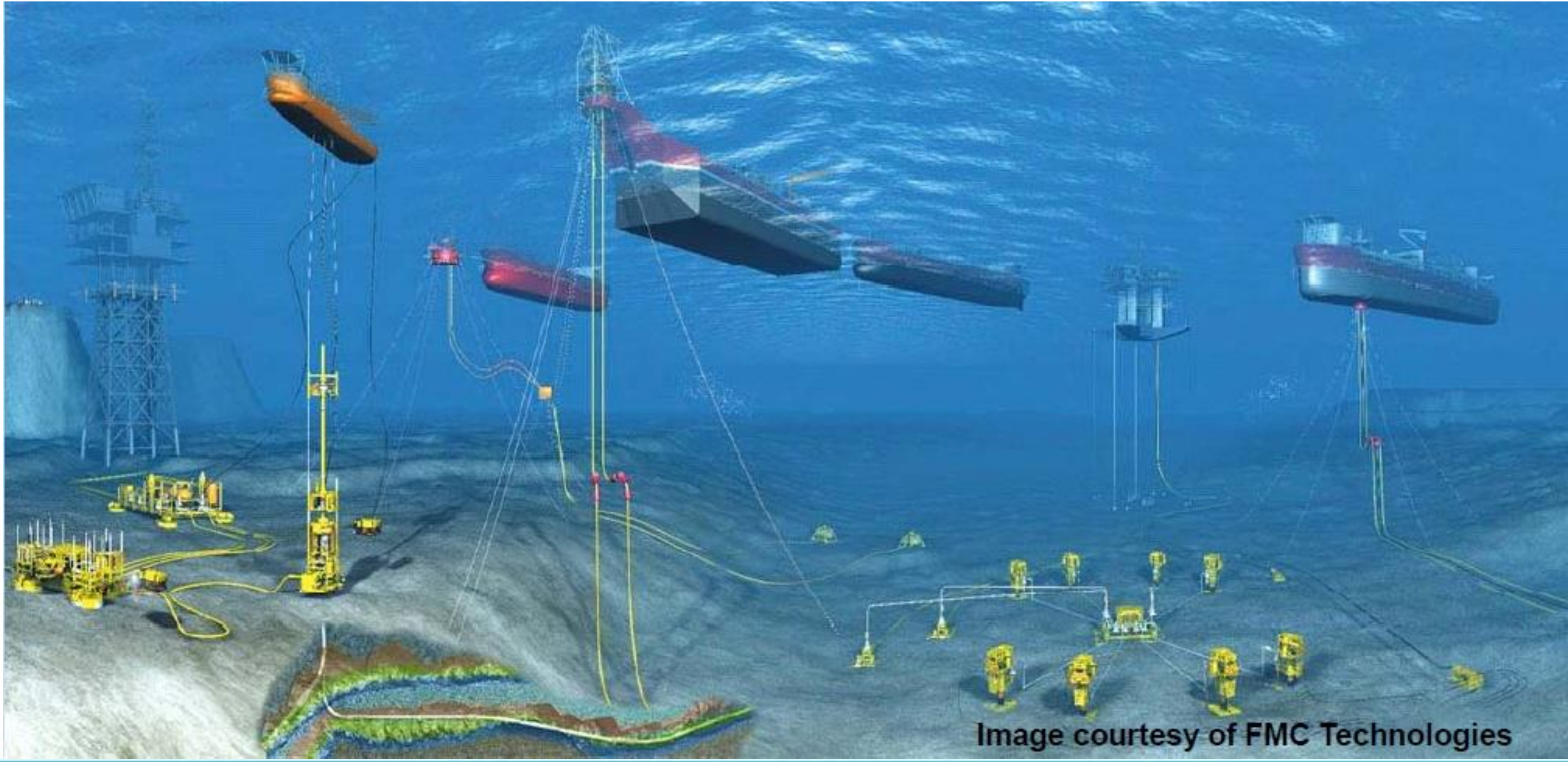


Offshore Equipment

Yutaek Seo

Reciprocating compressors

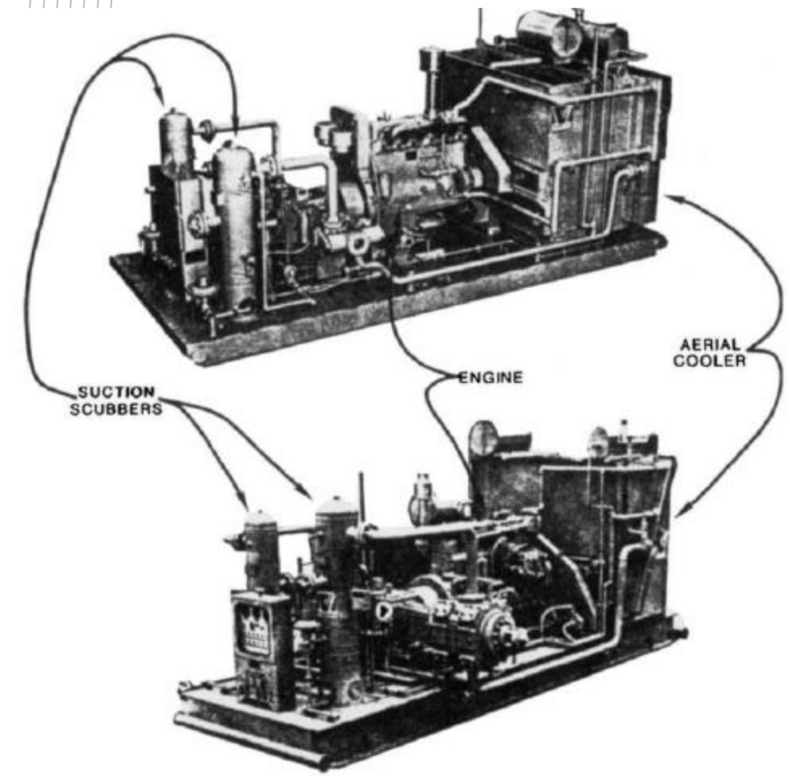


Figure 10-3. High-speed reciprocating compressor packages. (*Courtesy of Dresser-Rand Company.*)

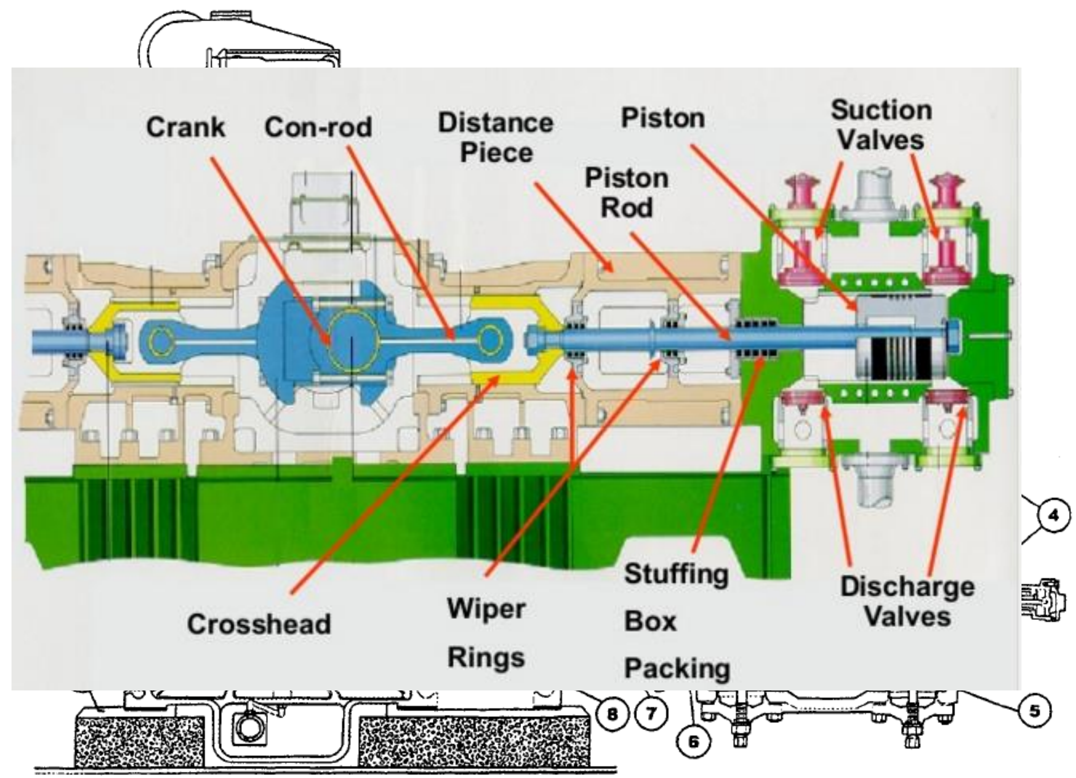


Figure 10-4. Sectional view of integral engine compressor. (*Courtesy of Dresser-Rand Company.*)

