Centrifugal and Positive Displacement Pumps

Website: www.ttetraining.ltd.uk

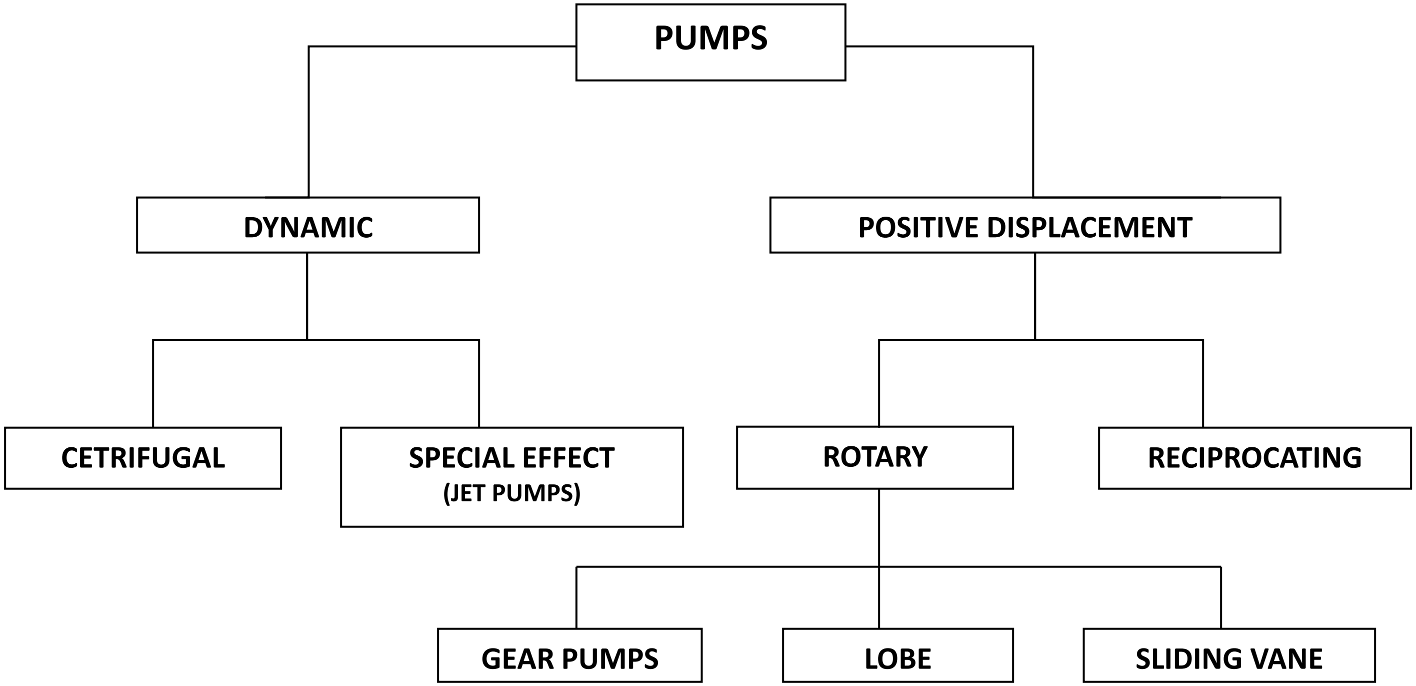
Objective of pumping system

Transfer liquid from source to destination

Circulate liquid around a system

Pump Classification

Classified by operating principle



Dynamic pumps

How they work

Rotating impeller converts kinetic energy into pressure or velocity to pump the fluid

Two types

Centrifugal pumps: pumping water in industry it is said they account for 75% of pumps installed

Special effect pumps: specialized conditions

Centrifugal Pumps

Impeller
Main rotating part that provides centrifugal acceleration to the fluid

Number of impellers = number of pump stages

Impeller classification: direction of flow, suction type and shape/mechanical construction

Shaft
Transfers torque from motor to impeller during pump start up and operation

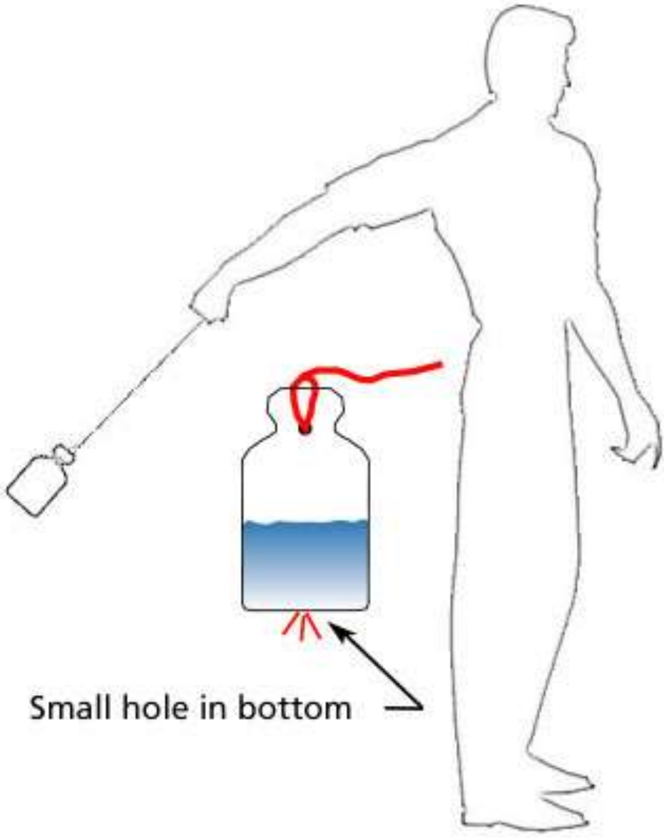
Centrifugal pump main components

Prime movers: electric motors, diesel engines, air system
Piping to carry fluid
Valves to control flow in system
Other fittings, control, instrumentation

End-use equipment

Heat exchangers, tanks, steam boilers, hydraulic machines, etc.

