What is a pump

A pump is a machine used to move liquid through a piping system and to raise the pressure of the liquid.

Why increase a liquid's pressure?

Static elevation – a liquid's pressure must be increased to raise the liquid from on elevation to a higher elevation.

Friction – it is necessary to increase the pressure of a liquid to move the liquid through a piping system and overcome frictional losses.

Pressure – to move the liquid into a pressurized vessel such as a boiler or fractionating tower.

Velocity – usually velocity of the liquid leaving the pump is higher than that entering the pump.

Common classification of pumps – Principle of energy addition
2 groups, rotodynamic pump and positive displacement pump

Rotodynamic of kinetic
In a rotodynamic pump, energy is continuously added to the liquid to increase its velocity. When the liquid velocity is subsequently reduced, this produces a pressure increase. Common example is a centrifugal pumps.

Positive displacement or PD
In a PD pump, energy is periodically added to the liquid by the direct application of a force to one or more movable volumes of liquid. This cause an increase in pressure up to the value required to move the liquid through ports in the discharge line.

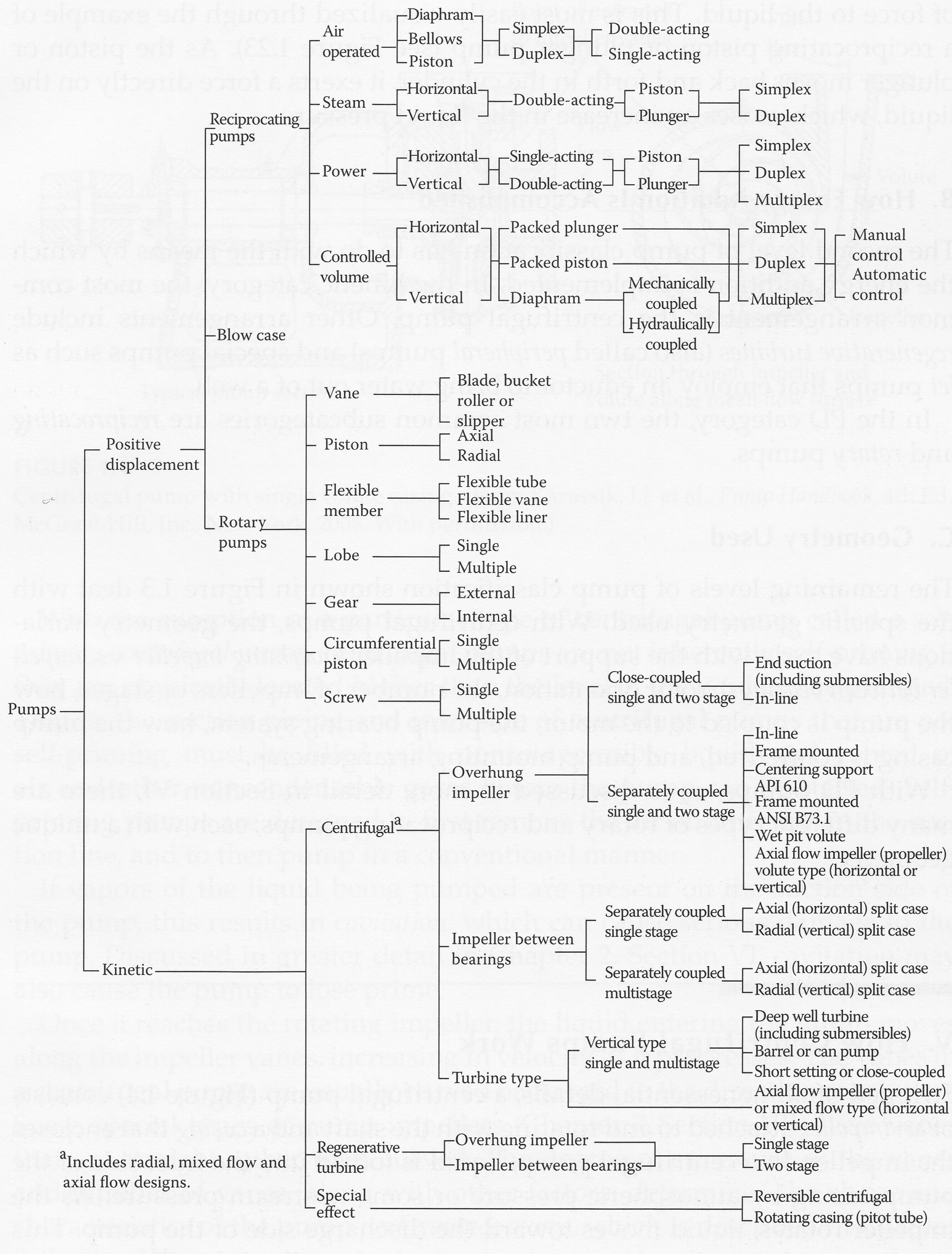


FIGURE 1.3
Classification of pumps. (Courtesy of Hydraulic Institute, Parsippany, NJ; www.pumps.org.)

