Mechanical Equipment - Course 430.1

POSITIVE DISPLACEMENT PUMPS

In the previous lesson it was explained that although centrifugal pumps have many operational and maintenance advantages over positive displacement pumps, there are services where positive displacement pumps cannot be replaced by centrifugal pumps. These services involve requirements for very high pressure, constant predetermined delivery which is not affected by system changes, and pumping of viscous liquids.

In our plants positive displacement pumps find limited application and are used in chemical injection systems (water treatment), hydraulic systems, especially fuel handling systems, pressurization systems (stand-by HT pressurizing pumps) and jacking oil systems.

Positive displacement pumps are either **rotary** or **reciprocating.**

Reciprocating Pumps

Reciprocating pumps are generally self-priming but this ability is limited and the manufacturer should be consulted if self-priming is the required feature. The discharge is pulsating and if the system demands a uniform pressure and flow an accumulator is employed on the discharge line which is a vessel partially filled with air cushioning pulses produced by the pump. They have to be fitted with check valves in suction and discharge. Reciprocating pumps are available as constant flow pumps or variable flow pumps. Variable delivery is usually accomplished by having a variable stroke feature on the pump. The second possibility of having a variable speed drive is seldom used with this type.

Three types of reciprocating pumps are available: **piston, plunger** and **diaphragm.**

Piston Pumps are usually double-acting which means that each side of the piston compresses the liquid. They can be horizontal or vertical. Depending on the number of cylinders in the pump, the pumps are referred to as simplex, with one cylinder, duplex with two cylinders, triplex with three cylinders and so on. Sealing of pistons is accomplished by piston rings carried by the piston.

Figure 1 shows a horizontal double-acting simplex piston pump.

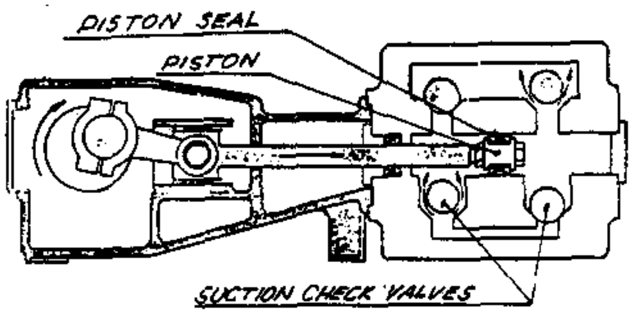


Figure 1

Plunger pumps are single-acting, are used for higher pressures than piston pumps and the plunger runs through a stationary seal, usually a stuffing box. They can be vertical or horizontal and simplex or multiplex. Designs with variable stroke are common. Plunger pumps are used for highest pressures in the industrial applications.

Figure 2 shows a horizontal single-acting simplex plunger pump.

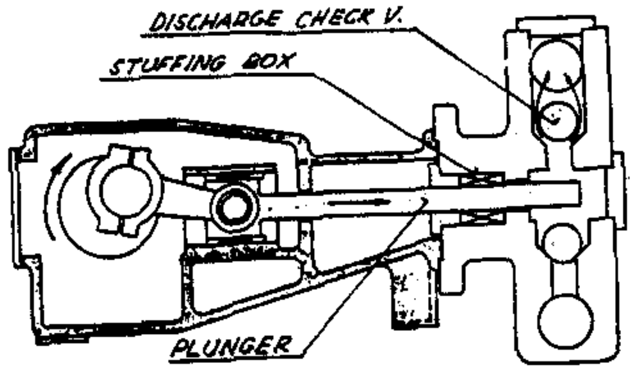


Figure 2

Diaphragm pumps can be either hydraulically or mechanically operated. In mechanically operated pumps the pumping action, resulting from the deflection of the diaphragm, is accomplished by direct pushing of a cam or a push rod on the diaphragm. In more common fluid operated pumps the deflection of a diaphragm is achieved by pressurized fluid. This fluid in turn is pressurized by a small plunger pump. The diaphragm pumps can be a simplex or multiplex design and can have a variable stroke arrangement.