Centrifuge Force



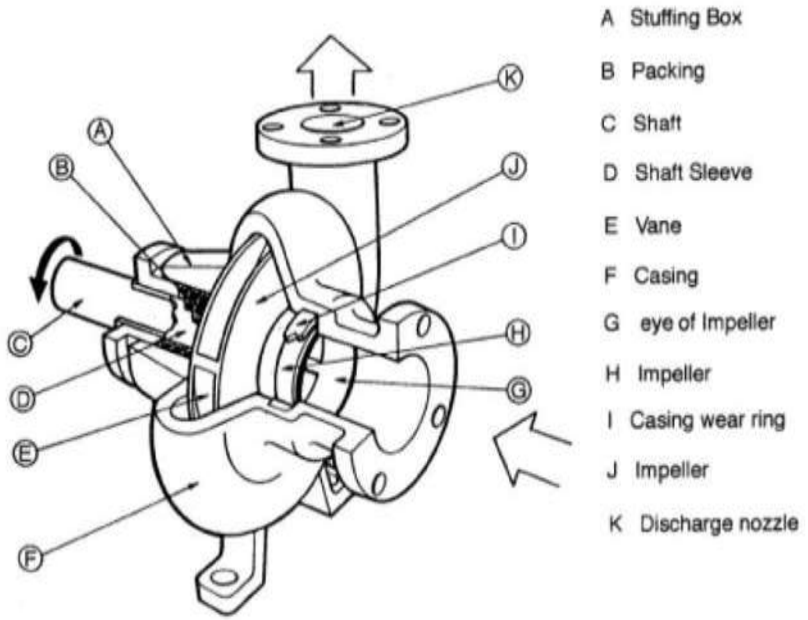
What is a centrifugal pump?

Three basic components:

Volute, casing, body or Diffuser

Impeller or impellers

Driver (motor)



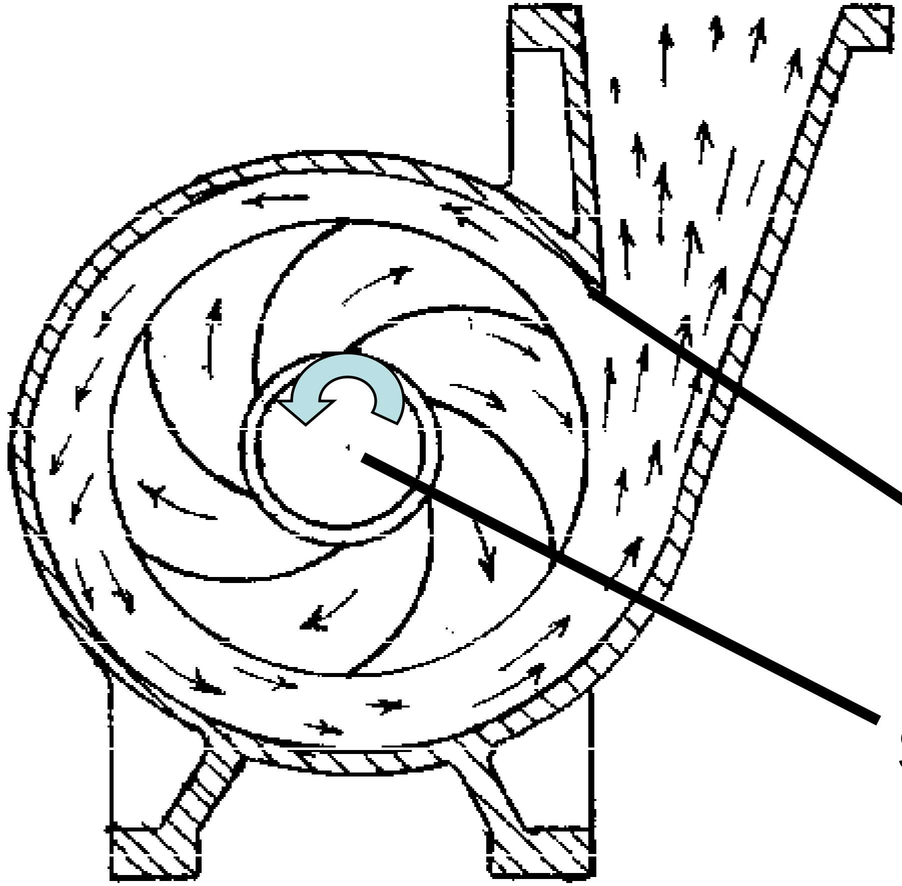
Centrifugal Pumps How do they work?

Liquid forced into impeller
Vanes pass kinetic energy to liquid: liquid rotates and leaves impeller