PD pumps

One of the earliest decisions that must be made in designing a system and applying a pump is the selection of the type of pump to be used, whether the pump should be of the centrifugal or the PD type.

Majority selection of pump is centrifugal pumps because of its reliability and lower maintenance.

Centrifugal pumps usually have fewer moving parts, have no check valves associated with the pumps, produce minimal pressure pulsations, do not have rubbing contact with the pump rotor, and are not subjected to the fatigue loading of bearing and seals.

But, centrifugal pumps are not always suited to the application.

When to choose a PD pump

PD pumps have the ability to pump viscous liquids. In centrifugal pump, it is possible to handle low viscosity liquid, however pump efficiency degrades rapidly as viscosity increases. There is an upper limit of viscosity above which it becomes impractical to consider centrifugal pumps due to excessive waste of energy.For high viscosity liquid, some type of PD pump may be the only practical solution.

Most PD pump types are inherently self-priming, meaning they can be located above the surface of the liquid being pumped without the necessity of the suction line being filled with liquid and the non-condensable gases in the suction line being removed before starting the pump.

The PD pumps could create high pressure at low flow, which is impossible to be created by centrifugal pumps.

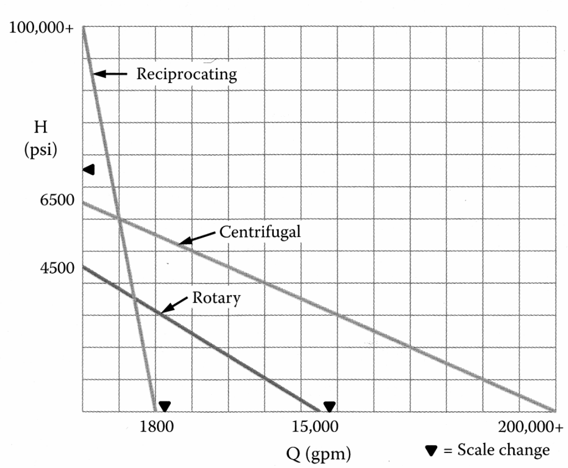


FIGURE 1.10
Head vs. flow for centrifugal, rotary, and reciprocating pumps.

If energy efficiency were the only consideration in selecting pumps, more PD pumps would be considered. However, another factor such as installed cost and maintenance expense often outweigh the energy savings.

PD pumps are good in pumping liquids containing solids such as sewage water.

Some types of PD pumps, such as peristaltic pump and diaphragm pump are inherently sealless, requiring no shaft seals and having zero product leakage.

PD pumps are suitable to pumping liquids containing gases.

<u>Major types of PD pumps</u>

Single-rotor rotary pumps

Sliding vane, sinusoidal rotor, flexible impeller, flexible tube, progressing cavity

Multiple-rotor rotary pumps

External gear, internal gear, rotary lobe, circumferential piston, multiple screw

Reciprocating pumps

Piston, plunger, diaphragm

TABLE 1.1

Key Application Data of Positive Displacement Pumps[a]

Pump Type	Maximum Capacity (gpm)	Maximum Pressure (psi)	Maximum Viscosity (million SSU)	Maximum Solid Size (in)	Dry Self-Priming (Y/N)	Maximum Suction Lift (ft H_2O)
Sliding vane	2500	200	0.5	0.031	N	28
Sinusoidal rotor	300	200	18.0	2	N	30
Flexible impeller	150	60	0.1	1	Y	24
Flexible tube (peristaltic)	200	220	0.2	1	Y	30
Progressing cavity	2400	2000	5.00	2	Y	30
External gear	1200	2500	2.00	—[b]	N	20
Internal gear	1500	200	2.00	—[b]	N	20
Rotary lobe	3000	450	5.00	4	N	20
Circumferential piston	600	200	5.00	2	N	20
Two-screw	15,000	1500	4.05	—[b]	N	31
Three-screw	4500	4500	1.00	—[b]	N	28
Piston	700	5000	0.05	0.50	Y	25
Plunger	1200	100,000	0.05	0.50	Y	20
Diaphragm	1800	17,500	1.00	1	Y	14
Air-operated diaphragm	300	125	0.75	2	Y	25
Wobble plate	50	1500	0.025	0.125	Y	8

(*continued*)

TABLE 1.1 (Continued)

Key Application Data of Positive Displacement Pumps[a]

Pump Type	Able to Run Dry (Y/N)	Abrasive Handling Rating[c]	Fragile Solids/ Shear Sensitive Liquids[c]	Pulsations[c]	Metering Ability[c]	Sanitary Designs Available (Y/N)
Sliding vane	Y	3	3	3	3	N
Sinusoidal rotor	N	4	1	1	3	Y
Flexible impeller	N	2	2	2	5	Y
Flexible tube (peristaltic)	Y	1	1	4	2	Y
Progressing cavity	N	1	1	1	2	Y
External gear	N	5	4	1	3	N
Internal gear	N	5	4	1	3	Y
Rotary lobe	Y	2	1	3	3	Y
Circumferential piston	Y	2	1	3	3	Y
Two-screw	Y	3	4	1	4	N
Three-screw	N	4	5	1	4	N
Piston	N	2	3	5	1	N
Plunger	N	4	3	5	1	Y
Diaphragm	Y	1	2	5	1	Y
Air-operated diaphragm	Y	1	2	5	5	Y
Wobble plate	Y	1	3	3	1	N

[a] Refer to guidelines in text for the use of this table.
[b] Friable solids only or rotors must be hardened and clearances opened.
[c] Rating of 1 is best, 3 is medium, 5 is worst.

