CHAPTER TWO

RECIPROCATING COMPRESSORS CONSTRUCTION DETAILS

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In general, materials for construction of the compressor and auxiliaries are normally the manufacturer's standard for the specified operating conditions except as required by the data sheet or certain specifications.

Figure 2.1 shows most of the components of a reciprocating compressor.

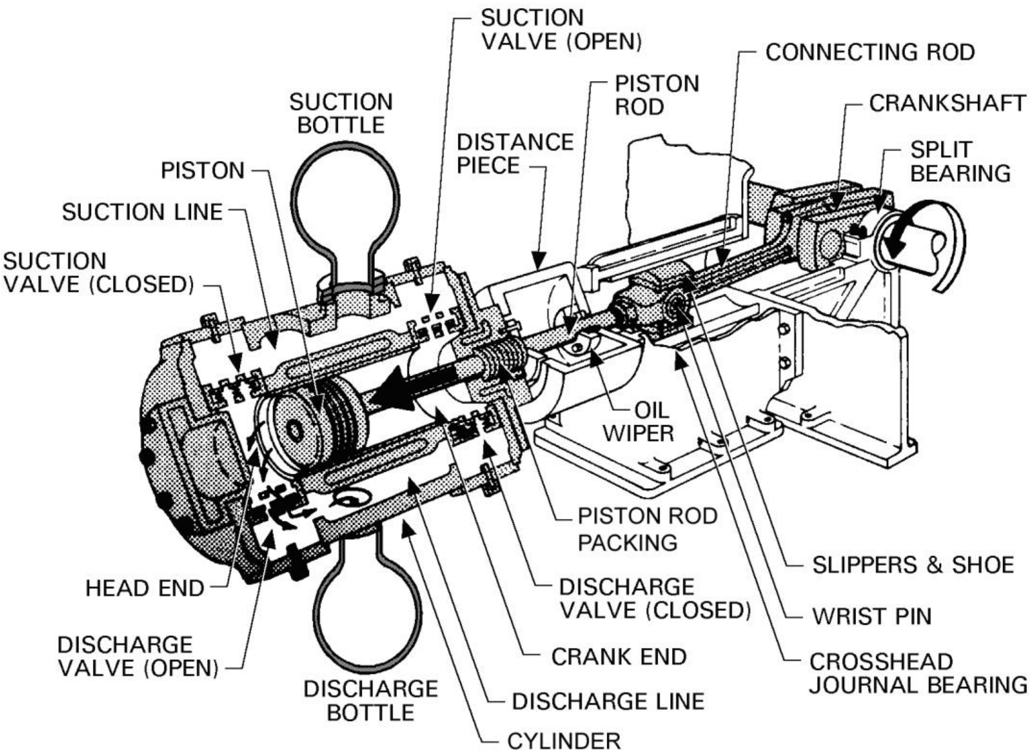

Figure 2.1 – Reciprocating compressor construction

2.1 Frame

Figure 2.2 shows a compressor frame which is a heavy, rugged casting containing all the rotating parts, and on which the cylinders and crosshead are mounted. All frames are rated by compressor manufacturers for a maximum continuous horsepower, which is determined by either the maximum horsepower that can be transmitted through the crankshaft to the compressor cylinders, or by the force load imposed on the frame by the pressure differential between the two sides of the piston at the design speed.

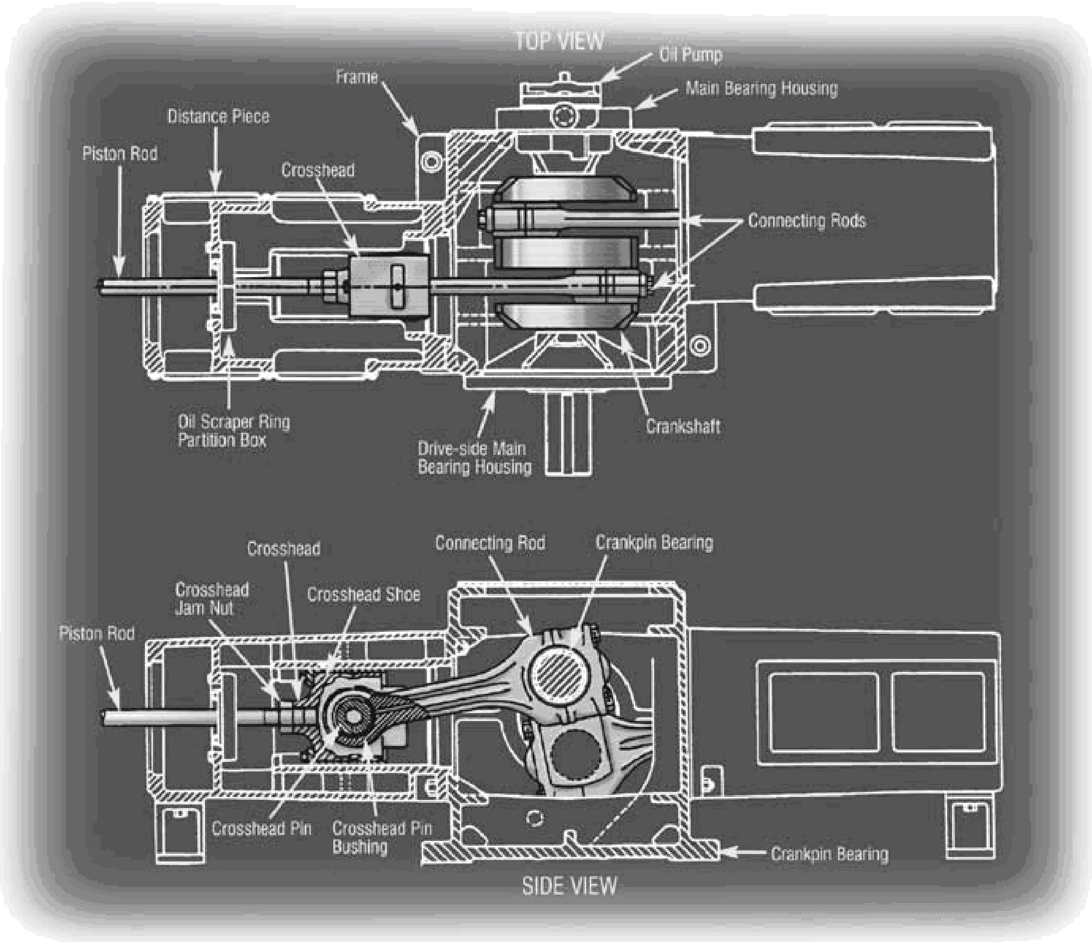

Figure 2.2 – Two throw frame and housing gear

Balanced opposed frames are characterized by an adjacent pair of crank throws 180° out of phase and separated only by a crank web. The frame is separate from the driver. Figure 2.3 shows a balanced opposed compressor. Integral type frames are characterized by having compressor cylinders and power cylinders mounted on the same frame and driven by the same crankshaft. Figure 2.3 also shows an integral type gas engine driven compressor.

