Class: Fourth Stage
Subject: Refrigeration Systems
Asst. Lecturer: Mustafa Mohmmad Jaber
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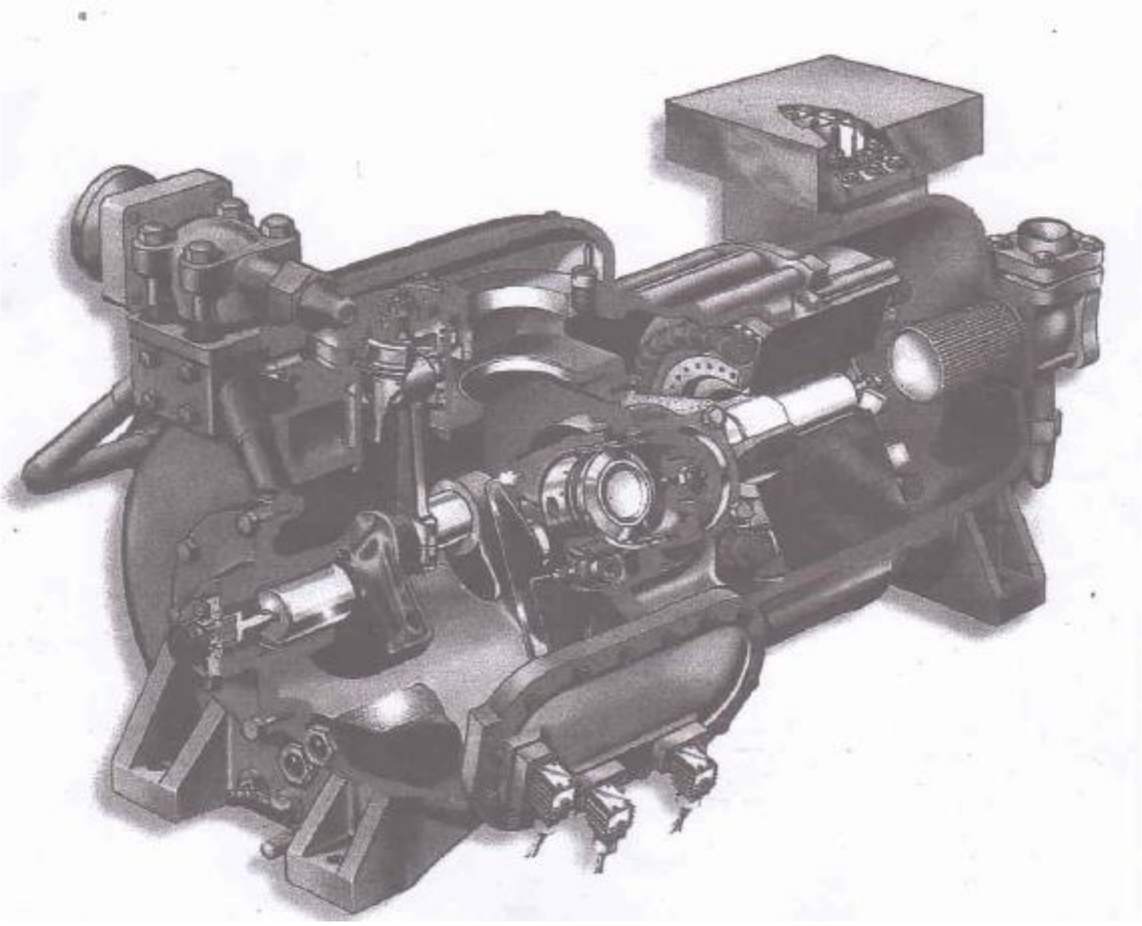
Reciprocating compressor



