CENTRIFUGAL COMPRESSORS

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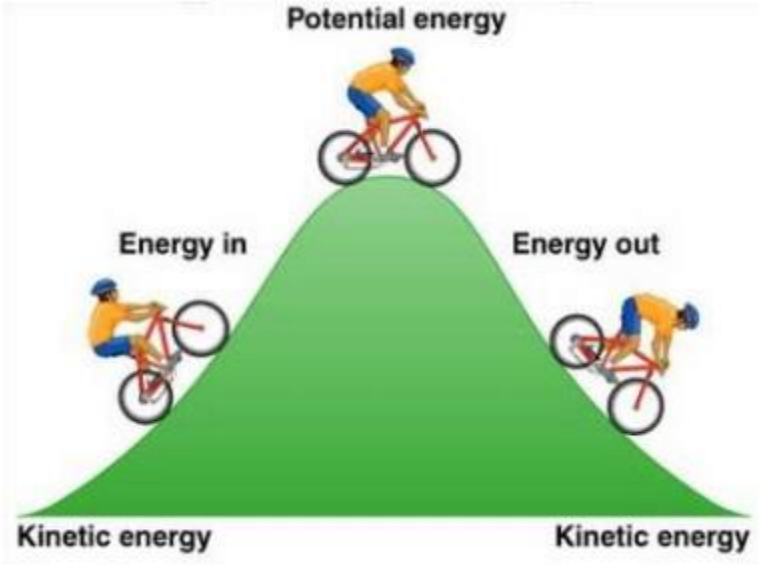
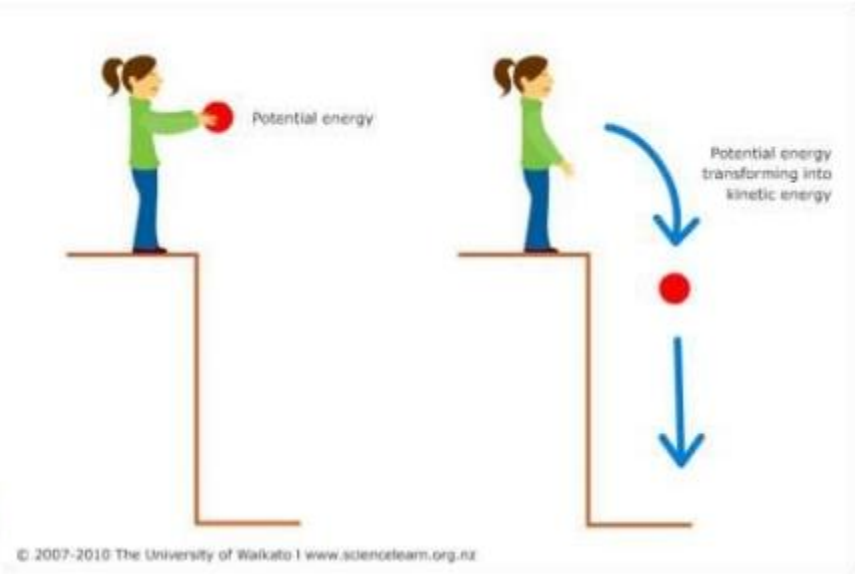
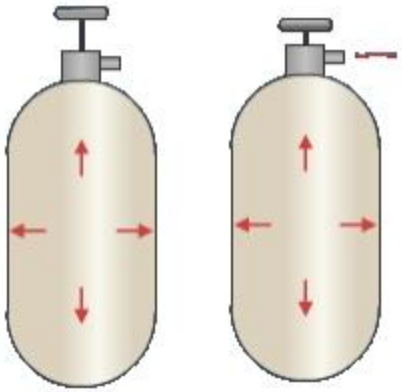
Potential and Kinetic Energy