Volute casing converts kinetic energy into pressure energy

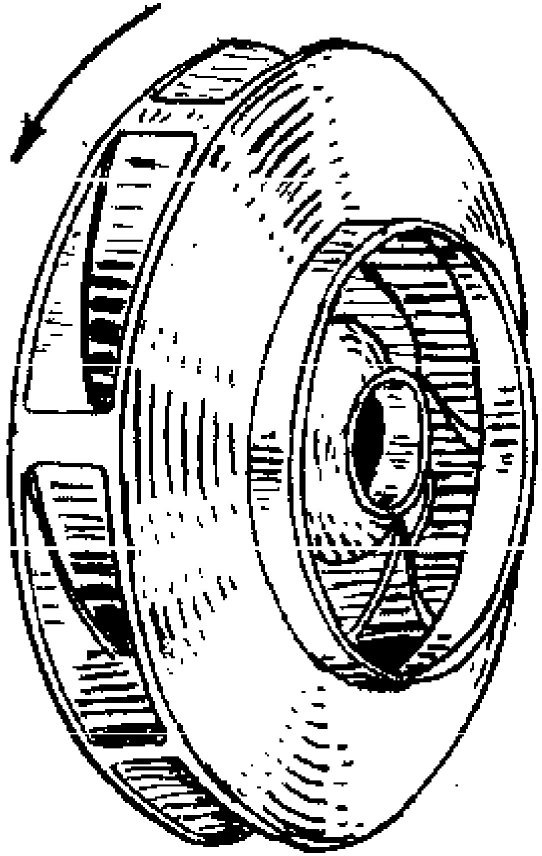
Impeller and volute

Arrows represent the direction of water flow



Pump Impeller

Direction of
rotation



A typical single sectioned suction impeller

Single suction impeller

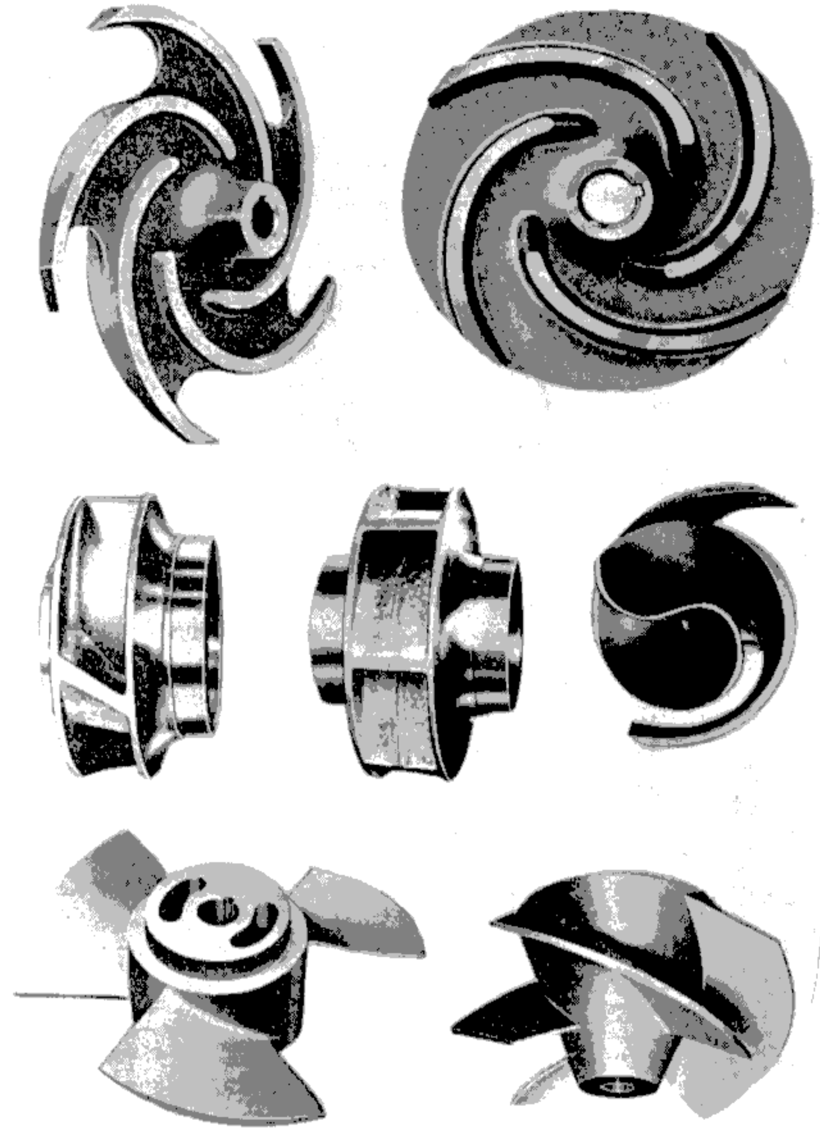
Impeller Types

- Open