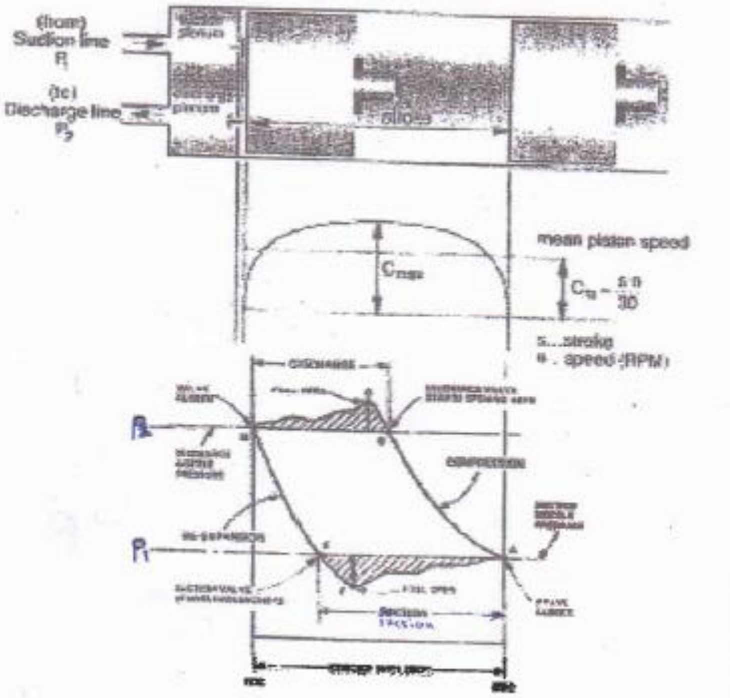
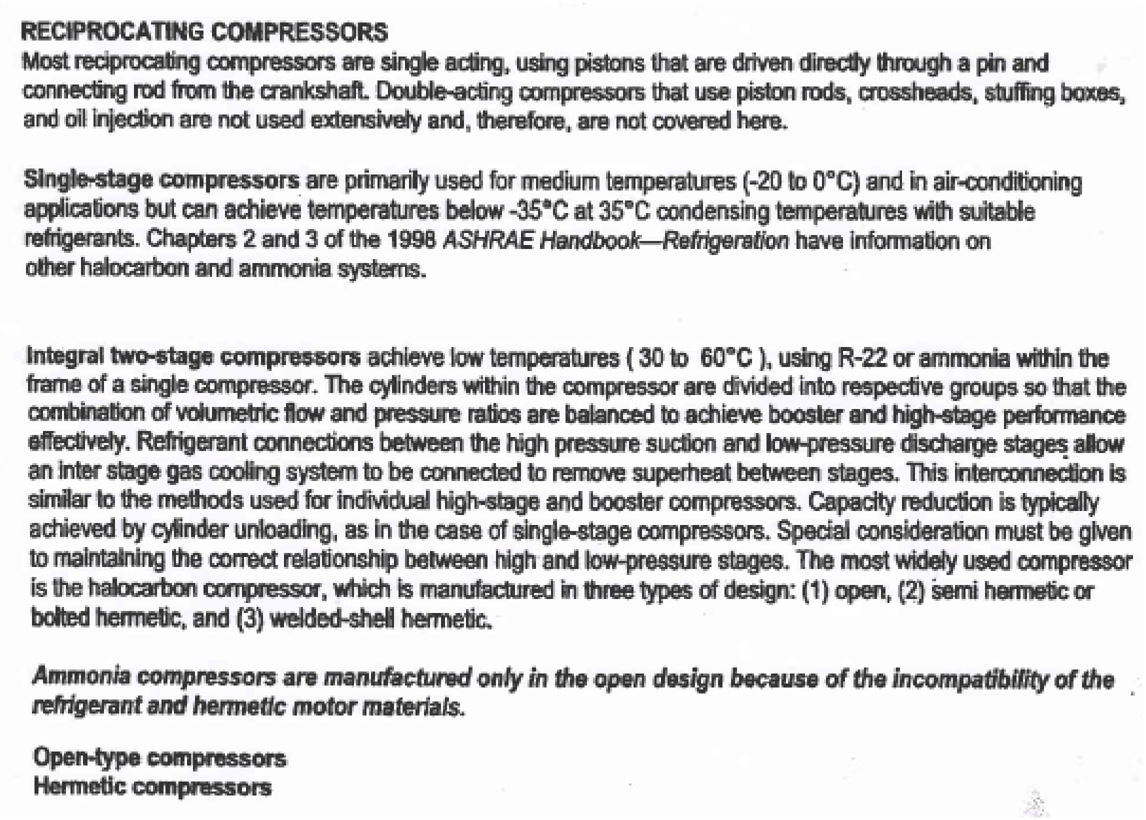


FIGURE 3-8. Piston stroke position superimposed on pV-diagram (*Source: Hoerbiger Corporation of America, Ft. Lauderdale, Florida*).