- This chapter presents greater detail concerning the major components, performance, operational and installation considerations, and standard specifications for reciprocating compressors

Components

Frame

- On which the cylinders and crossheads are mounted
- Rated for a max. horsepower, speed (rpm), and rod load
- Frames are classified as separable or integral-type

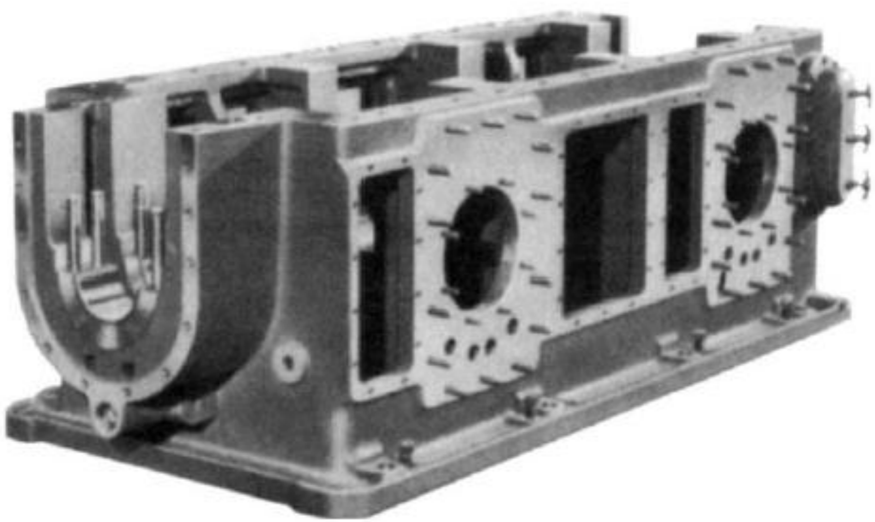


Figure 11-2. The compressor frame is the rugged casting that contains the rotating parts and on which the cylinders and crossheads are mounted. (*Courtesy of Dresser-Rand Company.*)

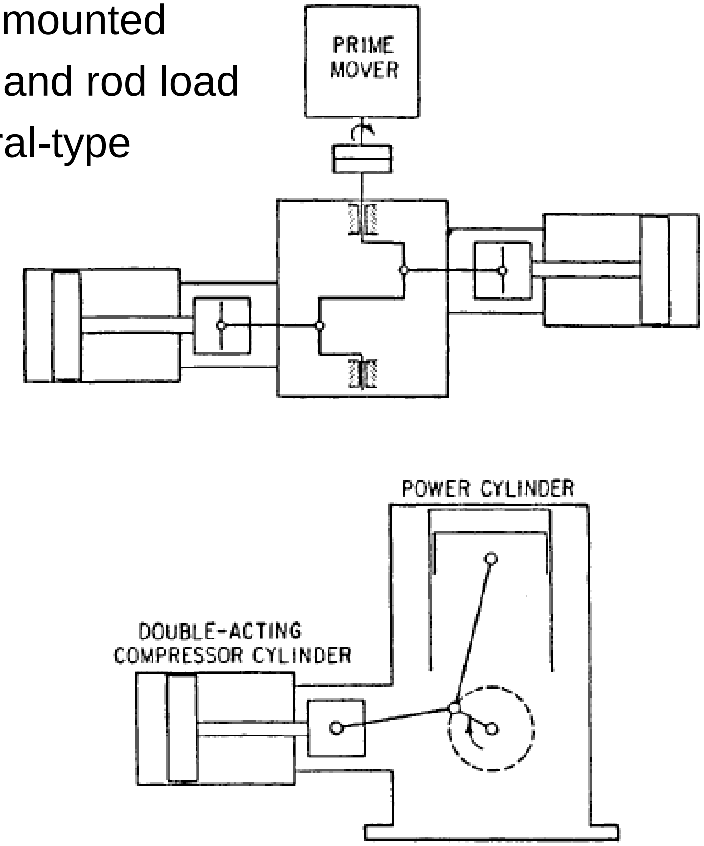


Figure 11-3. Separable (balanced-opposed) compressor (top) and integral-type gas engine compressor (bottom).

Cylinder

- A pressure vessel that holds the gas during the compression cycle.
  : Single action – compression occurs only once per crankshaft revolution
  : Double action – compression occurs twice per crankshaft revolution
- Materials
  : Cast iron (1000~1200 psig), nodular ion (1000~2500 psig), and forged steel (P>2500 psig)
  : MAWP determines the setting of the relief valve (10% or 50 psi greater than its operating pressure)

