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Compressor

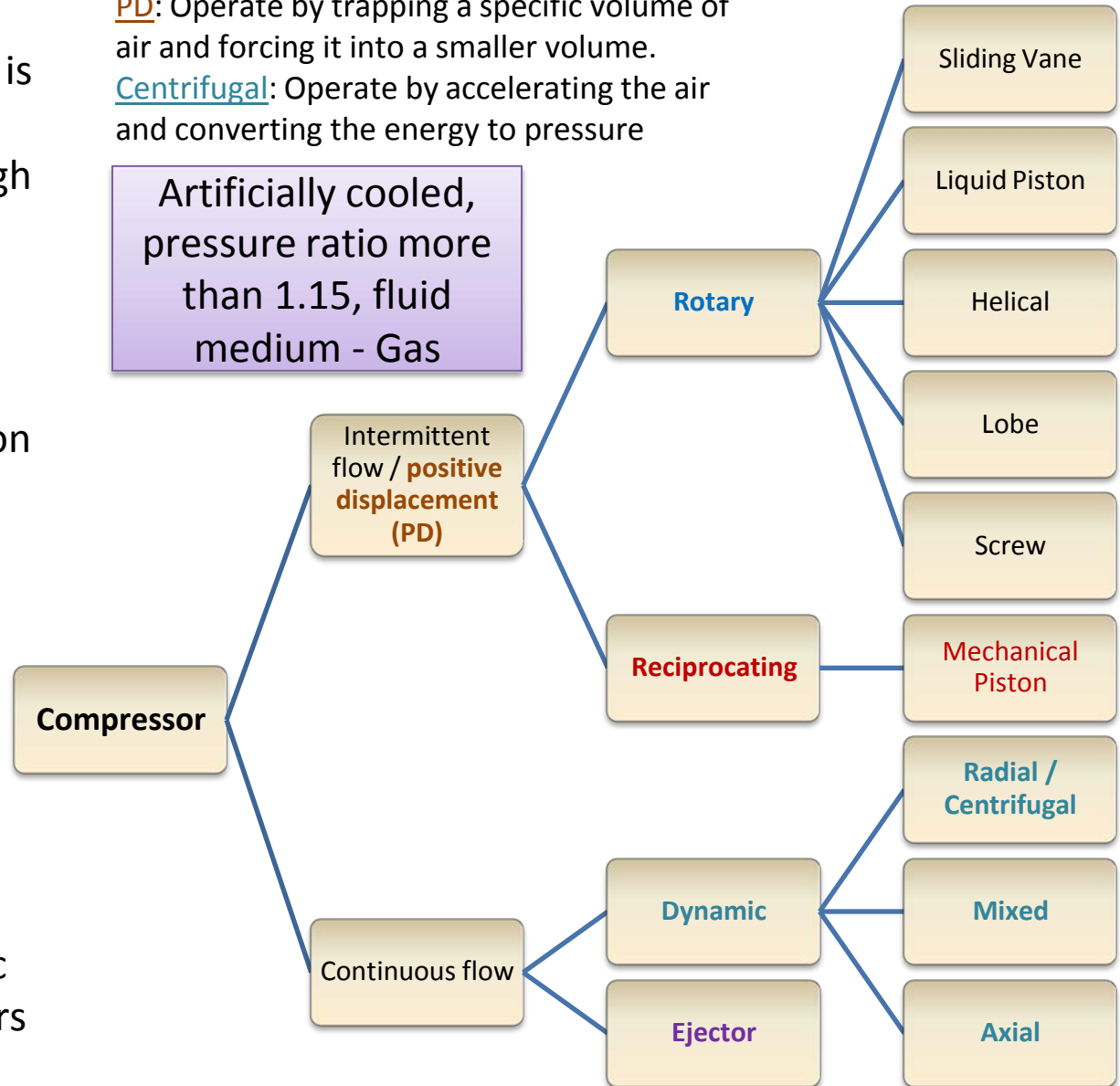
What is Compressor ?

Compressor is a device which is used to increase the pressure of air from low pressure to high pressure by using some external energy

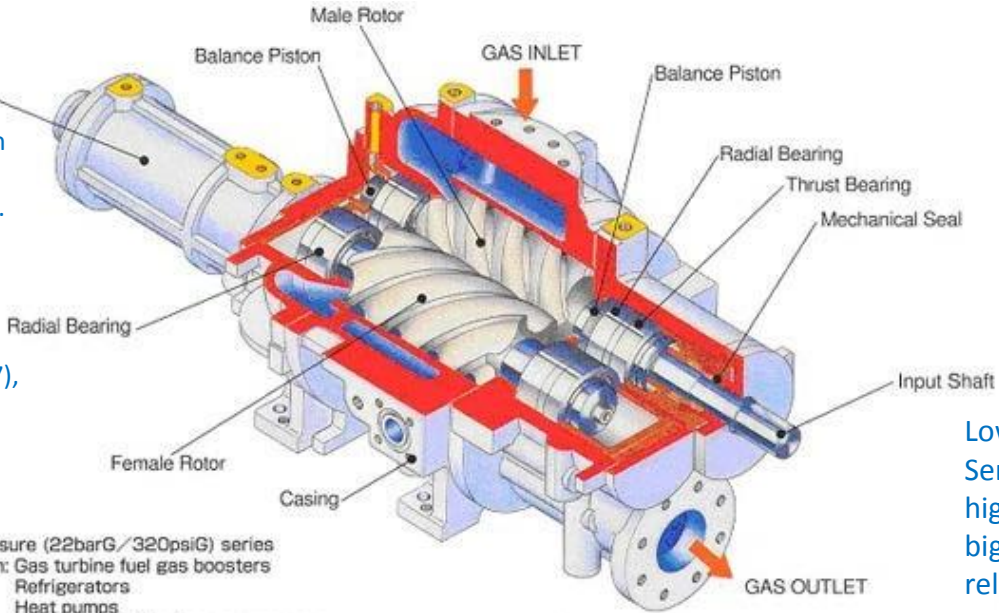
- For filling the air in tube of vehicles
- In automobile service station to clean vehicles.
- For spray painting in paint industries.
- In vehicle to operate air brakes.
- For cleaning workshop machines.
- For supercharging of an IC engines.
- For operation of pneumatic tools i.e. rock drills, vibrators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

PD: Operate by trapping a specific volume of air and forcing it into a smaller volume.

