All about pumps

- **A pump is a machine used to raise liquids from a low point to a high point.**
- **Alternatively it may simply provide the liquid with an increase in energy enabling it to flow or build up pressure.**

Pumping System

A pumping system on board ship consists of :

- **Suction piping**
- **Pump(s)**
- **Discharge piping**
- **Suitable valves**

Pumping System (continued)

The system is arranged to provide a positive pressure or head at some point and discharge the liquid. The pump provides the energy to develop the head and overcome any losses in the system. Losses are mainly due to friction within the pipes and the difference between the initial and final liquid levels.

Total System Losses

$$H_{total} = H_{Friction\ suct} + H_{Friction\ disch} + H_{Disch\ tank} + H_{Suct\ tank}$$

$H_{Friction\ suct}$ = Friction head loss in suction piping

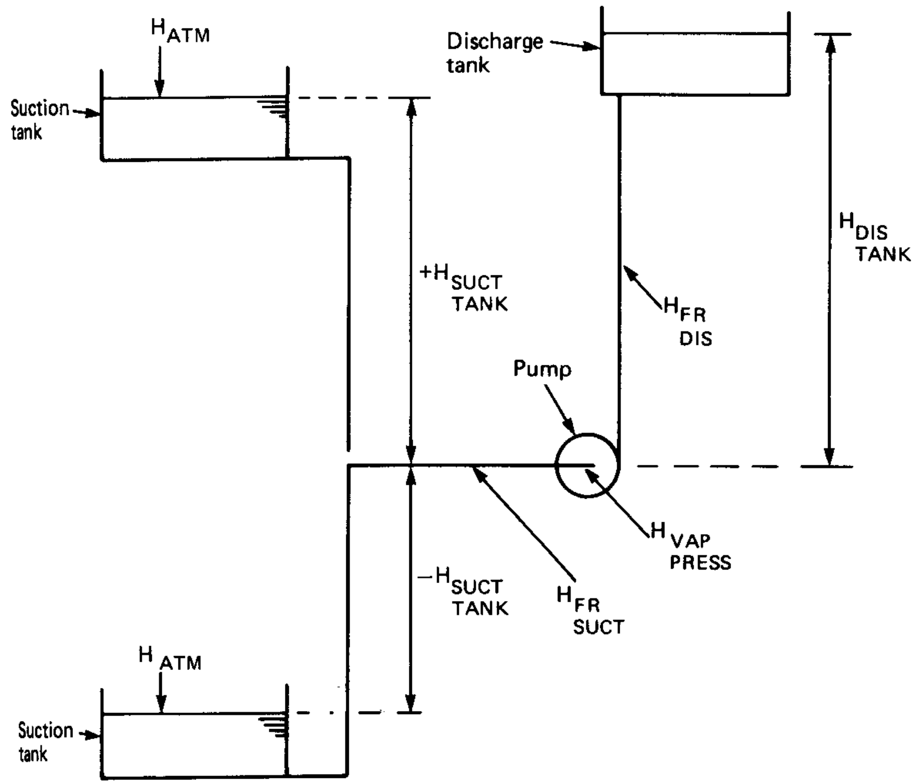
$H_{Friction\ disch}$ = Friction head loss in discharge piping

$H_{Disch\ tank}$ = Height of discharge tank level above pump

$H_{Suct\ tank}$ = Height of suction tank level above pump
(Negative when tank level is below suction)

All values are in metres of liquid

A Basic Pumping System



The System Head Loss/Flow Characteristics

The system flow rate or capacity will be known and the pump manufacturer will provide a head – flow characteristic for his equipment which must be matched to the system curve. To obtain the best operating conditions for the pump it should operate over its range of maximum efficiency.

Net Positive Suction Head

An important consideration, particularly when drawing liquids from below the pump, is the suction side conditions of the system. The determination of the Net Positive Suction Head (NPSH) is undertaken for both system and pump.

NPSH = (Absolute Pump Inlet Pressure) – (Liquid Vapour Pressure)

(Units: Metres Of Liquid)

Vapour pressure is temperature dependent and NPSH should be given for the operating temperature of the liquid.

Overall Pump System Characteristics For A Centrifugal Pump

Values Expressed in Metres head of sea Water.

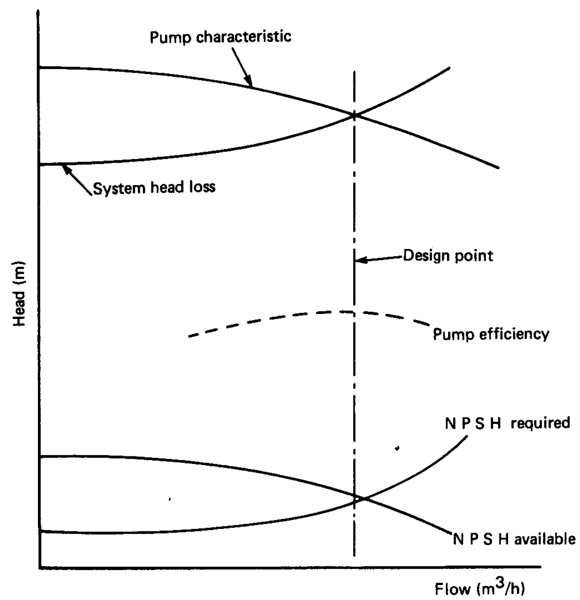


Figure 6.2 Overall pump system characteristics

$$NPSH_{AVAIL} = \underbrace{H_{ATM} + H_{SUCTTANK} - H_{FRSUCT}}_{\text{absolute pump inlet pressure}} - H_{VAPPRESS}$$

where H_{ATM} = atmospheric pressure
$H_{SUCTTANK}$ = tank level from pump (negative when tank level is below pump)
H_{FRSUCT} = friction head loss in suction piping
$H_{VAPPRESS}$ = liquid vapour pressure

Cavitation

The pump manufacturer provides a NPSH required characteristic for the pump which is in metres head of sea water. The pump and system must be matched in terms of NPSH such that the NPSH required is <u>always greater</u> than NPSH available.

An insufficient value of NPSH required will result in cavitation which is the forming and collapsing of bubbles in the liquid, which will affect the pumping operation and may damage the pump.

Pump Types

- **Centrifugal**
- **Axial Flow**
- **Displacement**

Centrifugal Pumps

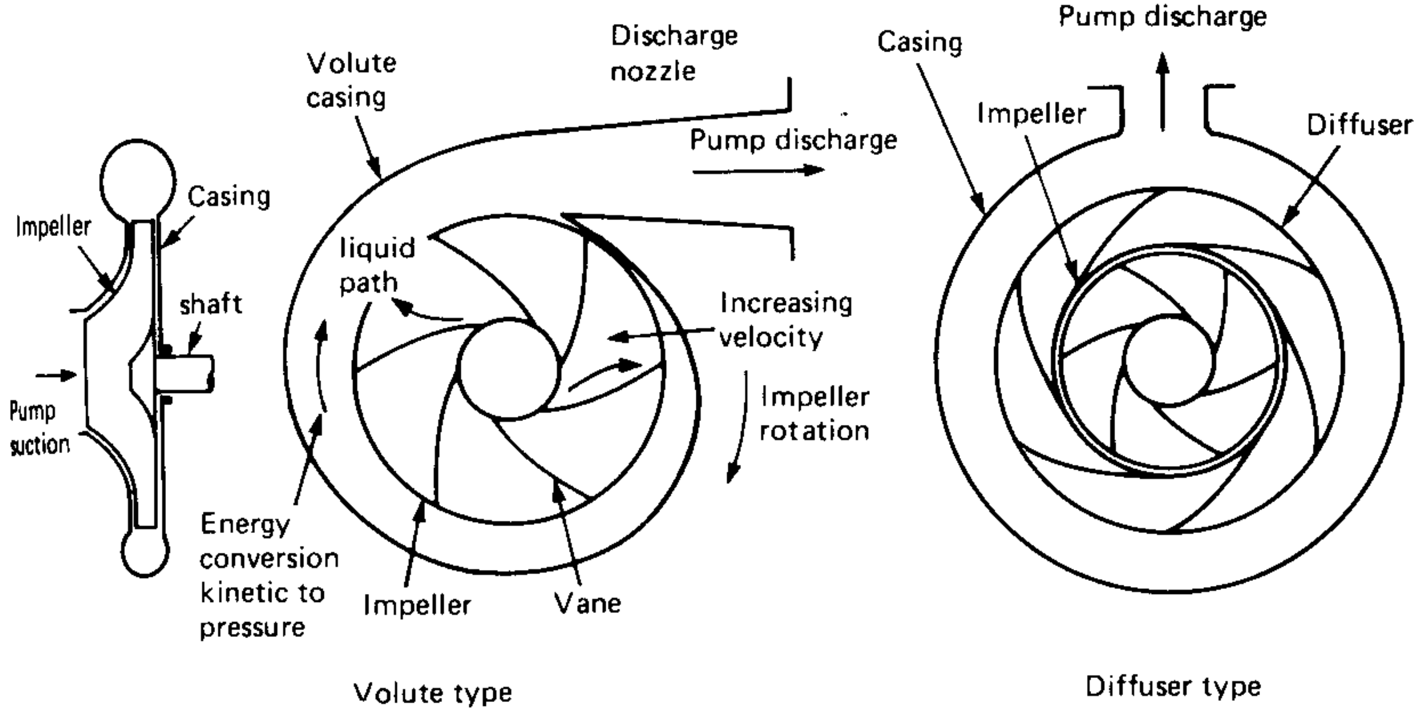
In a centrifugal pump liquid enters the eye of the impeller and flows radially out between the vanes.

The velocity of the liquid is increased by the impeller rotation.

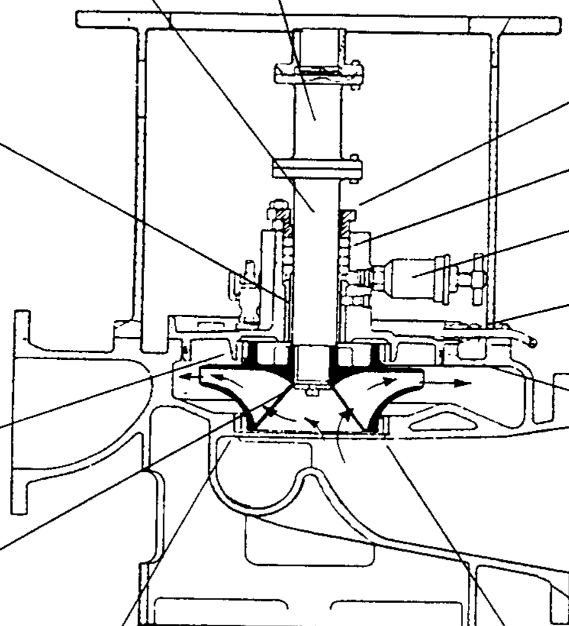
A volute or diffuser is then used to convert most of the *kinetic energy* of the liquid into *pressure*.