- Semi-open

- Closed
  - Single suction
  - Double suction
- Non-clogging

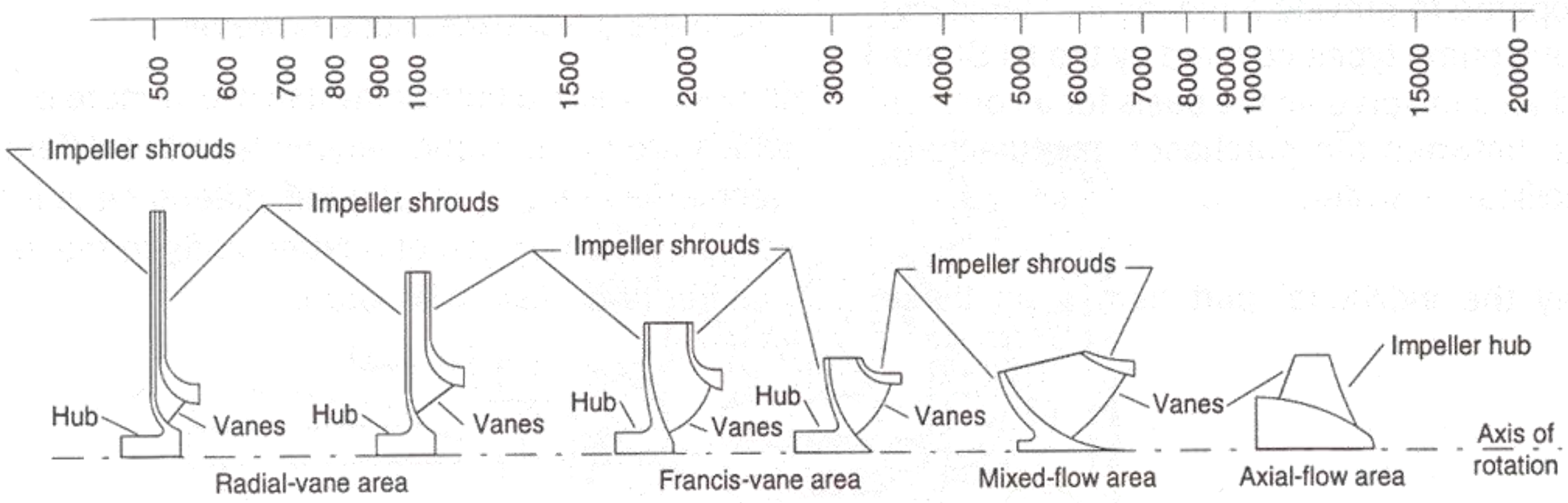
- Axial flow

- Mixed flow

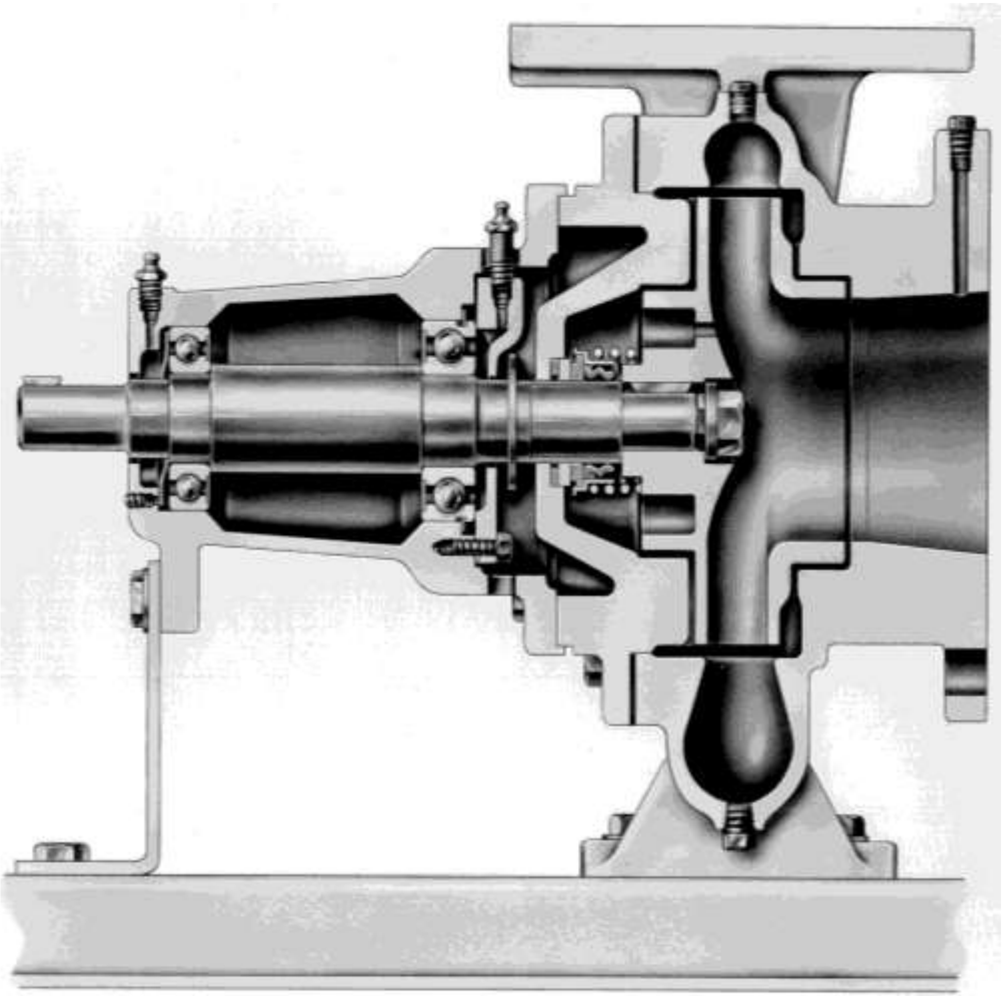


Impeller Profiles

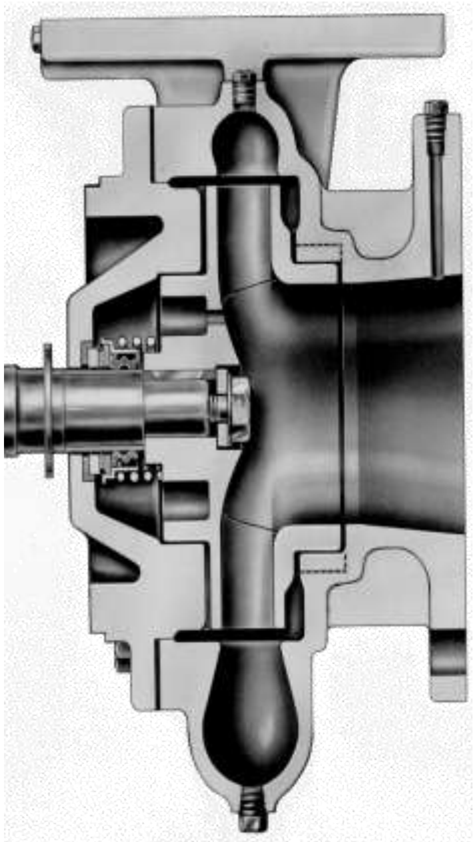
Speed of rotation



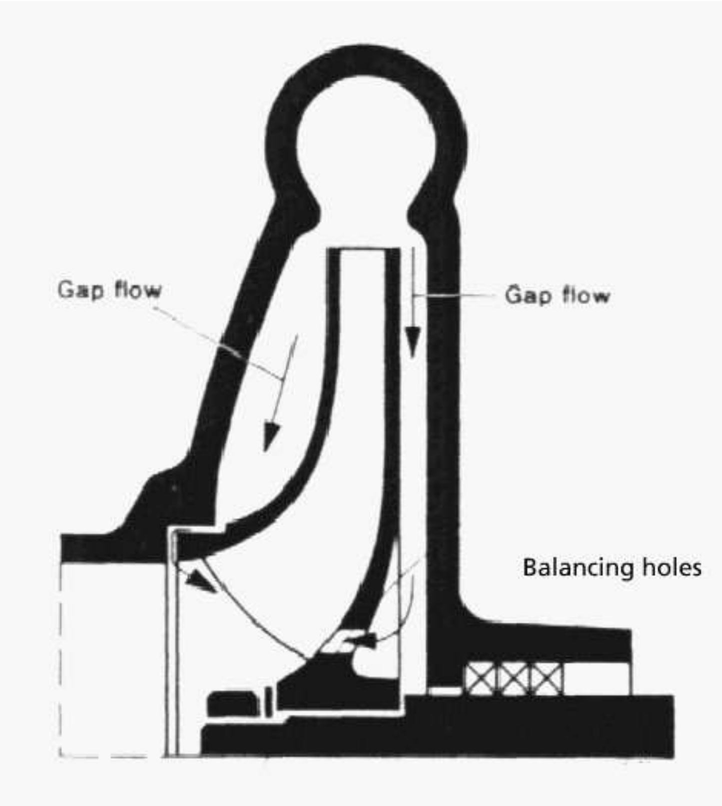
Section view of a typical pump