Centrifugal: Operate by accelerating the air and converting the energy to pressure

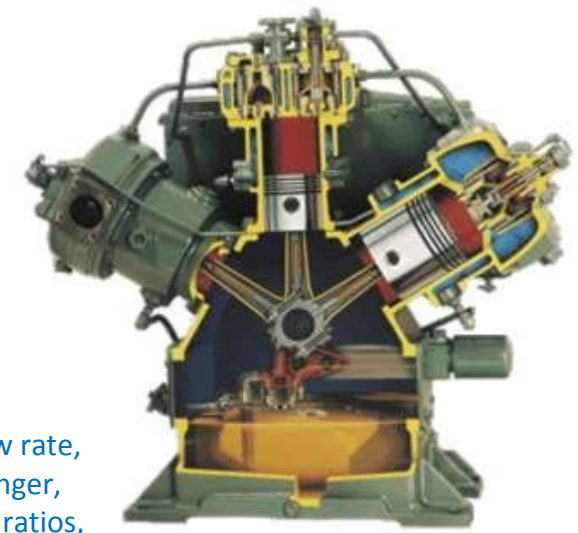


- Quiet operation
- High volume of air, steady flow.
- Lower energy cost, small size
- Suitable for continuous operation (24/7),
- low efficiency
- Low pressure ratio



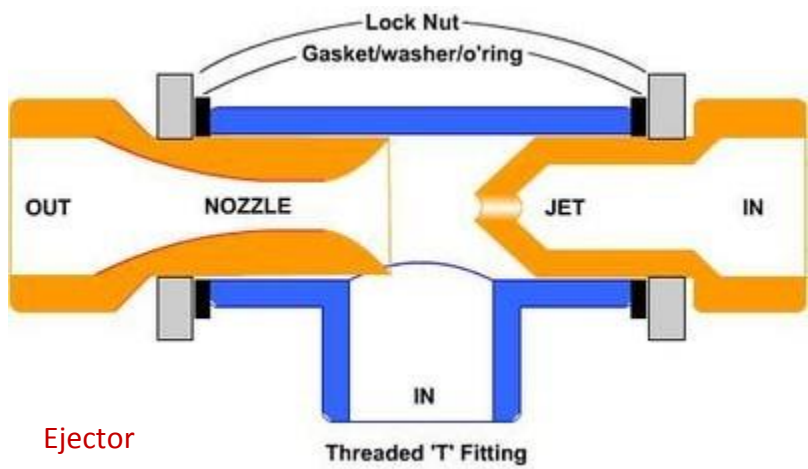
Middle-high pressure (22barG/320psiG) series
 Major application: Gas turbine fuel gas boosters
 Refrigerators
 Heat pumps
 Oil and gas gathering compressors
 LNG boil off gas compressors

Rotary – screw compressor



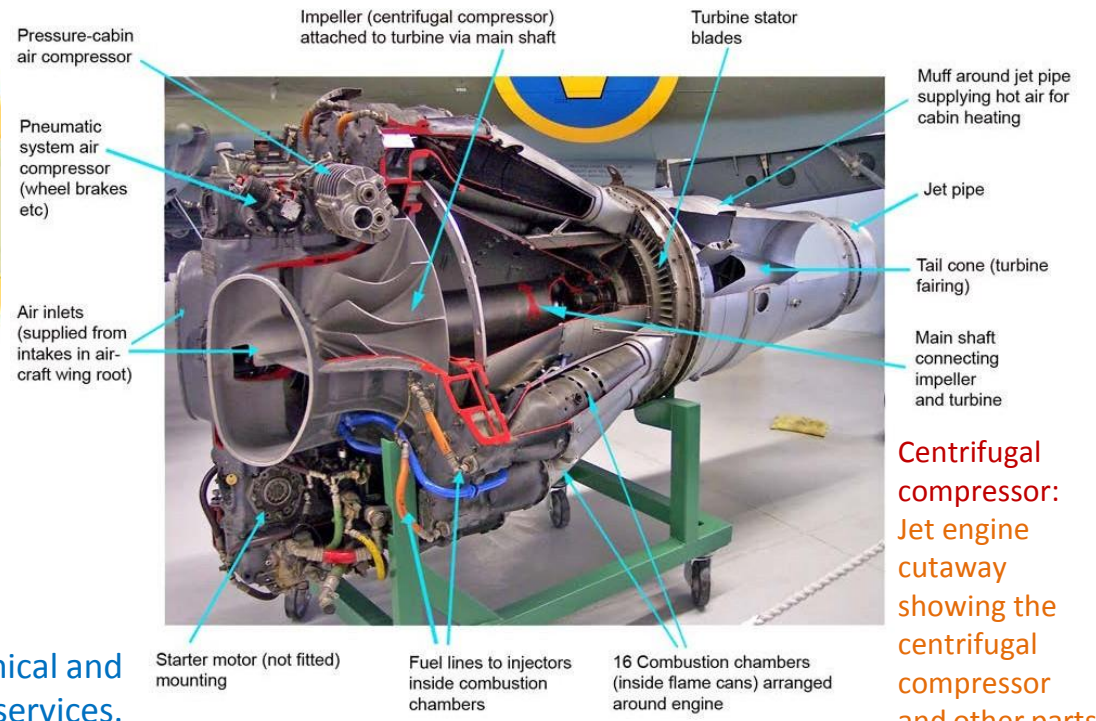
Low mass flow rate,
 Service life longer,
 high pressure ratios,
 bigger size, and is
 relatively cheap.