RECIPROCATING COMPRESSORS

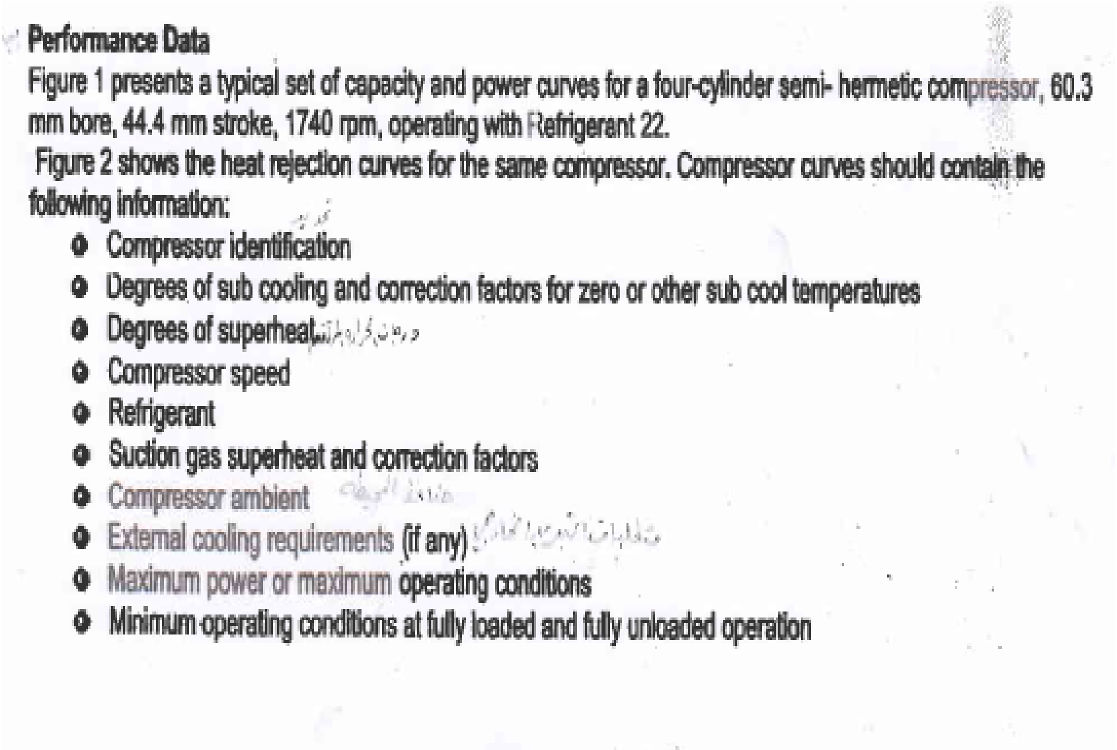
Most reciprocating compressors are single acting, using pistons that are driven directly through a pin and connecting rod from the crankshaft. Double-acting compressors that use piston rods, crossheads, stuffing boxes, and oil injection are not used extensively and, therefore, are not covered here.

Single-stage compressors are primarily used for medium temperatures (-20 to 0°C) and in air-conditioning applications but can achieve temperatures below -35°C at 35°C condensing temperatures with suitable refrigerants. Chapters 2 and 3 of the 1998 *ASHRAE Handbook—Refrigeration* have information on other halocarbon and ammonia systems.

Integral two-stage compressors achieve low temperatures (30 to 60°C), using R-22 or ammonia within the frame of a single compressor. The cylinders within the compressor are divided into respective groups so that the combination of volumetric flow and pressure ratios are balanced to achieve booster and high-stage performance effectively. Refrigerant connections between the high pressure suction and low-pressure discharge stages allow an inter stage gas cooling system to be connected to remove superheat between stages. This interconnection is similar to the methods used for individual high-stage and booster compressors. Capacity reduction is typically achieved by cylinder unloading, as in the case of single-stage compressors. Special consideration must be given to maintaining the correct relationship between high and low-pressure stages. The most widely used compressor is the halocarbon compressor, which is manufactured in three types of design: (1) open, (2) semi hermetic or bolted hermetic, and (3) welded-shell hermetic.

Ammonia compressors are manufactured only in the open design because of the incompatibility of the refrigerant and hermetic motor materials.