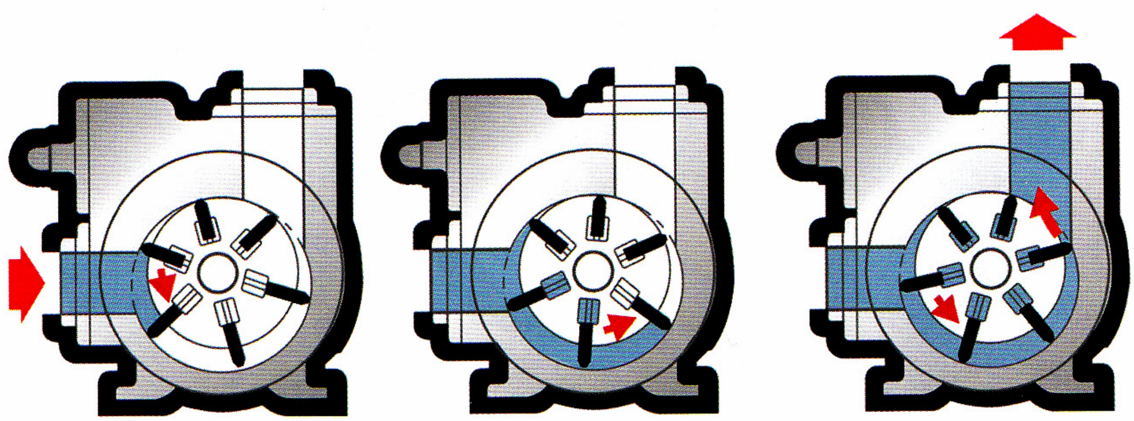
Single-rotor rotary pumps

Sliding vane pump

Vanes cooperated with a cam to draw liquid into and force it from the pump chamber. Some types of vane pumps also rely on springs to force the vanes outward, so that contact between the vanes and the casing walls is maintained even when the pump is operating at low speeds.

Advantage:
Simple construction.
Self-compensating for wear for wear on the vanes.
Well operated for thinner, low viscosity liquids.
Could operate with mildly erosive liquid.

Disadvantage:
Inability to pump highly viscous liquid.
Cannot handle fragile solids.



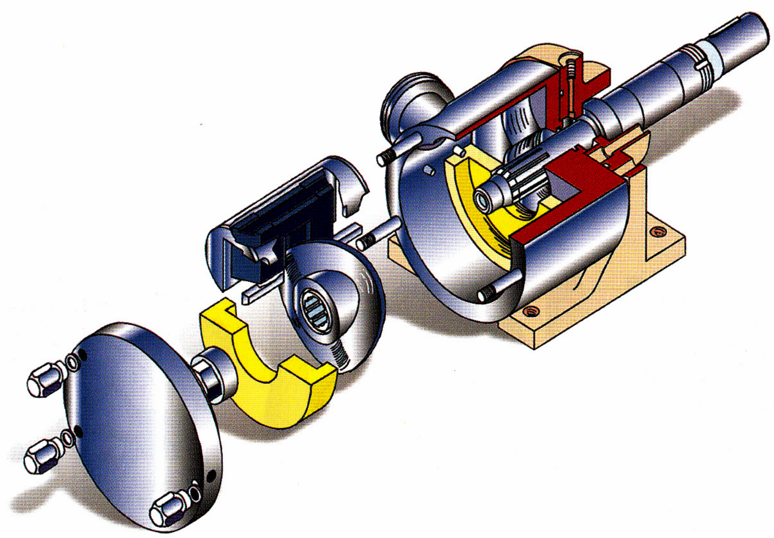
Sliding vane pump. (Courtesy of Blackmer, a Dover Company, Grand Rapids, MI.)

Sinusoidal rotor pump

In this pump type, a rotor having the shape of two complete sine curves turns in a housing, creating four separate, symmetrical pumping compartment. A sliding scraper gate covers part of the rotor, oscillates as the rotor turns, and prevents return of product past the discharge and back to the suction side of the pump.

Advantage:
Low shear and its gentle handling of fragile solids and highly viscous liquids.

Disadvantage:
Has limited ability to handle highly abrasive liquids.