Centrifugal Pump

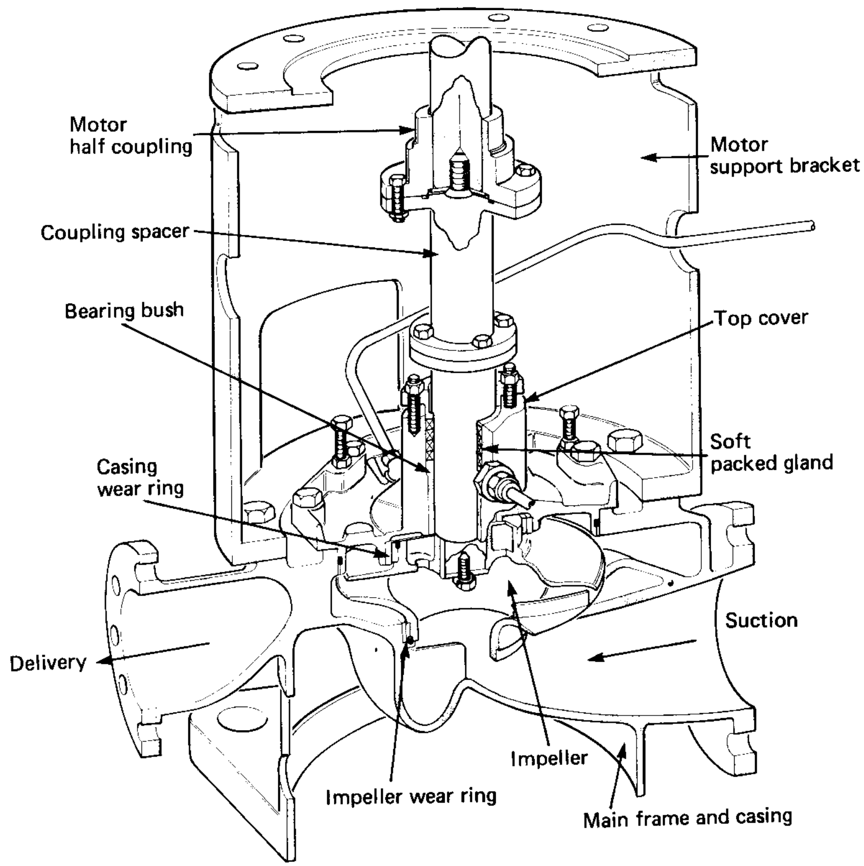
Centrifugal Pump Operation



Single Stage Centrifugal Pump



Single Entry Centrifugal Pump



Cross Section Of Pump

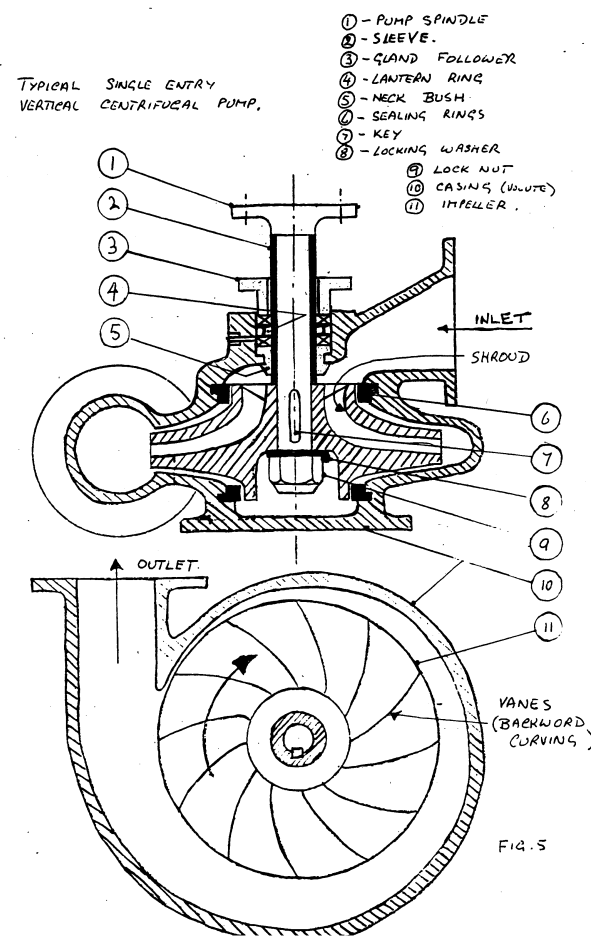


FIG. 5

Fully Shrouded Impeller

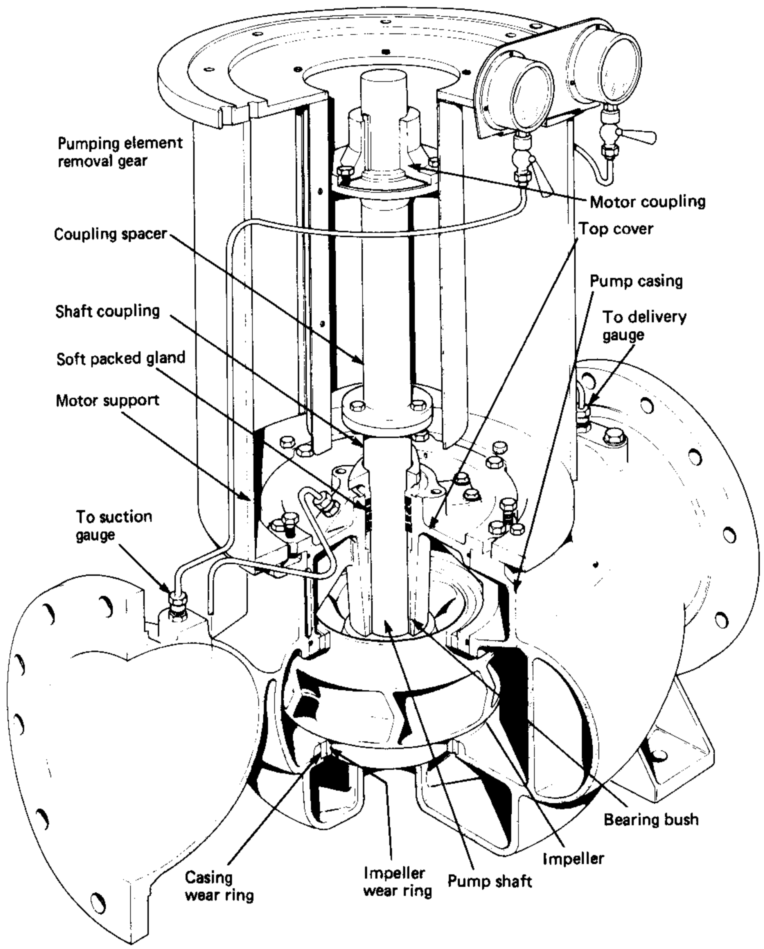
Probably this is the most versatile pump of all. Impeller mechanisms are the basis of thousands of types of pumps.

Double Entry Pump

The incoming liquid enters the double impeller from the top and the bottom and passes into the volute casing for discharge.

The advantage being that the double entry pump has a lower NPSH required characteristic which will be beneficial in poor suction conditions.

Double Entry Centrifugal Pump



Another Example Of A Fully Shrouded Impeller

The number of blades can vary from 1 to 10 or more. They operate over a wide speed range -- from less than 30 to more than 3000 RPM.

Multi Stage

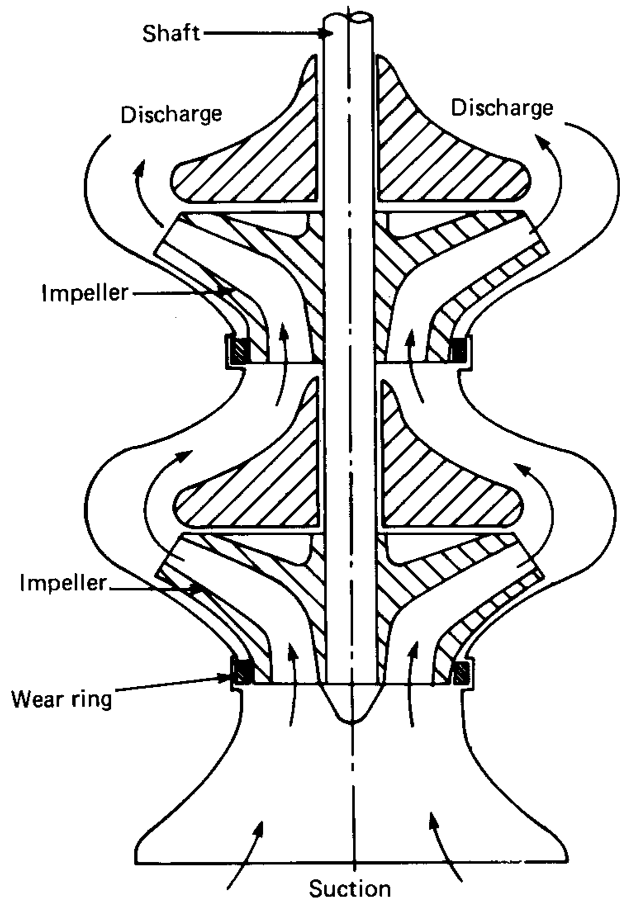
This type of pump can be used for deep well cargo pumping.

This can be considered as a series of centrifugal pumps arranged to supply on another in series and so progressively increase the discharge pressure.

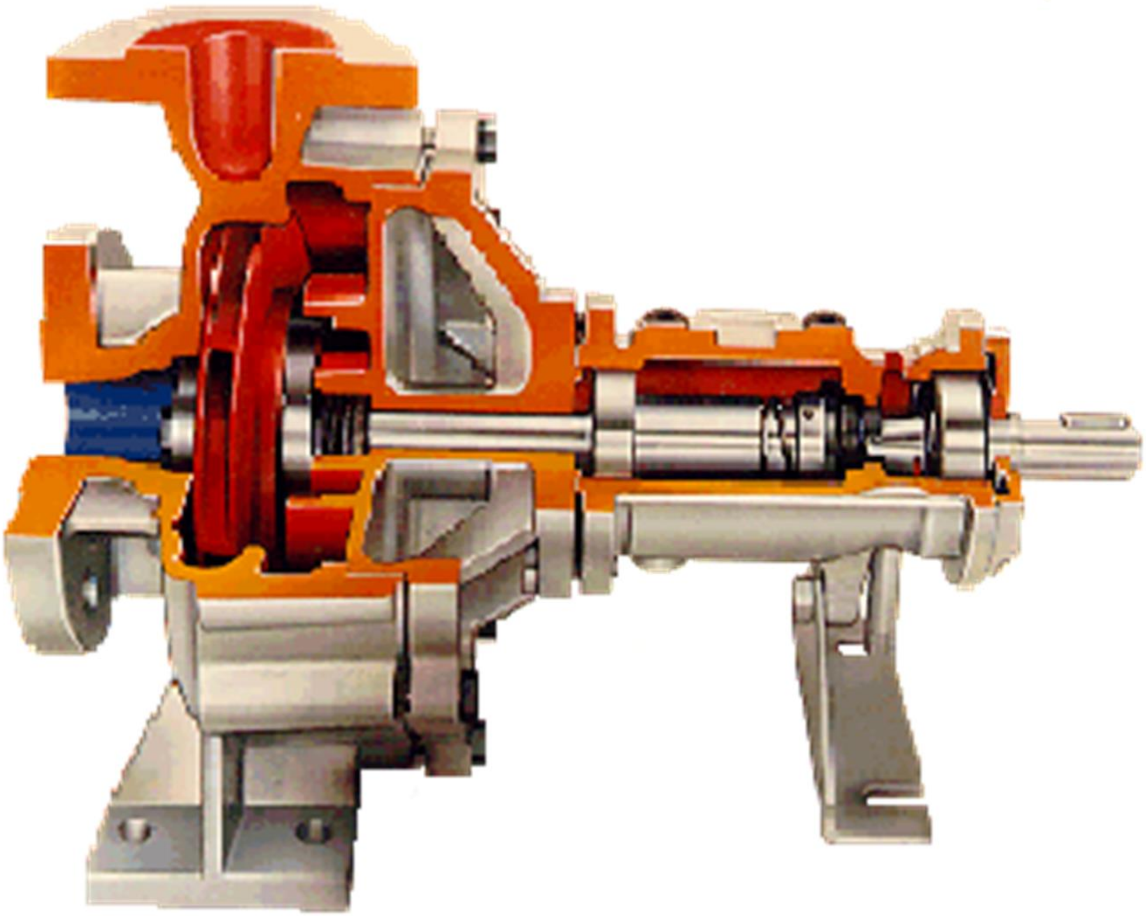
The pump drive is located outside the tank and can be either electric, hydraulic or some other Appropriate means suitable for the location.