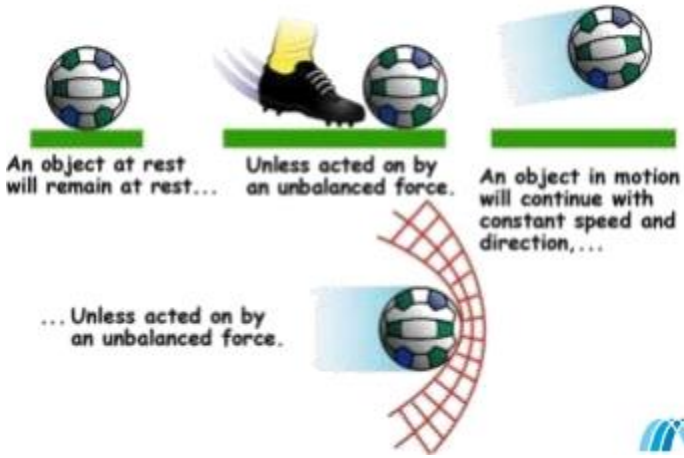


Pressure



When gas is compressed into a smaller volume, the pressure of the gas increases

Newton's First Law of motion



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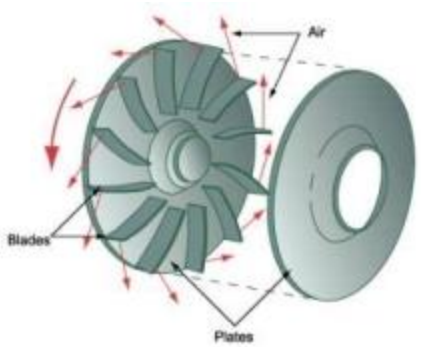
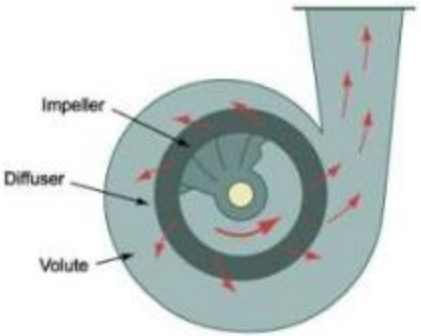
Introduction to Centrifugal compressors

Dynamic compressors

Centrifugal compressor



Blades force air in the impeller to move. The impeller adds both velocity and pressure to air.

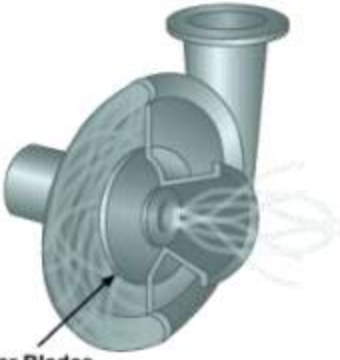


Gas passes from the diffuser into the volute. The conversion from velocity to pressure continues.

Impeller Eye

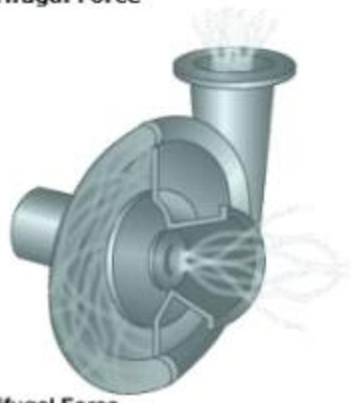
First, gas enters the eye of the impeller at the suction end.

Impeller Blades



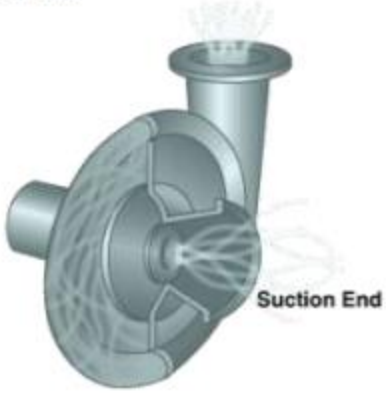
Second, the gas is accelerated to a high speed by the movement of the impeller blades.

Centrifugal Force



Third, as the impellers rotate, they produce centrifugal force which throws the gas outward.

Suction End



This creates low pressure in the eye of the impeller that, in turn, draws in more gas.

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Introduction to Centrifugal compressors

Example of Centrifugal compressors

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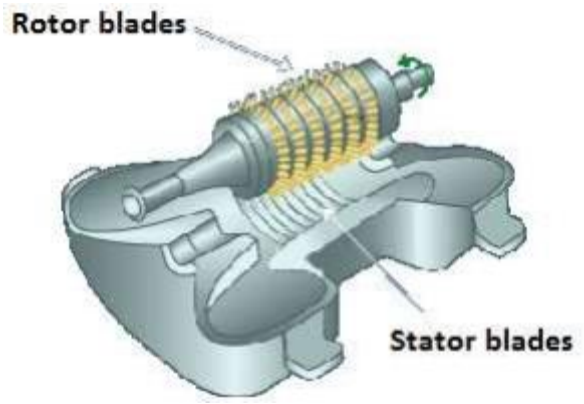
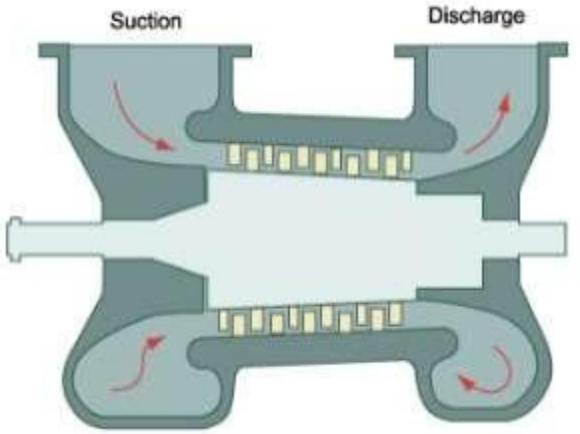
Introduction to Centrifugal compressors

Dynamic compressors

Axial compressor



- The stator blades are attached to the casing.
- The rotor blades force the gas to move, impart pressure and velocity



- As the gas flows through an axial compressor it occupies less volume increasing its pressure.
- The rotor blades increase velocity and stator blades convert it to pressure

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Example of Axial compressors