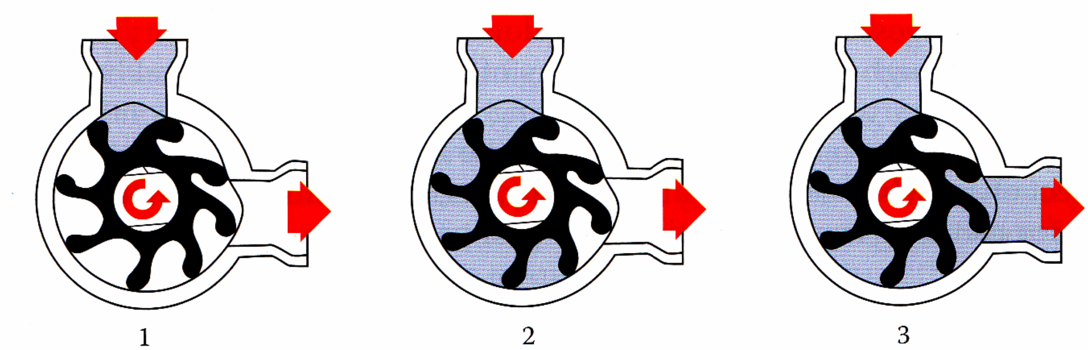
Sinusoidal rotor pump. (Courtesy of Watson-Marlow Pumps Group, Wilmington, MA.)

Flexible impeller pump

It sometimes called a flexible vane pump because the rotor is made of an elastometric material such as rubber. The blades of this impeller continuously deflect and straighten as they pass across a cam between the inlet and discharge ports. The flexible of the blades produces vacuum that causes liquid to flow in the space between the two blades and then moves the liquid through the pump.

Advantage:
Flexible impeller pump means it is dry self-priming, that can handle liquids with solids, abrasives or entrained air.
It is relatively inexpensive.

Disadvantage:
Has small range of Flowrate and pressure.
When it runs dry (more than a minutes), the rubber impeller will damage.



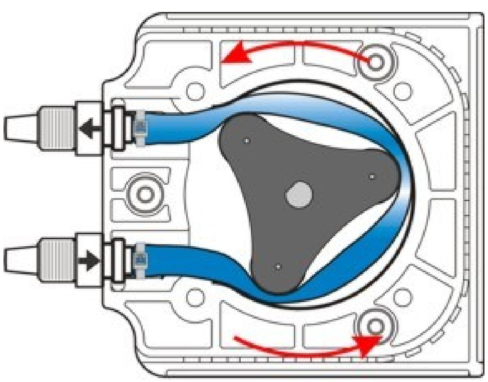
Flexible impeller pump. (Courtesy of Jabsco, a Xylem brand, Beverly, MA.)

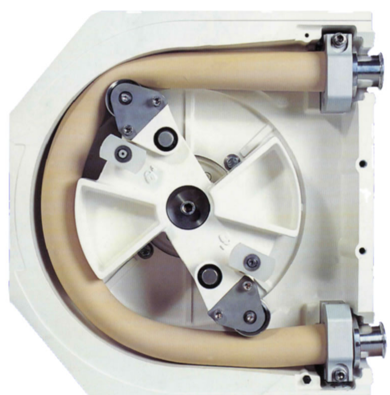
Flexible tube (peristaltic) pump

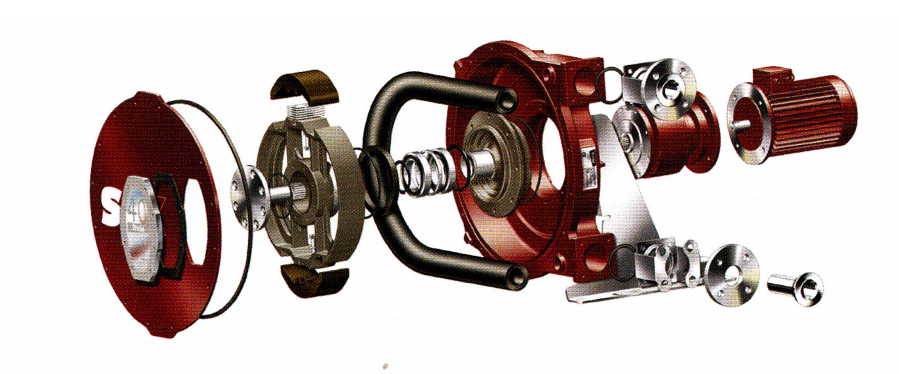
It is also called a peristaltic pump, or hose pump. In this pump type, a flexible tube made of rubber or other material is located inside a circular housing. Rollers or cams attached to the rotor squeeze the tube as they can pass across it, drawing the liquid through the pump. This action is similar to what happens when a person swallows, a process called peristalsis, which is how the pump gets its name.

Advantage:
They are sealless (require no packing assembly or mechanical seal).
It can handle quite corrosive liquids as long as the tube material is compatible.
It is dry self-priming and relatively inexpensive.
They frequently used as low cost metering pumps for application such as chlorine metering in commercial swimming pools.

Disadvantage:
It is relatively low flow and pressure capability for most models.
The hoses usually require changing about every several months.
The selection for the proper hose material for the application is the most critical aspect.
It is not too accurate for metering.