Open-type compressors
Hermetic compressors

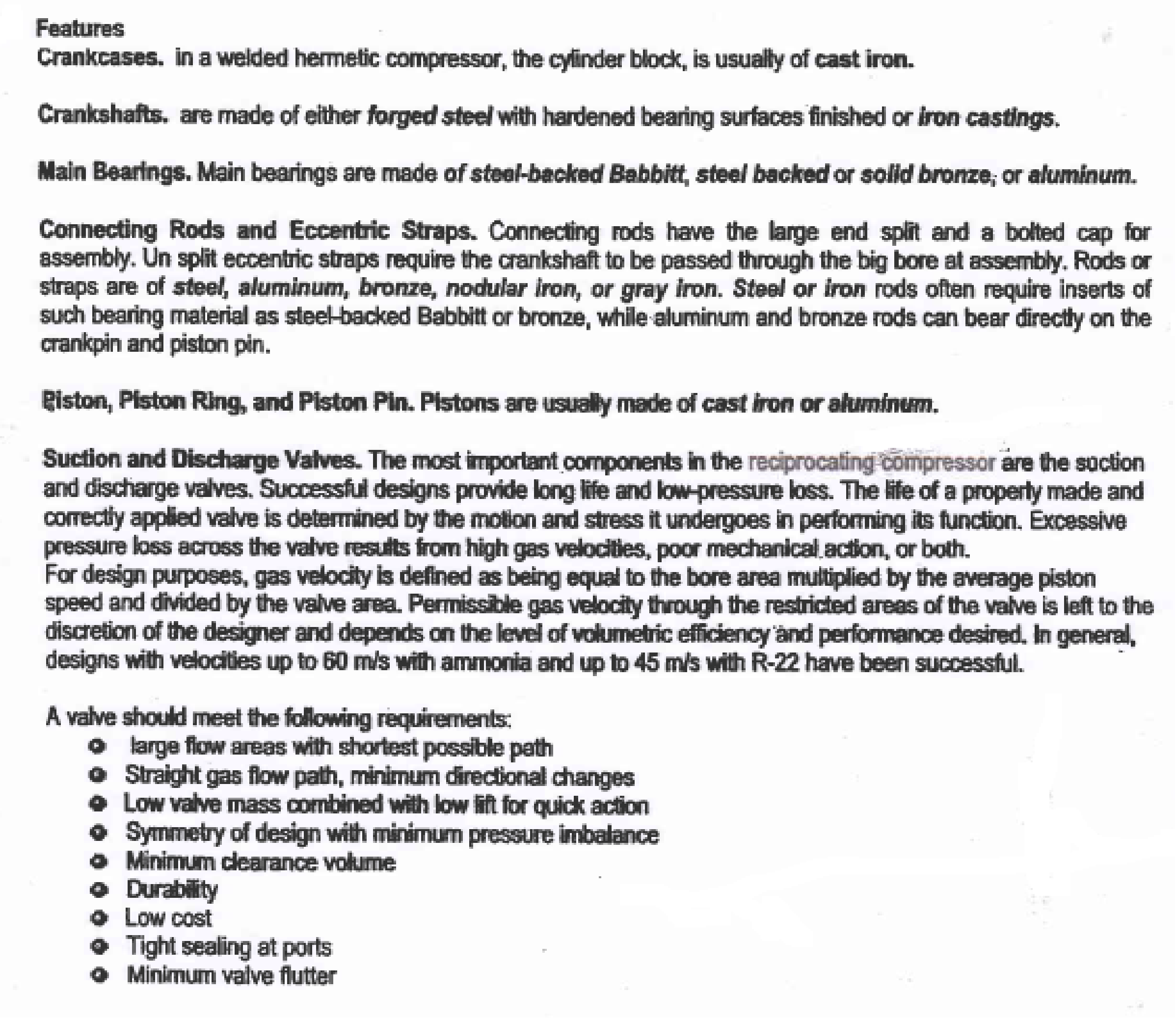


Performance Data

Figure 1 presents a typical set of capacity and power curves for a four-cylinder semi- hermetic compressor, 60.3 mm bore, 44.4 mm stroke, 1740 rpm, operating with Refrigerant 22.

Figure 2 shows the heat rejection curves for the same compressor. Compressor curves should contain the following information: تعريف

- Compressor identification
- Degrees of sub cooling and correction factors for zero or other sub cool temperatures
- Degrees of superheat [illegible]
- Compressor speed
- Refrigerant
- Suction gas superheat and correction factors
- Compressor ambient حالة المحيط
- External cooling requirements (if any) متطلبات التبريد الخارجي
- Maximum power or maximum operating conditions
- Minimum operating conditions at fully loaded and fully unloaded operation



Features

Crankcases. in a welded hermetic compressor, the cylinder block, is usually of **cast iron.**

Crankshafts. are made of either ***forged steel*** with hardened bearing surfaces finished or ***iron castings***.

Main Bearings. Main bearings are made ***of steel-backed Babbitt***, ***steel backed*** or ***solid bronze***, or ***aluminum***.

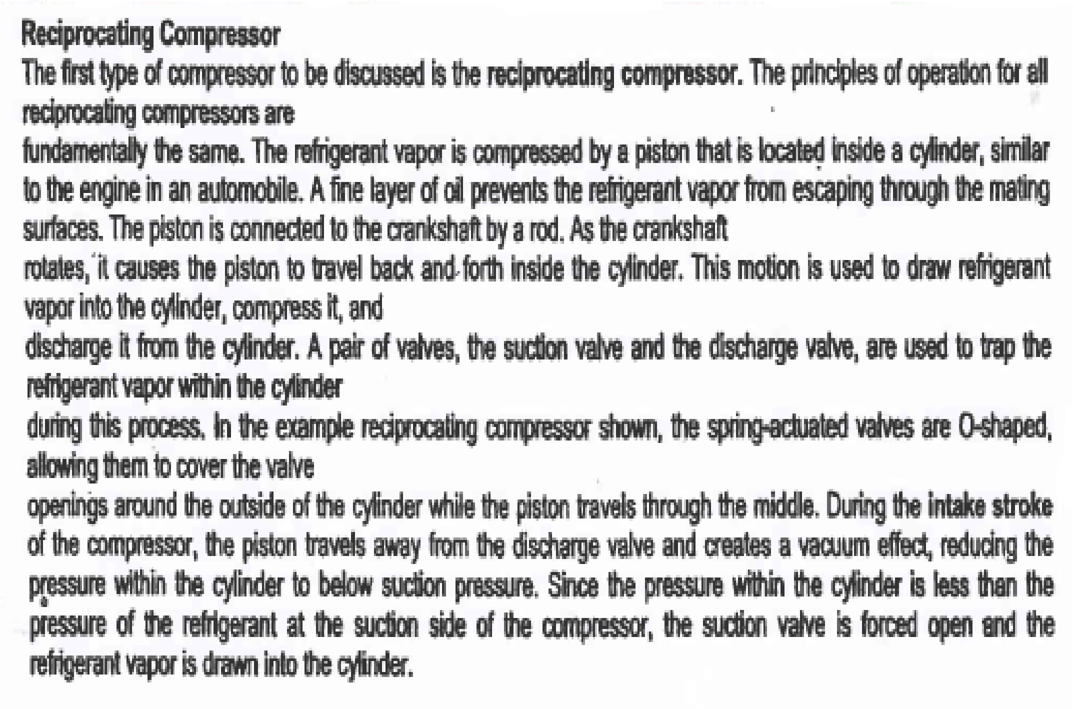
Connecting Rods and Eccentric Straps. Connecting rods have the large end split and a bolted cap for assembly. Un split eccentric straps require the crankshaft to be passed through the big bore at assembly. Rods or straps are of ***steel, aluminum, bronze, nodular iron, or gray iron. Steel or iron*** rods often require inserts of such bearing material as steel-backed Babbitt or bronze, while aluminum and bronze rods can bear directly on the crankpin and piston pin.