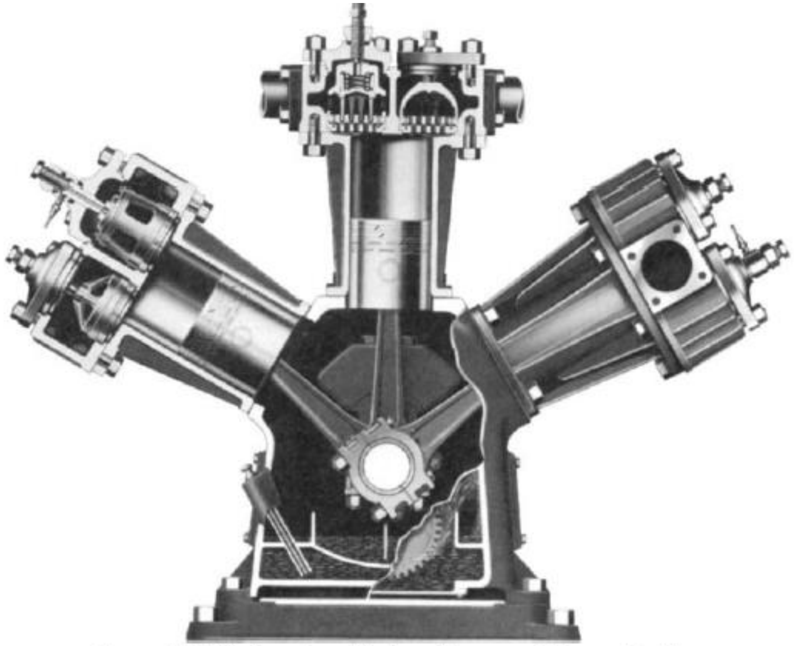


Figure 11-4. Single acting cylinders. *(Courtesy of Dresser-Rand.)*

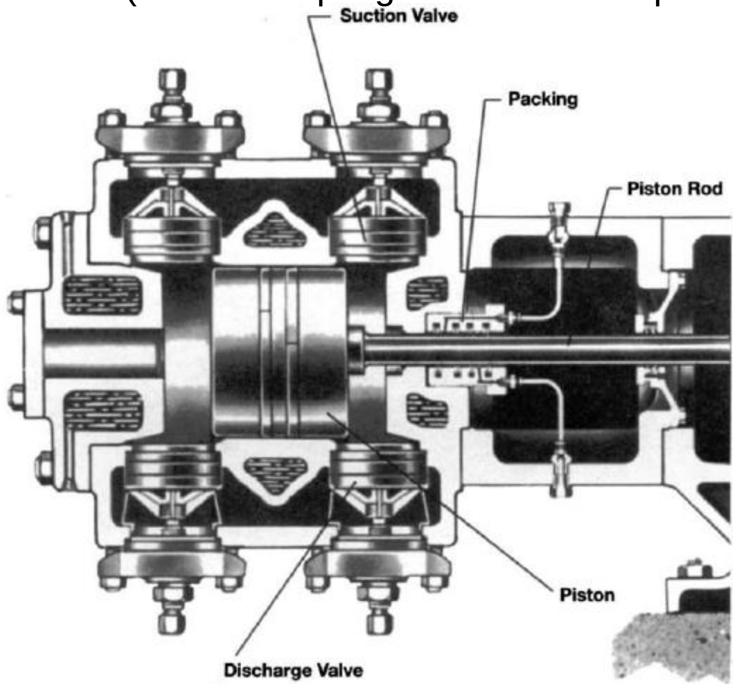


Figure 11-5. Typical double-acting compressor cylinder. *(Courtesy of Dresser-Rand Company.)*

- Cylinder liner

  : prolong the life of the cylinder and improve operating flexibility

  : as the surface of the liner wears, it is much easier and quicker to repair it than to repair the cylinder itself

  : provide flexibility to respond to different conditions of pressure and flow rate

  (Disadvantage)

  : increase the clearance by increasing the distance between the piston and the valve

  : less capacity and lower efficiency than no liner

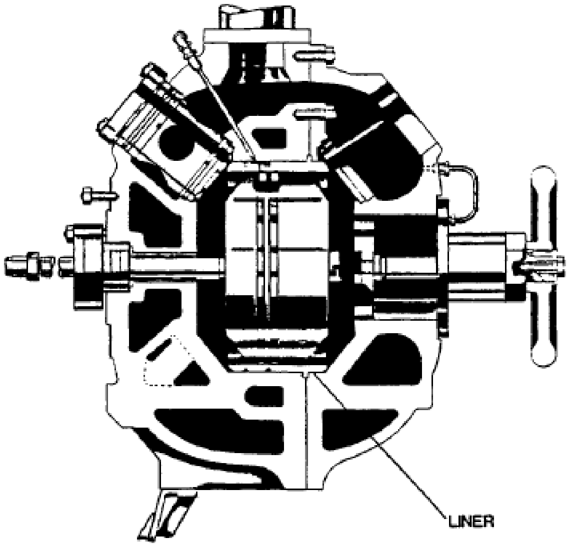


Figure 11-6. Cut-away view showing cylinder liner. (*Courtesy of Dresser-Rand Company.*)

Special compressor cylinder construction

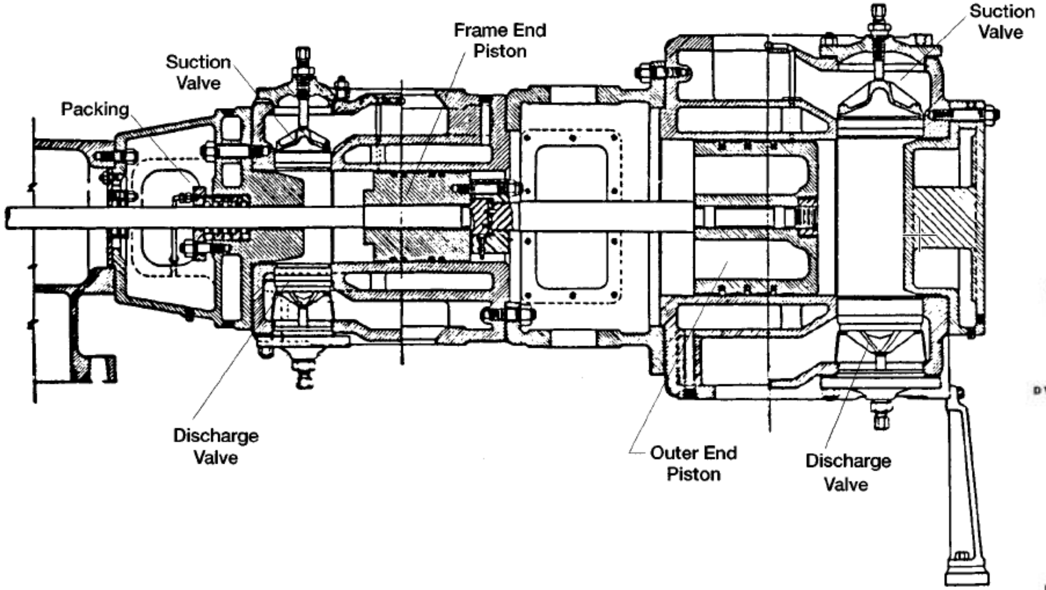


Figure 11-7. Steeple cylinder. (*Courtesy of Dresser-Rand Company.*)

: Two stages of compression on the same compressor throw
: Usually used in low capacity, low rod load application

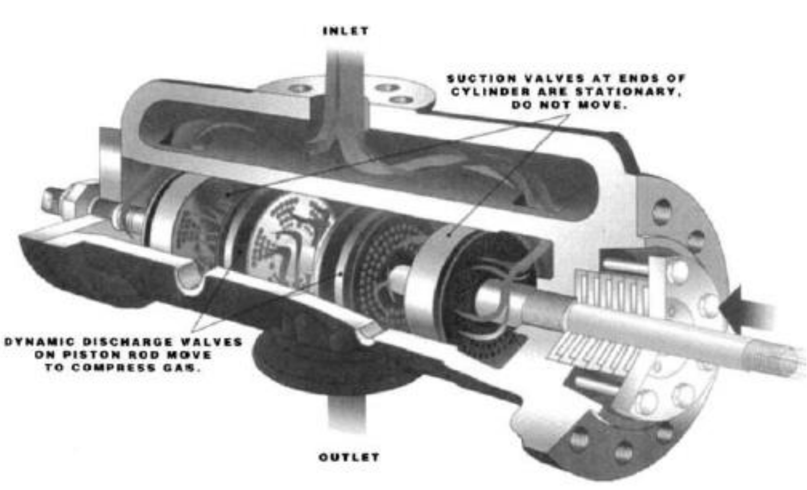
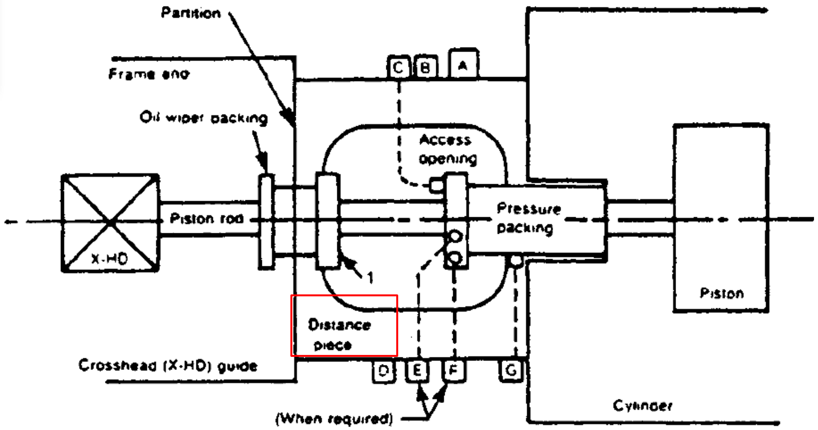


Figure 11-8. Valve-in-piston double-acting compressor cylinder. (*Courtesy of Dresser-Rand Company.*)