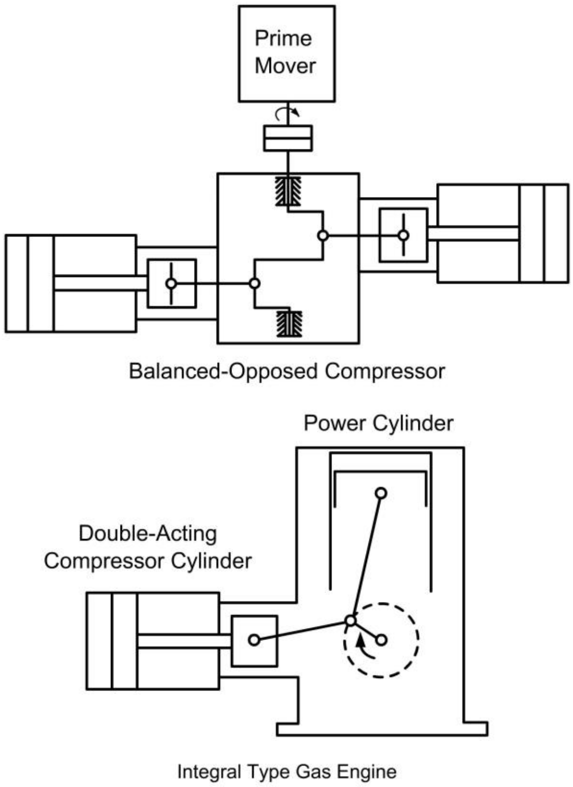

Figure 2.3 – Schematic diagrams of a balanced opposed compressor and an integral type gas-engine compressor

2.2 Cylinder

A cylinder is a pressure vessel that holds the gas during the compression cycle. There are two basic types:

1. Single-acting cylinders are those where compression takes place on only one of the two piston strokes per revolution.
2. Double-acting cylinders are those where compression takes place on both of the piston strokes per revolution.

Figure 2.4 shows a single-acting cylinder. As the piston moves to the right, gas is sucked in; as the piston moves to the left, gas is discharged. Figure 2.5 shows a double acting cylinder in which gas is being compressed in both left and right movements.

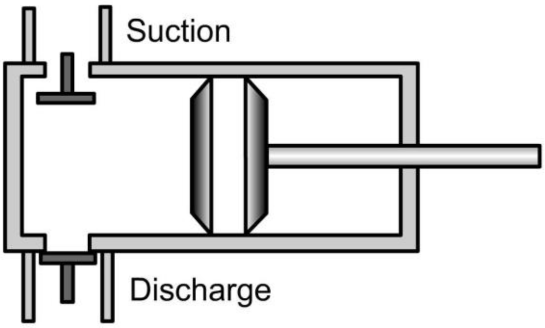

Figure 2.4 – Single acting compressor cylinder

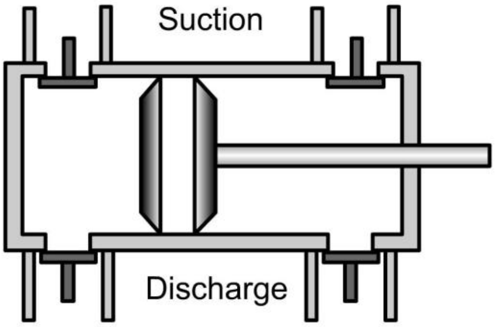

Figure 2.5 – Double acting compressor cylinder

Cylinders are made of different kinds of materials. Cast iron is generally used for cylinder operating pressures from 1,000 to 1,200 psig. Nodular iron is used for cylinder operating pressures up to 1,500 psig and cast steel is used for cylinder operating pressures in the 1,000 to 2,500 psig range. Forged steel is generally used for pressures above 2,500 psig.

Like all pressure vessels, the cylinder has a maximum allowable working pressure (MAWP). Normally the maximum allowable working pressure of the cylinder determines the setting of the relief valve that is downstream of the cylinder; however, it is possible that the downstream piping or cooler will have a lower MAWP which will determine the relief valve set pressure. The MAWP of the cylinder should be 10 percent or at least 25 psi greater than its maximum operating pressure.

Typically, in specifying a unit, the pressures, horsepower, inlet temperature and gas properties are given. The actual sizing of the cylinders is usually left to the manufacturer from his specific combinations of standard cylinders, pistons and liners. However, once a - proposal is received from a manufacturer, sometimes it is beneficial to check the cylinder sizing and make sure that the compressor will perform.

Sometimes it is necessary to size a new cylinder for an existing compressor or to verify that an existing compressor will perform in a different service. The capacity of the cylinder is a function of piston displacement and volumetric efficiency. This in turn is a function of Cylinder clearance, compression ratio and gas properties.

2.3 Cylinder Liners

A cylinder liner such as that shown in Figure 2.6 may be used to help prolong the life of the cylinder. Liners make repair less costly by taking the wear from the piston. It is often easier and less costly to replace a liner than to replace or remachine a cylinder.