Multi Stage Centrifugal Pump

Drawing Shows two of the stages



Horizontal Centrifugal Pump



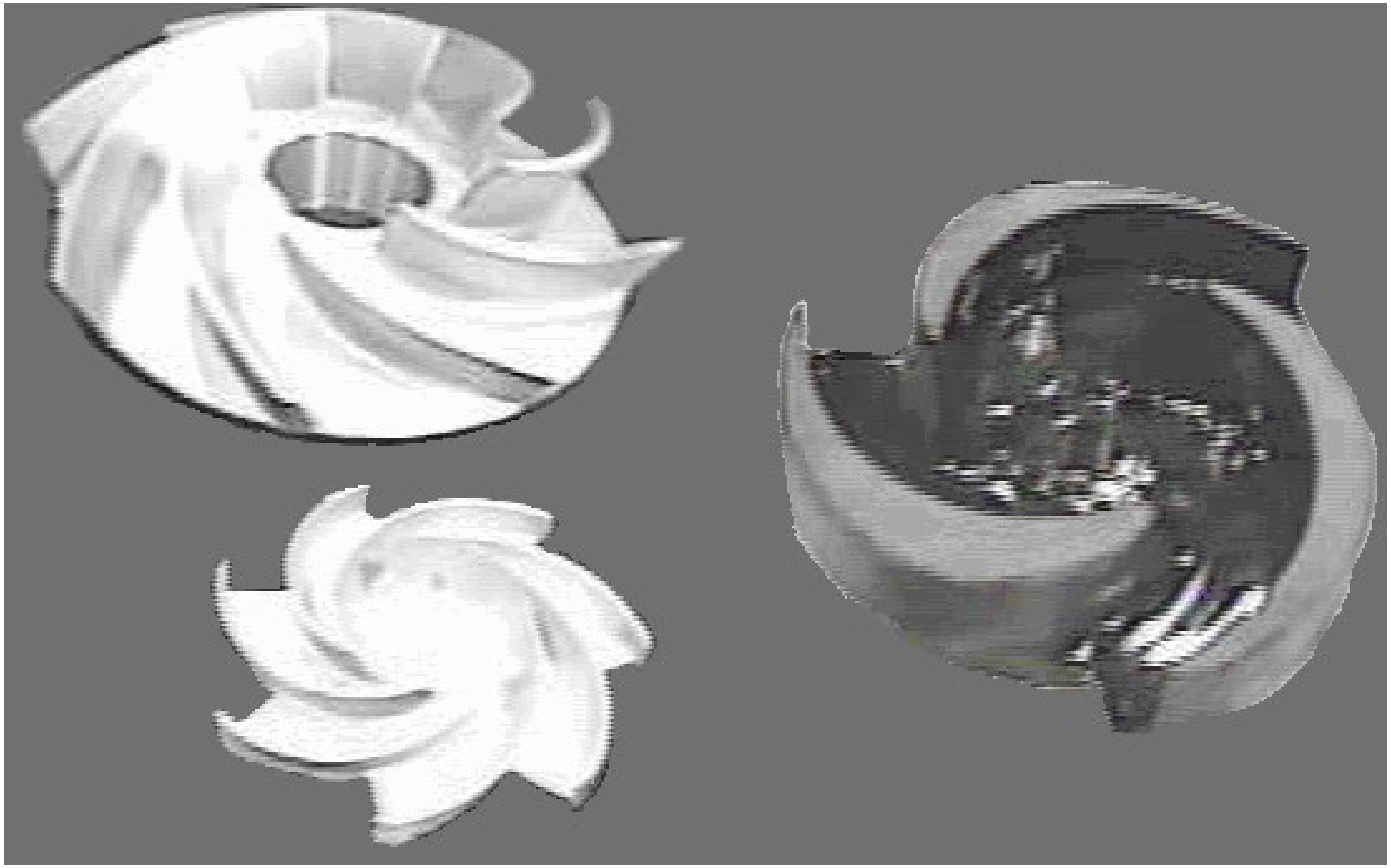
Diffusers

A diffuser is fitted to high pressure centrifugal pumps . This is a ring fixed to the casing around the impeller in which there are passages formed by vanes. The passages widen out in the direction of the liquid flow and act to convert the kinetic energy of the liquid into pressure energy.

Diffuser For A Centrifugal Pump

Impeller pumps range in diameter from less than a quarter inch to 10 feet or more. Sometimes they have diffusers to increase efficiency.

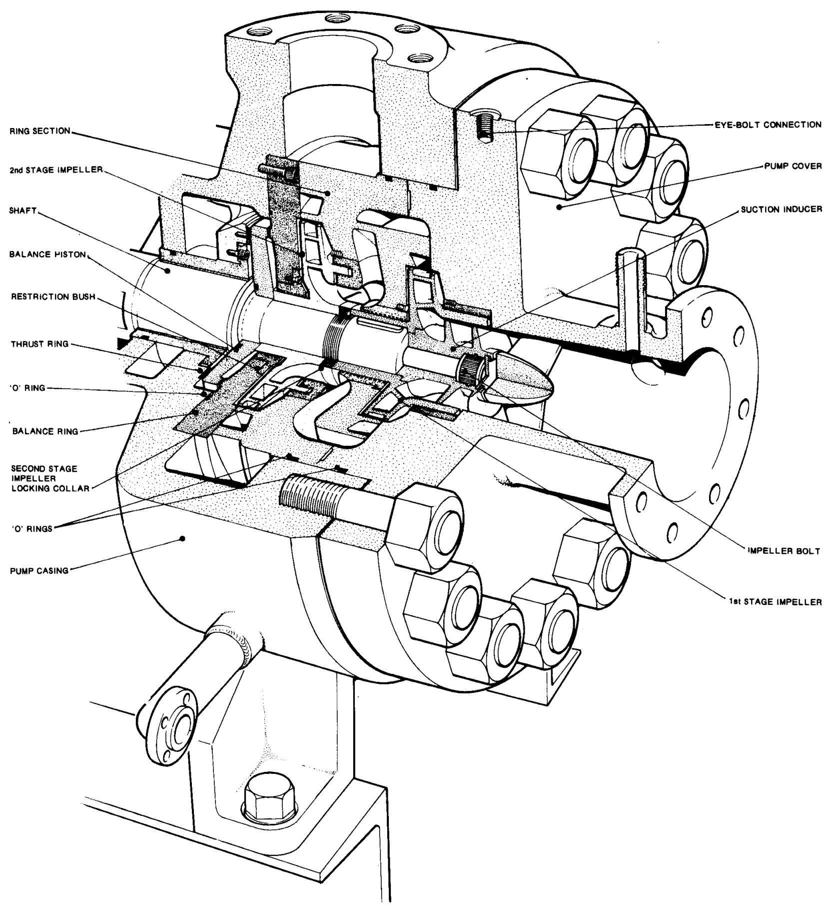
Open Type Impellers



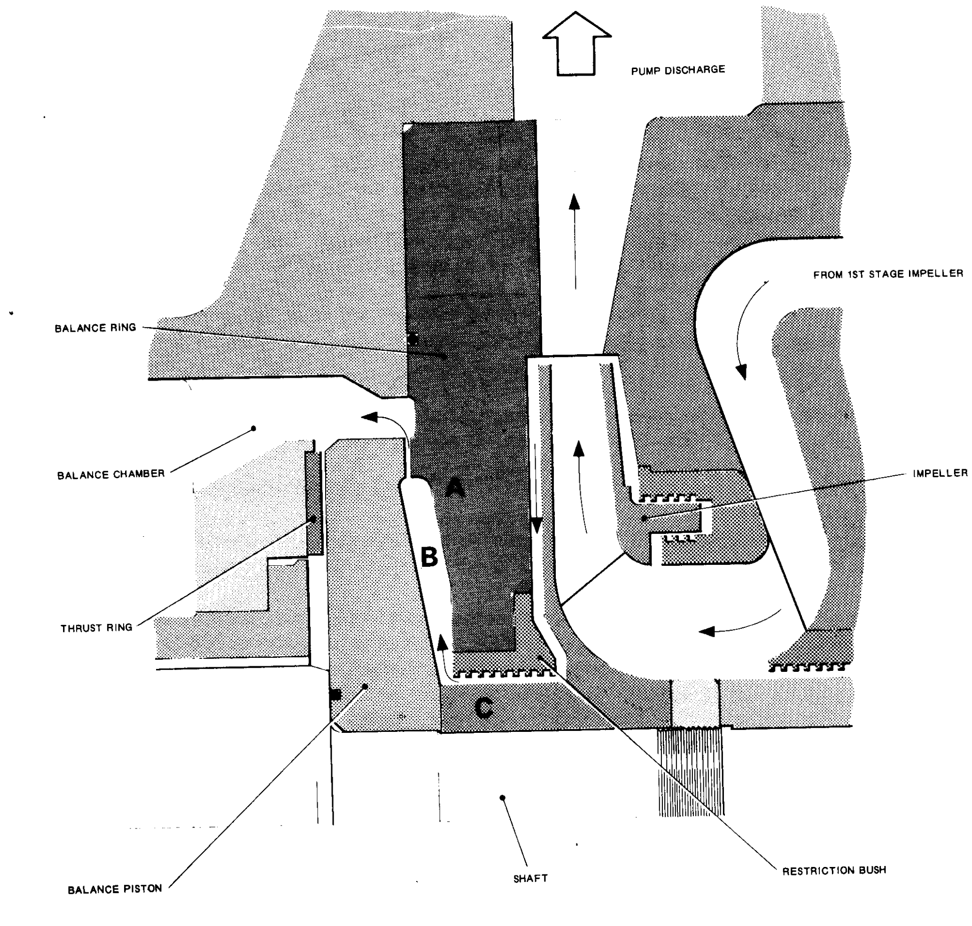
Hydraulic Balance Arrangements

Hydraulic balance arrangements are are also usual. Some of the high pressure discharge liquid is directed against a drum or piston arrangement to balance the discharge liquid pressure on the impeller and thus maintain it in an equilibrium position.