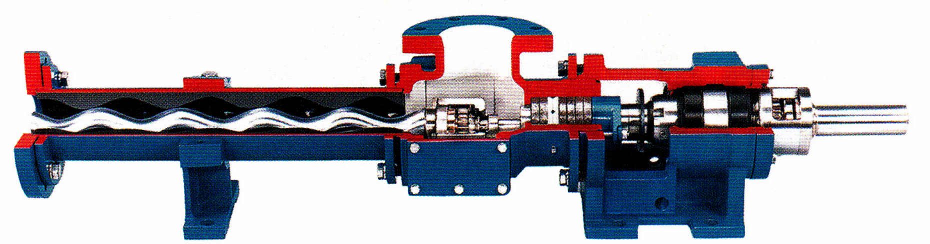
Peristaltic (hose) pump. (Courtesy of Watson-Marlow Pumps Group, Wilmington, MA.)

<u>**Progressing cavity pump**</u>

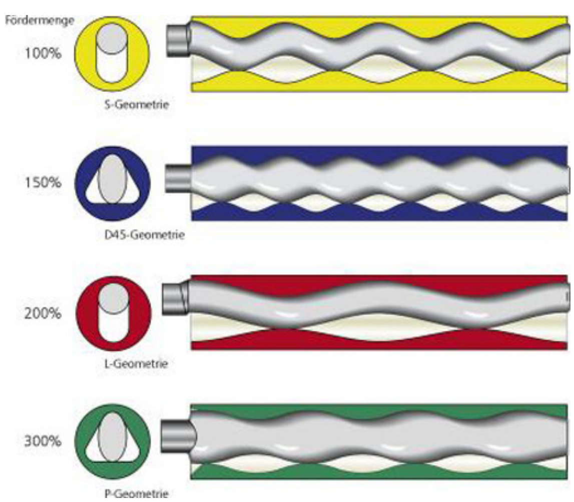
The progressing cavity pump (PC) pump in its most common design has a single-threaded screw or rotor, turning inside a double threaded stator. The stator is made of an elastomeric material, and the rotor has an interference fit inside the stator. As the rotor rotates inside the stator, cavities form at the suction end of the stator, with one cavity closing as the other opens. The cavities progress axially from one end of the stator to the other as the rotor turns, moving the liquid through the pump.

Advantage:
Capable to pump highly viscous liquids, as well as low viscosity liquids.
It is produces very little pulsation.
It is self-priming even when dry.
The maximum pressure is not so high but it can be installed in series to increase its pressure.

Disadvantage:
It has relatively higher cost of replacement.
It needs large floor space.



Progressing cavity pump. (Courtesy of Moyno, Inc., Springfield, OH.)



External gear pump

It has two meshing gear, which may be of the spur, helical or herringbone type. Liquid is carried between the gear teeth and displaced as the teeth mesh. Close clearances between the gear teeth and between the teeth and the casing walls minimize slippage of liquid from high-pressure side to the low-pressure side.

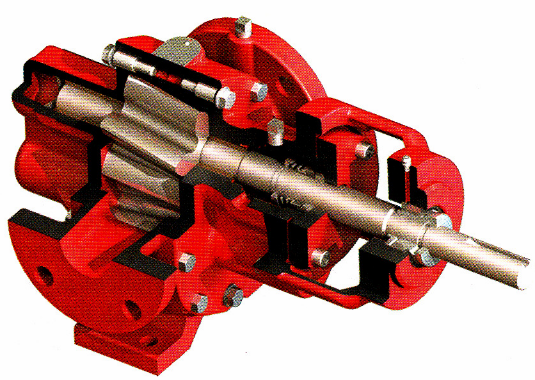
Spur gears are simple and inexpensive, but can be noisy and inefficient.

Helical gears give more paths for trapped liquid to escape. The helix shape gives the liquid a place to exit. Helical gear pumps are generally efficient and quiet. The disadvantage is the axial wear in a gear pump decreases performance much faster than radial wear.

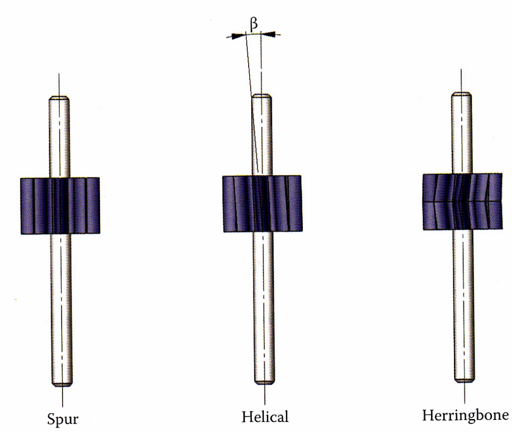
Herringbone gears are the most expensive to manufacture, but there are quiet, efficient and do not exhibit axial thrust. They are very difficult to machine. Sometimes they are made up with two helical gears butted together with the helix of the two gears oriented opposite to each other.