Reciprocating



Ejector
 Process plant optimization. Gas compression.
 Production boosting.

Centrifugal compressor is widely used in chemical and petroleum refinery industry for specific services.



Centrifugal compressor:
 Jet engine cutaway showing the centrifugal compressor and other parts

Definitions of 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/minute or m^3/sec .

Free air Delivered(FAD):- It is the volume of air delivered by compressor under the compressor intake conditions (i.e. temperature and pressure).

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

Clearance volume:- it is the difference between the total volume and the swept volume, basically the gap that remains between the piston head and the cylinder head when at top dead center.

Efficiencies:

Volumetric efficiency:-

It is the ratio of actual volume of the FAD at standard atmospheric condition in one delivery stroke (Actual air intake) to the swept volume (theoretical air intake) by the piston during the stroke.

Isothermal efficiency:-

It is defined as the ratio of isothermal power (P_{iso}) (i.e. required input power at isothermal process) done to the indicated power (IP) or actual work done.

Mechanical efficiency:-

It is the ratio of indicated power (IP) to the shaft(Brake) Power (P_{shaft}).

Overall efficiency:-

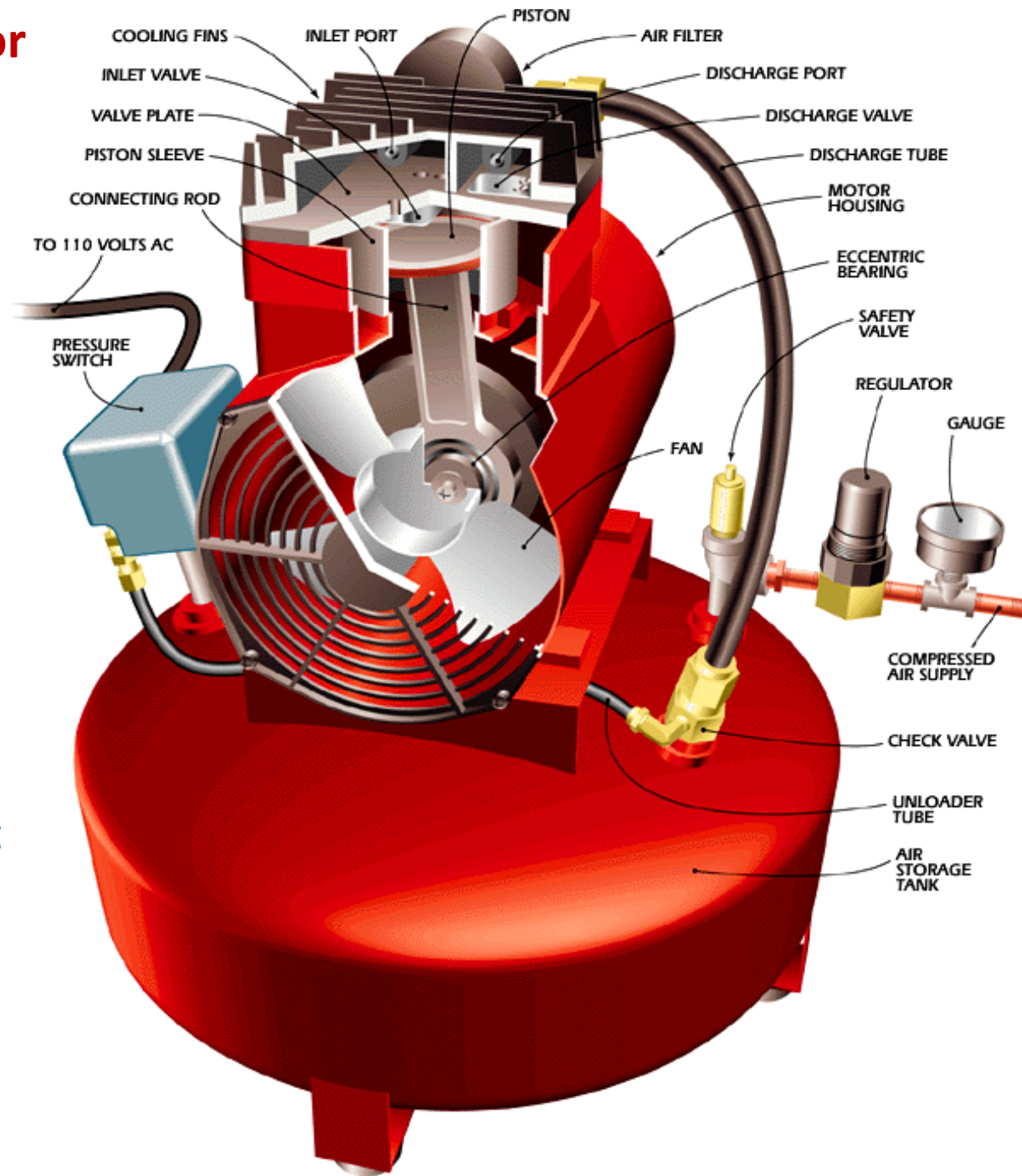
It is the ratio of isothermal power (P_{iso}) to the shaft(Brake) Power (P_{shaft}).