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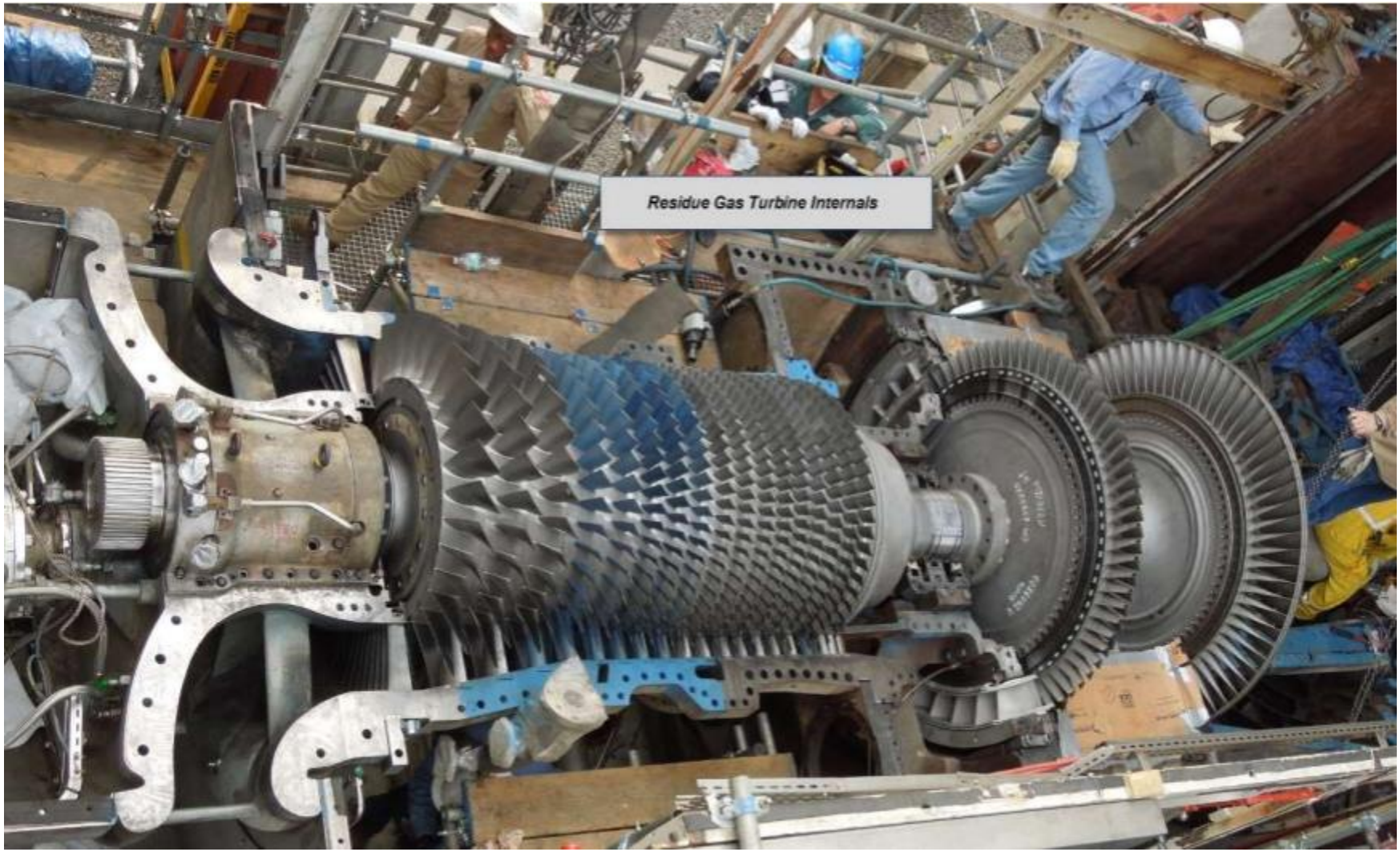
Example of Axial compressors



