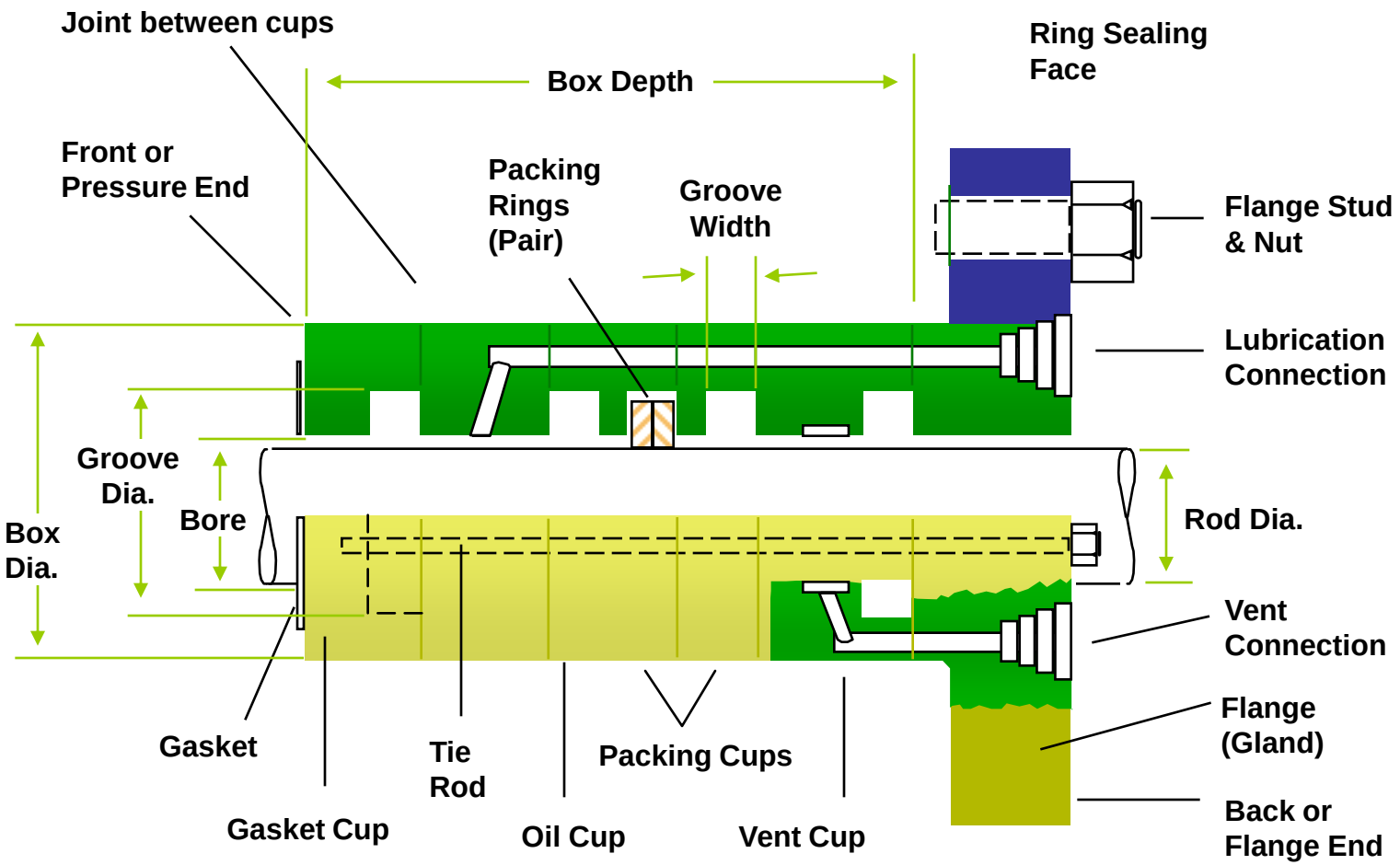


The tangential cuts provide a complete seal and provide compensation for wear.