Piston, Piston Ring, and Piston Pin. Pistons are usually made of ***cast iron or aluminum***.

Suction and Discharge Valves. The most important components in the reciprocating compressor are the suction and discharge valves. Successful designs provide long life and low-pressure loss. The life of a properly made and correctly applied valve is determined by the motion and stress it undergoes in performing its function. Excessive pressure loss across the valve results from high gas velocities, poor mechanical action, or both.
For design purposes, gas velocity is defined as being equal to the bore area multiplied by the average piston speed and divided by the valve area. Permissible gas velocity through the restricted areas of the valve is left to the discretion of the designer and depends on the level of volumetric efficiency and performance desired. In general, designs with velocities up to 60 m/s with ammonia and up to 45 m/s with R-22 have been successful.

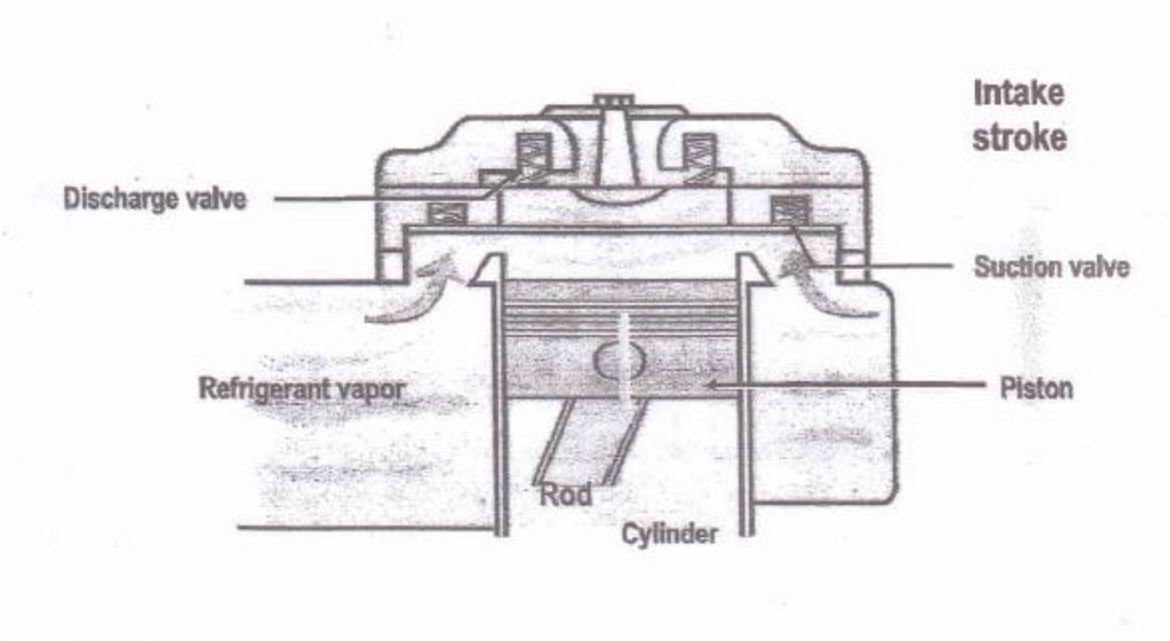
A valve should meet the following requirements:

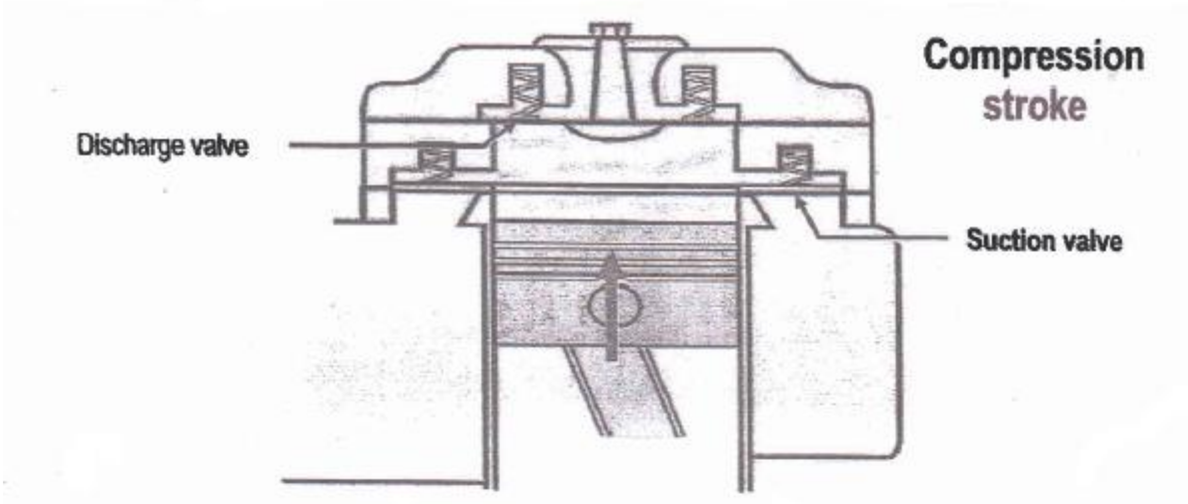
- large flow areas with shortest possible path
- Straight gas flow path, minimum directional changes
- Low valve mass combined with low lift for quick action
- Symmetry of design with minimum pressure imbalance
- Minimum clearance volume
- Durability
- Low cost
- Tight sealing at ports
- Minimum valve flutter



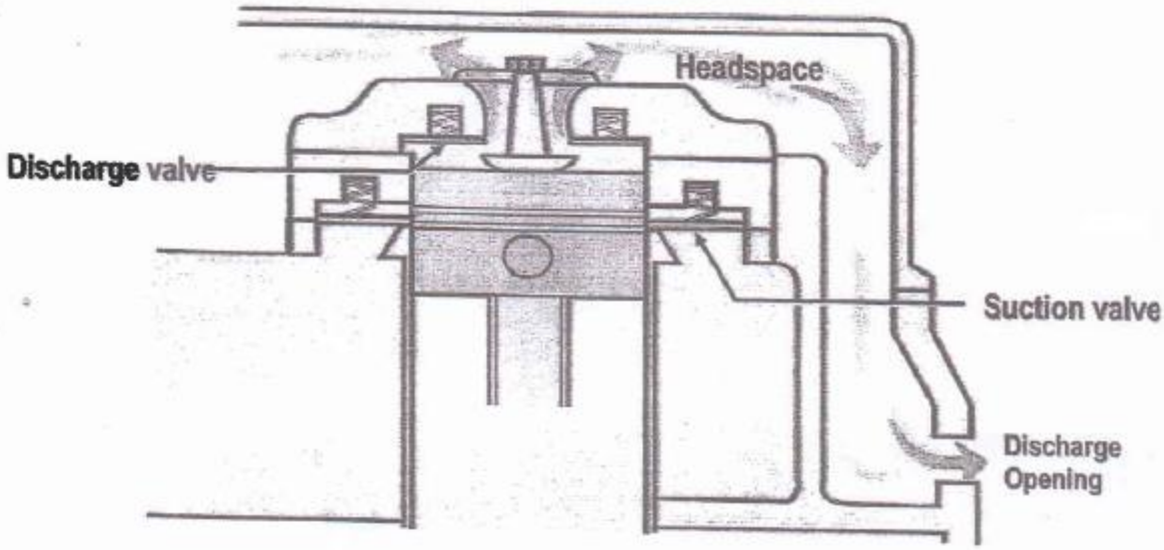
Reciprocating Compressor

The first type of compressor to be discussed is the **reciprocating compressor.** The principles of operation for all reciprocating compressors are fundamentally the same. The refrigerant vapor is compressed by a piston that is located inside a cylinder, similar to the engine in an automobile. A fine layer of oil prevents the refrigerant vapor from escaping through the mating surfaces. The piston is connected to the crankshaft by a rod. As the crankshaft rotates, it causes the piston to travel back and forth inside the cylinder. This motion is used to draw refrigerant vapor into the cylinder, compress it, and discharge it from the cylinder. A pair of valves, the suction valve and the discharge valve, are used to trap the refrigerant vapor within the cylinder during this process. In the example reciprocating compressor shown, the spring-actuated valves are O-shaped, allowing them to cover the valve openings around the outside of the cylinder while the piston travels through the middle. During the **intake stroke** of the compressor, the piston travels away from the discharge valve and creates a vacuum effect, reducing the pressure within the cylinder to below suction pressure. Since the pressure within the cylinder is less than the pressure of the refrigerant at the suction side of the compressor, the suction valve is forced open and the refrigerant vapor is drawn into the cylinder.