Turbo Feed Pump



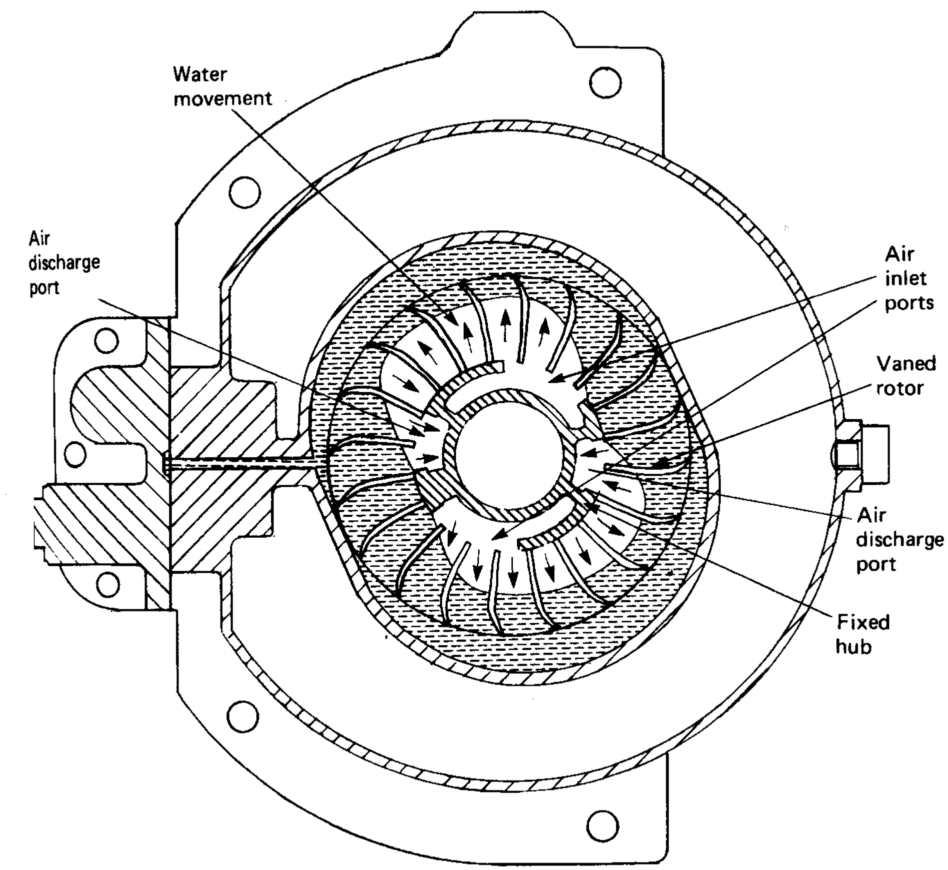
Hydraulic Balance (Turbo Feed Pump)



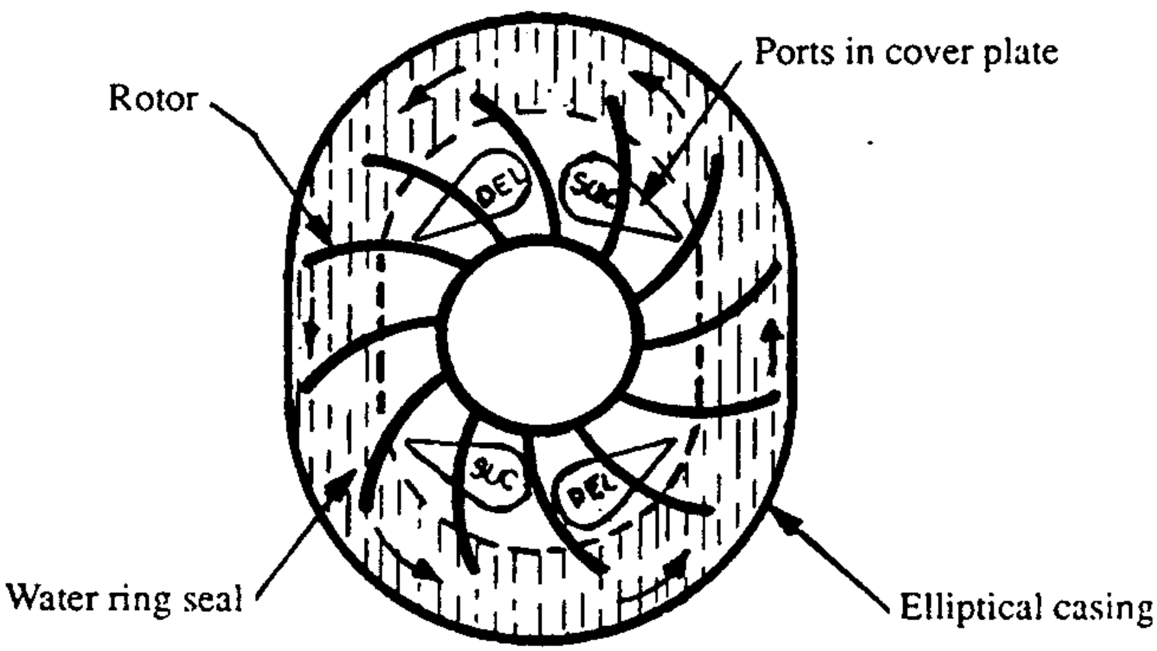
Air Pump Principle

The air pump or liquid ring primer consists of an elliptical casing which contains a vaned rotor and has a covering plate with ports cut in it. The casing is partly filled with water. The rotor is coupled to the electric motor so that when the pump is running the water spins with the rotor and being thrown outwards takes an elliptical shape. The tips of the vanes are sealed by the water and the volume between them varies during rotation. Beneath the suction ports the the volume increases so that air is drawn from the float chamber. Under the discharge Ports, the volume decreases forcing the air out.

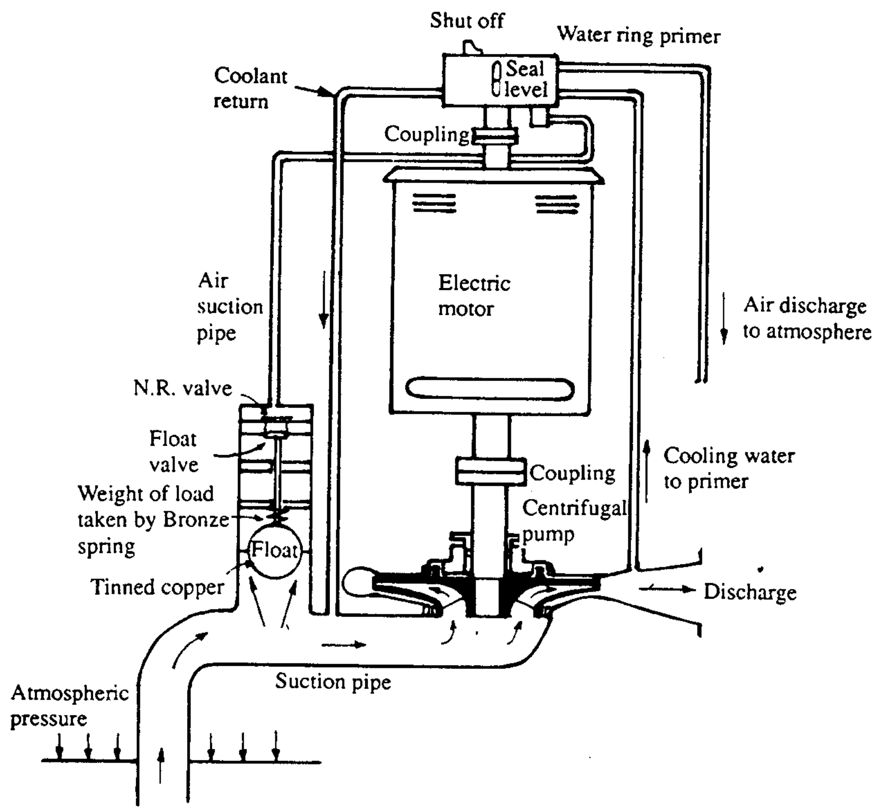
Liquid Ring Primer (i)



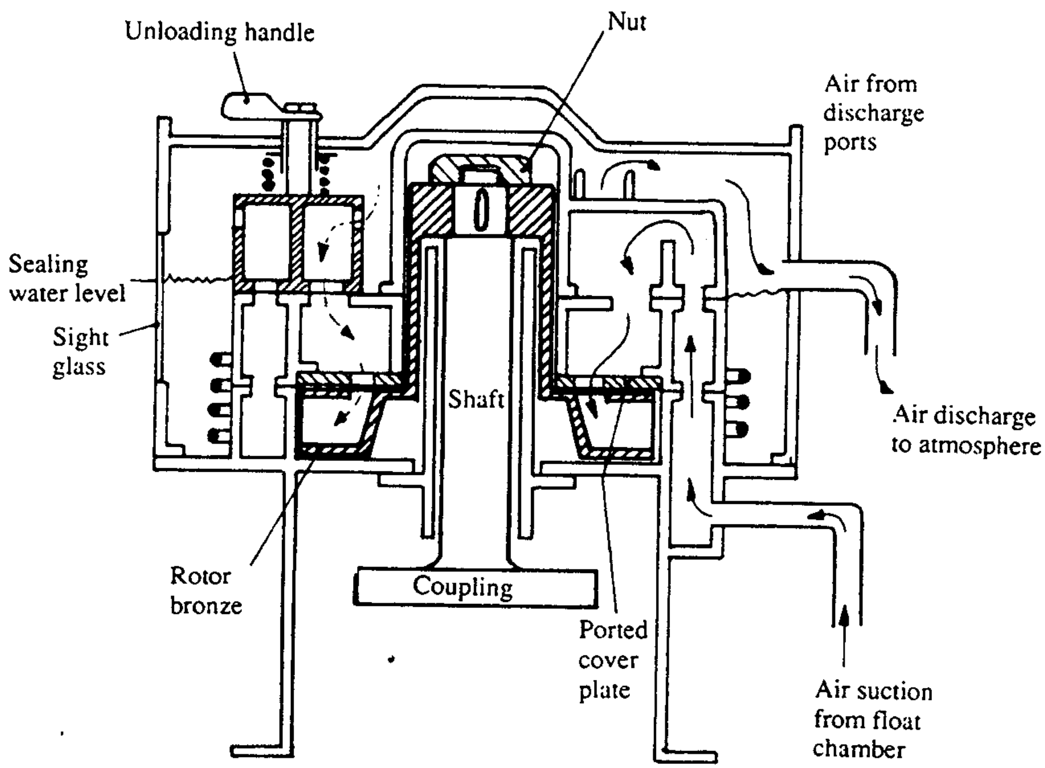
Liquid Ring Primer (ii)