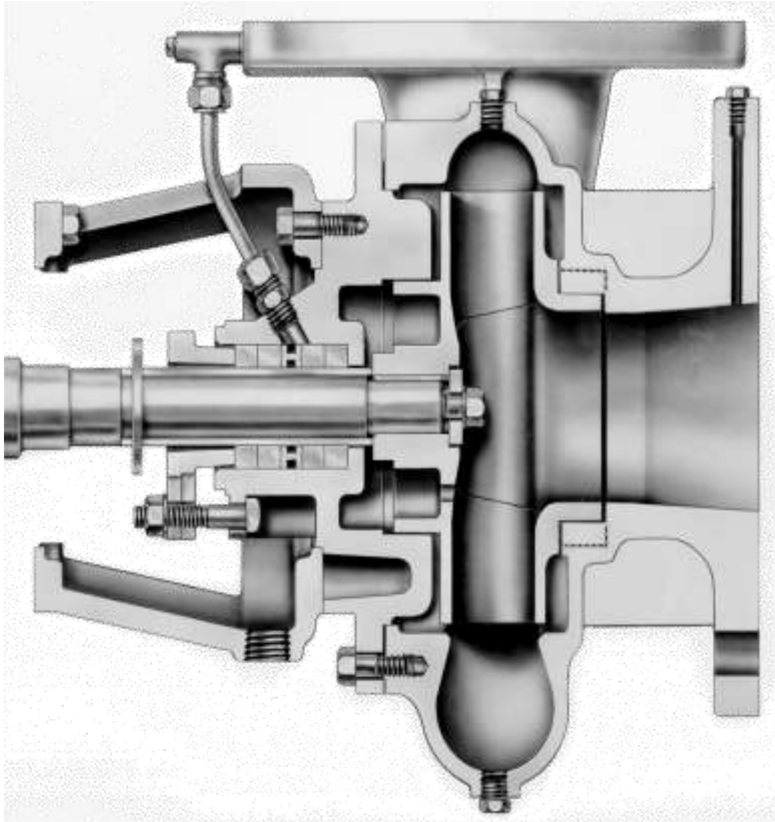
Standard closed impeller with balance holes fitted with a mechanical seal



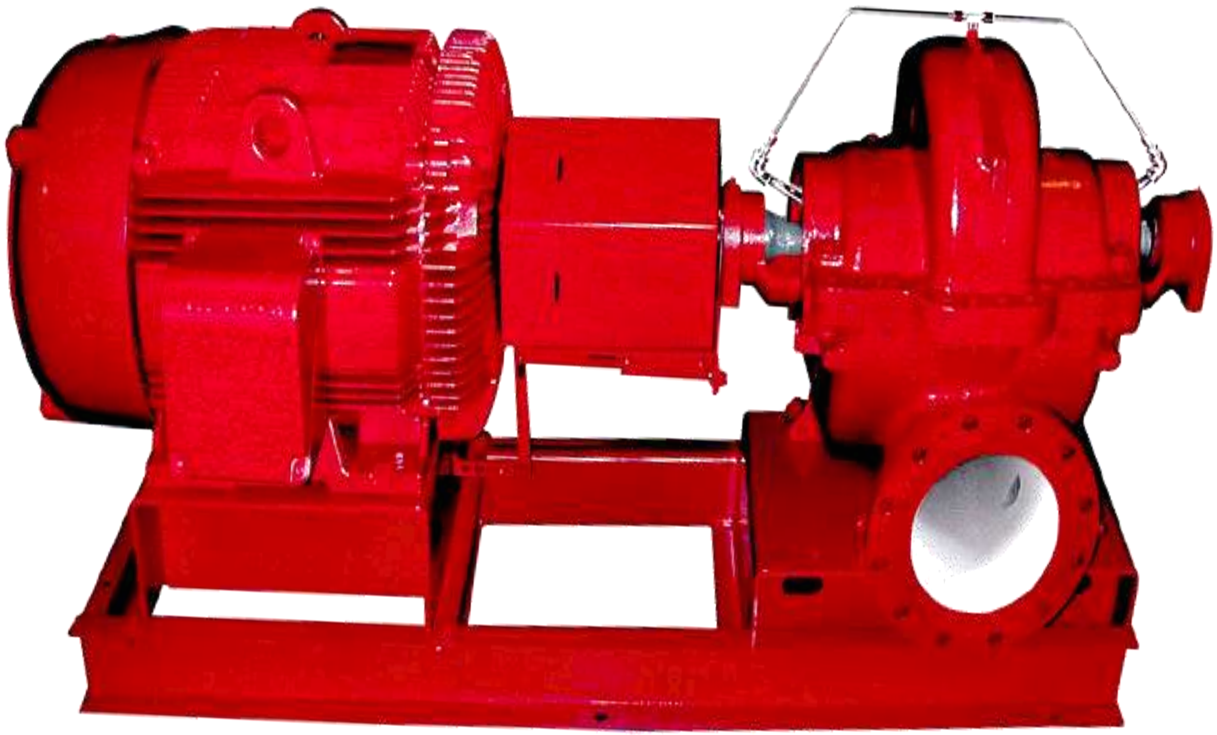
The flow of liquid around a closed impeller to help balance the forward thrust of the rotating element, but without a separate wear-ring system the effect is very ineffective.