Diaphragm pumps can be used when zero leakage is required or when contact by the pumped fluid with the plunger and cylinder might be detrimental to the pump.

Figure 3 shows a horizontal single-acting simplex flat diaphragm pump.

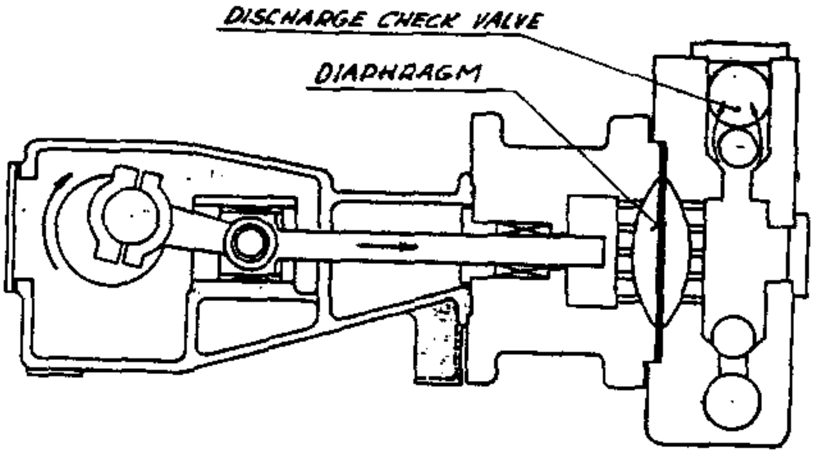


Figure 3

A special type of a piston pump is an axial piston pump. The principle of operation of these pumps is that liquid is drawn in an forced out by reciprocating pistons which rotate with the cylinders. They are multiple piston units and are available with constant or variable displacement. Figure 4 shows a constant displacement pump. The same unit can be used as a hydraulic motor.

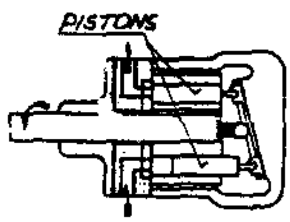


Figure 4

Rotary Pumps

Rotary positive displacement pumps are characterized by close running tolerances to minimize so called slip which is a leakage from the discharge back into the suction. They are generally self priming, do not require check valves in suction and discharge and produce negligible pulsations. Rotary pumps may be classified as: Vane, screw, gear and lobe type. Only the most common types are described here leaving a complete account for higher levels of this course.

Vane pumps usually have one or more vanes in the shape of blades sliding in radial slots in a rotor which is eccentrically located in the body of the pump. Pumps with blades in stator are also available. Figure 5 shows a blade-in-rotor sliding vane pump with constant delivery. A variable delivery feature of these pumps is accomplished by a variable speed drive or by changing the eccentricity of the rotor with respect to the stator-casing.

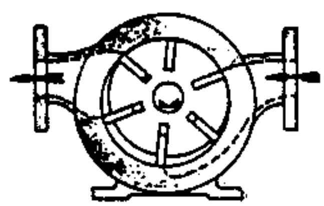
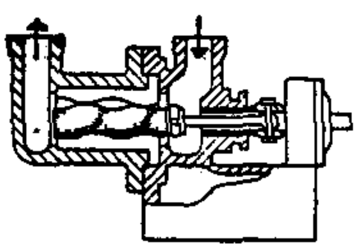
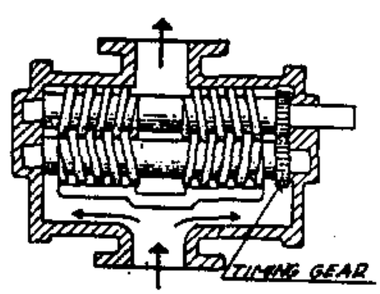


Figure 5

Screw pumps are available as single or multiple screw units shown in Figure 6(a) and (b).