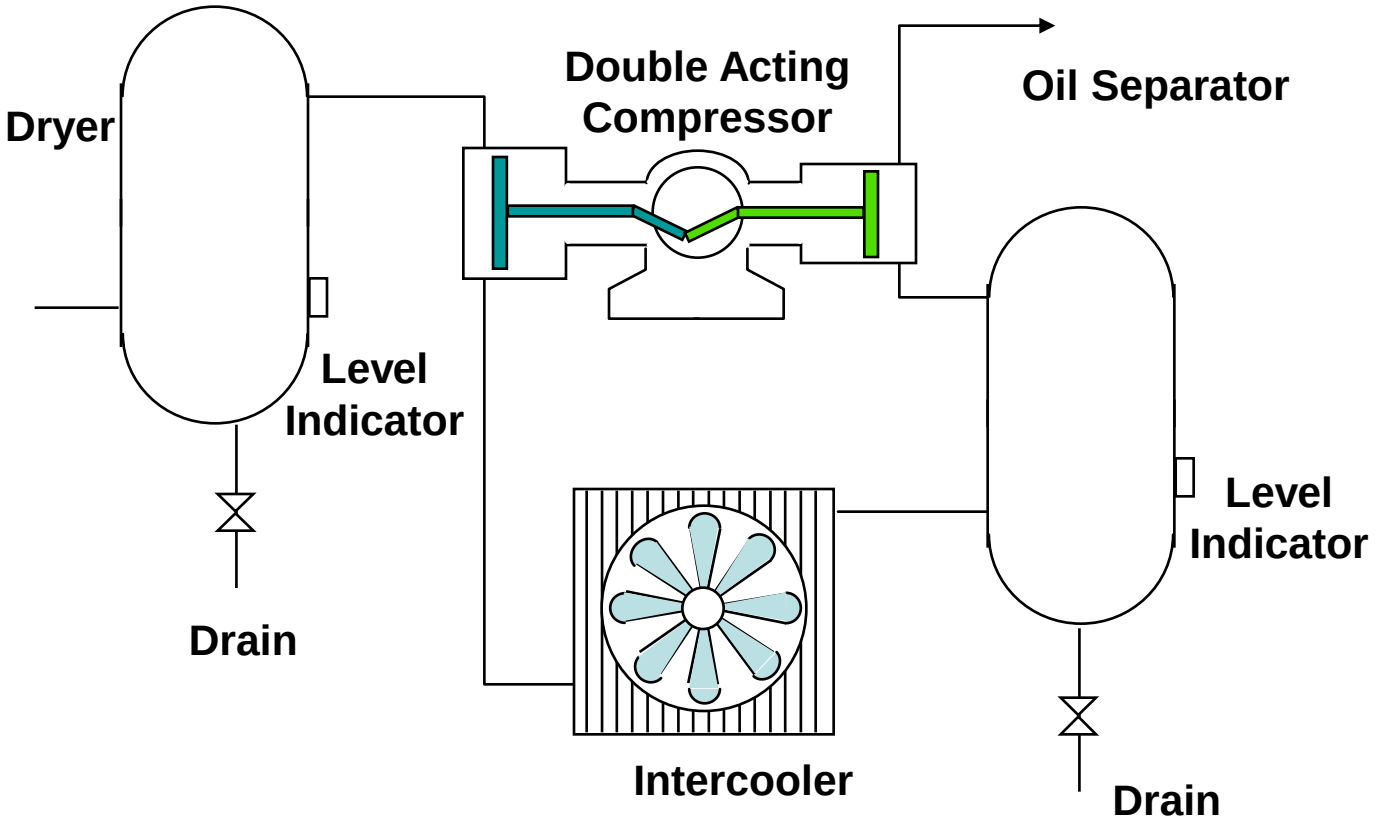
Packing Case



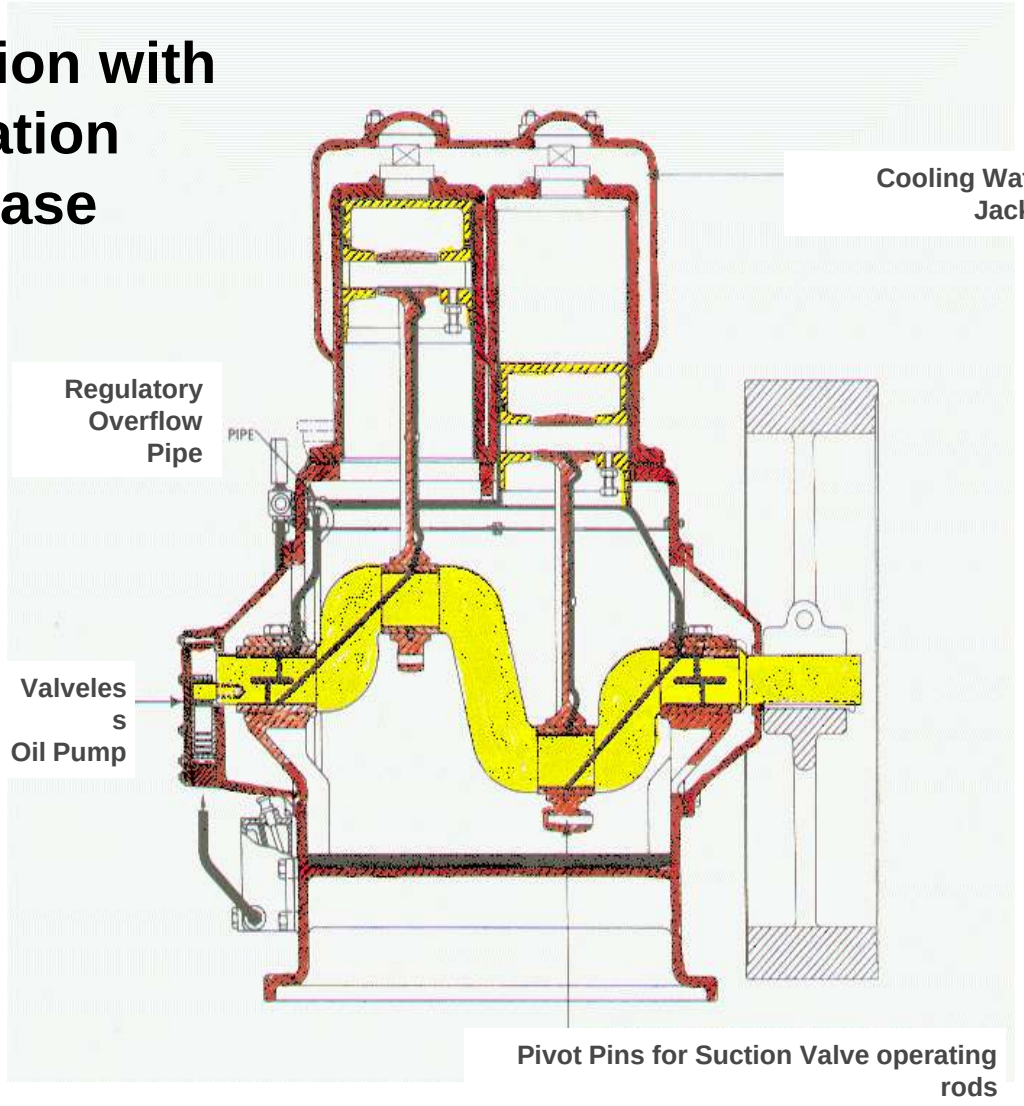
Packing Case



Compressor System



Forced Lubrication with Cylinder Lubrication from the Crankcase



In small high speed compressors such as this, the cylinders and bearings are both lubricated by the crankcase oil. Typical arrangements can be seen here for application of a pressure-recirculating system in a small machine.

Rotary Compressors

ROTARY COMPRESSORS

There are five types of rotary compressors, they are :

- Sliding Vane
- Liquid Ring
- Lobe
- Screw Compressor

Sliding Vane Compressors and Liquid Ring Compressors compress the gas in the Compressor