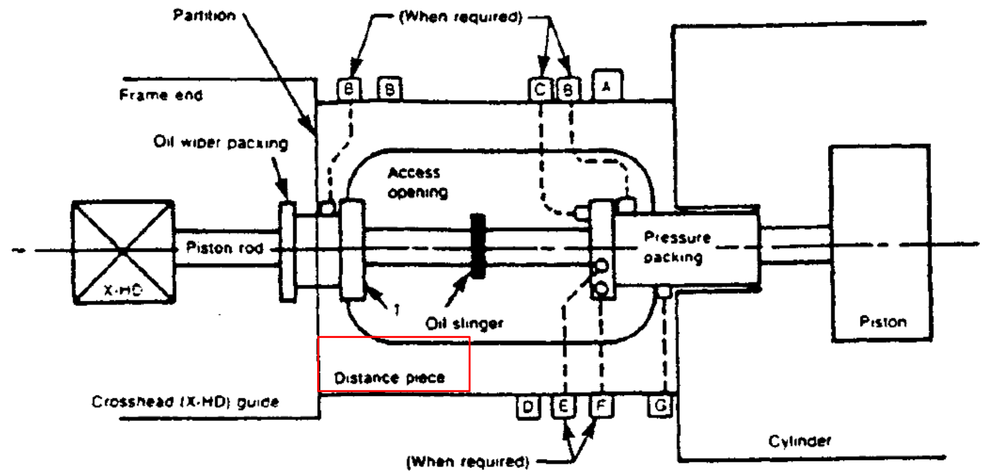
: Two suction valves (at cylinder) and two discharge valves (in pistion) are installed inside the cylinder bore.
: Lower clearance, fewer replacement parts, simpler maintenance, and reduced weight

Distance pieces

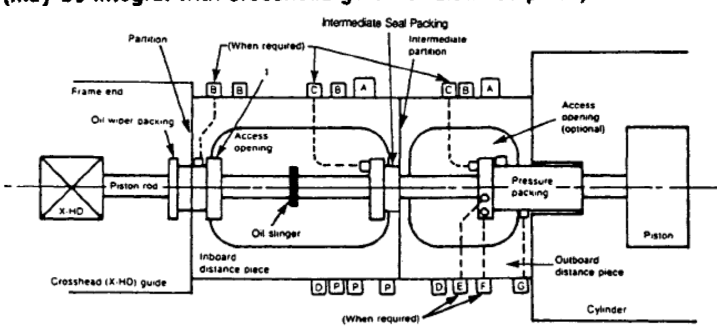
- Provides the separation of the compressor cylinder from the compressor frame
- Packing keeps the compressed gas from leaking out of the cylinder



TYPE A
Short single-compartment distance piece
(may be integral with crosshead guide or distance piece)



TYPE B
Long single-compartment distance piece
(sufficient length for oil slinger travel)



TYPE C
Short two-compartment or double distance piece arrangement
(inboard distance piece of sufficient length for oil slinger travel)

Figure 11-9. API type distance pieces. ***(Reprinted with permission from API, Std. 618, 3rd Ed., Feb. 1986.)***

: The space between the cylinder packing and the frame packing is to assure the no contamination between the gas being compressed and the oil to lubricate the crankcase.
: There are drains and vents off.
: Oil slinger to further reduce the amount of lube oil migrating down the rod into the crankcase

Crosshead, Rods, and Crankshaft

- Converts the rotating motion of the connecting rod to a linear, reciprocating motion, which drives the piston
- Crankshaft rotates about the frame axis, driving the connecting rod, crosshead, piston rod, and piston

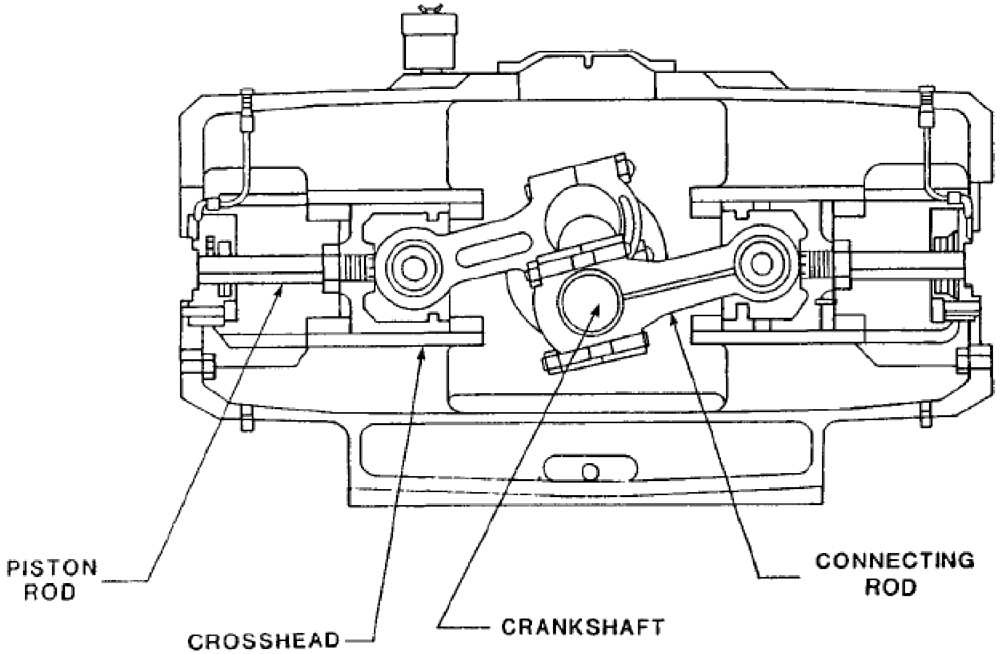


Figure 11-10. The crosshead converts the rotating motion of the connecting rod to a linear, reciprocating motion, which drives the piston. (*Courtesy of Dresser-Rand Company.*)

Piston

- Located at the end of the piston rod and acts as a movable barrier in the compressor cylinder
- Material – aluminum, cast iron
- Segmented compression rings and removable wear bands (brass or Teflon) – to reduce friction and improve compression efficiency

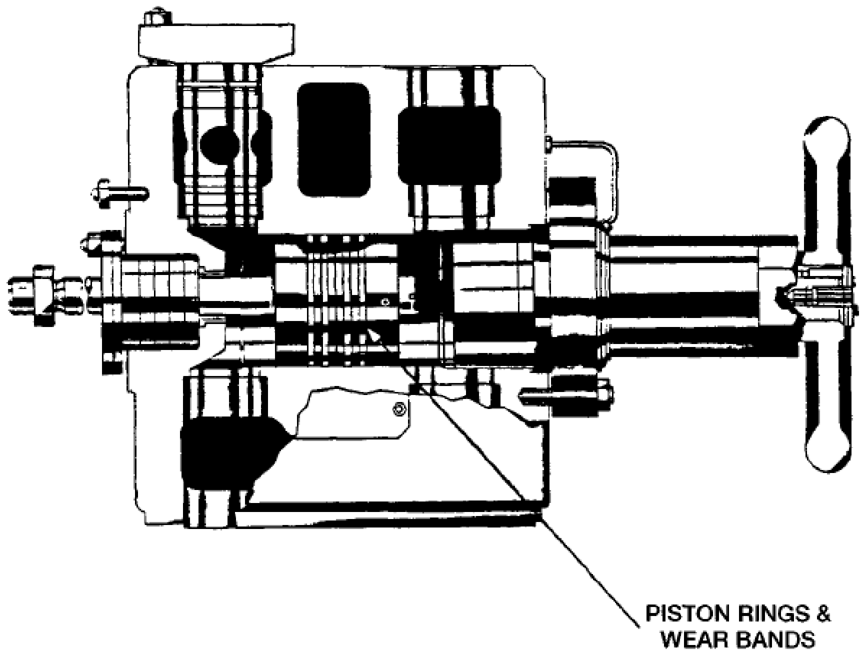


Figure 11-11. Piston rings and wear bands are made of material that is softer than the cylinder wall with which they are in constant contact, so they must be replaced regularly. (*Courtesy of Dresser-Rand Company.*)