The Analysis Objectives

- To calculate air pressure and temperature before and after compression process
- To calculate indicated work/power
- To obtain compressor efficiency
- To calculate free air delivery rate (kg/s or m³/s)

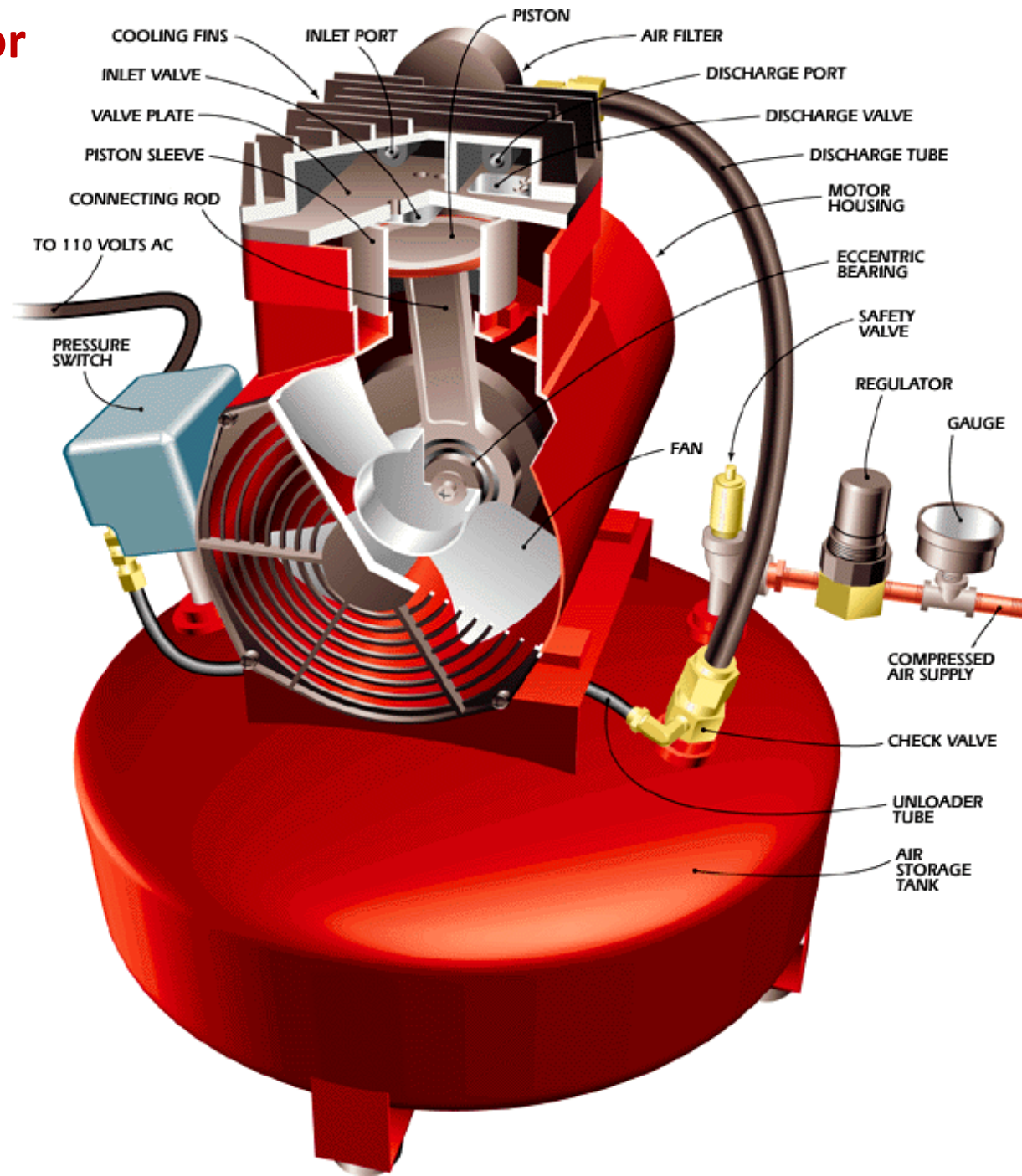
Reciprocating Compressor

The primary components of a typical reciprocating compressor system can be seen in Figures. The compression cylinders, also known as stages, of which a particular design may have from one to six or more, provide confinement for the process gas during compression. A piston is driven in a reciprocating action to compress the gas. Arrangements may be of single- or dual-acting design. (In the dual-acting design, compression occurs on both sides of the piston during both the advancing and retreating stroke.) Some dual-acting cylinders in high-pressure applications will have a piston rod on both sides of the piston to provide equal surface area and balance loads.



Reciprocating Compressor

Tandem cylinder arrangements help minimize dynamic loads by locating cylinders in pairs, connected to a common crankshaft, so that the movements of the pistons oppose each other. Gas pressure is sealed and wear of expensive components is minimized through the use of disposable piston rings and rider bands respectively. These are formed from comparatively soft metals relative to piston and cylinder/liner metallurgy or materials such as polytetrafluoroethylene (PTFE).



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.