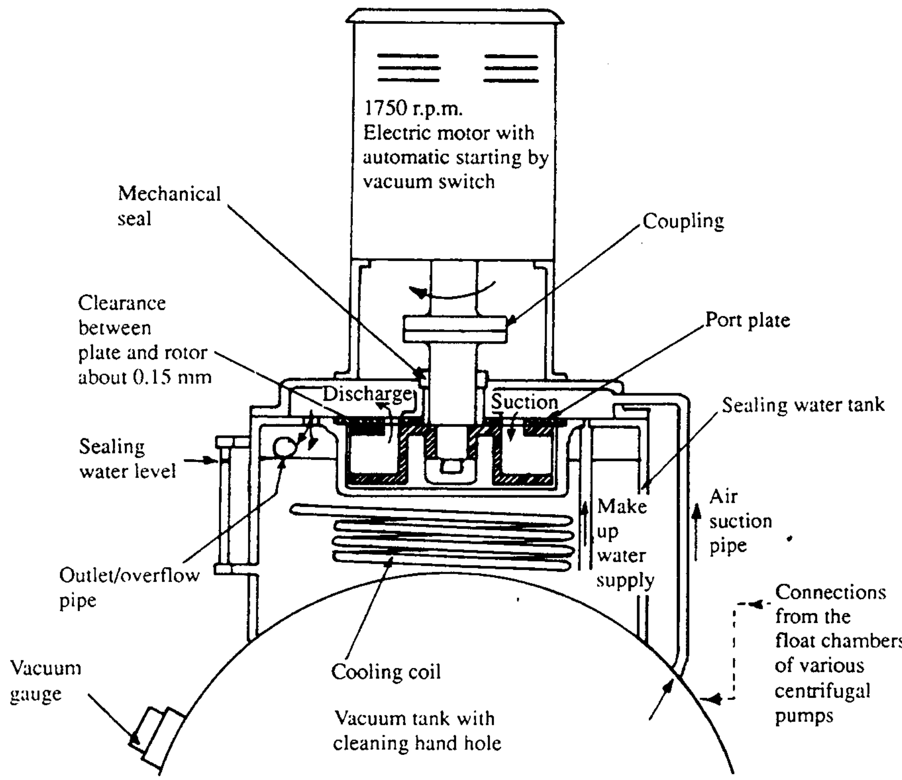
Centrifugal Pump With Primer



Detail Of Liquid Ring Primer



Liquid Ring Primer For A Central Priming System



Axial Flow Pumps

An axial flow pump uses a *screw propeller* to axially accelerate the liquid.

The outlet passages and guide vanes converts the *kinetic energy* of the liquid into *pressure energy.*

Pump casings are either split horizontally or vertically for access to propeller

A mechanical seal is fitted to the shaft to prevent leakage.

Axial Flow Pumps (continued)

A tilting type thrust bearing is fitted on the drive shaft.

The prime mover maybe either an electric motor or steam turbine.

Axial Flow Pump Applications

Used where large quantities of water is required at low head. For example, *condenser circulating.*

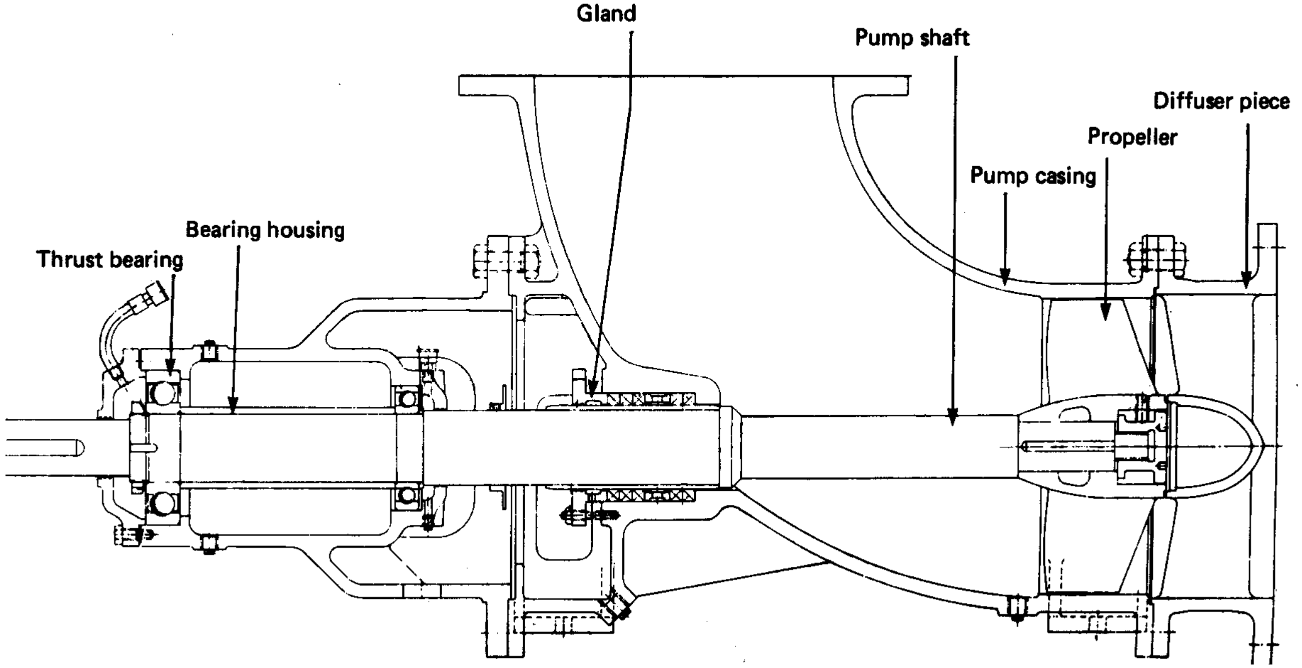
Suitable for supplementary use in *condenser scoop systems* since pump will offer little resistance to flow when idling.

Axial Flow Pump Advantages

The efficiency is equivalent to a low lift centrifugal pump.

Higher speeds enable a smaller driving motor to be used.

Axial Flow Pump



Displacement Pumps

The displacement pumping action is achieved by the reduction or increase in volume of a space causing the liquid (or gas) to be physically moved.

The method employed is either a *piston* in a cylinder using a reciprocating motion, or a rotating unit using *vanes, gears, or screws*.

Air operated *diapragm* pumps are also classified as displacement pumps.

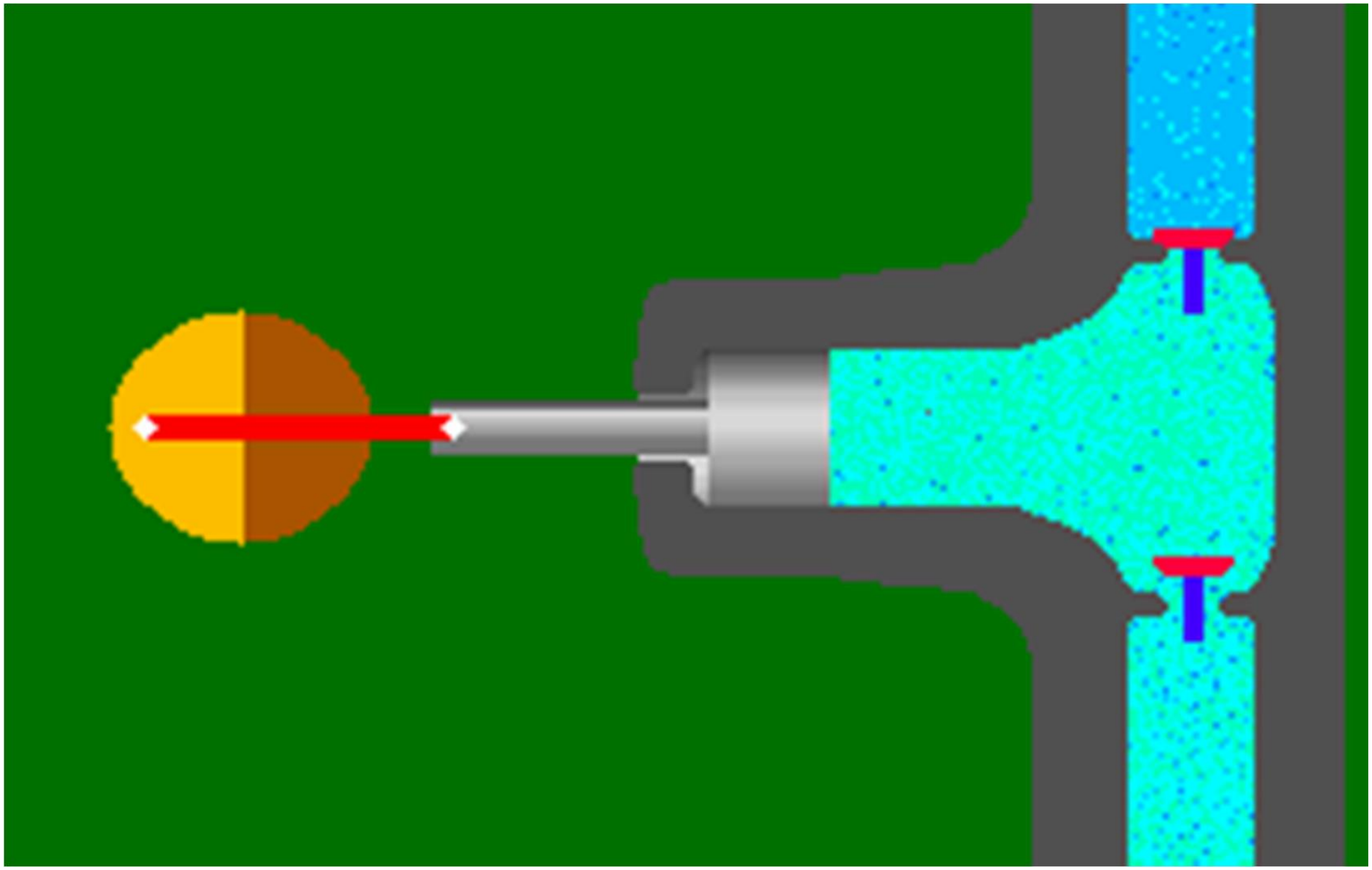
Piston Pump

The basic Piston Pump is very simple having just two valves and one stuffing box. In this example the reciprocating piston is driven back and forth by a rotating mechanism.

This piston pump uses suction to raise water into the chamber. The lower valve can be placed below water level.

The piston must be within about 8 metres of the water level, but the water can then be raised quite high.