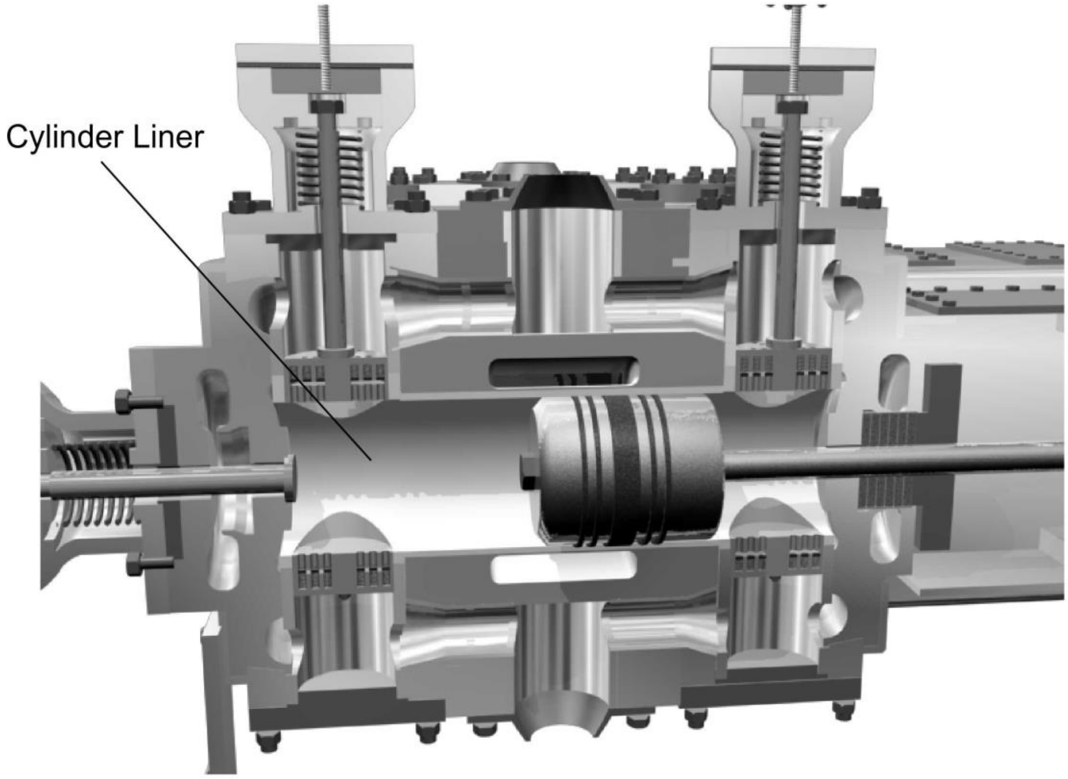

Figure 2.6 – View of a compressor cylinder showing the cylinder liner

Liners also allow the effective cylinder diameter to be changed without changing the complete cylinder. This provides flexibility for different conditions of pressure and flowrate.

Liners have the disadvantage of decreasing effective diameter and thus capacity for a given diameter cylinder, increasing clearance between valve and piston (thus decreasing capacity) and decreasing the effectiveness of jacket cooling.

2.4 Distance Piece and Packing Case

The drive unit and the compression unit (the cylinder) are connected by a distance piece. The distance piece adds mechanical strength to the unit. It prevents gas leakage from cylinder to compressor frame (oil) and vice versa. It also allows access to the piston rod packing and the oil wiper rings.

In a single-compartment distance piece, both the frame end and the cylinder end contain packing. The space between the cylinder packing and the frame diaphragm and packing is sufficiently long to assure that no part of the rod enters both the cylinder and the frame. Therefore, oil cannot carry contamination between the gas being compressed and the oil that is used to lubricate the crankcase.

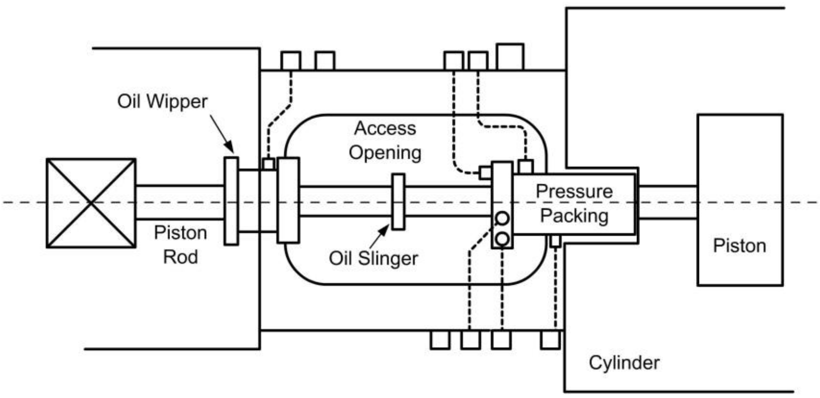

Figure 2.7 – Single compartment distance piece

There are drains and vents off the distance piece and off the packing/so if there is a packing failure, the high-pressure gas has a place to vent and not build up pressure that could leak through the frame packing into the crankcase. An oil slinger to prevent packing lube oil from entering the compressor frames is also shown.

A two-compartment distance piece is sometimes used for toxic gases, but it is not very common. In this configuration, no part of the rod enters both the crankcase and the compartment adjacent to the compressor cylinder. That is, even if there were one failure, the crankcase oil cannot be contaminated with the toxic gas.