(a)



(b)

Figure 6

The fluid is carried between rotor screw threads and is displaced axially as they mesh either with internal threads on the stator (single screw) or with each other (multi-screw). The discharge from these pumps is uniform, they are self-priming, do not require check valves and can pump a substantial amount of solids, gases or vapours mixed in liquid. A timing gear is used to transfer the rotation from a motor driven shaft to the other shaft, enabling contact between the two screws to be eliminated, thus reducing wear.

Gear pumps are self-priming, do not need check valves and can handle pumpage which is fairly clean. They are easily damaged when run dry. Although internal gear pumps are in existence, external gear pumps are more common. An example of an external gear pump is in Figure 7. Fluid is carried between gear teeth and the casing and displaced when the teeth mesh.

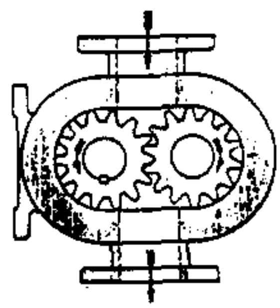


Figure 7

Changes in capacity can be realized with variable speed drives only. The motion from shaft to shaft is transferred by the gears themselves by direct tooth contact.

Lobe pumps are similar to gear pumps but the rotation from a driven shaft is transferred to the other shaft by the timing gear. The discharge is more pulsating because the rotor has only one to four lobes. Figure 8(a) shows a single lobe pump. 8(b) shows a three lobe pump. Liquid is trapped and carried between rotor lobe surfaces and the casing and discharged by meshing lobes.

(a) (b)

Figure 8

Flexible member pumps. The pumping action and sealing is derived from the elasticity of a flexible member which may be a vane, tube or some other less common element. They have good corrosion resistance, can pump in either direction and are light. They are temperature limited, discharge pressures and capacity are low. Figure 9(a) shows a flexible vane pump, 9(b) a flexible tube pump.

(a) (b)

Figure 9

Application of Positive Displacement Pumps

Positive displacement pumps have their place in pumping field and are applied in our plants for metering, pressurizing and hydraulic systems. The important fact is that due to their design, they cannot work with blocked or shut off discharge without immediately damaging the weakest member. That is why the discharge must be fitted with a relief valve which will open and prevent overpressurization and subsequent damage. Sometimes the pump is supplied with an internal relief valve but more often it is a responsibility of the user to fit the system with a relief valve which should be as close to the pump as possible and definitely before any other obstacle in the piping like a valve, pipe fitting or a heat exchanger.

Similarly, as in systems with centrifugal pumps majority of operating problems originate in suction. If a pump is working with excess suction lift the absolute pressure in the suction to the pump may drop below the vapour pressure corresponding to the temperature of pumpage and the pumpage starts boiling. As soon as it is in the pump, pressure increases, vapour condenses and the phenomenon of **cavitation,** explained in the previous lesson, damages the pump. The rules which should be followed to avoid cavitation are the same as in the case of centrifugal pump systems: put the pump as low as possible with respect to the suction tank, make suction piping as short and simple as possible, ie, as few elbows and fittings as possible, avoid valves and ensure that the diameter of the suction piping is adequate.

If the suction pressure is grossly below the vapour pressure a pump will suck in a variable quantity of liquid and boiled off vapour and its discharge flow rate will drop. Positive displacement pumps can discharge gases and vapours so that vapourlocking as understood in centrifugal pumps operations does not happen. Similarly airlocking is not a problem but it is important to realize the certain positive displacement pumps cannot run dry without being soon damaged.

ASSIGNMENT

1. Describe the difference between a piston and a plunger pump in design and application.

2. (a) Describe a problem associated with reciprocating pumps.

   (b) What solutions are possible?

3. How can flow rate be changed with a reciprocating piston pump?

4. Can the discharge from a gear pump be regulated by throttling (partially closing) a valve on the discharge? Explain.

5. Why is it necessary to have a relief valve in a system with a positive displacement pump?

6. Where into the system would you mount a relief valve?

7. Can a positive displacement pump cavitate? Explain.

8. Can airlocking be an operational problem in systems with positive displacement pumps? Explain.

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