Single – Acting compressor

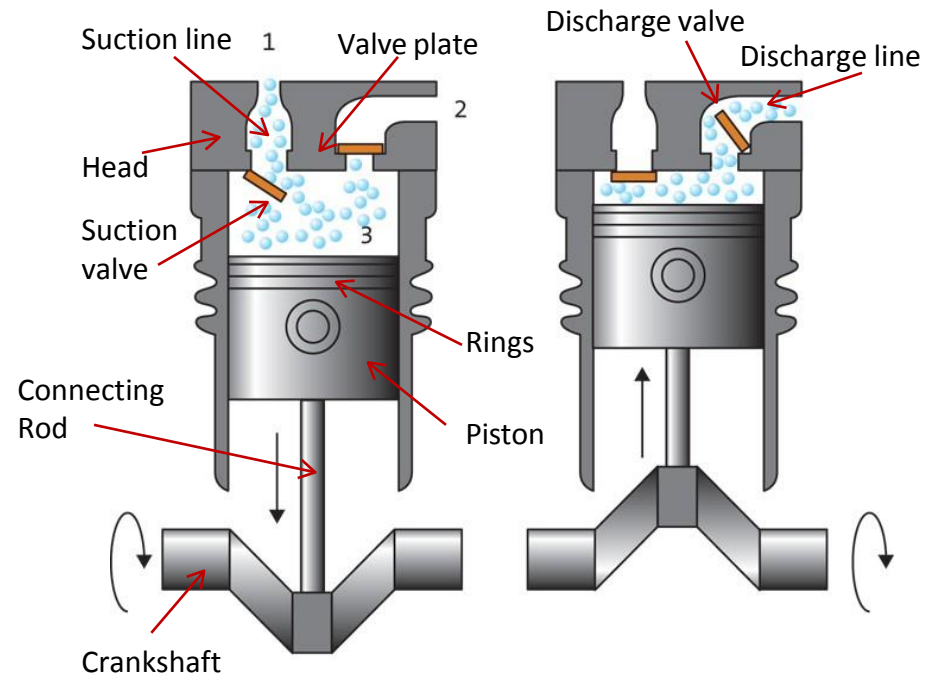
It is a compressor that has one discharge per revolution of crankshaft.

Double – Acting Compressor

It is a compressor that completes two discharge strokes per revolutions of crankshaft. Most heavy-duty compressors are double acting.

Multi-staging :Reduction in power required to drive the compressor.

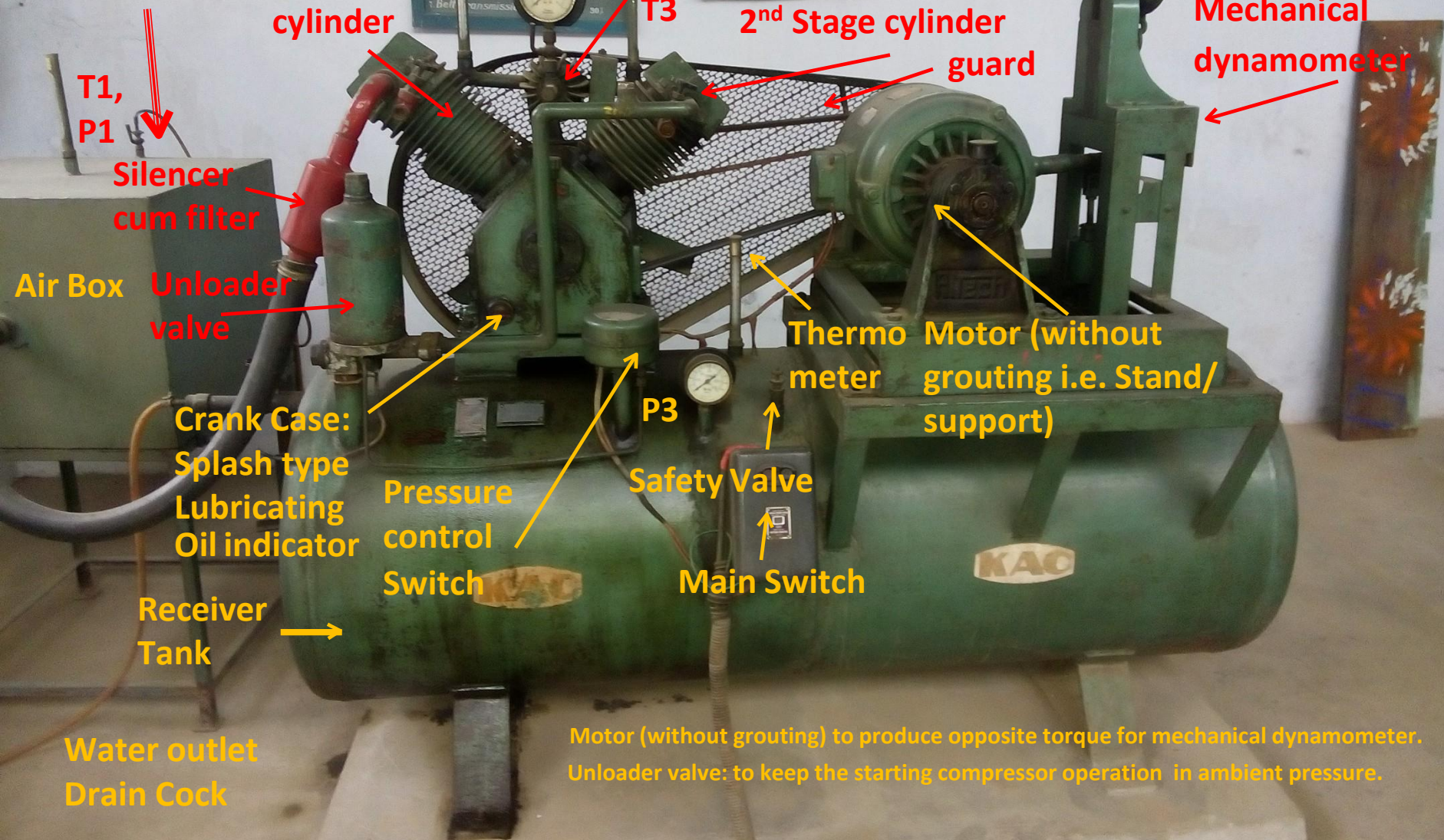
- Better mechanical balance of the whole unit and uniform torque.
- Increase in volumetric efficiency.
- Reduced leakage loss.
- Less difficulty in lubrication due to low working temperature.
- Lighter cylinders can be used.
- Cheaper materials can be used for construction as the operating temperature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