Bearing

- Hydrodynamic type or journal bearings
- Lubrication oil enters into the bearing from supply holes and build up oil film between the stationary and rotating parts of the bearing.
  : 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

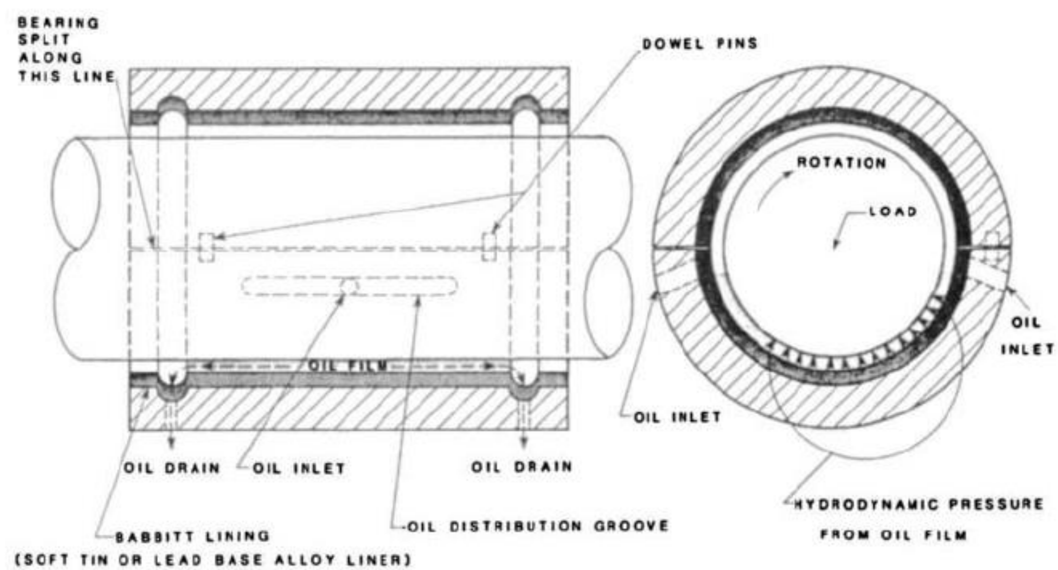


Figure 11-12. Journal bearings allow axial and circumferential oil flow along the bearing.

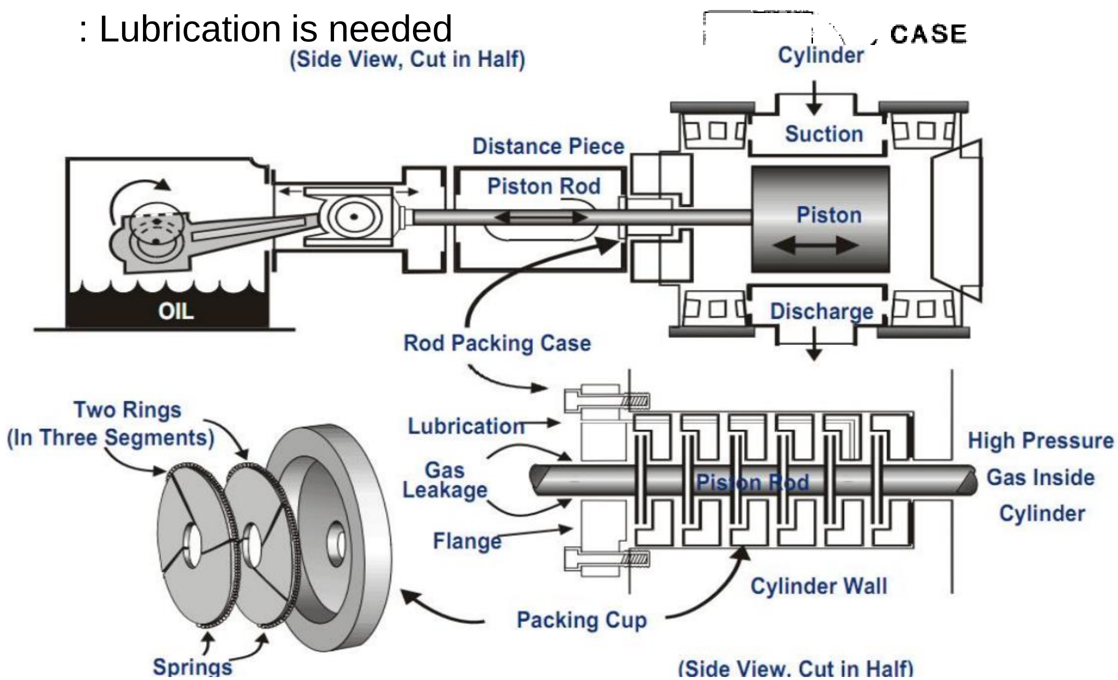
Packing

- Provides the dynamic seal between the cylinder and the piston rod
- Consists of a series of Teflon rings mounted in a packing case
- Packing case is constructed of a number of pairs of rings

  : Each pair of rings consists of one radial cut ring and one tangential cut rings

  : Gas flows around the front face of the radial cut ring and then around the outside of both rings. A squeezing force is exerted on the rod. → This seals the path between the rings and the rod

  : Lubrication is needed



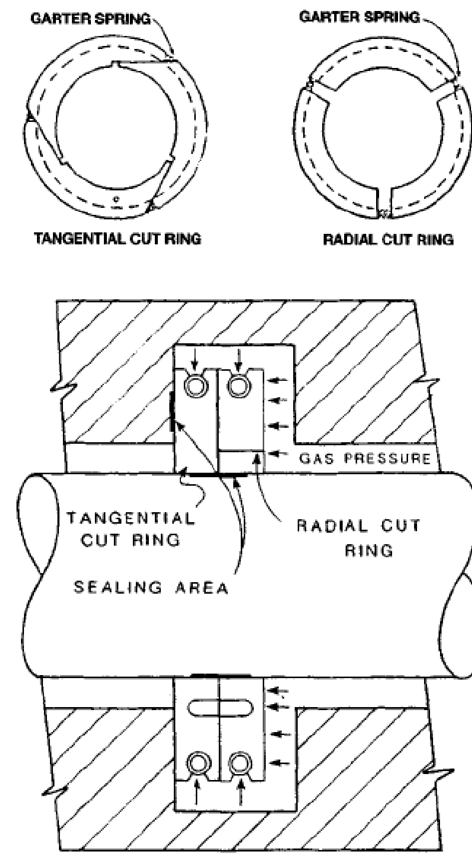


Figure 11-14. Compressor rod packing.