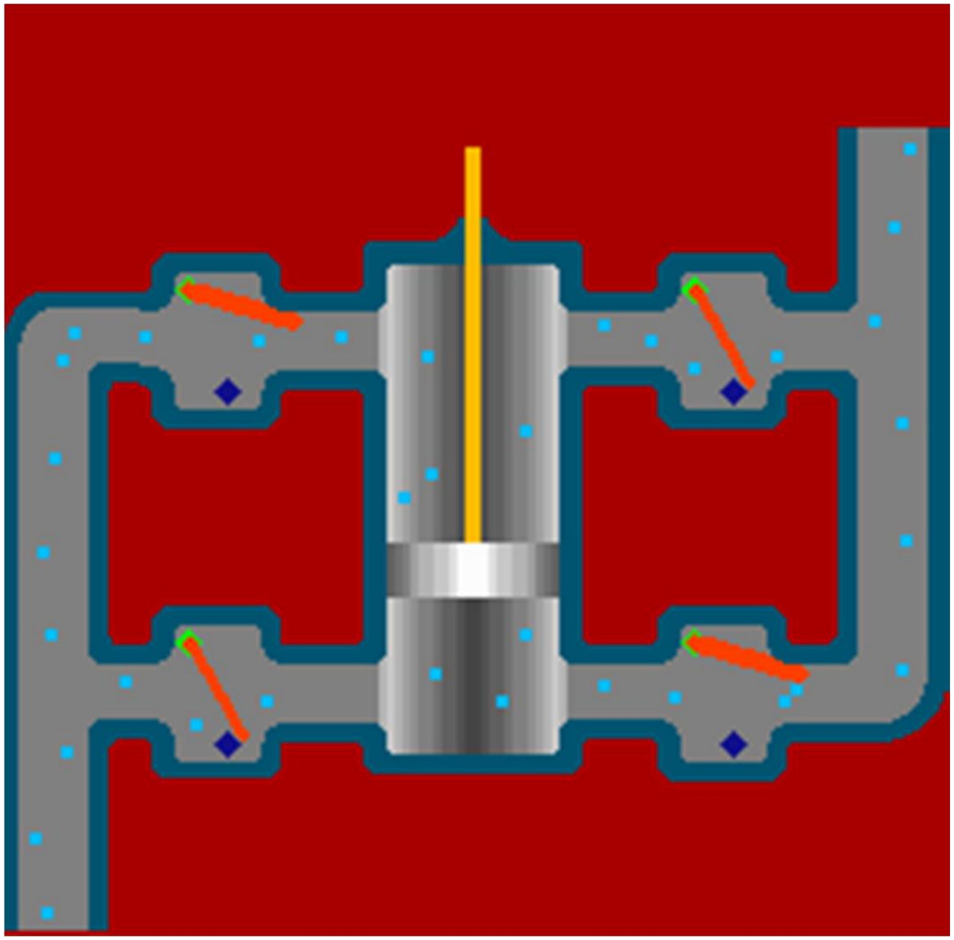
Piston Pump



Double Acting Piston Displacement Pump

This pump is more efficient than a single-acting force pump such as a simple Lift Pump or a hand-operated Bilge Pump. Each stroke of the piston fills one chamber and empties another, which nearly doubles the flow rate (less the volume of the piston rod) over a single-acting force pump. It also smooths the flow.
From the outside this pump can take many forms, but the basic principal of operation will be identical.

Double Acting Piston Displacement pump

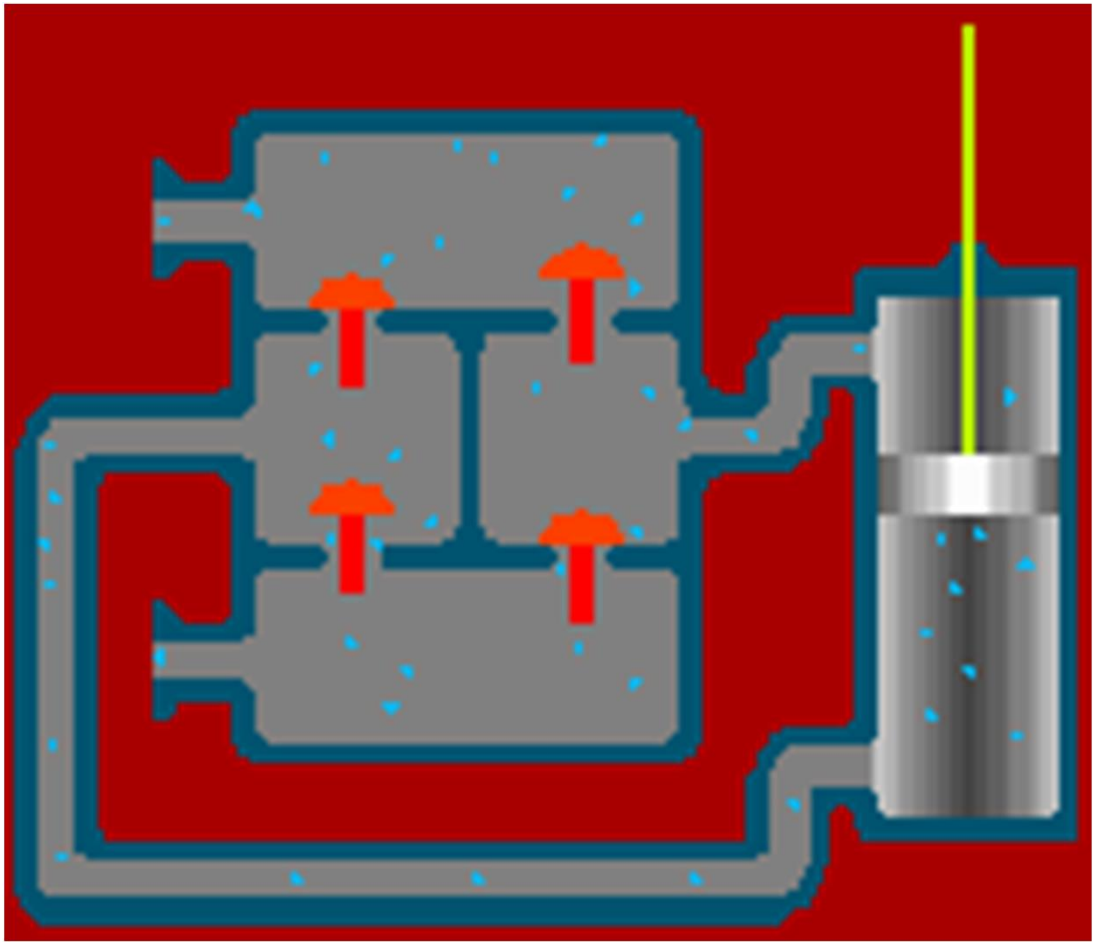


Simplex Pump (Double Acting)

The Simplex, or Single-Cylinder Double Acting, Pump was invented in 1840 by Henry R. Worthington. A Simplex Pump is a reciprocating pump. This pump has a single liquid cylinder which forces liquid out through the top outlet on both the in and the out stroke (here up and down.)
This basic type of pump might be used for Air Pumps, Boiler Feed Pumps, Fire, Bilge, and Fuel Oil Service. All might rely on this fundamental pump.

The DUPLEX PUMP is similar to the Simplex pump, having two pistons instead of one, providing smoother operation.

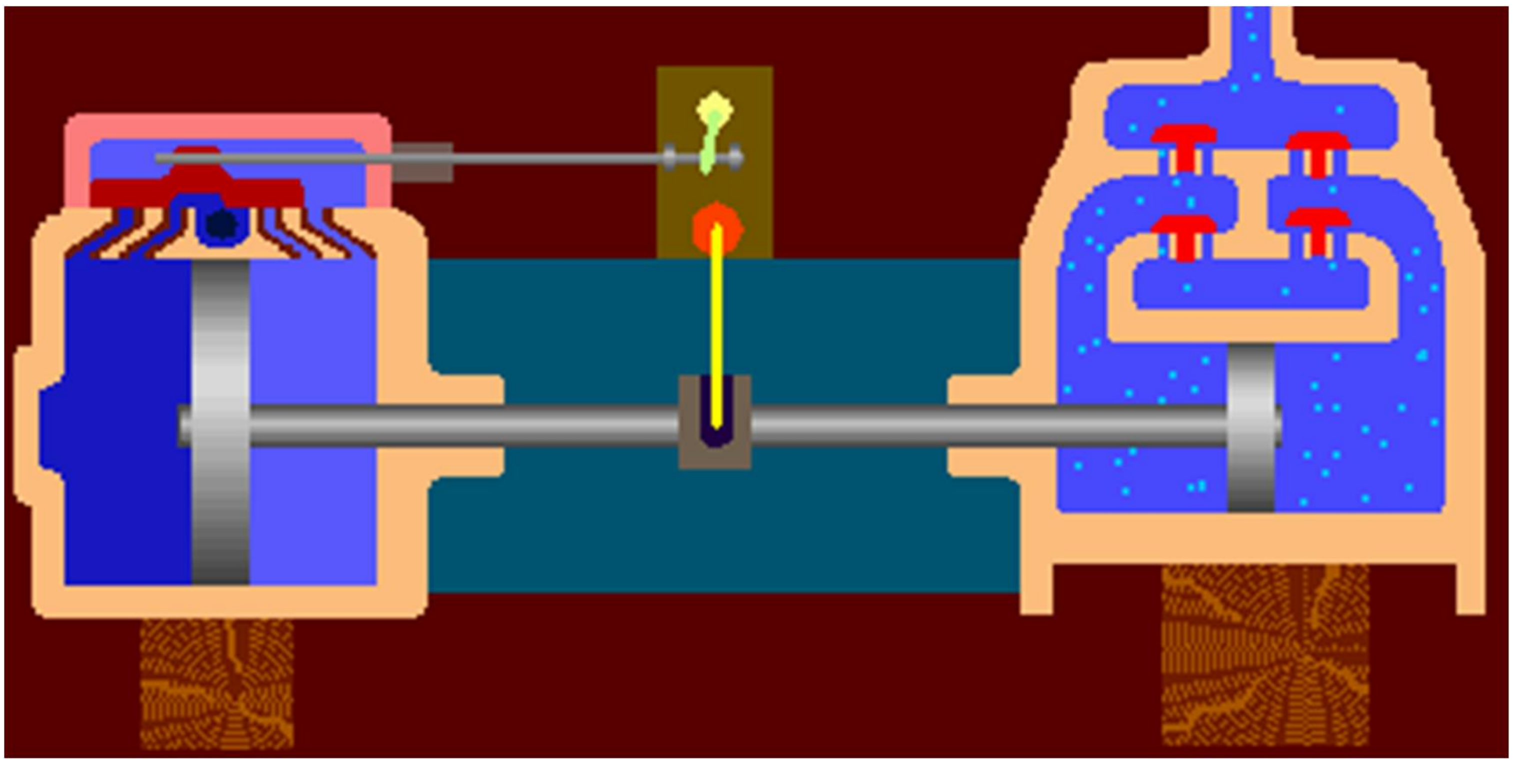
Simplex Pump (Double Acting)



Duplex Pump

The steam enters the system through the top chamber on the left where the steam valve slides back and forth over the various intake and exhaust pipes. The black hole just under steam valve is the exhaust vent for used steam.
The back pump controls the steam valve for the pump shown which controls, through the rocker arm in the middle, the steam valve for the piston in back.
On the water end of the pump, on the right here, the lower two valves are the intake valves and the upper valves are the discharge valves. A hydraulic accumulator is usually located just above the pump to smooth the flow and prevent water hammer.
As many as five sets of steam and water cylinders are linked together in various types of reciprocating steam pumps