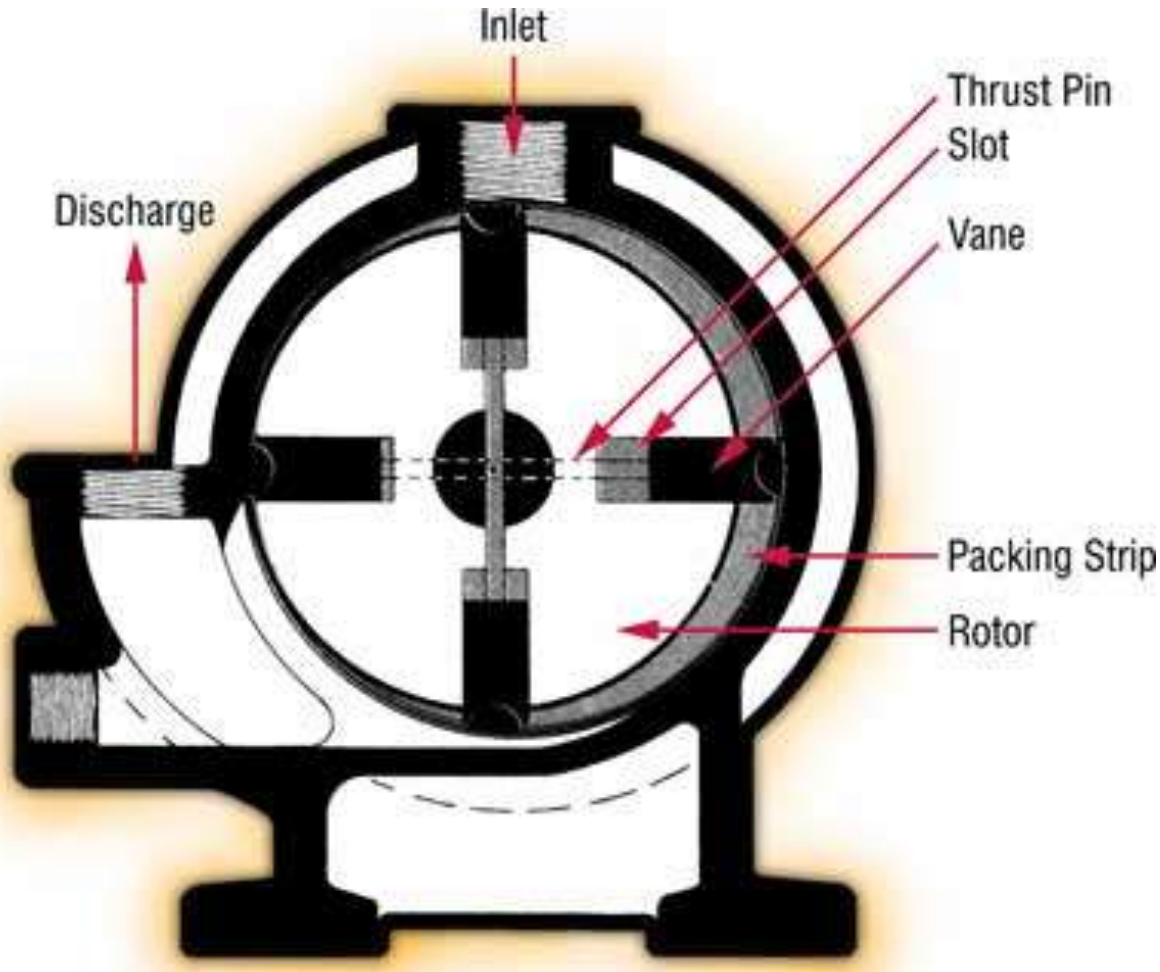
Lobe and Screw Compressors carry the gas without changing its pressure. The pressure increase occurs in the receiving vessel

ROTARY COMPRESSORS

There are four recognised ways of controlling flow rate on a rotary compressor :

- A regulatory valve on the suction (the use of this is limited)
- The speed of the rotors
- A recycle valve, recirculating gas from discharge back to suction
- A vent on the discharge