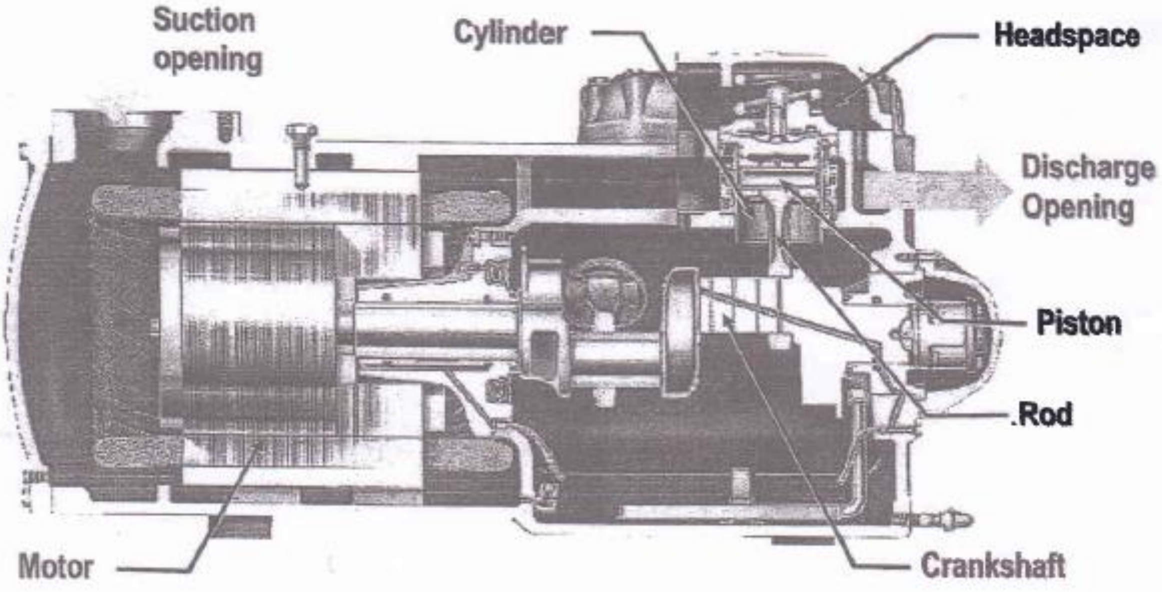




During the **compression stroke**, the piston reverses its direction and travels toward the discharge valve, compressing the refrigerant vapor and increasing the pressure within the cylinder. When the pressure inside the cylinder exceeds the suction pressure, the suction valve is forced closed, trapping the refrigerant vapor inside the cylinder. As the piston continues to travel toward the discharge valve, the refrigerant vapor is compressed, increasing the pressure inside the cylinder.



When the pressure within the cylinder exceeds the discharge (or head) pressure, the discharge valve is forced open, allowing the compressed refrigerant vapor to leave the cylinder. The compressed refrigerant travels through the headspace and leaves the compressor through the discharge opening.



In the reciprocating compressor shown, the refrigerant vapor from the suction line enters the compressor through the suction opening. It then passes around and through the motor, cooling the motor, before it enters the cylinder to be compressed. The compressed refrigerant leaves the cylinder, travels through the headspace, and leaves the compressor through the discharge opening. Most reciprocating compressors have multiple pistons–cylinder pairs attached to a single crankshaft.

In the air-conditioning industry, reciprocating compressors were widely used in all types of refrigeration equipment. As mentioned earlier, however, scroll and helical-rotary compressors have become more common, replacing the reciprocating compressor in most of these applications because of their improved reliability and efficiency.