Standard closed impeller with balance holes fitted with a packed gland stuffing box seal

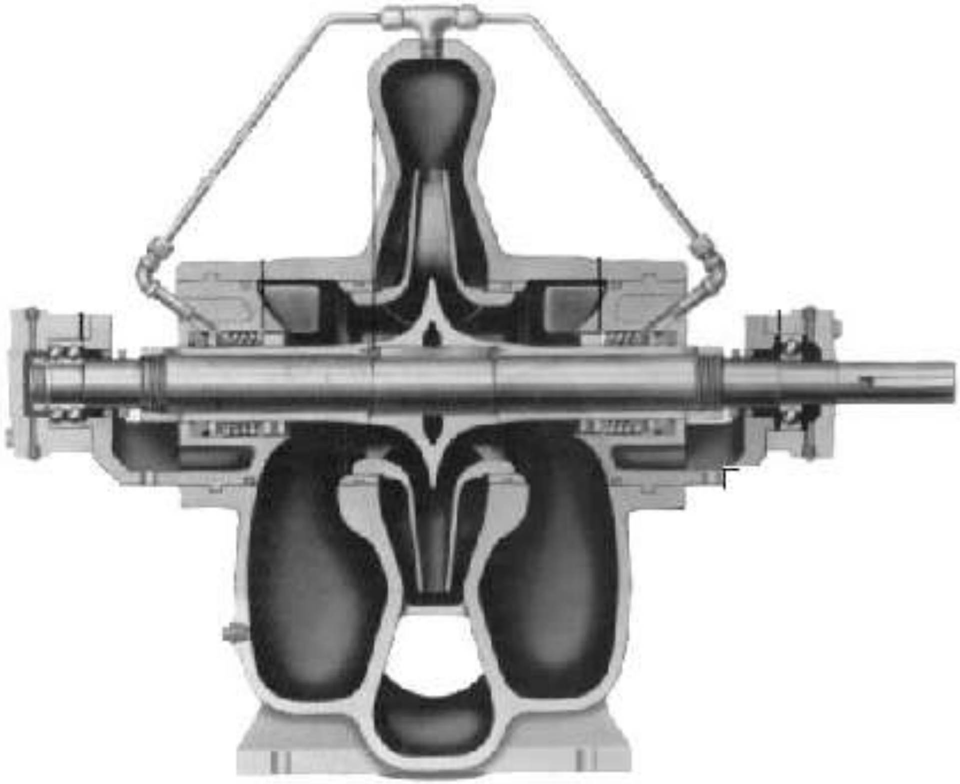


Double Suction Pump



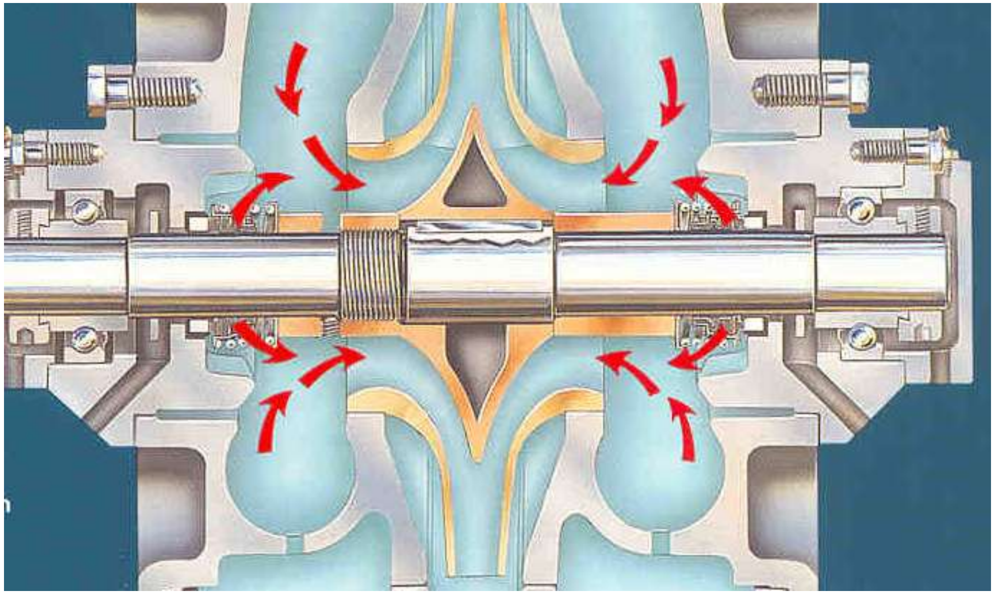
Double Suction Split Case Pump

The design permits removal of upper half for inspection, maintenance without disturbing piping or motor and the pump is radially and axially balanced for long life.