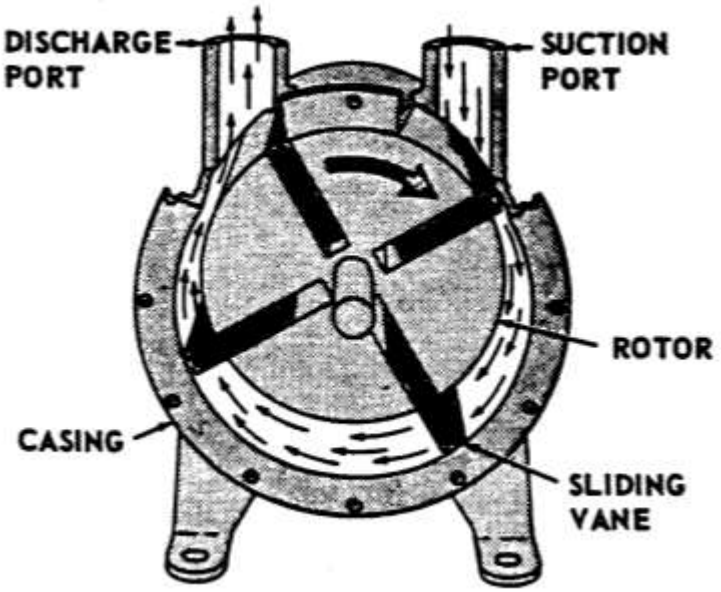
Rotary Sliding Vane Compressor



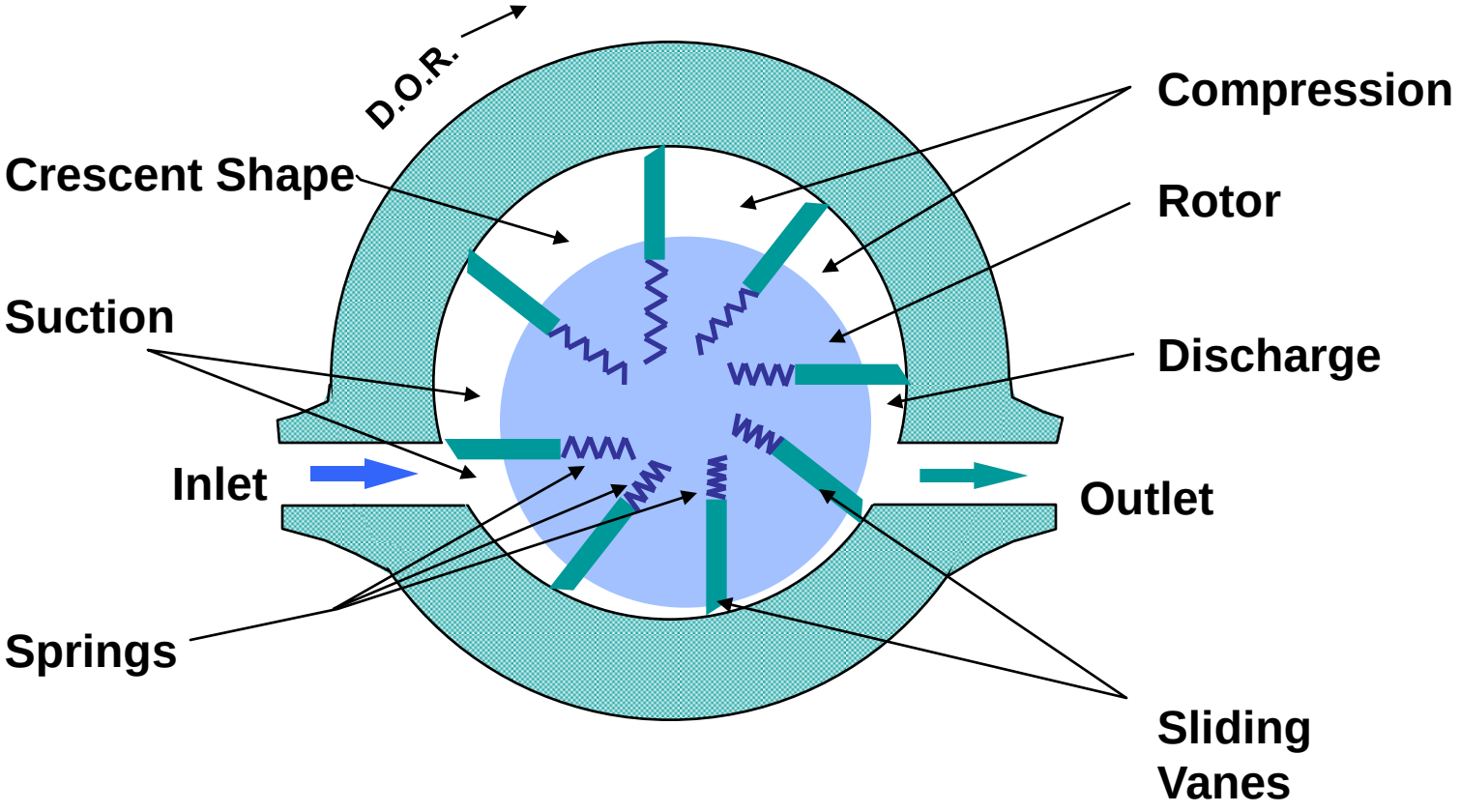
SLIDING VANE COMPRESSORS

Sliding vanes are kept in contact with the casing by centrifugal force and by springs within the slots.

The compressors are lubricated by oil mist, this helps maintain the seal between the vanes and the casing and also helps to avoid wearing of the vanes and casing.



SLIDING VANE COMPRESSOR



Vane Compressors

Rotary lobe compressors

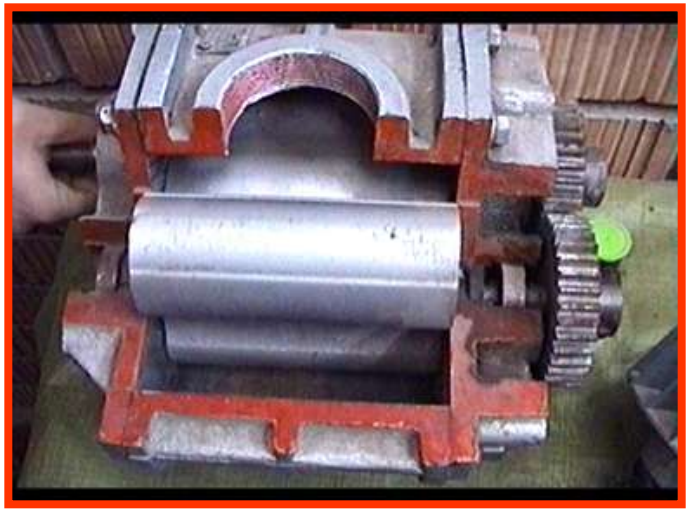
Advantages.

Simple design.
Medium to low cost.
Few moving parts.
Low to medium maintenance costs.
Easy to install.
Low rotational speeds

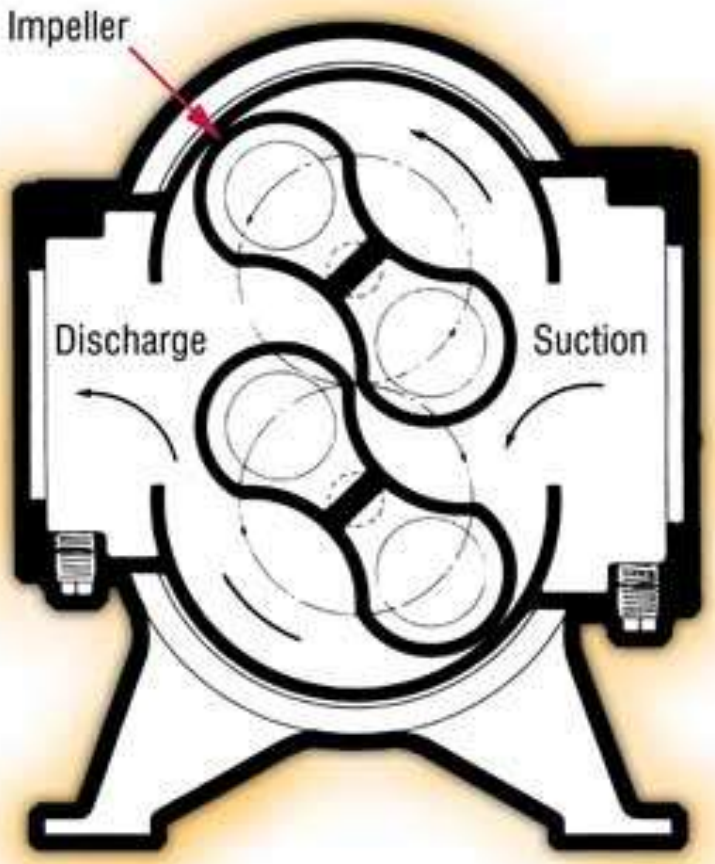
Disadvantages.

