

present discussion is limited to positive displacement reciprocating compressors, and centrifugal compressors.

Reciprocating Compressors

Reciprocating compressors (see Fig. 15) may be classified according to (a) cylinder design, (b) compressor drive, (c) valves, and (d) lubrication and cooling.

Cylinder Design. Cylinder design may vary as to number, arrangement, and action (i.e., single-acting or double-acting). Single-acting compressors usually have their cylinders arranged vertically, radially, or in a V or W shaped arrangement. Double-acting compressors, with refrigerant gas drawn in, and compressed on both the head and crank ends of the cylinder, are usually arranged horizontally. Reciprocating units are available with from one to sixteen cylinders with the V, W, or radial arrangements best adapted to the greatest numbers. The present trend is

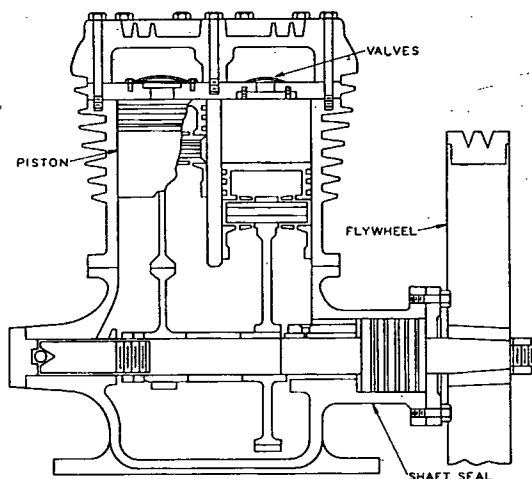


FIG. 15. DIAGRAMMATIC VIEW OF A RECIPROCATING COMPRESSOR

toward higher operating speeds with a low displacement per cylinder, together with an increase in the number of cylinders. Whereas the original reciprocating compressors were slow speed (50 to 55 rpm) steam driven devices, modern electric motor-driven compressors range up to 3500 rpm. Cylinder heads are usually bolted tight to the cylinders, but in some large compressors where there is danger of wet compression or of foreign materials entering the compressor space, a secondary head known as a safety head, may be seated at the end of the cylinder and held in position with heavy springs. Normally, this head remains stationary, but excessive pressures in the clearance space are relieved by movement of the safety head, and thus prevent damage to the cylinder.

Compressor Drives. Reciprocating compressors may be subdivided on the basis of source of motive power, and whether they are open or hermetic. Practically all modern compressors are electric motor-driven, although a few large, steam-driven compressors are still being installed where steam forms the most economical source of energy. In a few cases, as with truck transportation, the compressor may be driven by an internal-combustion engine.

The division of compressors into open or closed types is dependent upon whether the motive power is received from an external source, or whether the motor is direct drive and sealed within the housing. In the open type, power is received from an external source with one end of the compressor crankshaft extending through the crankcase, and usually V-belt driven. The point of emergence of the shaft from the crankcase forms a weak point of refrigerant leakage, and is most frequently sealed with a bellows type crankshaft seal. Horizontal double-acting compressors operate

with a sliding piston rod, moving back and forth through a stuffing box. If the motor is direct-drive and enclosed within the compressor housing, the compressor is classified as closed or hermetic. This eliminates the necessity of any shaft seal, and not only prevents refrigerant leakage at this point, but reduces operating noise. One disadvantage is the inaccessibility of moving parts for repairs, but lubrication is greatly simplified since both the motor and compressor operate in a sealed space with the lubricating oil.

Compressor Valves. All refrigeration compressor valves are dependent for their operation upon a difference in pressure between the inside of the cylinder and the suction or discharge line. Although mechanically-operated valves might have some advantage, they have proved unsatisfactory because each change in the evaporator or condenser operating pressures requires a change of valve setting. The pressure differentials required for operation of the valves depend upon the valve design and the compressor speed. The suction and discharge valves may be arranged with both located in the compressor head, or with the suction valve on the top of the piston and the discharge valve in the compressor head (uniflow arrangement). The valves themselves are usually classified as either poppet, ring-plate or flexing.

Lubrication and Cooling. Lubrication of modern compressors is accomplished by either splash lubrication or forced lubrication. The latter is used on large compressors, while simple splash lubrication is used in the smaller units.

Large compressors are usually water cooled with the water jacket either cooling the cylinder walls, or both the cylinder walls and the compressor head. Small compressors are either water cooled or air cooled with extended finned surfaces cast on the exterior of the cylinder. In a few cases small compressors may be found in which there is no attempt to add any purposive cooling other than through non-finned surfaces to the lower temperature air.

Water cooling is more effective than air cooling, but even under the best conditions cylinder cooling removes only a portion of the superheat in the refrigerant gas. This removal of heat from the cylinder results in some decrease in the work of compression, as well as reduction in condenser load.

Control of Reciprocating Compressors

Capacity Control of reciprocating compressors to match the imposed load is accomplished by a controller responding to load variations, and operating one of the several means for changing the compressor capacity. This controller may respond to the condition being controlled, such as space temperature in the case of a direct expansion system, or water temperature in the case of a water chiller; or it may respond to suction pressure, which varies with the imposed load. The common methods of varying the compressor capacity are:

1. **Starting and stopping the compressor.** This is more common on small units where frequent cycling of the compressor offers no serious complications. On large installations two or more smaller compressors may be employed and these may be started and stopped in sequence, thus providing more capacity steps. Sequence control of multiple compressors is accomplished by the use of a program or step controller, and in most cases this is arranged to return to the off position when the system is shut down or in the event of power failure, and to provide a suitable time delay between steps on start-up to prevent the full electrical load from being thrown across the line at one time. Means for manually or automatically varying the sequence to equalize wear on the compressors are sometimes employed.

2. **Cylinder Unloaders.** These usually are available on all but the smaller compressors and are used on both single and multiple compressor installations. They consist of a device built into the cylinder head to hold the suction valve open for unloading the cylinder. Oil pressure or head pressure is applied to these devices to load the cylinders, hence the compressor always starts at minimum capacity. Depending upon the make of compressor, the application of pressure to the unloaders is accomplished by:
 - a. Solenoid valves usually operated by the program controller in sequence with starting and stopping of the compressor or compressors. The program controller starts the compressor at minimum capacity, then loads the cylinders in sequence as the demand increases. If more than one compressor is used, it starts and loads the second compressor in sequence after the first is fully loaded, etc.
 - b. A self-contained stepping valve built into the compressor and actuated by a