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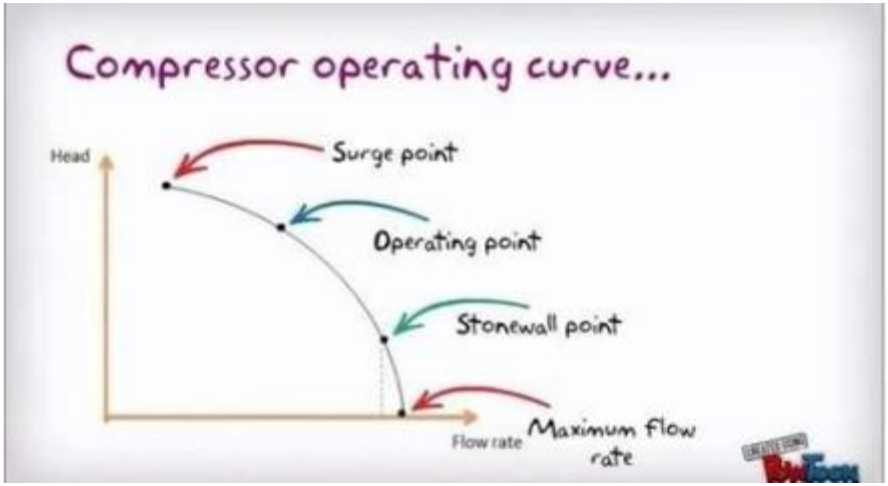
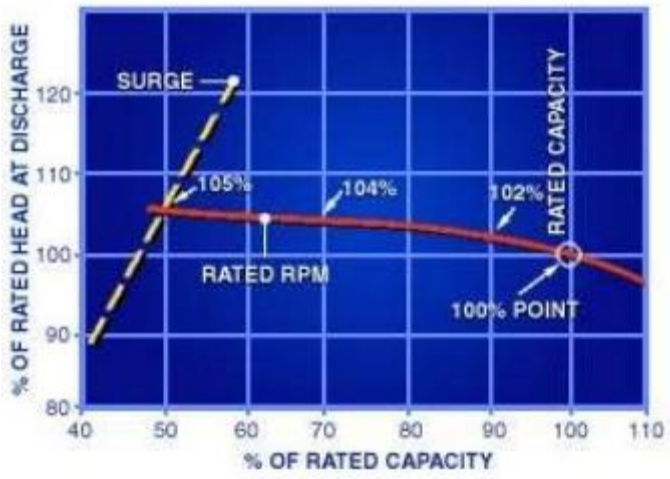
Introduction to Centrifugal compressors

Surging

Surging occurs when gas rapidly flows back and forth through the compressor. It occurs when the compressor is operated below minimum capacity





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Introduction to Centrifugal compressors

Operating characteristics

Compressor Ratio : Relationship between discharge pressure and suction pressure

$$R = \frac{\text{Discharge Pressure}}{\text{Suction Pressure}}$$

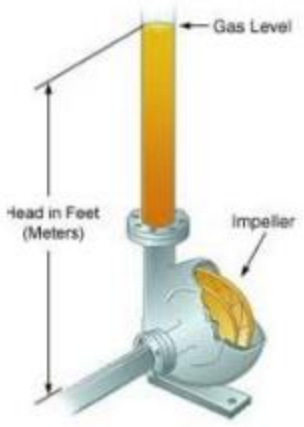
Pressure in the head

- The design of the compressor.
- The amount of flow.
- The operating RPM.

Compressor Capacity : Volume of gas that the compressor moves in a given period of time (CFM)

Work of compression: The work of compression can be thought of as straight lifting of a given weight of gas (foot-pound)

- The faster the RPM of the impeller, the more work is done on the gas.



If a compressor at a given RPM handles two different kinds of gases:

- The less dense gas will require a larger volume per given weight.
- Both gases require the same amount of work done per each unit of weight.
- The denser gas has the most units of weight per given volume.
- The denser gas will have a higher discharge pressure for the same head developed.
- More pounds (newtons) of a denser gas are moved at a given RPM although the actual CFM (M^3M) that the compressor moves is constant.

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Introduction to Centrifugal compressors

Control Objectives

- **Constant Weight flow** : Some processes require a constant weight flow of gas or air during a given time period.

  Use Flow Element → Discharge end of the compressor

- **Variable Flow Equal to Make:** This objective is met in relation to a set pressure point that will optimize the process.

  Use Pressure Element → Suction end of the compressor

- **Variable Flow Equal to Demand :** Some processes require that a variable amount of gas be moved as fast as it is needed by other components in the system

  Use Pressure Element → Discharge end of the compressor

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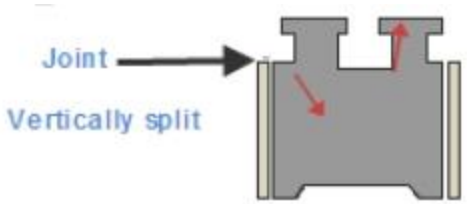
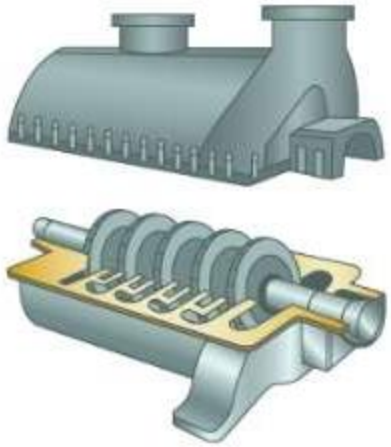
Compressor construction

Casing Design

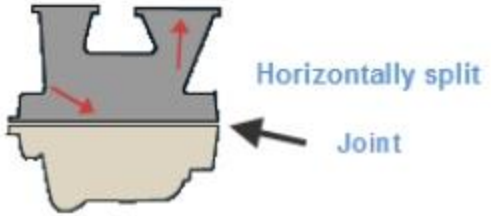
Vertically–Split Casing



- Vertically Casing requires less sealing
- Horizontally casing has easier access