Duplex Pump (One cylinder Shown)



Lobe Pump

This is a basically a type of Gear Pump but with lobes instead of gears. The three-lobe gear pump, like the <u>two-lobe</u> version, is commonly used to force high-pressure air into combustion compartments of a diesel engine.
The output of these pumps is more pulsed than the output of a gear pump because there are fewer teeth. The fluid is delivered in comparatively larger packets.
Gases are compressible (whereas liquids basically are not), therefore the three lobe and two lobe gear pumps work particularly well with gases, since the compressibility helps smooth the flow.
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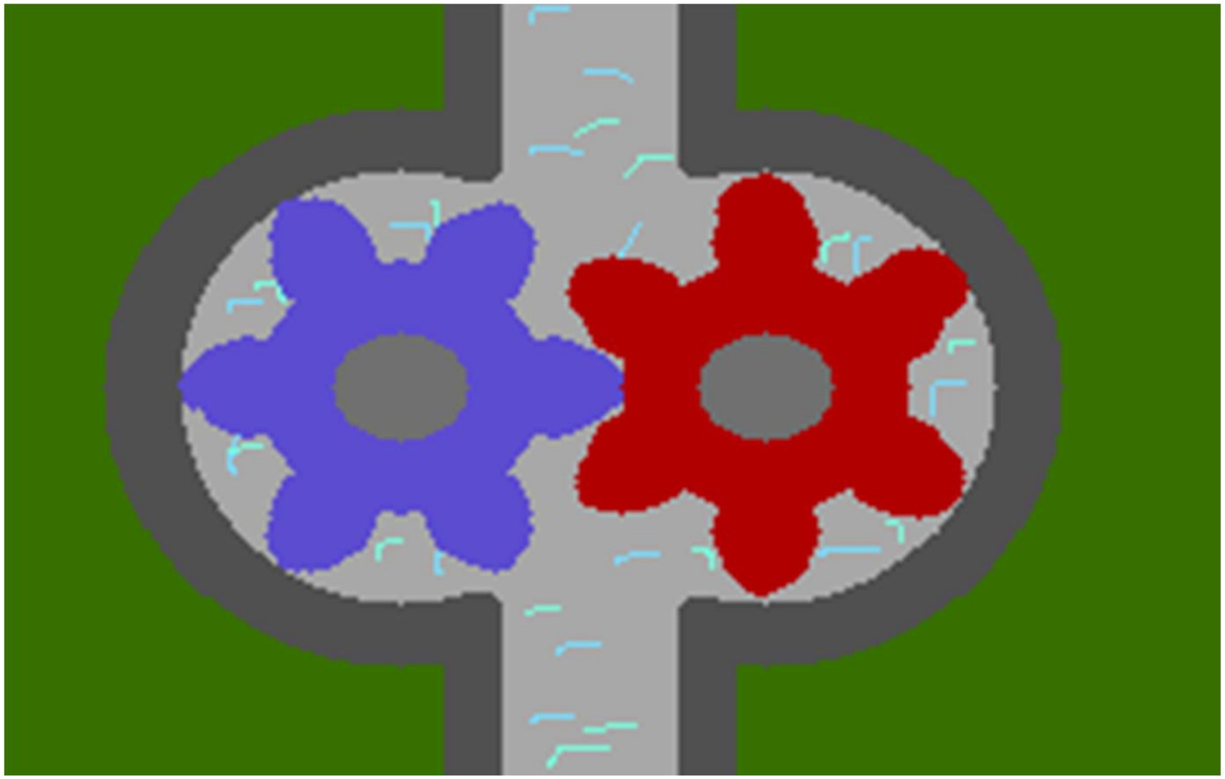
Lobe Pump

Gear Pump

This is a type of Rotary Force Pump. Gear pumps are extremely simple and reliable. Depending on the number of teeth, the "idler" gear might be driven directly by the "drive" gear. Generally with six or more teeth this is possible. In other cases an extra gear external to the pump drives the secondary gear at the same rate.
The teeth on Gear Pumps can be spur (straight), helical (slanted), herringbone, etc. There can be two, or more teeth on each gear -- twenty is not uncommon. The diameter of the gears and their thickness varies widely.
The many variations have different effects on the efficiency, strength, smoothness and other areas of operation.
This pump will pump in the reverse direction if you reverse the direction of rotation of the gears. Two pairs of valves can be added to make this a Reversing Gear Pump, which pumps in the same direction regardless of which direction the gears rotate.

Gear Pump



Radial Piston Pump

Radial Piston Pumps can produce a very smooth flow under extreme pressure. Generally they are variable-displacement pumps. In variable models, flow rate changes when the shaft holding the rotating pistons is moved with relation to the casing (in different models either the shaft or the casing moves.) Output can also be varied by changing the rotation speed.

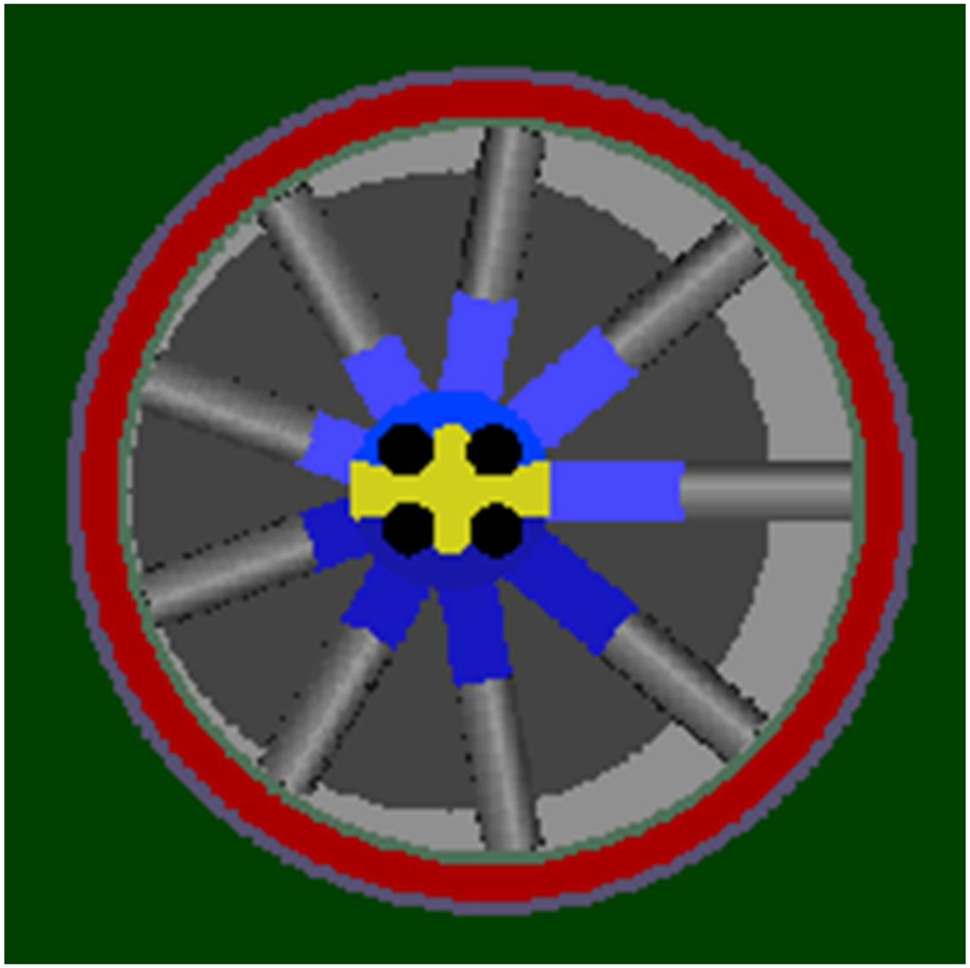
In this animation if the casing (shown in red) is moved to the left, the flow rate would decrease to zero. If it is moved even further to the left the flow would reverse.

Input in this animation is through the two black holes near the centre below the "Pintle" (shown in yellow). Output is through the top two black holes, above the pintle. Higher pressure areas are indicated with a lighter blue fluid color.

The pistons are usually forced out by springs. They are forced back in, expelling liquid, by the casing.

An odd number of pistons is always used to smooth the hydraulic balance. These pumps revolve at speeds up to about 1200 RPM.