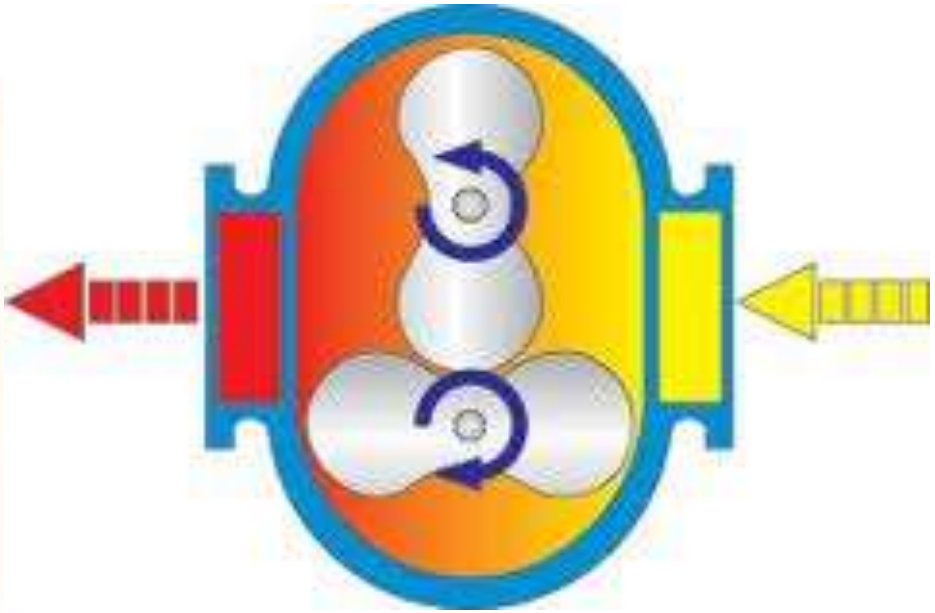
Relatively low pressures.

Lobe Compressors



Lobe Compressors



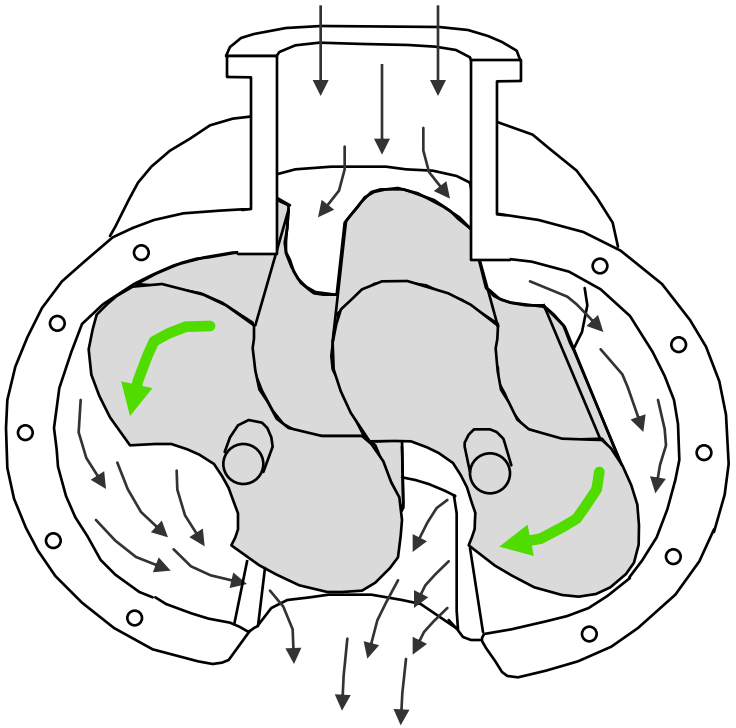


LOBE COMPRESSORS

A Lobe compressor has two rotors which are driven via a set of gears

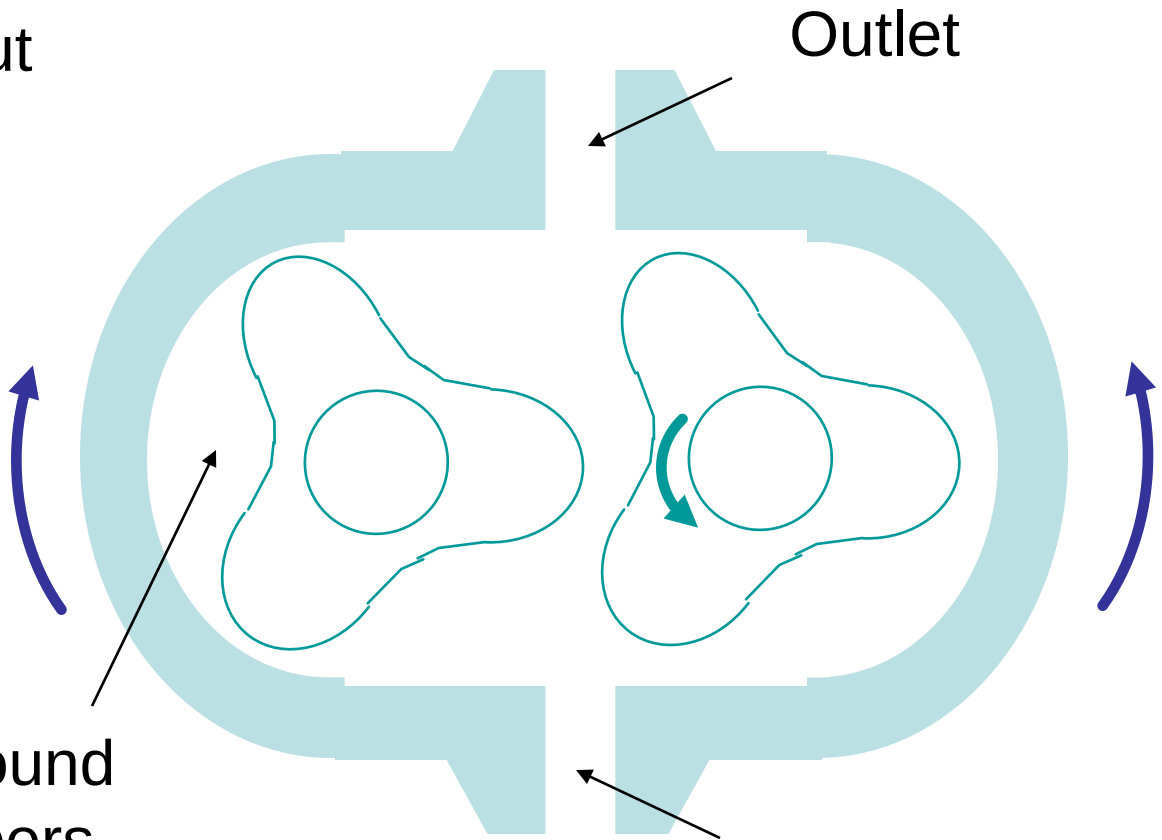
The two rotors rely on tight tolerances between the casing and the lobes

These rotors never come into contact with each other



LOBE COMPRESSOR

Gas is forced out of port as lobes go back into mesh.