Horizontally–Split Casing



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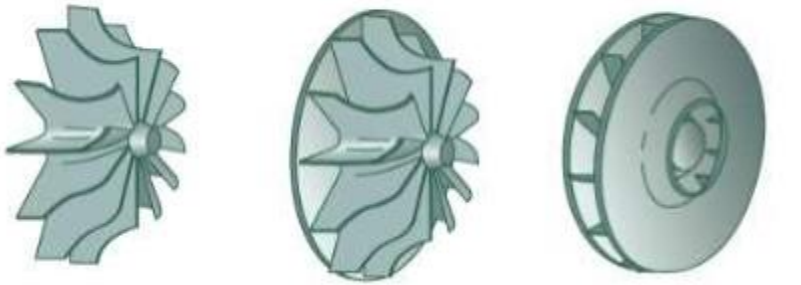
Compressor Construction

Impellers and Diaphragms

Types of impellers



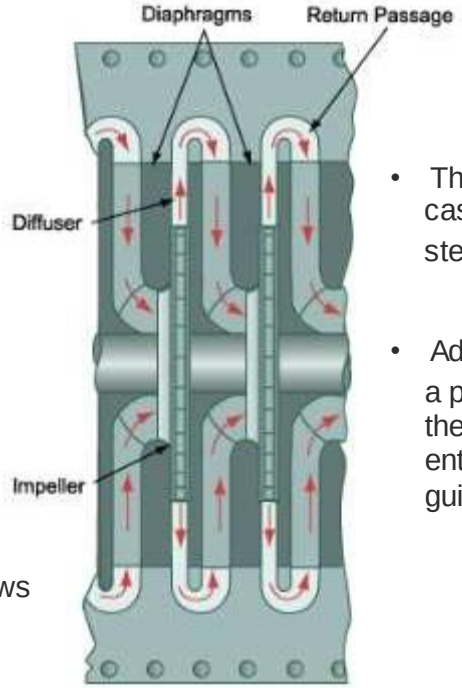
Open impeller

Semi-enclosed impeller

Enclosed impeller

- An open impeller is used for high heads and small-to-large-flow.
- A semi-enclosed impeller is used for large flow.
- In an enclosed impeller, the gas is drawn into the eye and flows out the edge or rim.

Diaphragms



- The diaphragms are usually made of cast iron or other hard metal, like steel, and do not rotate with the shaft.
- Adjacent walls of the diaphragms form a passage called the diffuser. After the gas travels through the diffuser, it enters the return passage which guides it into the next impeller

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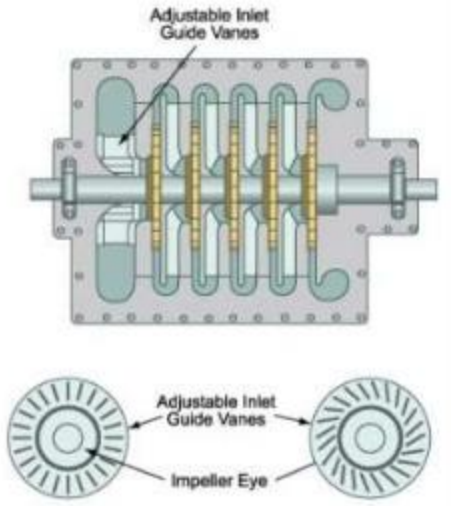
Compressor Construction

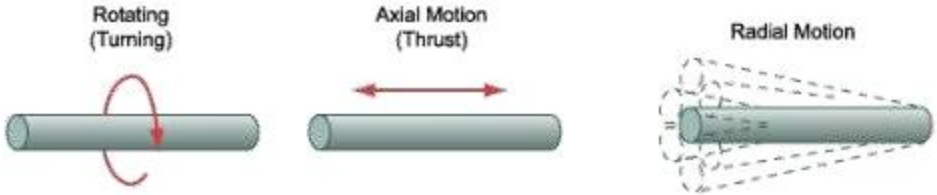
Guide Vanes and Bearings

Guide Vanes

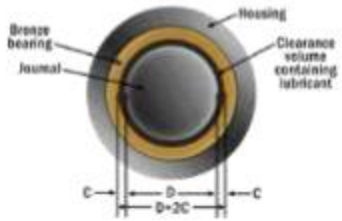


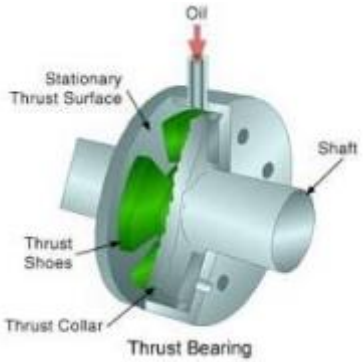
- The guide vanes in multi-stage centrifugal compressors are placed at the end of the return passage of the diaphragm.
- The angle of flow affects the characteristic performance curve of the impeller

Bearings



The impellers and shaft must be free to rotate, but they must not move any other way. Damage and leakage can result from erratic motion of the impellers or shaft