Advantages of external gear pumps are, they operate at relatively high speeds, producing relatively high pressure. The gears are usually supported by bearing, so there are no overhung loads.

The disadvantages are, they are not suitable for abrasive fluid. The wear on gear and other part sometimes cause the pressure drop.



External gear pump. (Courtesy of Roper Pump Company, Commerce, GA.)



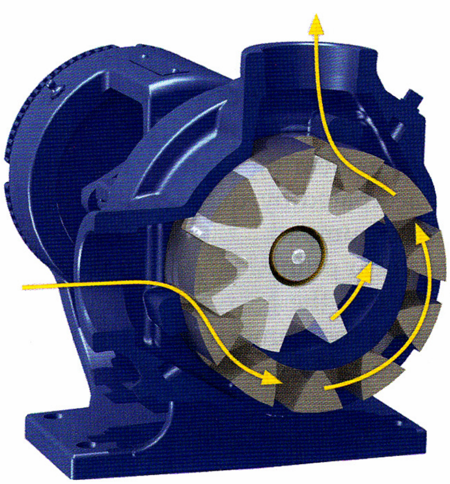
Spur, helical, and herringbone gears. (Courtesy of Diener Precision Pumps, Lodi, CA.)

Internal gear pump

It likes external gear pumps, move and pressurize liquid by meshing and unmeshing of gear teeth. With an internal gear pump, a rotor having internally cut teeth meshes with and drives an idler gear having externally cut teeth. Pumps of this type usually have a crescent-shape partition that moves the liquid through the pump with minimal slip.

Advantage: It has less moving parts, relatively low cost, and only has one seal. It can be operated well in either direction.

Disadvantage: It has only one bearing, so the bearing needs to support an overhung load. This pump usually will not work with abrasives or solid.



Internal gear pump. (Courtesy of Viking Pump, Inc., a unit of Idex Corporation.)

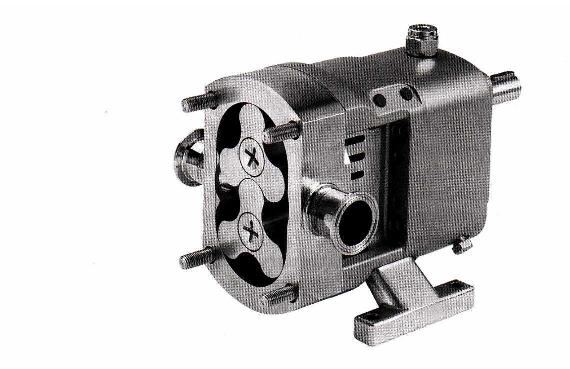
Rotary lobe pump

A lobe pump is similar to an external gear pump, in that the liquid is carried between the rotor lobe surfaces that cooperate with each other as they rotate to provide continuous sealing, as do the teeth of a gear pump.

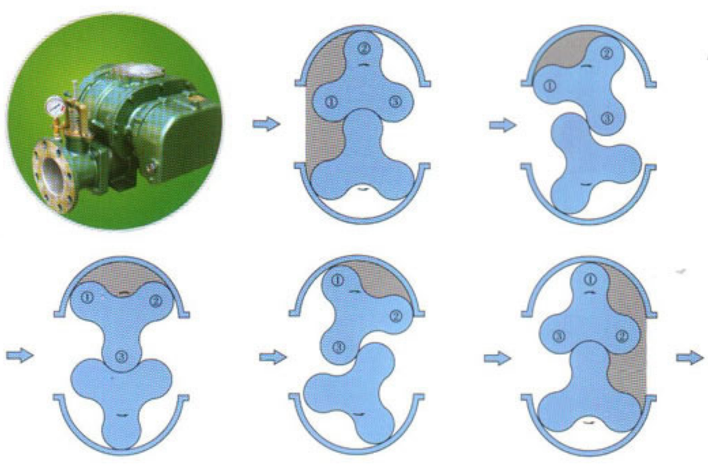
Unlike a gear pump, however, one lobe cannot drive the other, so this type of pump must have timing gears to allow the lobes to remain in synch with each other. Three lobes being most common.

The wide spaces between the lobes and the slow speed at which these pumps operate make this style of pump ideal for handling food products containing fragile solids.

The disadvantages are, they are easy to have pressure pulsation, and they have fairly high amounts of slip with low viscosity liquids.



Lobe pump. (Courtesy of Viking Pump, Inc., a unit of Idex Corporation.)