Compressor valves

- The differential pressure across the seat must be greater than the balance spring force before gas may flow through the valve.
- Poppet valves

  : Low compression ratio – booster compressor

  : Pressure differential increase across each of the individual poppets, they lift and gas pass through

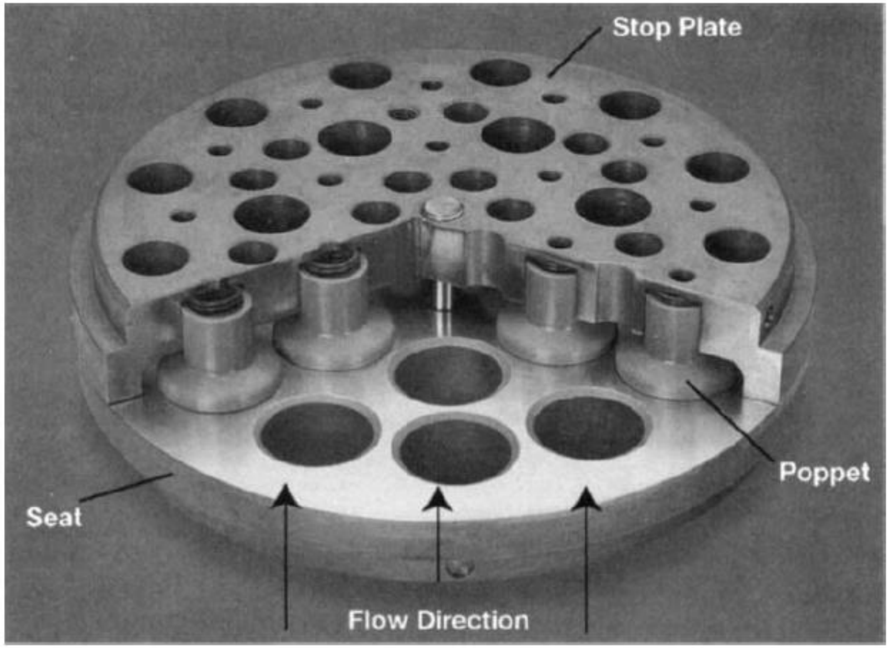


Figure 11-16. Cut-away view of poppet valve. (*Courtesy of Dresser-Rand Company.*)

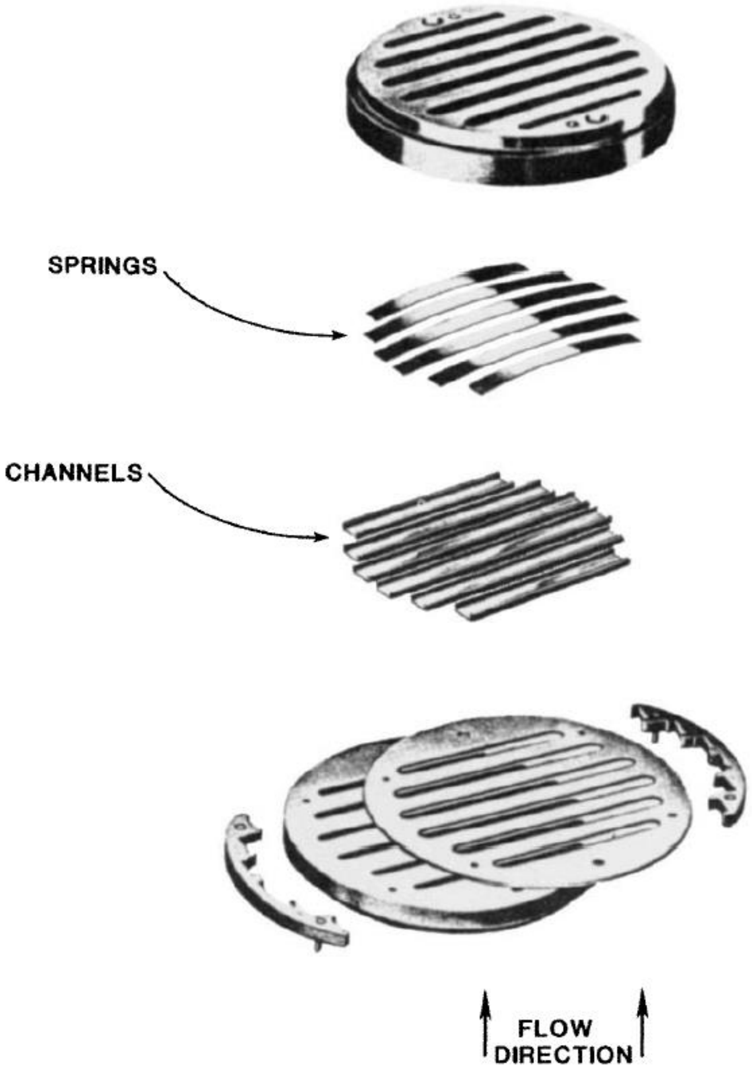
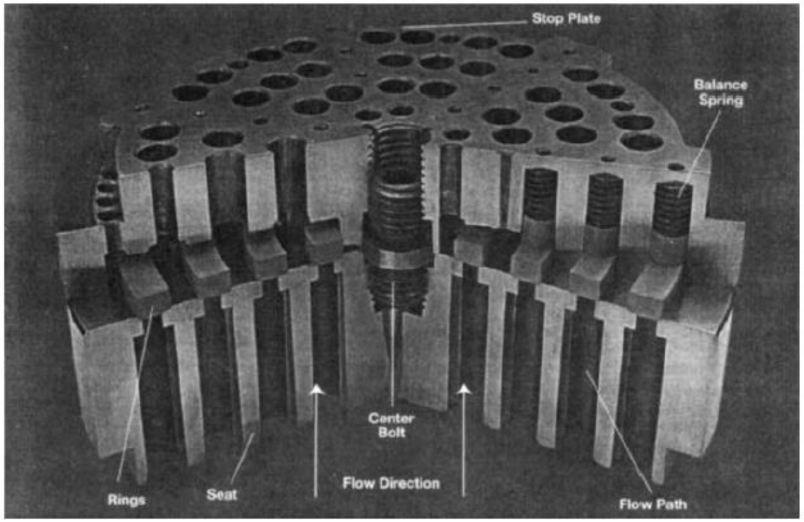


Figure 11-15. Channel valves. (*Courtesy of Ingersoll-Rand Company.*)

- Ring valve
  : slow speed, high pressure process compressor
  : instead of poppets, use concentric rings which open and close he valve ports
- Plate valve
  : high speed, separable compressor
  : similar to ring valves with the rings connected by ribs.
  : all valve ports open and close at the same time



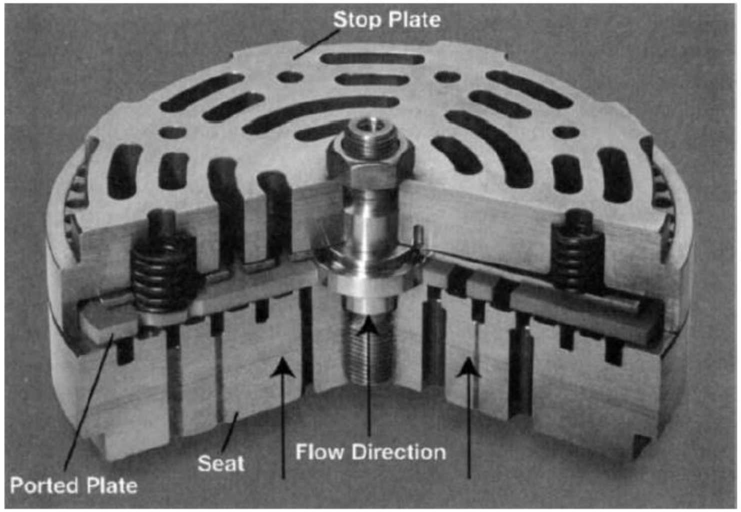


Figure 11-18. Cut-away view of plate valve. (*Courtesy of Dresser-Rand Company.*)

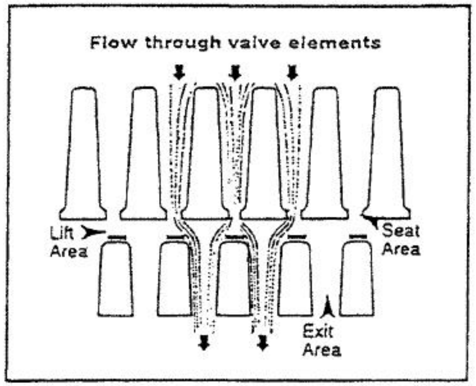


Figure 11-17. Cut-away view of ring valve. (*Courtesy of Dresser-Rand Company.*)

Valve type and size specification

- Valve velocity

  : At lower velocities the valve has less pressure drop and thus has less maintenance associated with it.