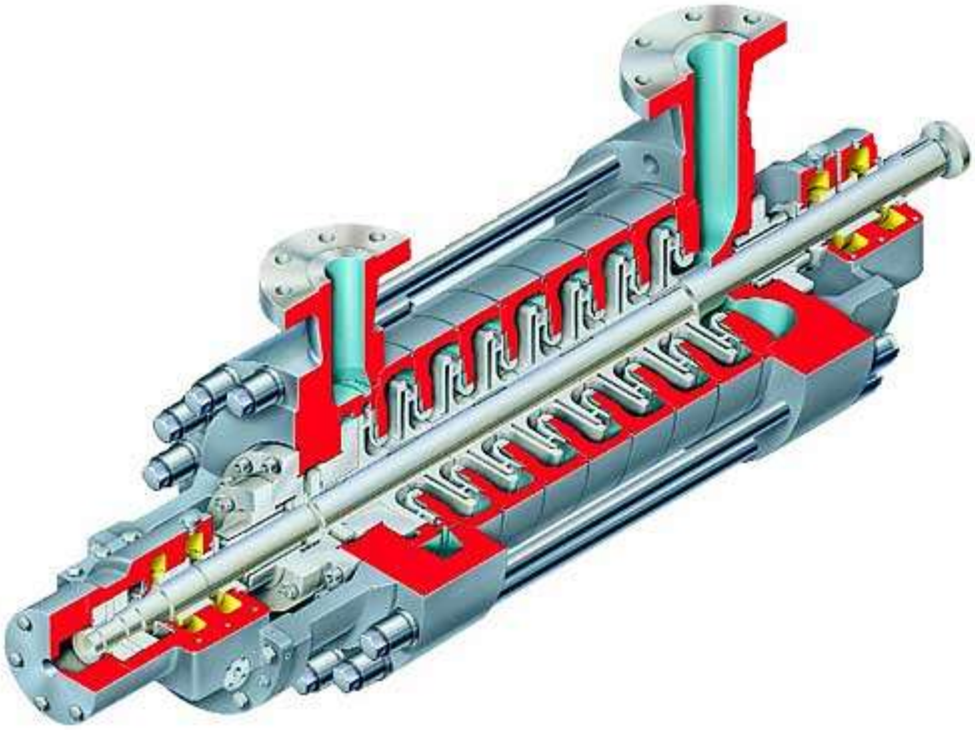
Split case Suction Flow

The inlet area of the fluid to the impeller is larger (each side of the impeller) than single inlet pumps and therefore these pumps can cope with low or negative suction applications.



Radially Split Case Multistage Pump

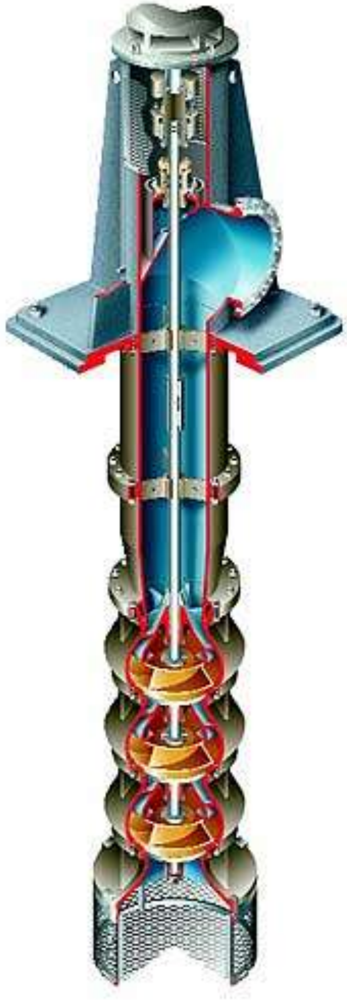
Mainly used in boiler feed, high pressure process, and some high pressure cleaning applications. The design develops a very high axial thrust that has to be contained by using a shaft mounted thrust piston at the discharge end pump. The pumps are always protected by a minimal flow setup.



Horizontal Split Case Multistage Pump

Turbine Vertical Multistage Pump

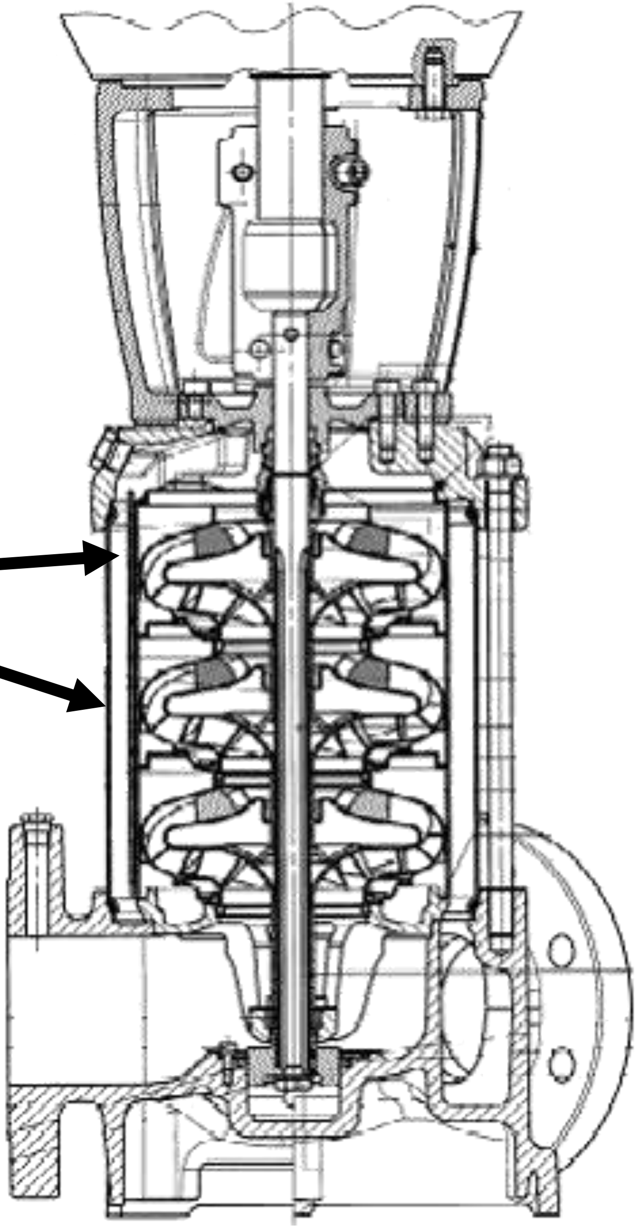
This type of pump has a large range of capacity and head. It has the advantage that it reduces a negative suction head in difficult site pumping applications. Designed for ease of maintenance and can have stages added quite easily.