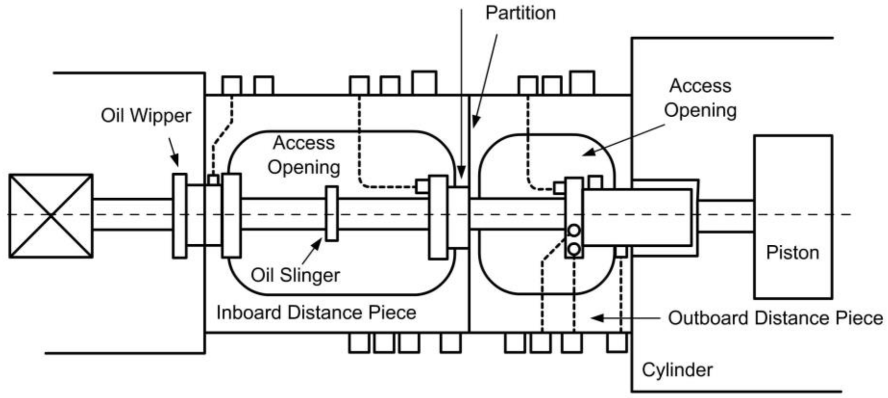

Figure 2.8 – Two compartment distance piece

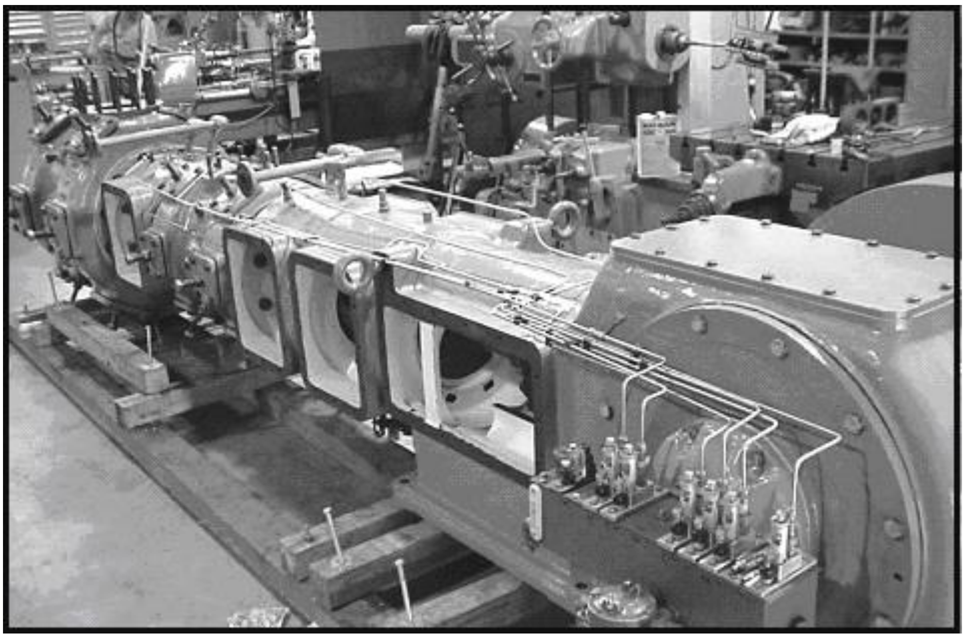

Figure 2.9 – A typical two compartment distance piece

2.5 Crankshaft, Connecting Rod, Crosshead and Piston Rod

Figure 2.10 shows the crankshaft, connecting rod, crosshead and piston rod. The crankshaft rotates around the frame axis, driving the connecting rod, crosshead, piston rod, and piston.

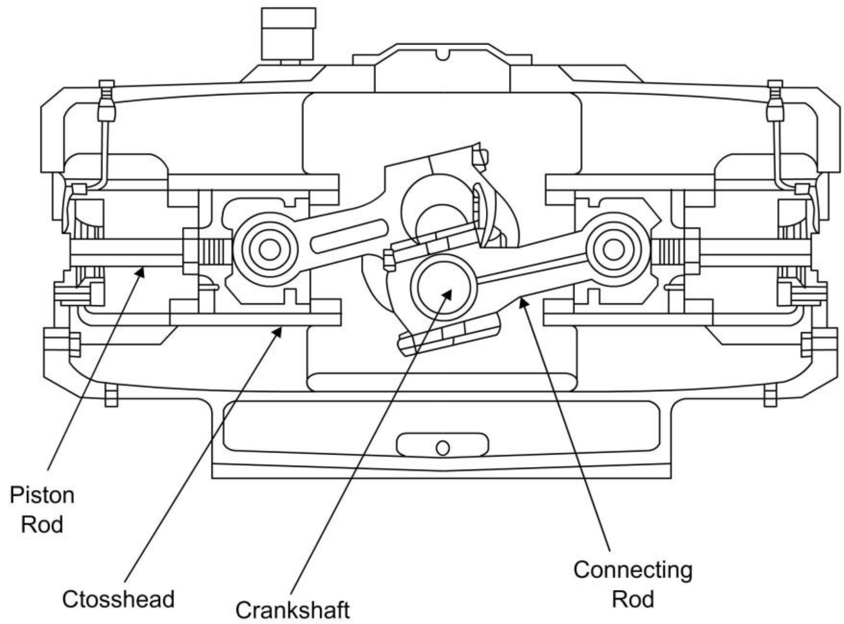

Figure 2.10 – Schematic diagram showing crankshaft, connecting rod, crosshead and piston rod