  : Velocities can be used to compare valve designs

  V = 288 D/A, ft/min

  D: Cylinder displacement, ft^3/min

  A: product of the actual lift, valve opening periphery, and the number of inlet or discharge valves per cylinder, in^2

- Effective flow area of the valve

  : The area is determined by measuring the pressure drop across the valve with a known flow rate and then calculating an equivalent orifice area that provides the same pressure drop.

  : Valves with larger effective flow areas have less pressure drop and better efficiencies.

  : Effect of seat area, lift area, flow path are included in the effective flow area when comparing the compressor valves

Capacity control devices

- Compressor capacity adjusted by changing compressor speed, cylinder clearance, unloading compressor cylinder inlet valves, recycling gas, or a combination of these.
- In this chapter, cylinder inlet valve unloader and changing cylinder clearance
- Valve unloader

  : used to deactivate a cylinder end and reduce its capacity to zero

  : Depressor type – hold inlet valve open during suction and discharge so that all the gas is pushed back through the inlet valve on discharge stroke

  : Plug type – open a port to bypass the inlet valve and connect cylinder bore with the inlet passage

  : used for capacity control and reducing the compression load during starting and up-set
- Cylinder clearance

  : Clearance – volume remaining in a cylinder end when the piston is at the end of its stroke. sum of the volume between the cylinder head and the piston, and the volume under the valve seats. (4~30% of total piston displacement)

  : As cylinder clearance is increased, the longer it takes for the suction valves to open and less gas will be compressed.

- Fixed clearance can be adjusted by:
  : Removing a small portion of the end of the compressor piston
  : Shortening the projection of the cylinder heads into the cylinder
  : Installing spacer rings between cylinder head and body or under the valves
- Fixed volume clearance pocket
  : mounted on the cylinder and separated from the cylinder by a valve
  : added to the outer end of the cylinder by adding a fabricated clearance bottle
- Variable volume clearance
  : Plug built into the outer cylinder head. When moved, the clearance volume of the outer end of the cylinder changes

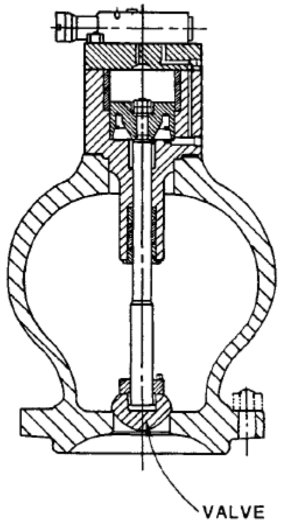


Figure 11-19. Fixed volume clearance pocket. (*Courtesy of Dresser-Rand Company.*)

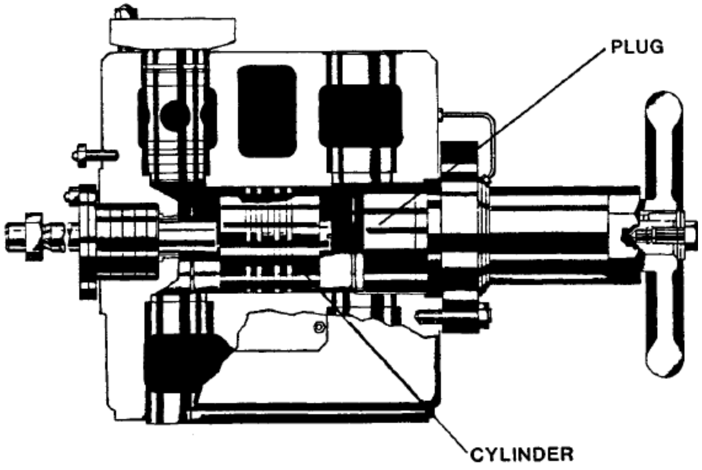


Figure 11-20. Variable volume clearance pocket. (*Courtesy of Dresser-Rand Company.*)

Cylinder sizing

- The capacity of the cylinder is a function of piston displacement and volumetric efficiency. This is in turn a function of cylinder clearance, compression ratio, and gas properties.
- Capacity of the cylinder is a function of piston displacement and volumetric efficiency, thus a function of cylinder clearance, compression ratio, and gas properties.
- Piston displacement
- Volumetric efficiency
- Cylinder throughput capacity
- Compressor flexibility

Rod load

- The allowable rod load depends on rod diameter and material, and will be quoted by the manufacturer.
- Single-acting cylinder, head end
- Single-acting cylinder, crank end
- Double-acting cylinder

Cooling and Lubrication systems

Compressor cylinder cooling

- Static system

: Cooling jackets are filled with a glycol and water mixture for uniform heat distribution

: Discharge temp. less than 190 oF

- Thermal siphon

: Use the density difference between the hot and the cold coolants to establish flow

: Discharge temp. less than 210 oF

- Forced coolant system

: A pump is used to circulate the coolant through the cylinders and the lube oil heat exchanger and then to an aerial cooler

: If the cylinder is too cool, liquids could condense from the suction gas

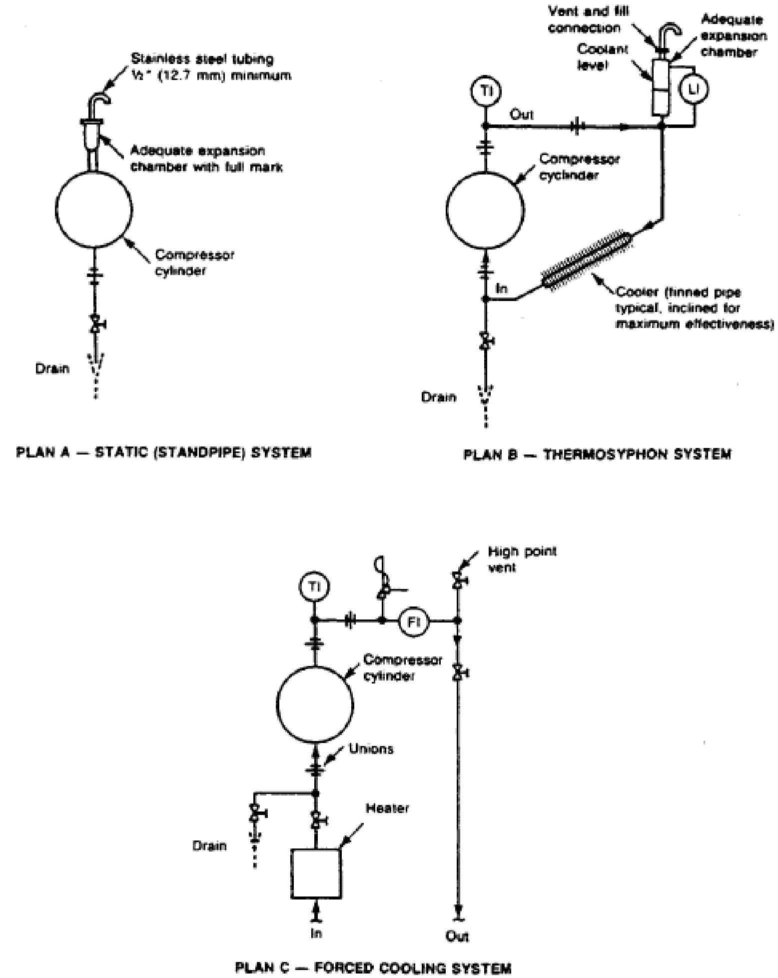
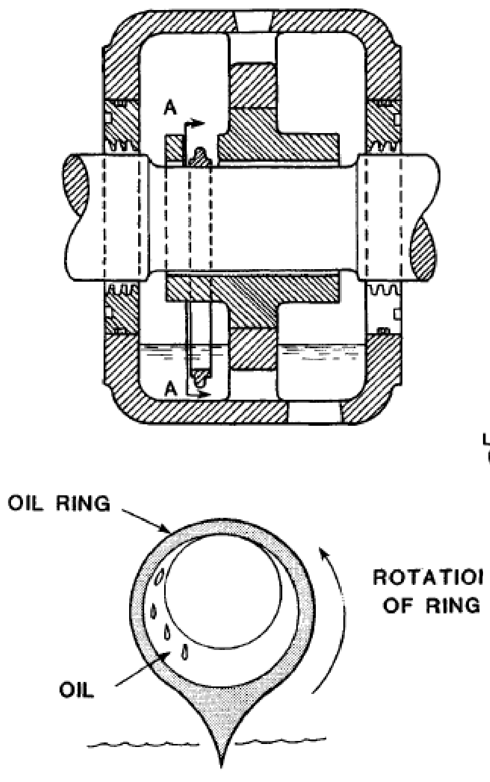