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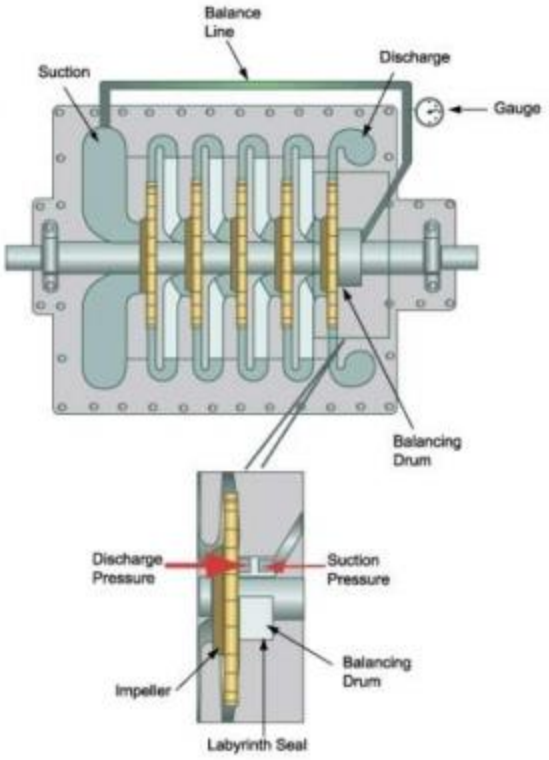
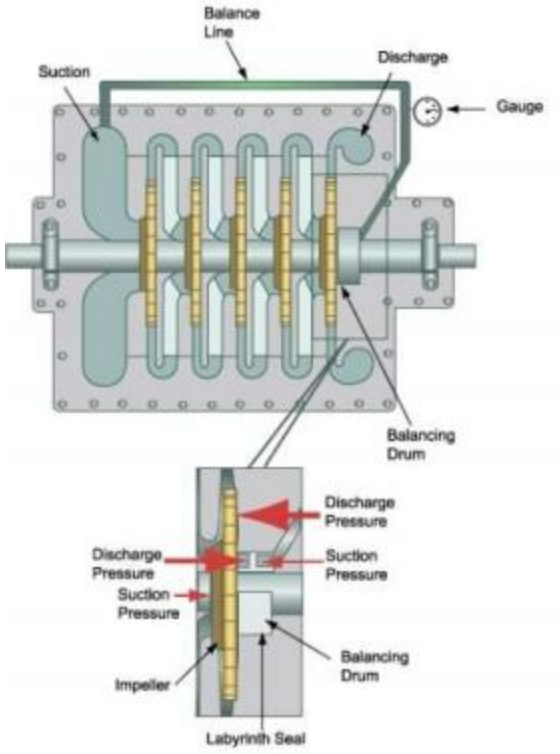
Compressor Construction

Balancing Drums

The balancing drum is attached to the shaft at the discharge end of the compressor. One end of the drum is vented to the suction end of the compressor. The pressure on the vented end is the same as the suction pressure. The non-vented side of the drum is exposed to the gas at discharge pressure





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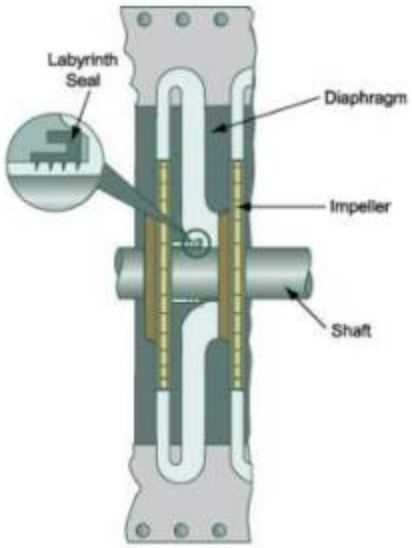
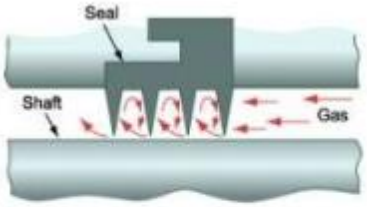
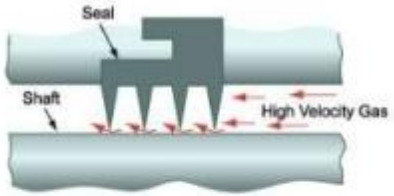
Type of seals

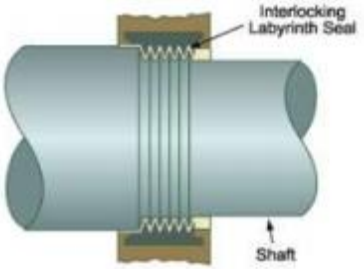
Labyrinth Seals

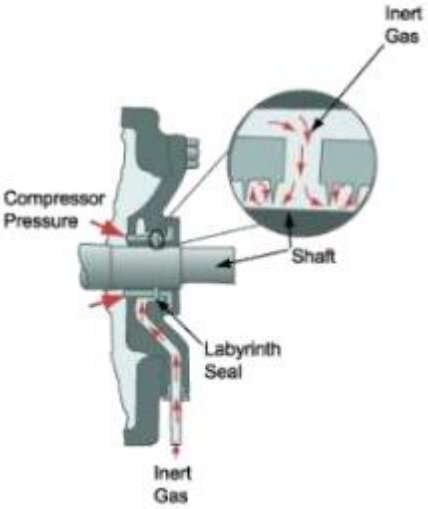


The labyrinth seal is a set of metal rings or teeth that encircle, but do not contact, the shaft.