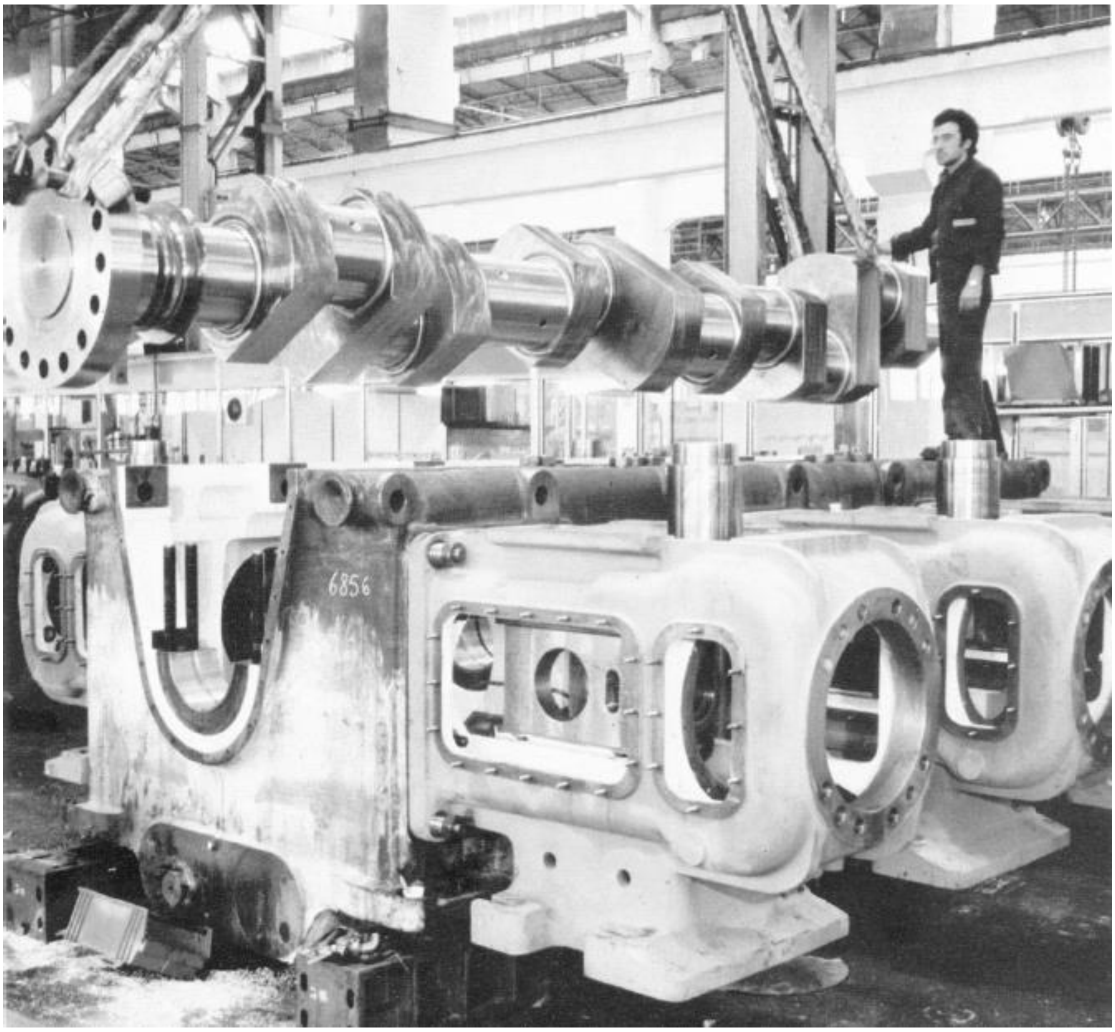

Figure 2.11 - Crankshaft being lowered into compressor crank case

The connecting rod connects the crankshaft to the crosshead. The crosshead converts the rotating motion of the connecting rod to a linear, reciprocating motion, while driving the piston rod. The piston rod, in turn drives the piston which compresses the gas in the cylinder.

The crosshead travels horizontally and must have little vertical movement. Its movement is limited by the crosshead guides. Inside the guides the crosshead guide shoes and slippers prevent any vertical movement of the crosshead.

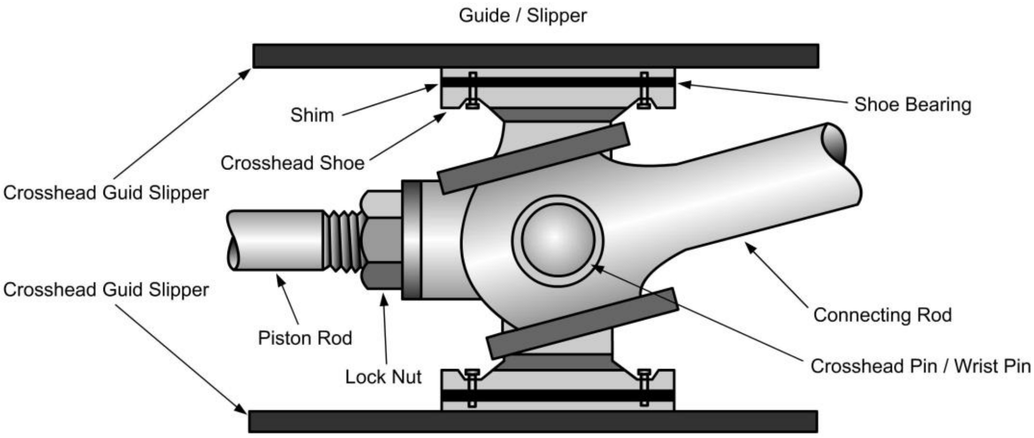

Figure 2.12 – The crosshead.

The crosshead joins the connecting rod to the piston rod. The crosshead allows the piston rod to move back and forth in a reciprocating motion, yet allows the connecting rod to have rotary motion. A lock nut secures the piston rod to the crosshead. The connecting rod is attached to the crosshead by the crosshead pin.

2.6 Piston Wear Bands

The piston is located at the end of piston rod, and acts as the movable barrier in the compressor cylinder. Pistons are generally made from lightweight materials such as aluminum, or steel with a hollow center. To prevent friction wear, the piston is generally equipped with removable wear bands, such as those shown in figure 2.13, which are in continuous contact with the cylinder wall. Because of this contact, piston wear bands incorporate oil channels to permit cylinder lubrication. These bands, made of softer material than the cylindrical wall, and they are replaced at regular maintenance intervals.

Figure 2.13 – Piston wear bands

2.7 Bearings

Most field compressors use hydrodynamic type or "journal" bearings. As shown in Figure 2.14, oil enters into the bearing from supply holes strategically placed along the bearing circumference. The oil then flows axially and circumferentially along the bearing and out the ends. As the oil flows through the bearing, the load compresses the oil film, which generates a high pressure within the bearing supporting the load. For the crosshead shoe the principle is identical, except the motion is linear and oscillating. In a reciprocating compressor the bearing locations are:

Main Bearings	Between crankshaft and frame
Crank Pin Bearing	Between crankshaft and connecting rod
Wrist Pin Bearing	Between connecting rod and crosshead
Crosshead Bearing (shoe)	Underneath the crosshead

Table 2.1 – Bearing locations in a reciprocating compressor

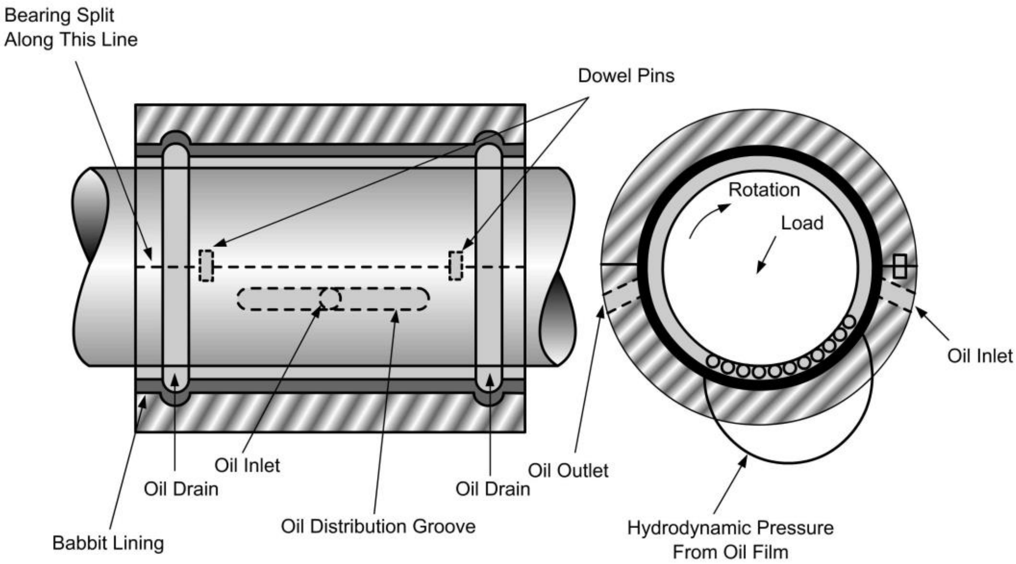

Figure 2.14 – Schematic diagram of a journal bearing

2.8 Packing Case

Packing provides the dynamic seal where the piston rod penetrates the cylinder. It consists of a series of rings mounted in a packing case. This case is bolted to the cylinder. The piston rod moves in a reciprocating motion through this case. Figure 2.15 shows a typical packing case.