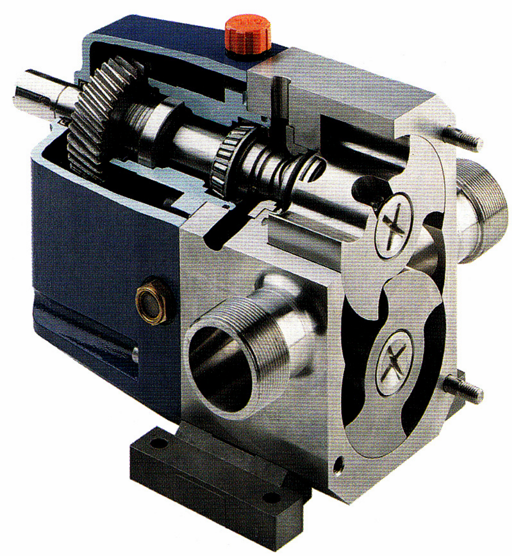


Circumferential piston

The circumferential piston and bi-wing lobe pumps are very similar to the traditional lobe pump, both in the way they operate and in their applications. For bi-wing lobe pump, the rotor have arc shaped "piston", or rotor wings. The rotor are not in direct contact with each other and require the use of timing gear.

It has less slip than traditional lobe pump. This is because the rounded lobes of a traditional lobe pump only come in close contact with the casing at a single point on the outer surface of each lobe, whereas the circumferential piston and bi-wing lobe pumps have a close clearance between the rotor and the casing over the entire length of the arc. However, with liquid viscosity greater that 440 mPa.s, this advantage disappears.

It is good for food processing but cannot handle abrasives as well as traditional lobe pumps.



Bi-wing lobe pump. (Courtesy of Viking Pump, Inc., a unit of Idex Corporation.)

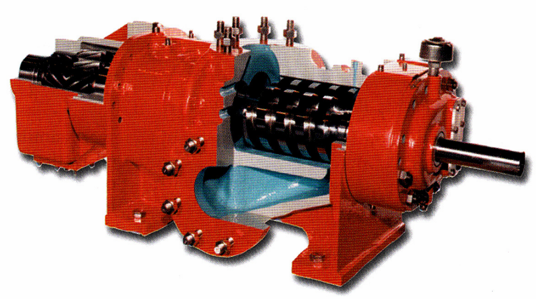
Multiple screw pump

Progressing pump is also called single screw pump.

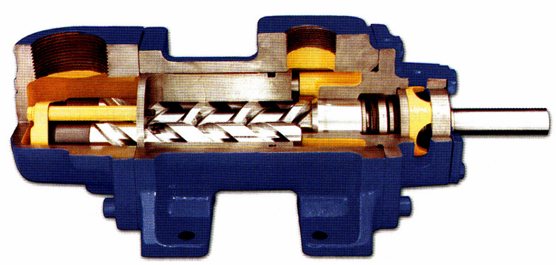
In a multiple screw pump, liquid is carried between motor screw threads and is displaced axially as the screw threads mesh. It can be either two-screw or three-screw

Two-screw pump usually have timing gears. The screws are not contact with each other, this style can handle more abrasive liquids than three-screw pump. This pump usually used to pump crude oil containing sand. It can produce usually limited to about 1500 psi.

Three-screw pump is usually the most economical choice if the liquid is not overly abrasive because it has fewer parts. It can produce higher flow rates than any other type of rotary PD pump. It can operate at high speed and can produce very high pressure (about 4500 psi) with almost no pulsations. It is relatively quiet operation.



Two-screw Warren Pump. (Courtesy of Colfax Fluid Handling, Monroe, NC.)



Three-screw Imo Pump. (Courtesy of Colfax Fluid Handling, Monroe, NC.)

Piston pump

The liquid end of a reciprocating piston pump consist of a chamber having liquid inlet and outlet ports, with most designs having check valves in both the inlet and outlet ports. When the reciprocating piston strokes in one direction, the inlet check valve opens, while the outlet check valves remains closed, directing liquid into the liquid end of the pump. When the piston strokes in the opposite direction, the inlet check valve closes and the outlet check valve opens, allowing liquid to move into the discharge port and out into the system.

Piston pumps can be single-acting or double-acting, although most are double-acting.

A single-acting piston pump has liquid discharging only during the forward stroke of the piston.

A double-acting piston pump, liquid is discharged during both the forward and return motions of the piston. It is requiring 4 check valves for each piston.

Double-acting designs are generally associated with slower speeds and medium pressures, while single-acting designs are more generally associated with higher speeds and higher pressures.

Double-acting piston pumps are quite a bit more efficient than single-acting pumps when the inlet pressures are quite high.