Front Face View



Manometer Reading (orifice)



Dial weight Reading (Kg)

Mechanical dynamometer

2nd Stage cylinder guard

Intercooler

1st Stage cylinder

Thermo Motor (without grouting i.e. Stand/support)

Main Switch

Safety Valve

Pressure control Switch

Crank Case: Splash type Lubricating Oil indicator

Receiver Tank

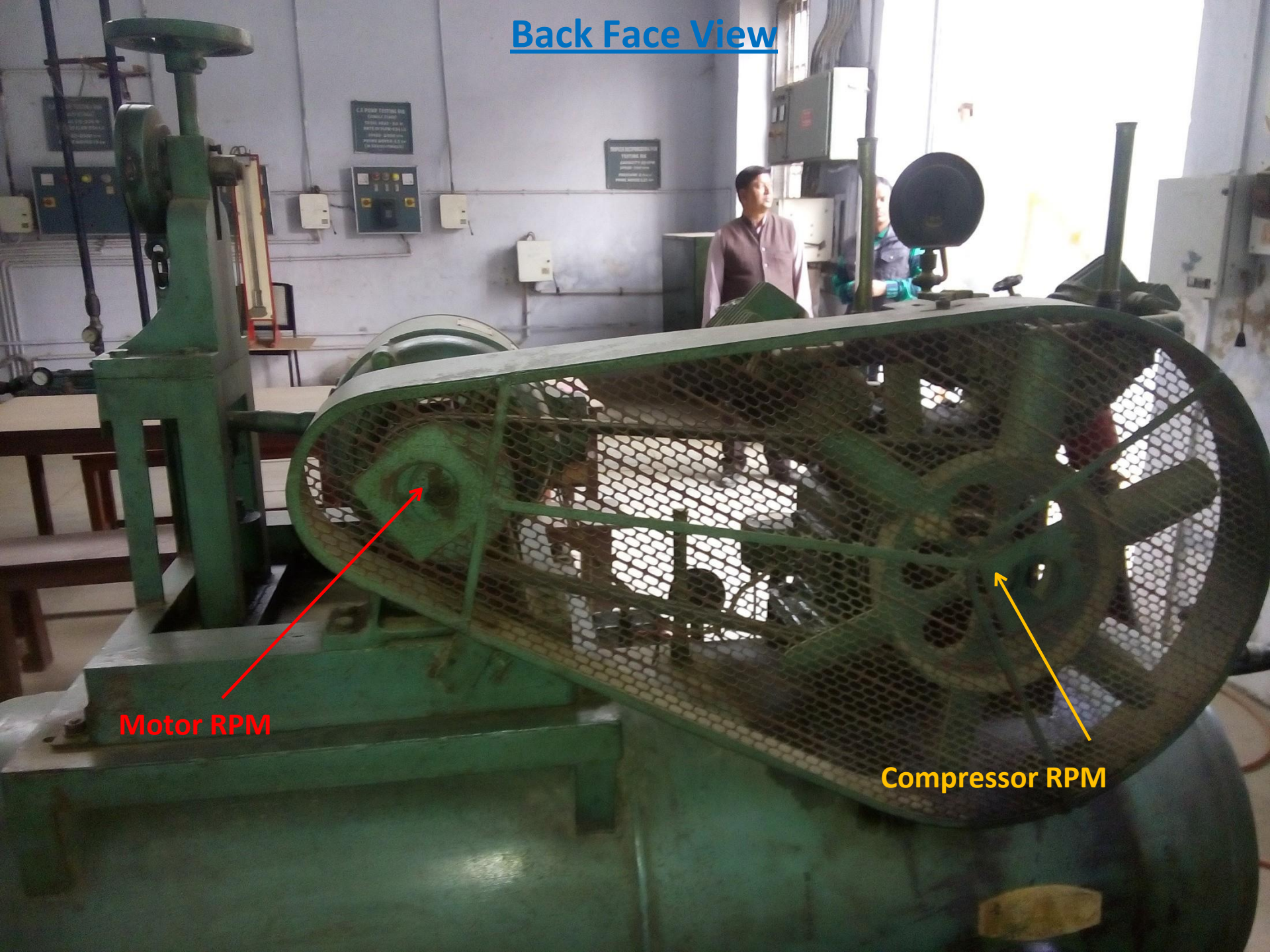
Water outlet Drain Cock

Motor (without grouting) to produce opposite torque for mechanical dynamometer. Unloader valve: to keep the starting compressor operation in ambient pressure.

TWO STAGE RECIPROCATING AIR COMPRESSOR
1. Three phase A.C. Induction Motor 25 H.P.
2. H.P. Cylinder Diameter 100 mm
3. L.P. Cylinder Diameter 150 mm
4. Stroke Length 125 mm
5. Crank Diameter 100 mm
6. Belt Transmission 30 mm



Back Face View



Motor RPM

Compressor RPM

Reciprocating Compressor

Assumptions

The **working fluid** is assumed as a **perfect gas** and P - v - T can be calculated by using **simple equation of state**. Usually, these assumptions are used to calculate estimate pressure, P , volume, V , and temperature, T , of the working fluid.