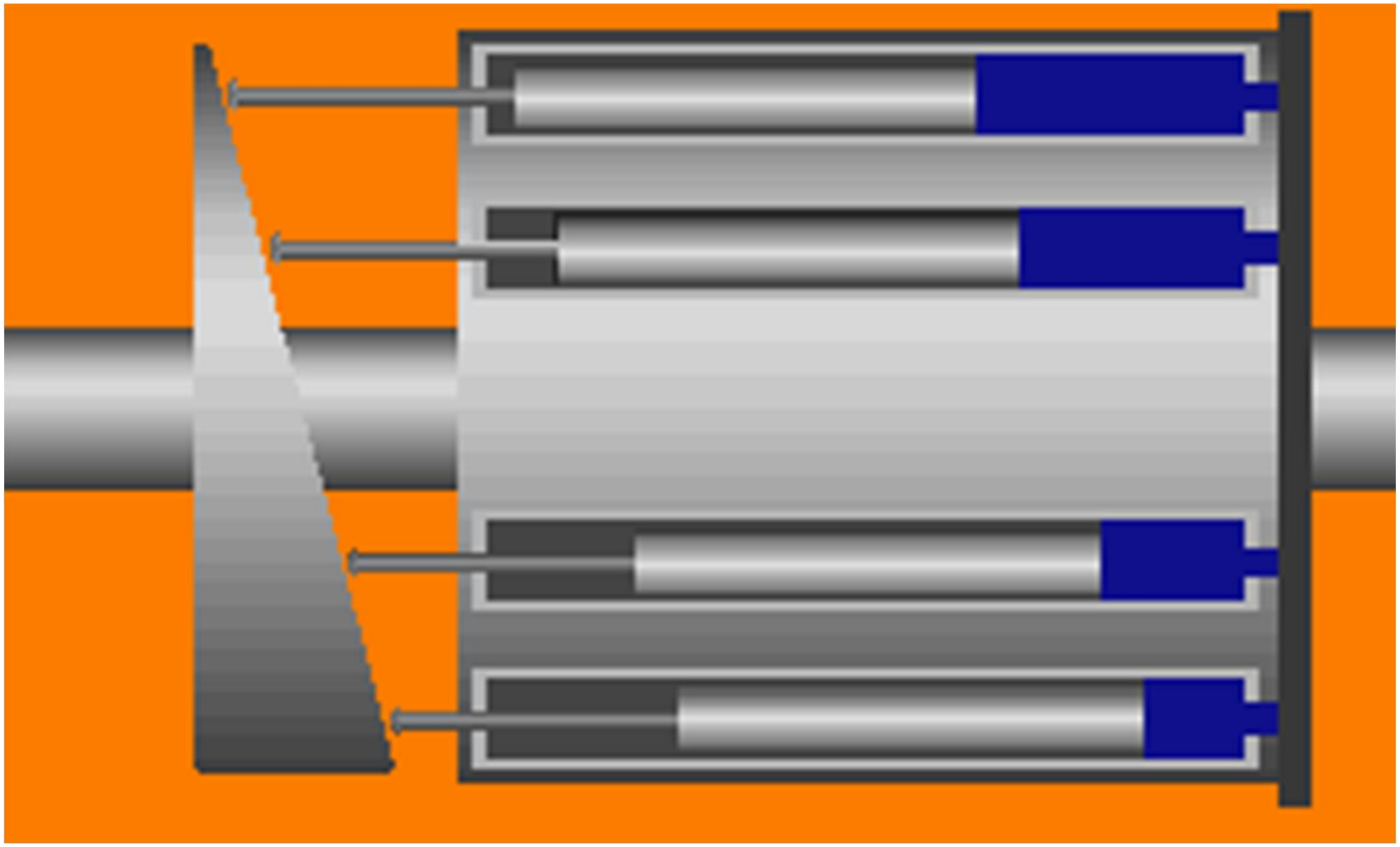
Radial Piston Pump



Swash Plate Pump

Swash plate pumps have a rotating cylinder containing pistons. A spring pushes the pistons against a stationary swash plate, which sits at an angle to the cylinder. The pistons suck in fluid during half a revolution and push fluid out during the other half. Shown on edge on the far right in the animation is a dark stationary disk. It contains two semi-circular ports. It is shown again in a head-on view below, right.
These ports allow the pistons to draw in fluid as they move toward the swash plate (on the backside and not shown here) and discharge it as they move away.
For a given speed swash plate pumps can be of fixed displacement like this one, or variable by having a variable swash plate angle. The greater the slant the further the pistons move and the more fluid they transfer.

Swash Plate Pump



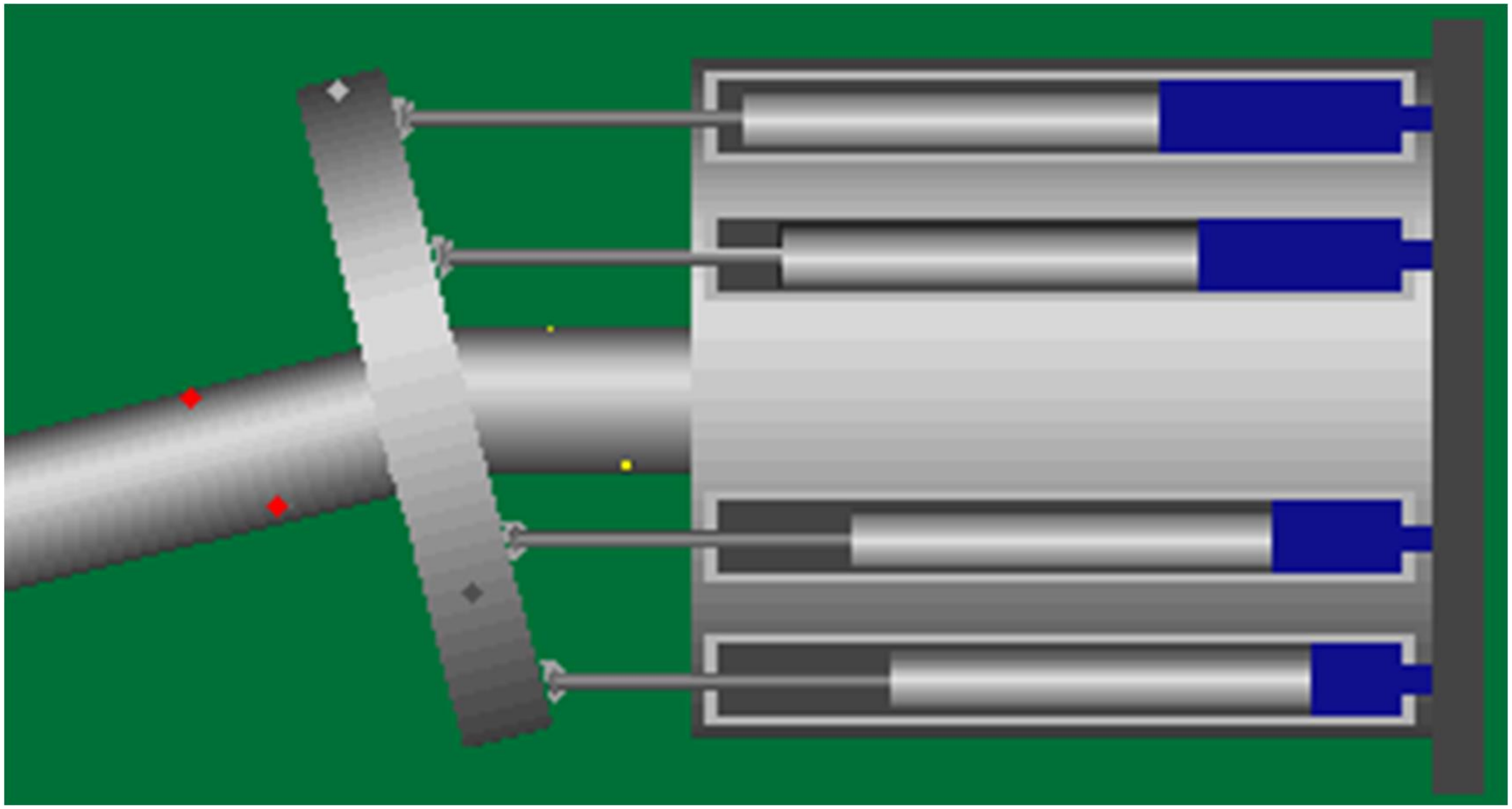
Bent Axis Swash Plate Pump

In this pump, the pistons are at an angle to the drive shaft and Thrust Plate. The piston block shaft is connected to the drive shaft by a universal joint, not shown. The drive shaft, thrust plate, piston block shaft, and piston block all revolve. The connecting rods are attached to the thrust plate and revolve with it, unlike the swash plate pump where the piston rods slide past a stationary swash plate.

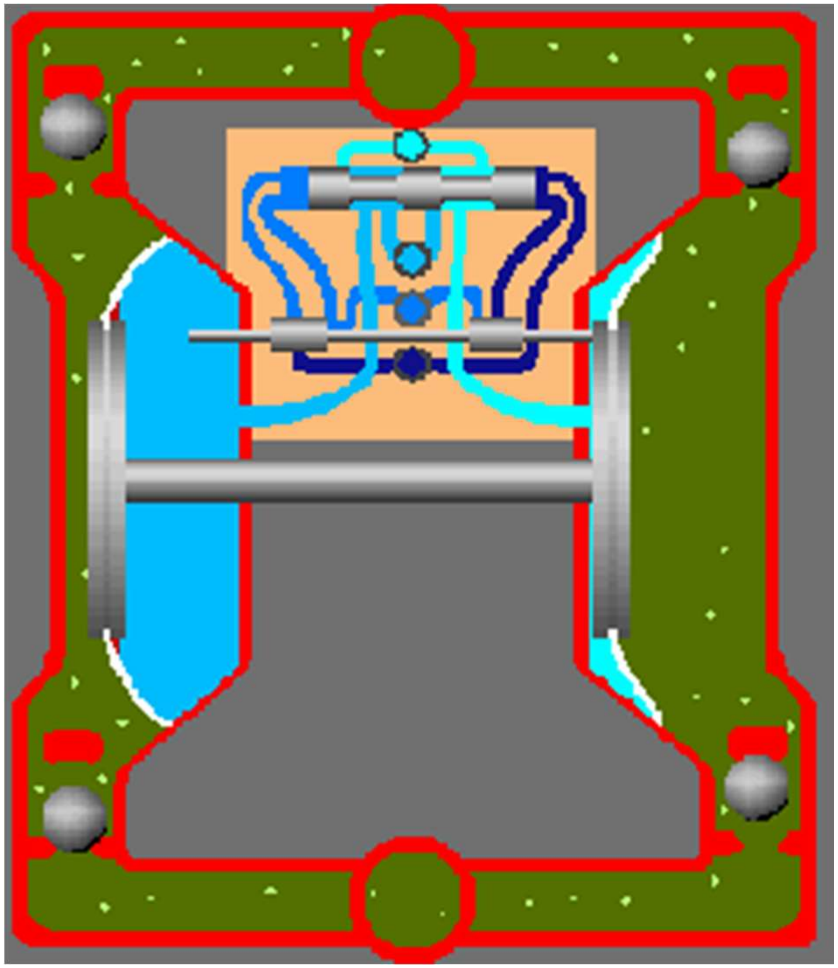
The outlet ports are semi-circular holes in the Valve Plate, shown on the far right of the animation on edge and in a head-on view below, right.

As the pump revolves, half the pistons suck in fluid as they pass over the intake port. The other pistons discharge their fluid through the outlet port.

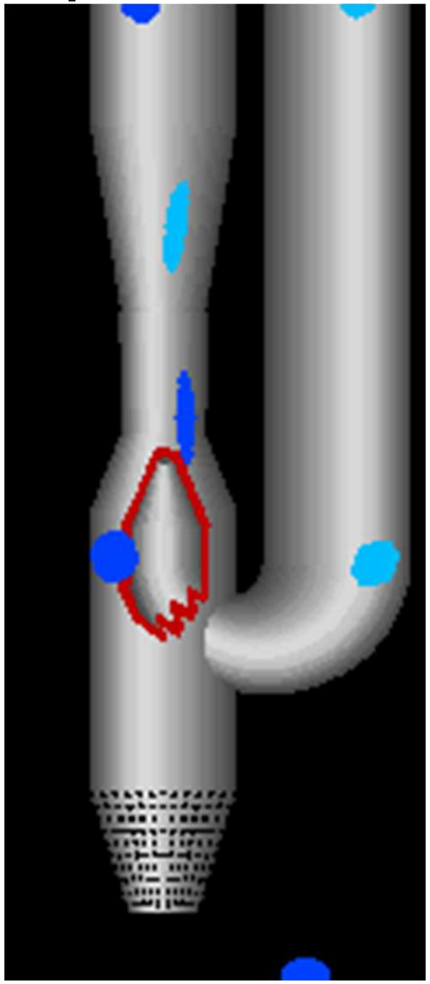
Bent Axis Swash Plate Pump



Diaphragm Pump



Jet Eductor



At the end of the pressure pipe the water is accelerated through a cone-shaped nozzle at the end of the pressure pipe, shown here within a red cutaway section. Then the water goes through a Venturi in the Suction Pipe (the pipe on the left). The venturi has two parts: the Venturi Throat, which is the pinched section of the suction tube; and above that is the venturi itself which is the part where the tube widens and connects to the suction pipe.
The venturi speeds up the water causing a pressure drop which sucks in more water through the intake at the very base of the unit. The water goes up the Suction Pipe and through the impeller -- most of it for another trip around to the venturi.

The End