When using a labyrinth seal with dangerous gas, it must be ported. The port is placed on the seal between the process gas and the atmosphere.

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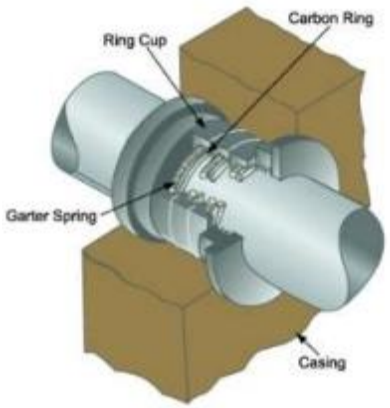
Type of seals

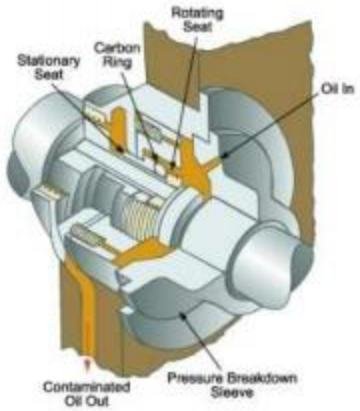
Restrictive rings & mechanical contact Seals

Restrictive Rings



- The rings are made out of low friction metal and are held in position around the shaft by stationary ring cups.
- The ring cups do not contact the shaft. Leakage over the ring is prevented by the vertical contact between the ring and the cup

Mechanical contact



❖ Contact seals must be lubricated to:

- Reduce friction.
- Carry away heat.
- Seal the shaft against leakage

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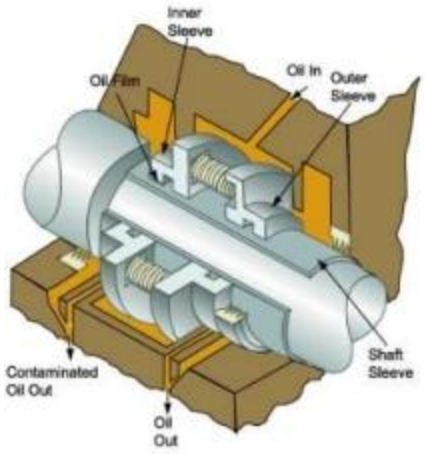
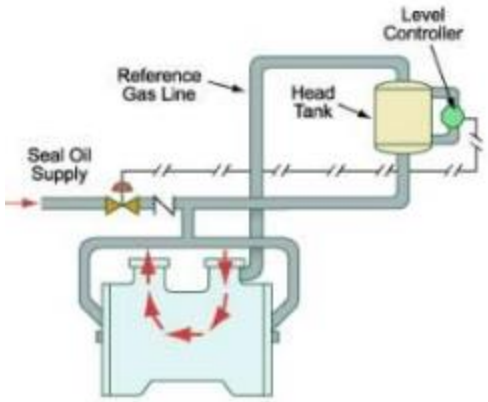
Type of seals

Liquid Film Seals



- The pressure of the oil must be slightly higher than the pressure of the gas



- Because the oil in the tank has its own head, it will have its own pressure that will ensure oil flow to the bearings

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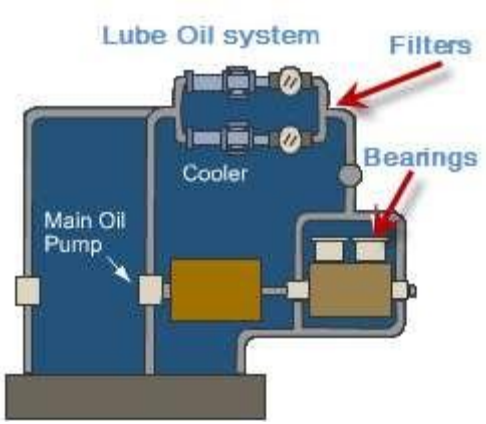
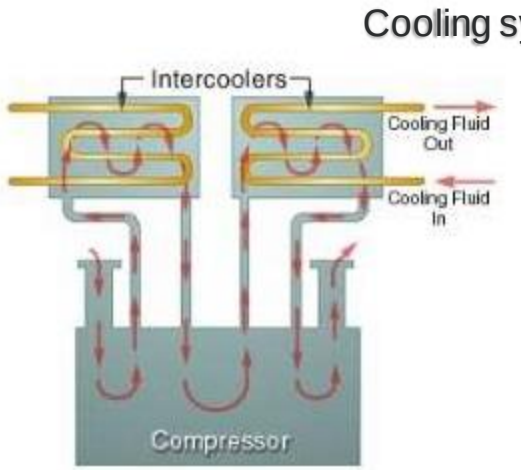
Compressor systems

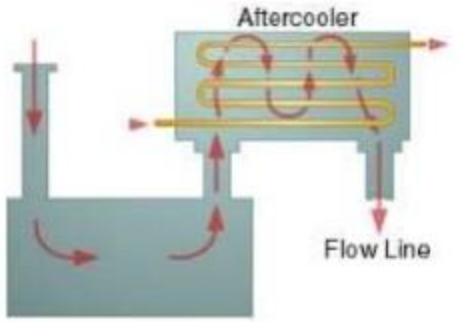
Oil circulation & cooling system



- If the oil system fails to deliver oil to the bearings, severe damage from heat and friction may result, and the bearings may fail



- The gas is cooled outside of the compressor. Once the gas is cooled, it is returned to the compressor.