Gas is carried around housing in chambers formed between lobes.

Liquid ring compressors.

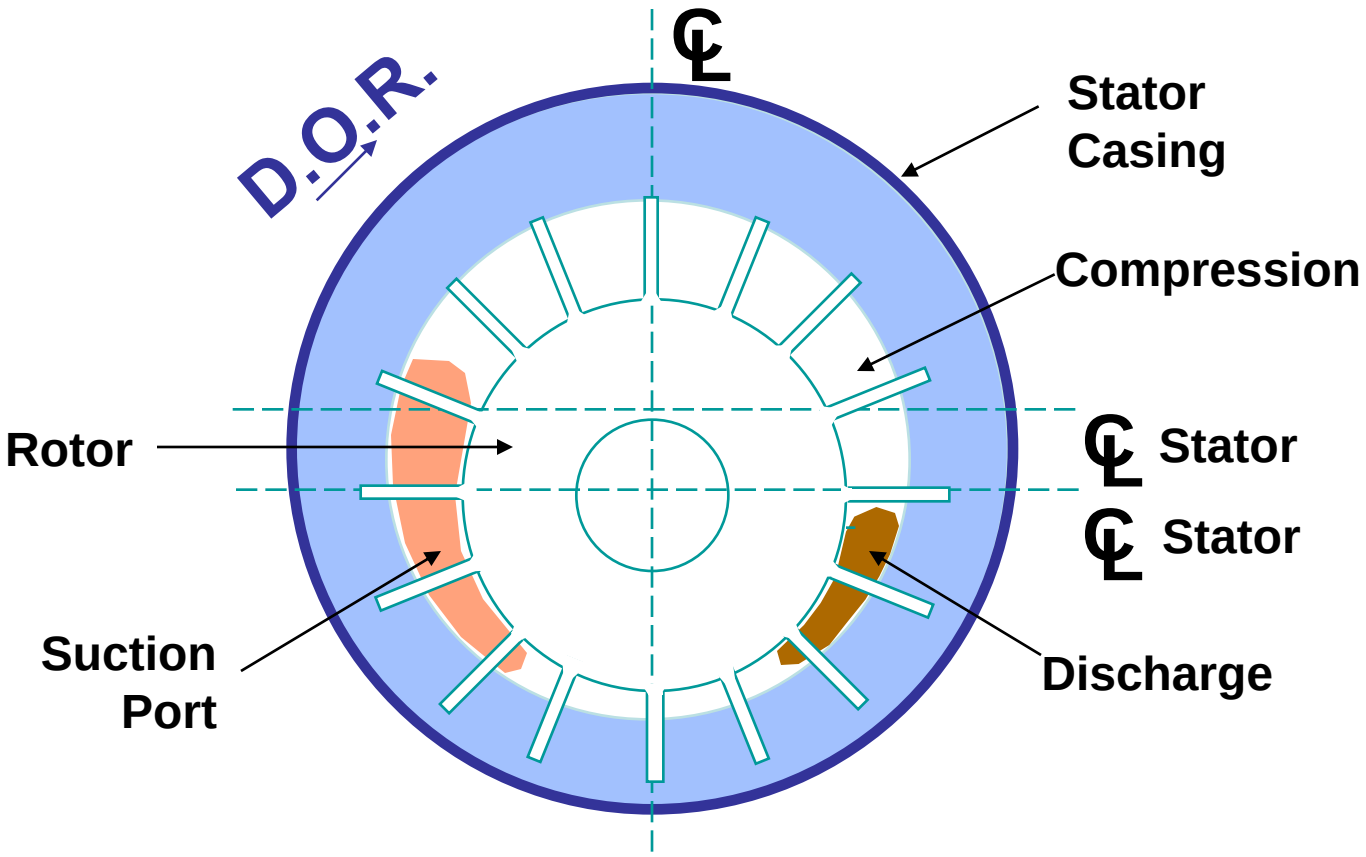
Advantages.

Simple design.
Few moving parts.
Low maintenance costs.

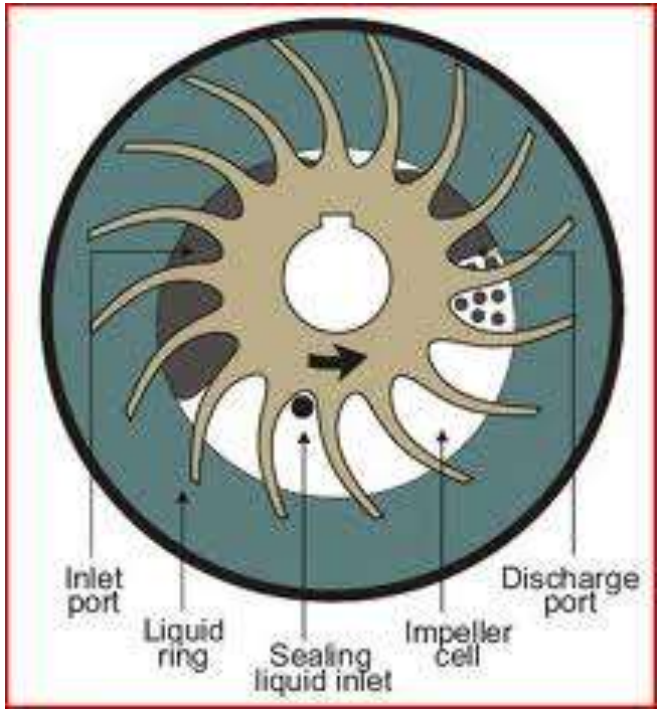
Disadvantages.