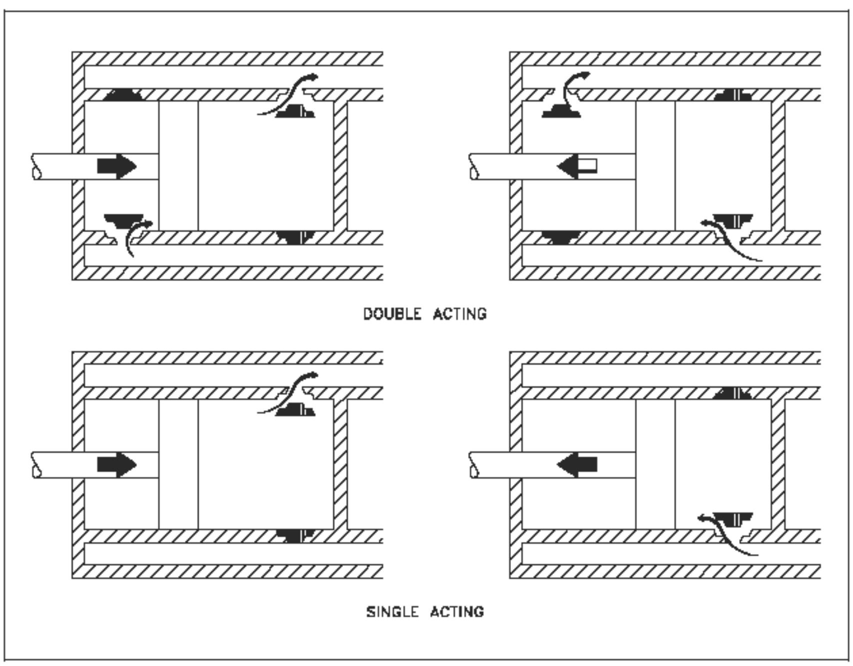


Figure 13 Single-Acting and Double-Acting Pumps

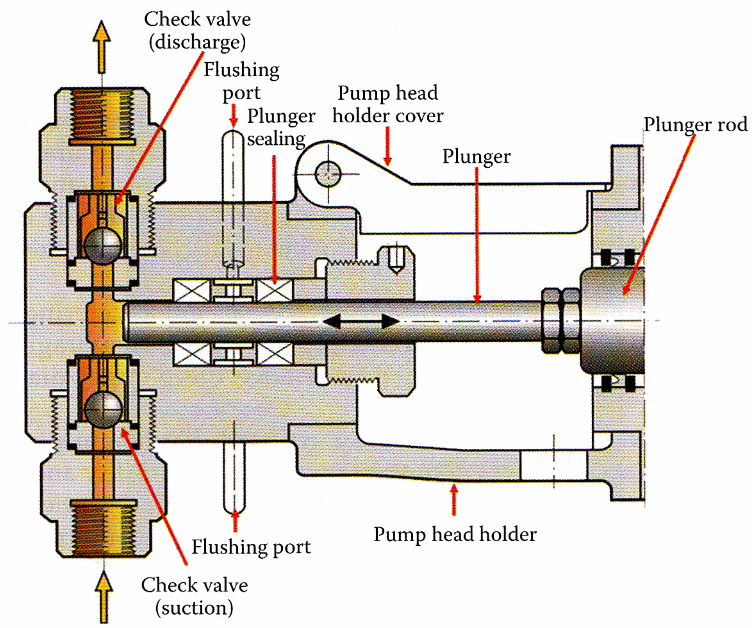
Plunger pump

A plunger pump is similar to a piston pump, except the reciprocating member is a plunger rather than a piston. The plunger is single-acting, and the plunger is sealed with packing in the cylinder walls.

Plunger pumps are used for higher pressure applications that piston pumps.

They are generally run at higher speeds, and has lower capital cost than piston pumps.

However, they may have higher maintenance expense and lower abrasion resistance than a piston alternative.



Plunger pump. (Courtesy of Lewa, Inc., Holliston, MA.)

Diaphragm pump

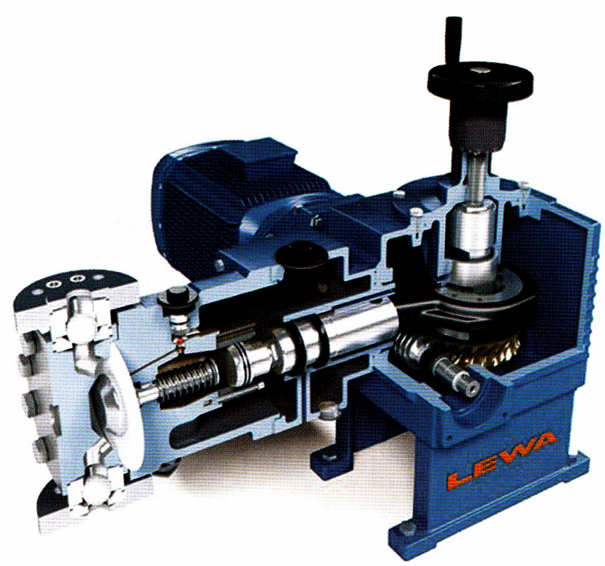
Diaphragm pumps are similar to piston and plunger pumps, except that the reciprocating motion of the pump causes a diaphragm to flex back and forth, which in turn causes the liquid to flow into and out of the liquid end of the pump.

Diaphragm pumps require check valves at inlet and outlet ports.

The diaphragm is usually made of an elastomeric material to allow it to flex. The diaphragm can be mechanically attached to the reciprocating member or it can be separated and actuated by a reservoir of hydraulic fluid.

One common application of this pump is for metering application. These types of pump are highly accurate in measuring flow.

The diaphragm makes the pump leak-free and compatible with variety of liquids.



Diaphragm metering pump. (Courtesy of Lewa, Inc., Holliston, MA.)