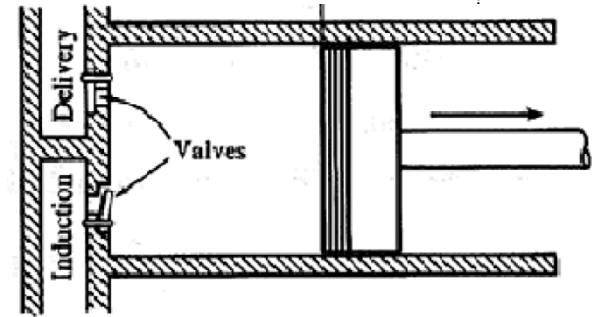
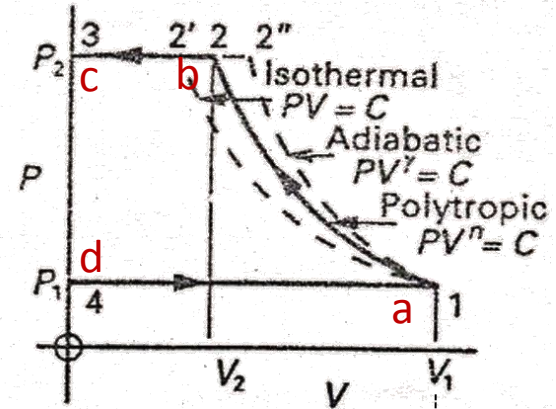
$$PV = mRT \quad PV/T = K_1 \quad PV^n = K_2$$

- Compressor without clearance volume
- Compressor with clearance volume
- Multistage compressors

Compressor without clearance volume

The Cycle of Operation

- The cycle of operation of a reciprocating air-compressor is best shown on a pressure-volume (p - V) diagram.
- It is known as an *indicator diagram* for the compressor.
- The cycle comprises of three processes:
 - $d - a$: An *induction stroke*
 - $a - b$: A *compression stroke*
 - $b - c$: A *delivery stroke*



Reciprocating Compressor

Compressor without clearance volume

Description of the Processes

d – a: The induction stroke

Intake valve opens, while exhaust valve closed.

Atmospheric air is drawn into the cylinder at constant pressure p_1 and temperature T_1 . Ideally, there is no heat loss to the surrounding from the air.

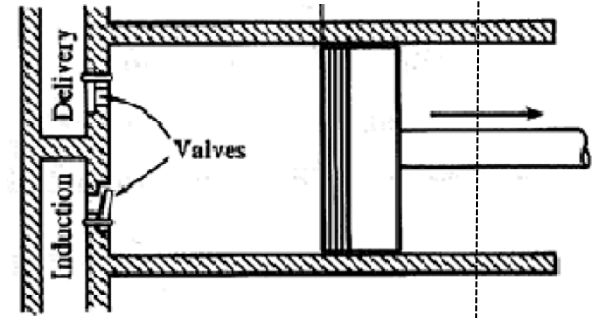
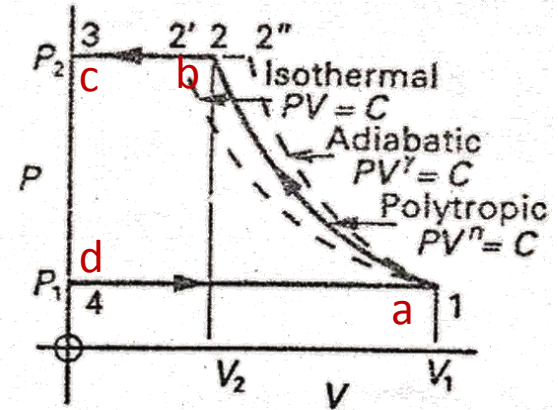
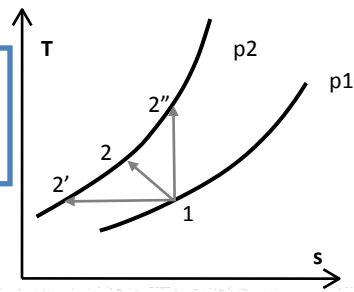
a – b: The compression stroke

Both intake and exhaust valves closed. The air is compressed according to a polytropic law $pV^n = \text{constant}$. Its pressure is increased from p_1 to p_2 . The temperature is also increased from T_1 to T_2 .

b – c: The delivery stroke

The intake valve closed while the exhaust valve opens. The compressed air is pushed out of the cylinder at constant pressure p_2 and temperature T_2 . There is no heat loss from the air to the surroundings.

During compression, due to its excess temperature above the compressor surrounding, the air will lose some heat. Thus neglecting the internal effect of friction the index is less than γ (i.e. <1.4), the adiabatic index. If $n = \gamma = 1.4$, area under curve is biggest, i.e. reversible adiabatic or entropy constant. Since work must be put into an air compressor to run it, every effort is made to reduce this amount of work input. It is observed that if compression is along isothermal, work done is less (though in practical it is not possible). Isothermal is attempted by cooling the compressor either by adding cooling fan or water jacket.



Reciprocating Compressor

Compressor with clearance volume

Effect of the clearance volume is to reduce the volume actually aspirated.

Analysis of Cycle

It is a spacing between the top of the piston and the valve's heads when the piston is at the end of the delivery stroke. Good quality machines has a clearance volume of about 6%. But compressors with clearance of 30 – 35% are also common.