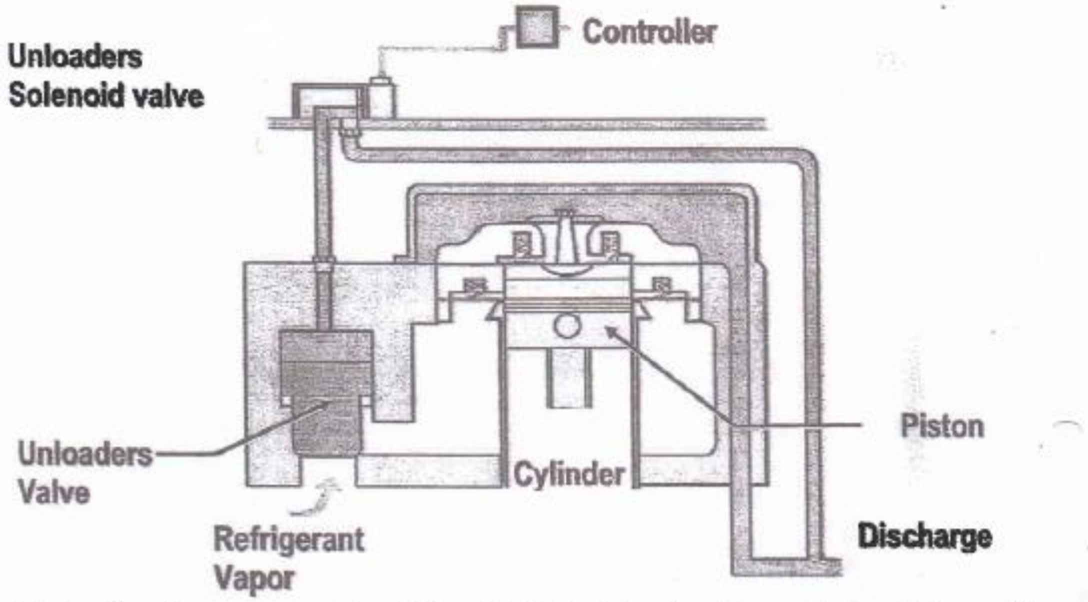
Compressor Capacity Control

The capacity of a compressor is defined by the volume of evaporated refrigerant that can be compressed within a given time period. The compressor needs a method of capacity control in order to match the ever-changing load on the system.

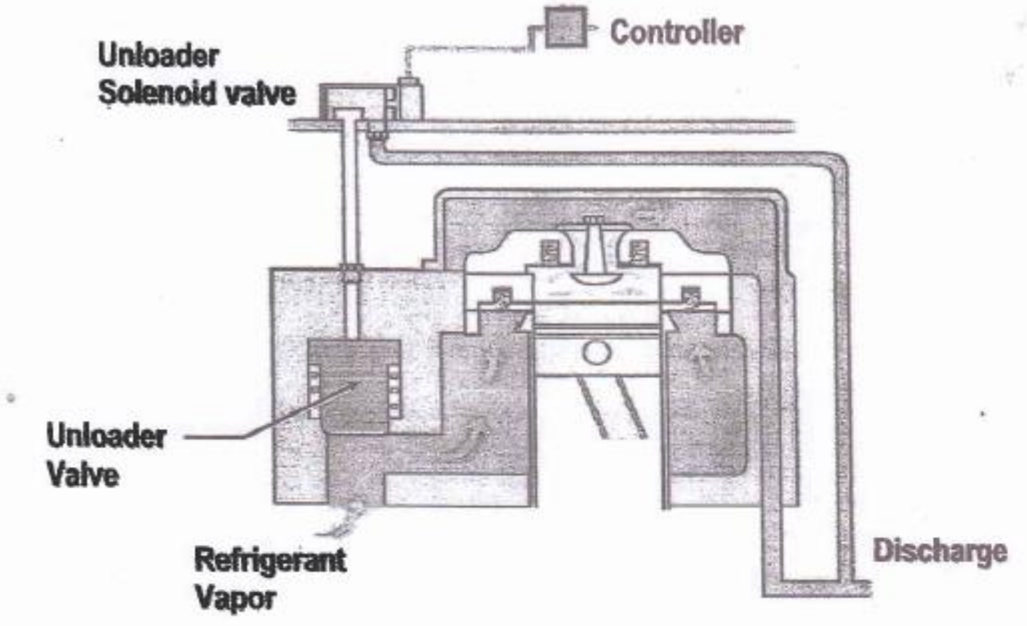
Methods of Compressor Unloading

Reciprocating Cylinder Unloaders

Capacity control is commonly accomplished by unloading the compressor. The method used for unloading generally depends on the type of compressor.
Many reciprocating compressors use cylinder unloaders or compressors could use variable speed to control their capacity.



Most large reciprocating compressors (above 10 tons [35 kW]) are fitted with **cylinder unloaders** that are used to match the compressor's refrigerant pumping capacity with the falling evaporator load, by progressively deactivating piston–cylinder pairs. The cylinder unloader shown in this example reciprocating compressor uses an electrically-actuated unloader valve to close the suction passage to the cylinder that is being unloaded. In response to a decreasing load, an electronic controller sends a signal to open a solenoid valve. This solenoid valve diverts pressurized refrigerant vapor from the compressor discharge to the top of the unloader valve,causing the unloader valve to close and shut off the flow of refrigerant vapor into the cylinder. Even though the piston continues to travel back and forth inside this cylinder, it is no longer performing compression since it cannot take in any refrigerant vapor.



In response to an increasing load, the controller sends a signal to close the solenoid valve. This closes the port that allows the pressurized refrigerant vapor to travel to the top of the unloader valve. A controlled leakage rate around the unloader valve relieves the pressure, allowing the valve to open and refrigerant vapor to once again flow to the cylinder to be compressed. Another type of cylinder unloader uses either pressure or electrically-actuated valving mechanisms to hold open the suction valve of the piston–cylinder pair. Since the suction valve is prevented from closing, no compression occurs in that cylinder and the discharge valve does not open. Still other types of cylinder unloaders divert the compressed refrigerant vapor back to the suction side of the compressor. In contrast to the cylinder unloaders shown, these other methods expend energy in moving refrigerant vapor during both the upward and downward piston strokes within the unloaded cylinders.