The packing rings work in pairs, and are designed and installed for automatic compensation for wear. The amount of pressure differential that one set of rings can withstand is limited. Therefore, several pairs must be installed to handle typical oil field gas compression applications. Packing rings materials may be Teflon impregnated with fiber-glass, carbon fibers or soft metal (brass, etc.)

Packing lubrication reduces friction and provides a cooling effect. It must be finely filtered to prevent grit from entering the case. Lubrication is generally injected in the second ring assembly where pressure moves the oil along the shaft.

Additional cooling may be required for pressures above 3,000 psi where a large amount of frictional horsepower can be generated between the packing and the piston rod. Cooling may also be required at high compression ratios and where long packing cases are installed.

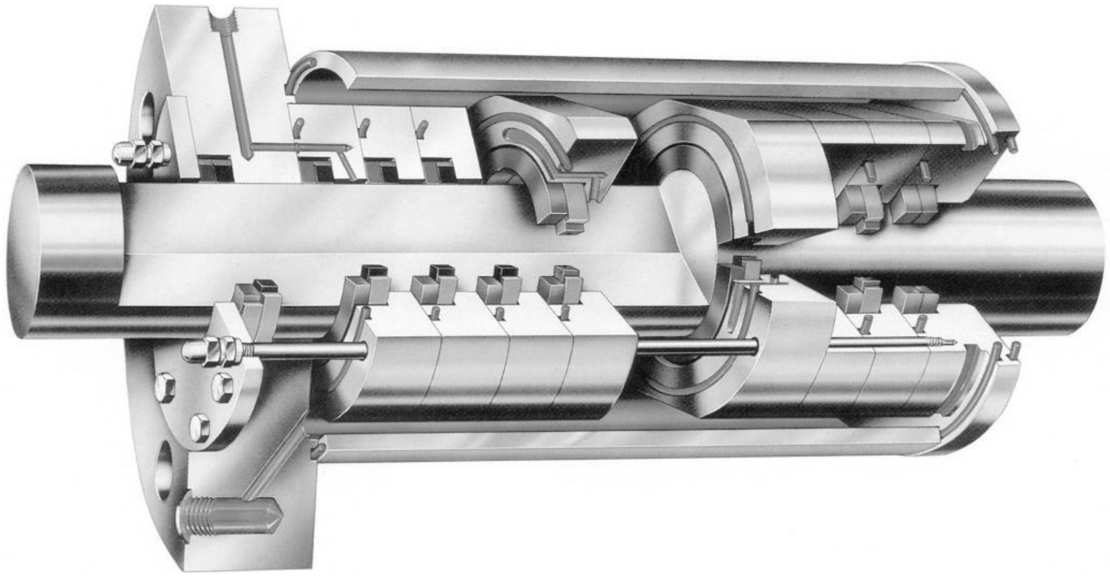

Figure 2.15 – Typical packing case

2.9 Compressor Valves

Compressor valves are one of the most important parts of a reciprocating compressor. A worn or damaged valve will allow gas to leak back. Dirt or other foreign matter can cause damage or prevent a valve from working correctly. Valves must be properly installed.

Poppet valves (Figure 2.16) are the most expensive, but also the most efficient. They are common in pipeline booster applications. As the pressure builds above each of the individual poppet, they open, allowing gas to pass through the flow openings in the lower portion. The greater the distance between the upper and lower portions, the smaller the resistance to flow.

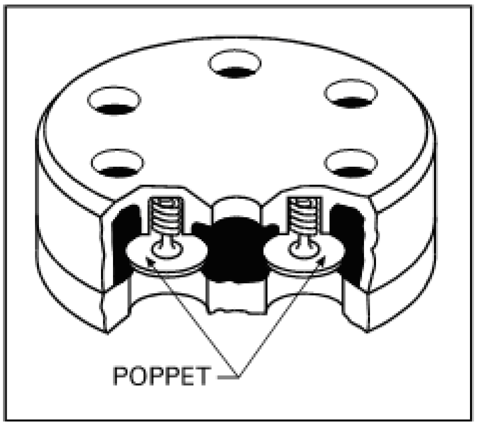

Figure 2.16 – Poppet valve

Disc or plate valves (Figure 2.17) are used for high-pressure services. They work in a similar manner to poppet valves except that, instead of individual poppets, there are circular discs that open and close.

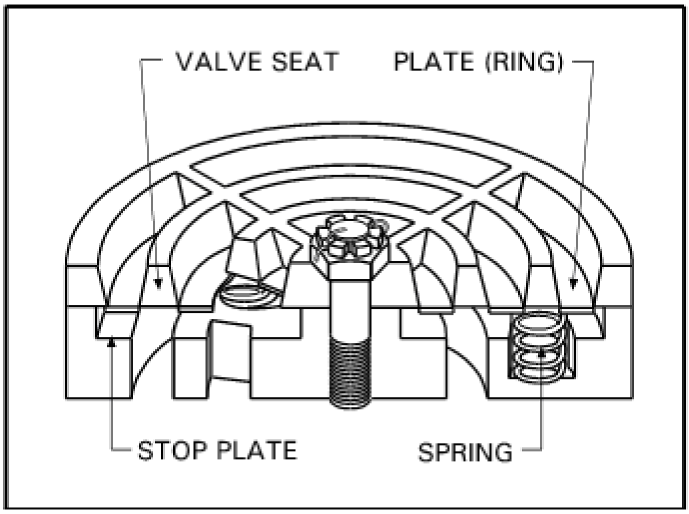

Figure 2.17 – Disc valve

Channel valves (Figure 2.18) are the least expensive and are common for standard applications. The springs hold the individual channel over the slots in the lower portion of the valve. As the pressure increases under the valve, the channels lift and allow flow up through the valve.