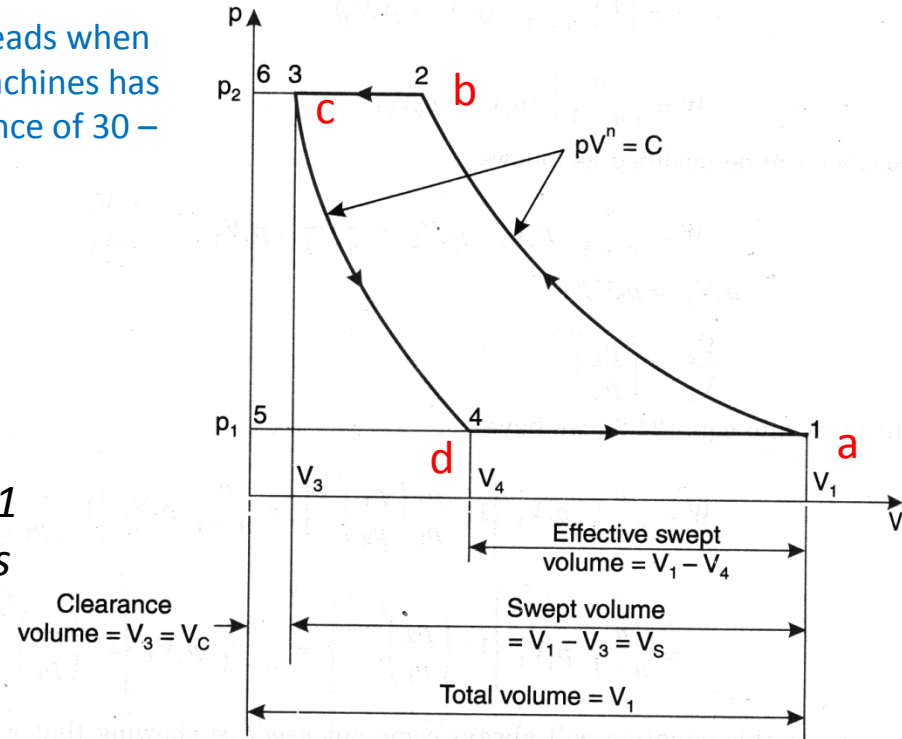
Processes

d – a: Induction process

The inlet valve opens. Fresh atmospheric air is induced into the cylinder at constant pressure p_1 and temperature T_1 . The volume of air induced is $(V_a - V_d)$. Ideally, there is no heat transfer from the air to the surroundings.

a – b: Compression process

Both valves closed. The induced air is compressed according to the polytropic law of $pV^m = \text{const.}$, until the pressure and temperature increases to p_2 and T_2 , respectively. Ideally, there is no heat transfer from the air to the surroundings of cylinder.



Clearance volume:

- Give a mechanical freedom to the moving parts
- Reduce noise and vibration during operation
- Prevent damage to moving components

Reciprocating Compressor

Compressor with clearance volume

V_c , residual gas

Deliver valve open, compress gas starts delivering from the cylinder

Analysis of Cycle

It is a spacing between the top of the piston and the valve's heads when the piston is at the end of the delivery stroke. Good quality machines has a clearance volume of about 6%. But compressors with clearance of 30 – 35% are also common.

Because of presence of clearance volume, volumetric efficiency is always less than unity, between 60% to 85%.

Processes

b – c: Delivery process

The exhaust valve opens. The compressed air is delivered out of the cylinder at constant pressure p_2 and temperature T_2 . Ideally, there is no heat transfer from the air to the surroundings.

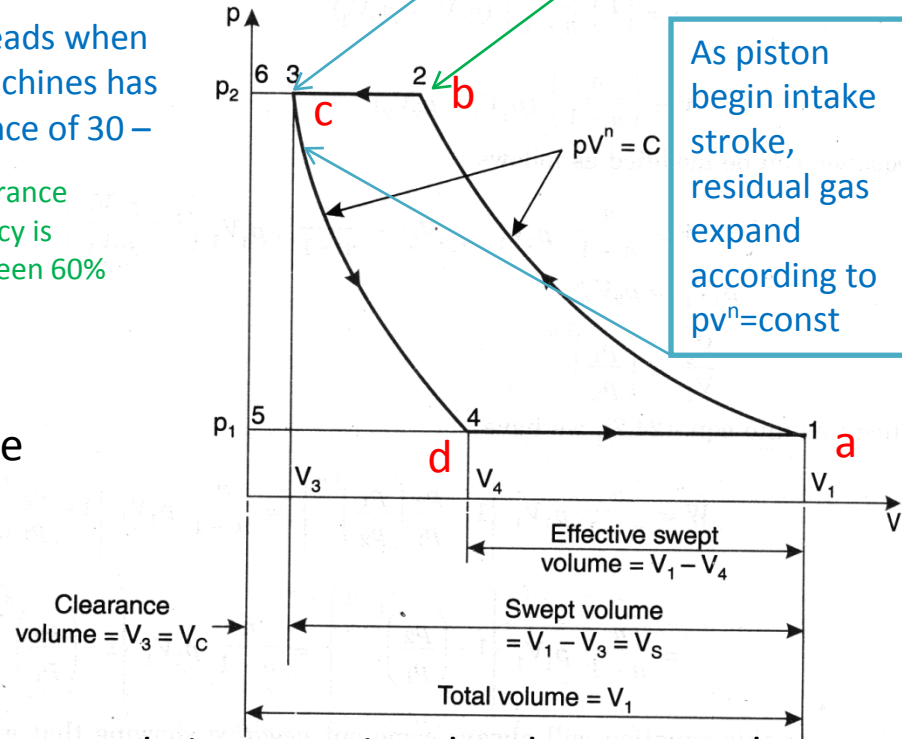
c – d: Expansion process

The piston begins the induction stroke. The compressed air occupying the clearance volume V_c expands according to the polytropic law of $pV^n = \text{const.}$, until the pressure and temperature fall to p_1 and T_1 , respectively. Ideally, there is no heat transfer from the air to the surroundings.

Note: At the end of the delivery stroke, the clearance volume V_c is filled with compressed air at pressure p_2 and temperature T_2 .

$$\text{Volumetric efficiency} = \frac{V_1 - V_4}{V_1 - V_3}$$

It is the ratio between FAD at standard atmospheric condition in one delivery stroke (Actual air intake) to the swept volume (theoretical air intake)



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.
- 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.