- the gas is cooled after it leaves the compressor. The gas flows through the aftercooler and on into the flow line.

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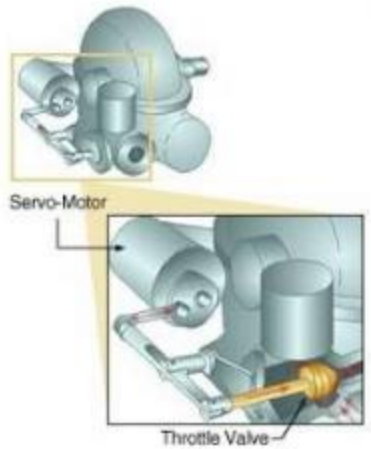
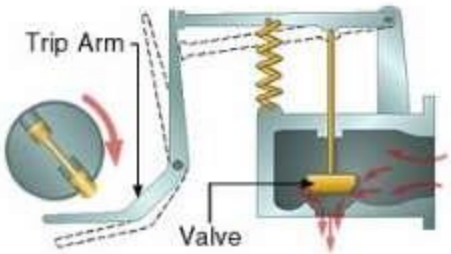
Compressor systems

Safety devices

Speed devices

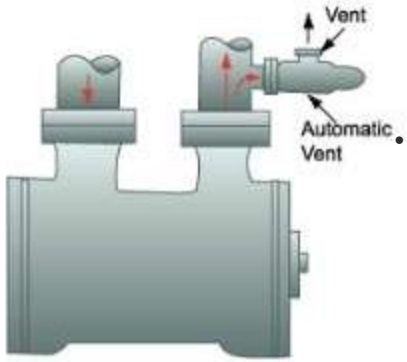
- An overspeed trip is always located in the turbine shaft





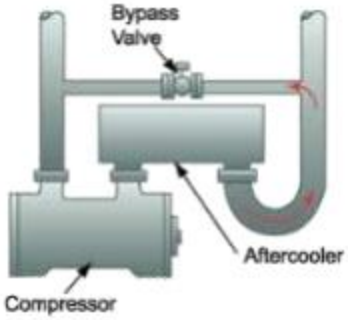
- Servo-motor is designed so that when the turbine begins to slow down, the throttle is opened. If the turbine begins to speed up, the throttle is closed.

Vents & Bypasses



- If the compressor nears surge, the vent automatically opens to increase the flow. This flow increase will prevent surging.

- The bypass moves the gas from the discharge back to the suction area of the compressor



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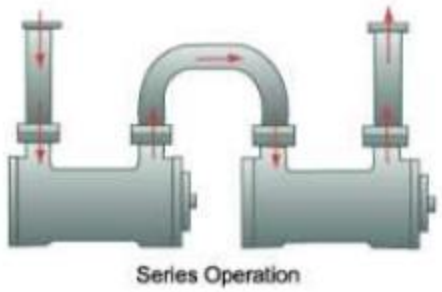
Operating compressors

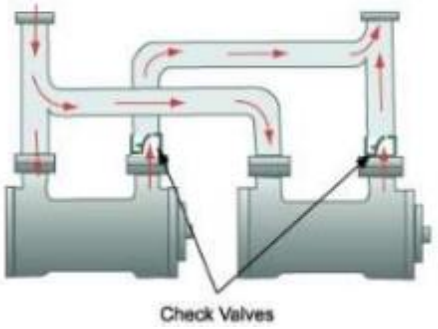
Compressors configuration

Series Operations



- In a series setup, the discharge of the first compressor feeds into the suction line of the next.
- The compressed gas that enters the second compressor is at a higher pressure than when it entered the first compressor

Parallel Operations



- The gas flow is divided so that all the gas does not flow through both compressors
- Parallel compressors draw to their full capacity from a common source of gas increasing overall flow

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Operating compressors

Performance Features

PDC vs DC

Positive Displacement: The principle of compression in this type of compressors is by decreasing the volume. For gases, as volume decreases, pressure increases known as compression.

Dynamic Compressors: In these compressors, the gases are first accelerated i.e. velocity is increased, then its made to flow through increasing cross section area, where kinetic energy is converted into pressure energy i.e. pressure is increased.

- Dynamic compressors Less maintenance
- Dynamic compressors lower efficiency.

Rule of Thumb : Dynamic compression technology is best suited for base load requirements, while positive displacement compression is better suited to variable load. For larger flows and variable demand applications, a combination of both technologies often helps to reach the optimal usage of compressed air while simultaneously reducing energy consumption.

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Thanks for coming!

Hector Nguema Ondo

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