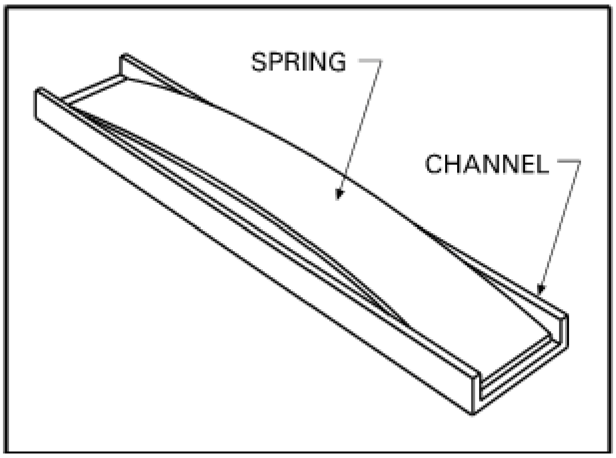

Figure 2.18 – Channel valve

Valve types and sizes are normally specified by the compressor manufacturer. An important parameter in selecting valves is the average gas velocity, which can be calculated from:

$$V_g = \frac{288PD}{A}$$

Where,

Vg = average gas velocity, ft/min

PD = piston displacement, ACFM

A = the total product of the actual lift in service and the valve-opening for all inlet valves per cylinder, in2

At lower velocities, valves have less pressure drop, and thus, less maintenance. Velocities calculated from this equation can be used to compare compressor designs.

2.10 Capacity Control Devices

The capacity of a compressor cylinder can be adjusted by using inlet valve unloaders or by adjusting clearance. An inlet valve unloader holds the inlet valves open during both the suction and discharge strokes, so that all the gas is pushed back through the intake valves on the discharge stroke.

Valve unloaders can be either plug or depressor type. Plug valve unloaders consist of an external plug type valve which separates the cylinder from the suction side. Plug valves can be operated automatically or manually. Figure 2.19 shows a plug type valve unloader.

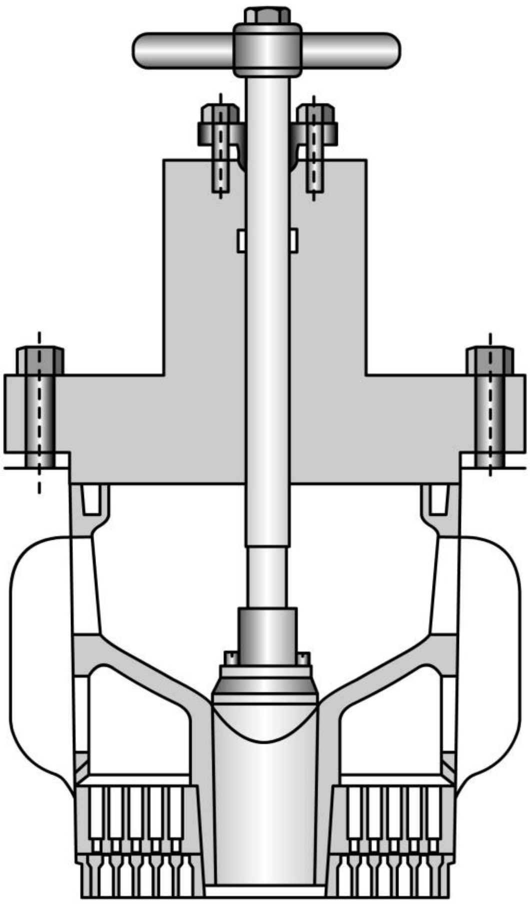

Figure 2.19 – Sectional view of a plug type valve unloader.

Depressor valve unloaders consist of a piston connected to a number of fingers or valve depressors. When activated, the piston is forced downward, thus forcing the depressors downward until the valve is lifted off its seat. Figure 2.20 shows a depressor type valve unloader. This type of valve unloader is actuated hydraulically or pneumatically. Care must be taken to ensure "fail-safe" operation in the event of a control system failure.

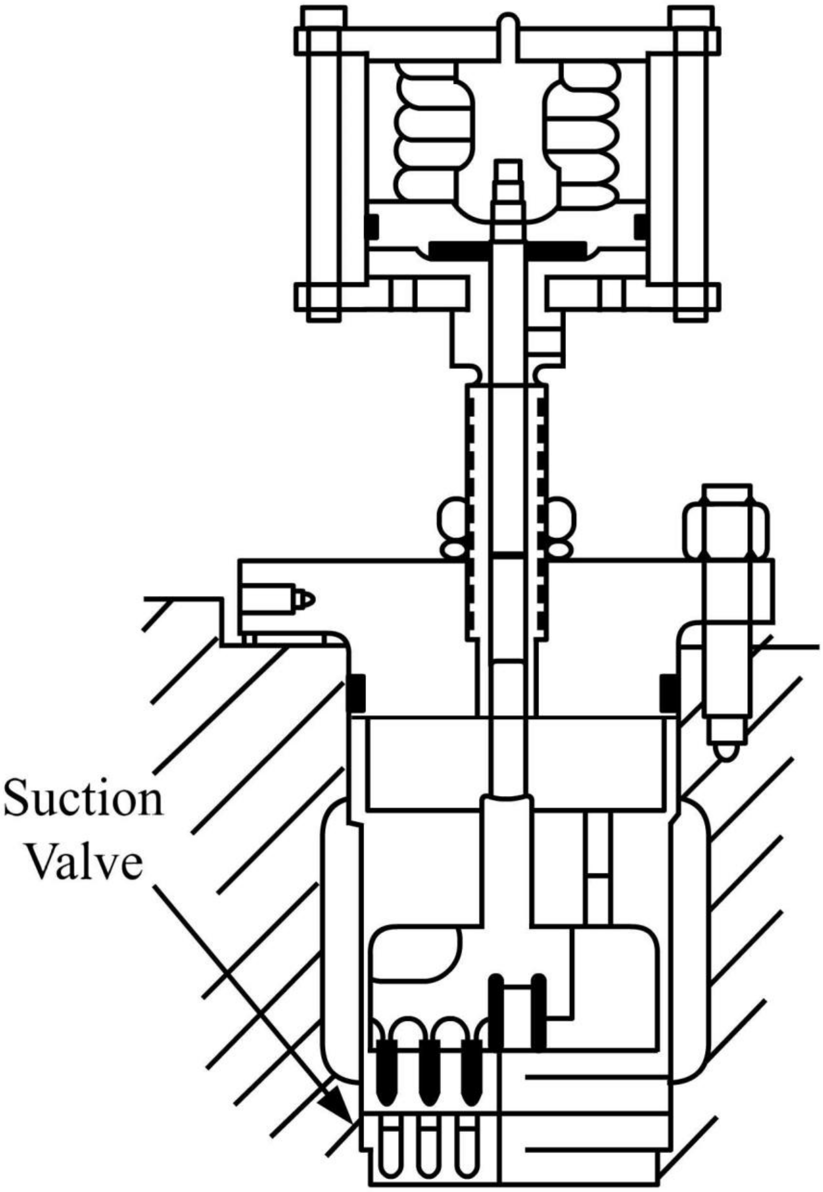

Figure 2.20 – Sectional view of a depressor type valve unloader

The number of cylinders deactivated at any operating condition should be minimized, as heating and vibration problems could occur. When a cylinder or a cylinder end is deactivated the pulsation levels in the piping system can increase significantly. Unloaded conditions must be considered during the acoustic study of the piping system.