Contaminated water from carry over.
Relatively low pressures.
Relatively costly installation

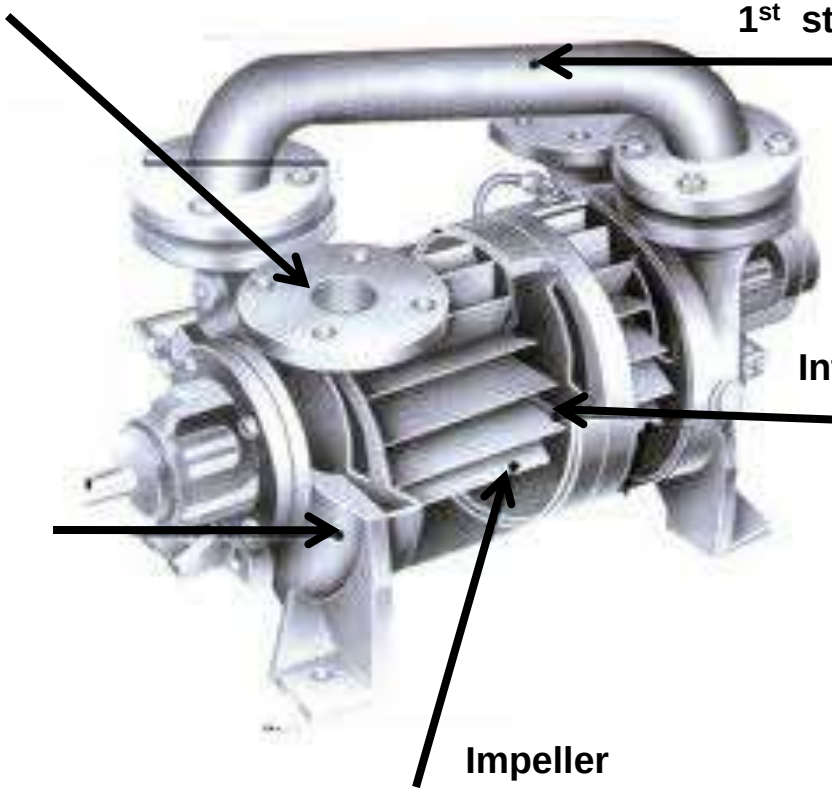
LIQUID RING COMPRESSORS



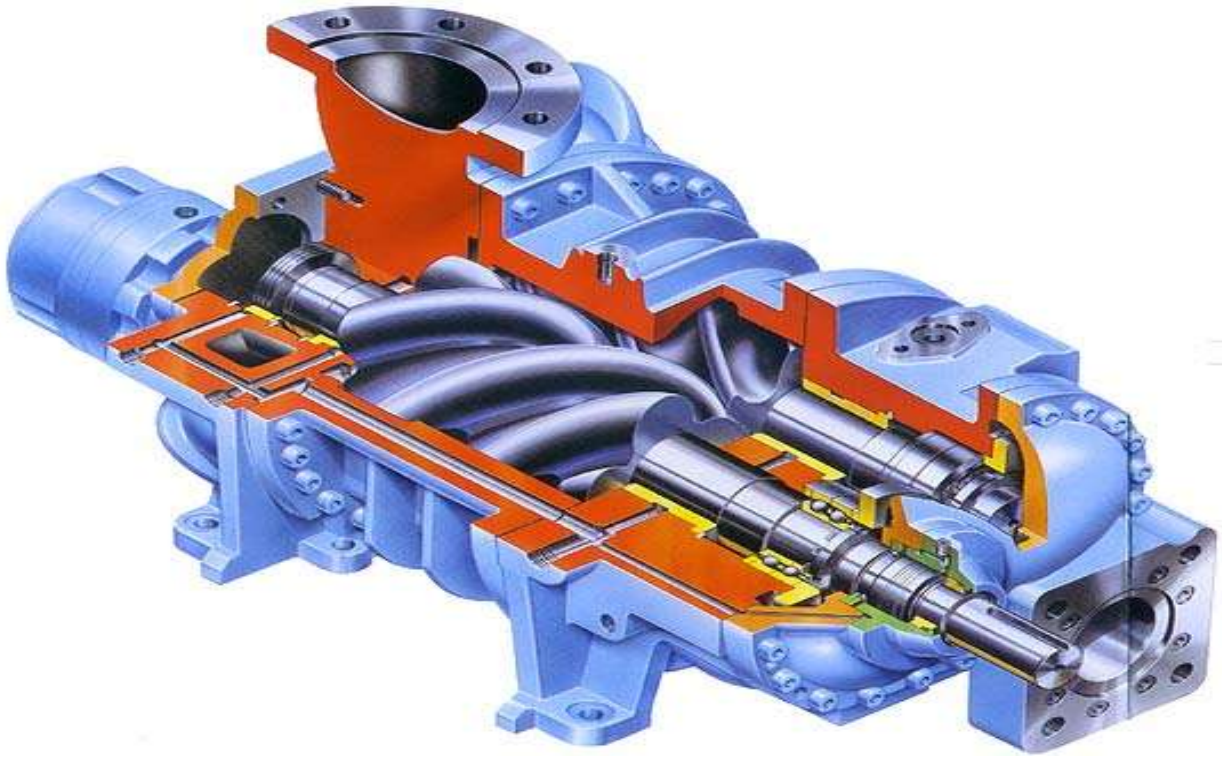
Liquid Ring Compressor



Liquid Ring Compressor



Rotary Screw compressors



Rotary screw compressors

Advantages.