Figure 11-21. Cylinder cooling systems. *(Reprinted with permission from API, Std. 618, 3rd Ed., Feb. 1986.)*

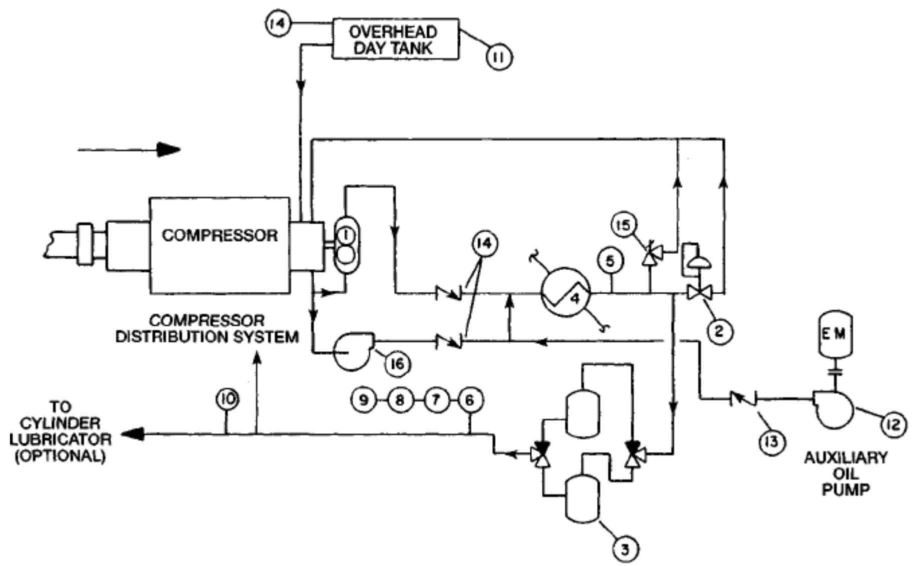
- Frame lubrication system
  : Splash lubrication system
  : Forced-feed system
- Cylinder/Packing lubrication system

pump-to-point (pump per each point) vs. divider-block (one or two pumps for divided block)



SECTION A–A

Figure 11-22. Splash lubrication system (oil slinger).



1. SHAFT DRIVEN MAIN OIL PUMP
2. PRESSURE-REGULATING VALVE
3. FULL-FLOW FILTER (dual)
4. OIL COOLER
5. TEMPERATURE GAGE
6. PRESSURE GAGE
7. LOW-PRESSURE ALARM & SHUTDOWN SWITCH
8. STARTUP SWITCH FOR MAIN PUMP
9. AUXILIARY PUMP PRESS. SWITCH (optional)
10. PIPING (supply & return)
11. OIL RESERVOIR (day tank)
12. AUXILIARY OIL PUMP
13. CHECK VALVE
14. OIL LEVEL INDICATOR
15. RELIEF VALVE
16. PRE-LUBE PUMP

NOTE: THIS ILLUSTRATION IS A TYPICAL SCHEMATIC AND DOES NOT CONSTITUTE ANY SPECIFIC DESIGN, NOR DOES IT INCLUDE ALL DETAILS (for example, vents and drains).

Figure 11-23. Forced-feed lubrication system.

Pipe sizing considerations

- Because of the reciprocating action of the piston, care must be exercised to size the piping to minimize acoustical pulsations and mechanical vibrations.
- As a rule of thumb, suction and discharge lines should be sized for a maximum actual velocity of 30 ft/sec (1,800 ft/min) to 42 ft/sec (2,500 ft/min).
- API 618 Section 3.9.2
- For smaller, high-speed compressors, the sizing rule of thumb in conjunction with pulsation bottles sized from Figure 11-24.
- To minimize pipe vibrations, it is necessary to design pipe runs so that “acoustic length” of the pipe run does not create a standing wave that amplifies the pressure pulsations in the system.

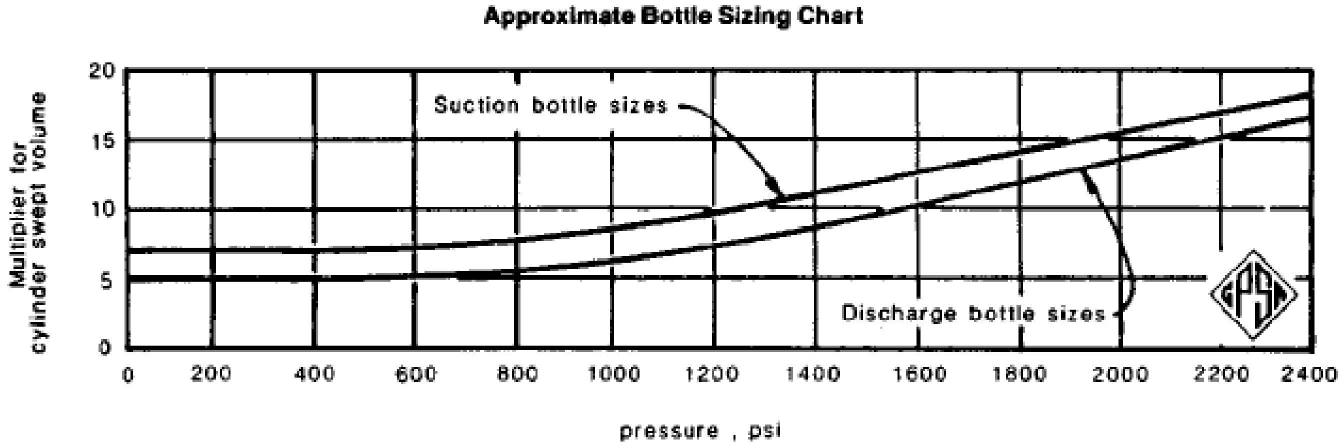


Figure 11-24. Pulsation bottle sizing chart (approximation). ***(Reprinted with permission from GPSA Engineering Data Book, 10th Ed.)***

- The acoustic length is the total overall length from end point to end point including all elbows, bends, and straight pipe runs.
  : Pipe length from suction pipeline to suction scrubber
  : Pipe length from scrubber to suction pulsation dampeners
  : Pipe length from discharge pulsation dampeners to cooler
  : Pipe length from cooler to scrubber
  : Pipe length from discharge scrubber to pipeline
- The wave length

$$\lambda = 13,382 \frac{\left(\frac{kT}{MW}\right)^{1/2}}{R_c}$$

where λ = acoustic wavelength, ft
k = ratio of specific heats, dimensionless
T = gas temperature, °R
MW = molecular weight of gas
R_c = compressor speed, rpm

For similar ends,
0.5λ, λ, 1.5λ, 2λ, ….
For dissimilar ends,
0.25λ, 0.75λ, 1.25λ, 1.75λ, 0…

- The pulsation frequency

$$f_p = \left(\frac{R_c}{60}\right)n$$

where f_p = cylinder pulsation frequency, cps
$n = 1$ for single-acting cylinders and $n = 2$ for double-acting
R_c = speed of compressor, rpm

- Normally, if the pipe support spacing is kept short, the pipe is securely tied down, the support spans are not uniform in length, and fluid pulsations have been adequately dampened, mechanical pipe vibrations will not be a problem.
- It is good practice to ensure that the natural frequency of all pipe spans is higher than the calculated pulsation frequency.

Thank you, Question?