Clearance (the volume of the cylinder not swept by the piston) can be adjusted by changing fixed clearance or by the use of clearance pockets (the greater the clearance the lower the volumetric efficiency and the lower the capacity of the cylinder). End clearance is required to keep the piston from striking the compressor head or crank end. It is usually 3/32 inches.

Some small clearance is also required under suction and discharge valves so that the valves can be removed and reinstalled.

These clearances are called fixed clearances and can be adjusted by:

- Removing a small portion of the end(s) of the compressor piston.
- Shortening the projection of the cylinder heads into the cylinder.
- Installing spacer rings between cylinder head and body or under valves.
- Changing from single deck to double deck valves. Single deck valves reduce clearance.

Clearance can also be changed by attaching fixed or variable pockets to the cylinder. Figure 2.21 is an example of a fixed clearance pocket mounted on the cylinder. This type is separated from the cylinder by a valve that can be opened and closed from the outside allowing flow into a fixed volume chamber. Several of these can be installed on the same cylinder so that different combinations can be used to achieve the desired clearance.

Some fixed clearance pockets do not have valves. To change the performance of the cylinder, the clearance can be changed by shutting down the compressor, unbolting one pocket, and installing another pocket with a different volume. In this way, it is easy to add or subtract clearance if the cylinder is set up to receive clearance pockets.

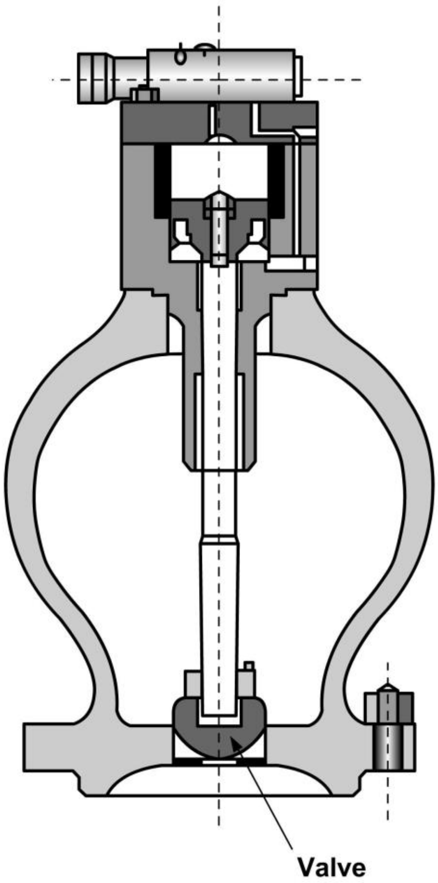

Figure 2.21 – Sectional view of a fixed clearance pocket

More flexibility can be obtained with a variable-volume clearance pocket such as that shown in Figure 2.22. This is a plug built into the cylinder wall and forming part of the cylinder boundary. When moved, the volume within the cylinder changes. Variable clearance pockets are generally limited to the head end of the cylinder and are not normally found on the frame (or crank) end.

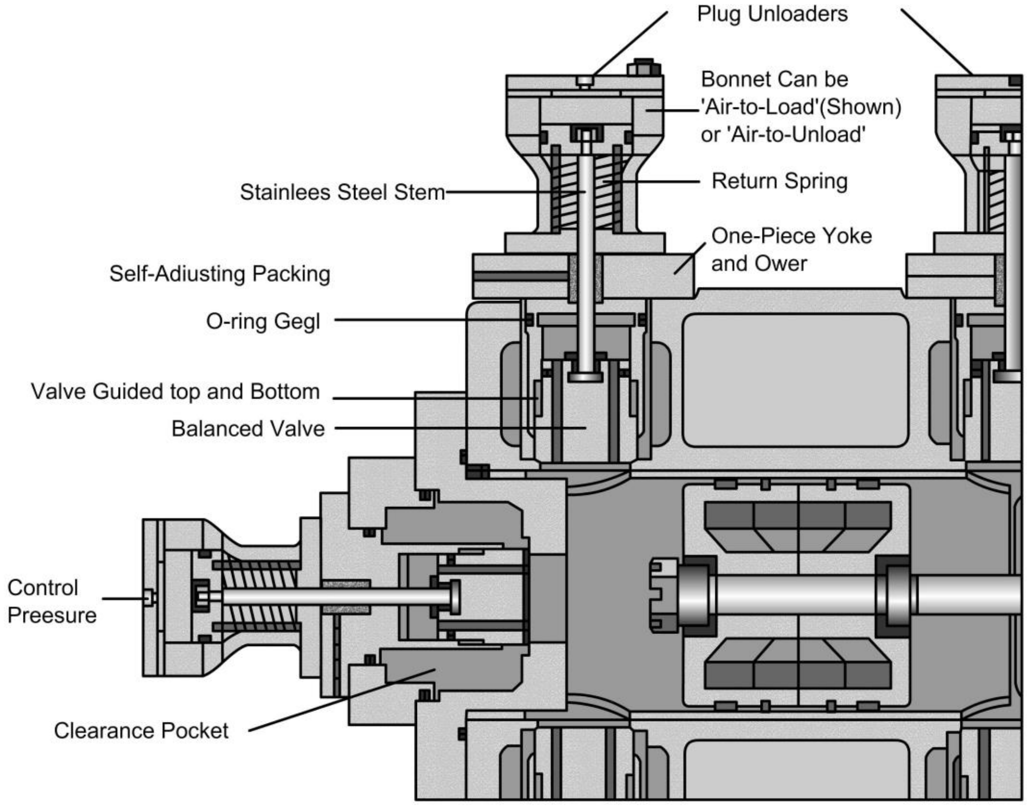

Figure 2.22 – Plug unloaders (top) and variable clearance pocket (left)