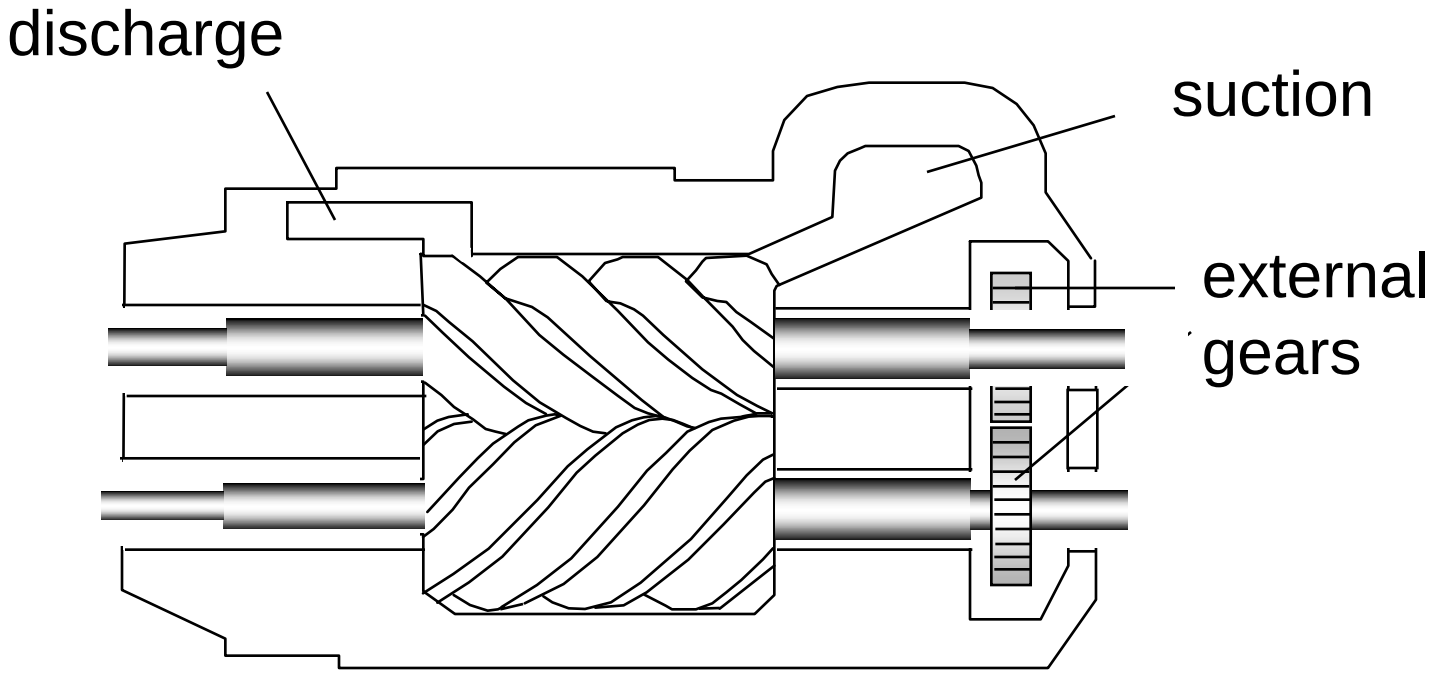
Simple design.
Low to medium initial cost.
Low to medium maintenance costs.
Two stage designs have good efficiency.
Easy to install.
Few moving parts.

Disadvantages.

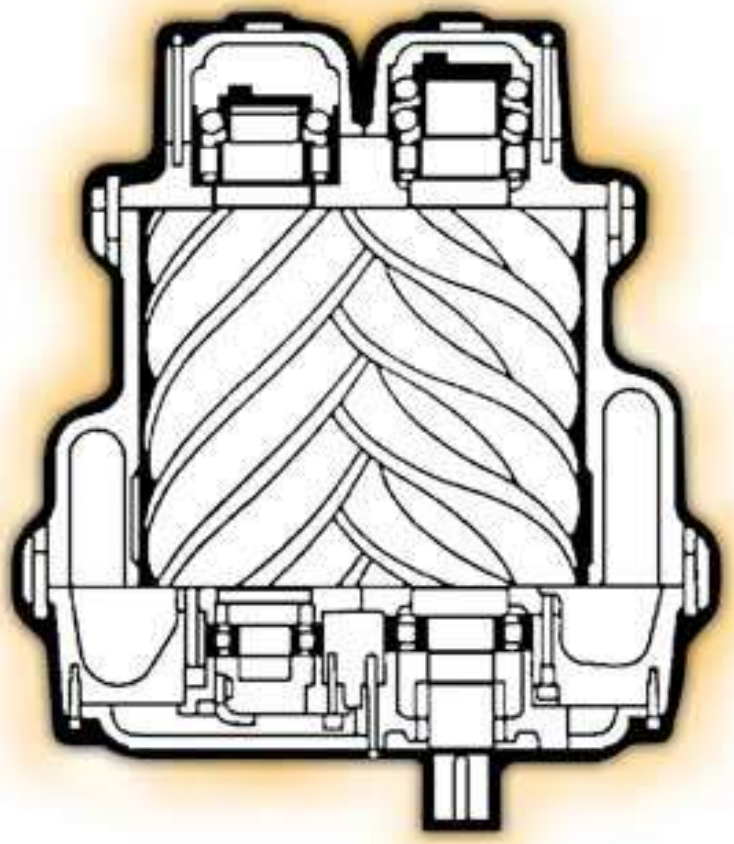
Shorter life.
High rotational speed.
Oil injected designs have oil carry over.
Single stage designs have lower efficiency.
Two stage oil free design high initial cost.
Must have clean environment.

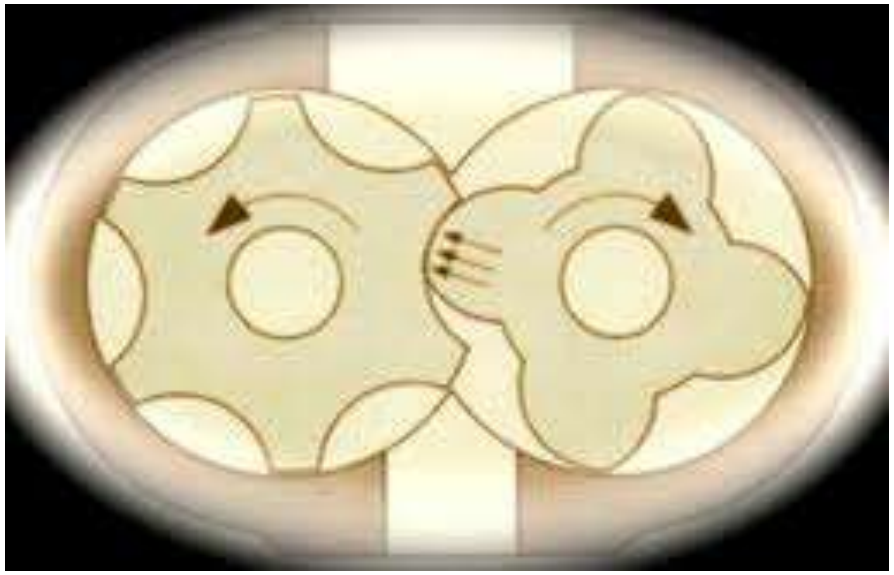
SCREW COMPRESSORS

In this compressor, gas is displaced by helically lobed rotors



Screw Compressors





END OF PRESENTATION

ANY QUESTIONS