Multi-stage vertical pumps

Multi-stage pump

“Diffusers



Close-Coupled Pump

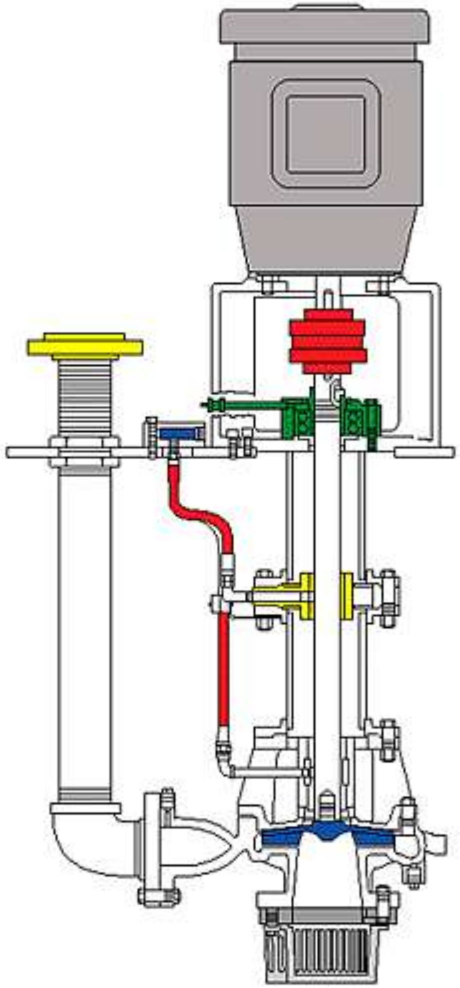
General use in commercial or Small industrial type pump cheap and sometimes see as uneconomical to repair. Compact design, motor mounted to pump, no need for additional coupling or base plate.

Large, Line Mounted Pump

Mainly used in the petrochemical, chemical and refining industries.
Mounts in and is supported by the piping system.
Eliminates the foundation and grouting costs.

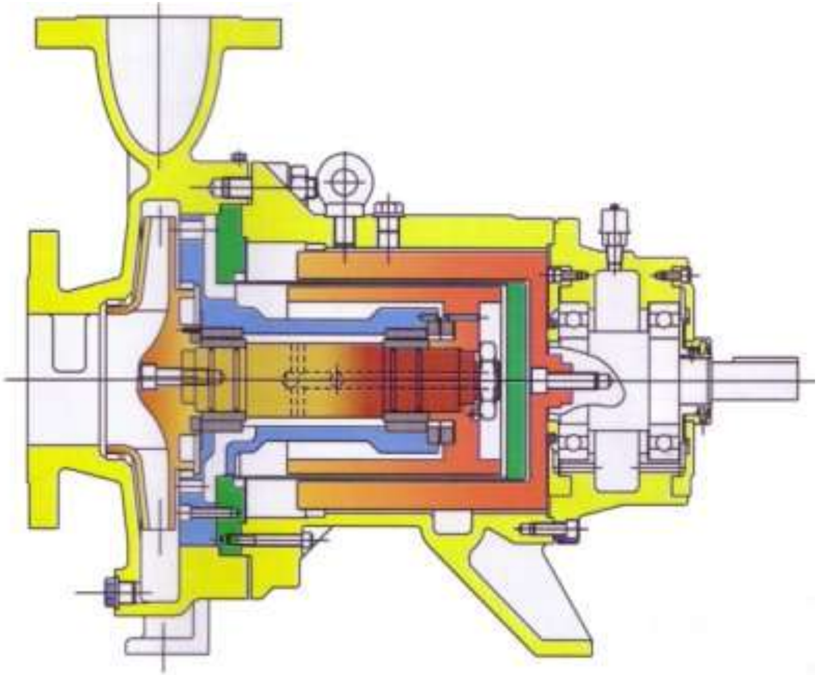
Wet Sump Pump

This pump is designed to be suspended from an tank top by means of a drop pipe and can be used for pumping hazardous or other solids laden liquids. This is also called a cantilever-shaft pump and has the feature that there are no seals or bearings below the liquid level.



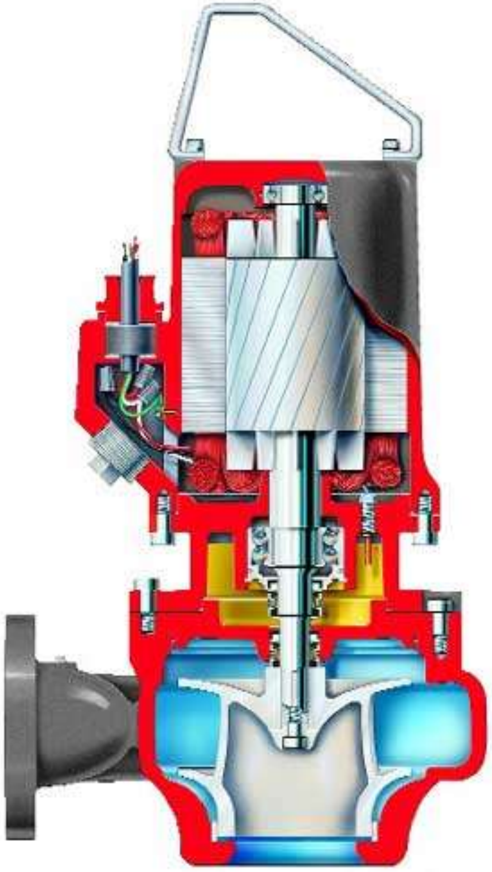
Can or Magnetic Drive Pump

This is a sealless volute type pump and is used for fluids that are corrosive, volatile, high temperature, solids bearings liquids, radioactive and toxic fluids. This type of pump is used where leaks, even the smallest, cannot be tolerated



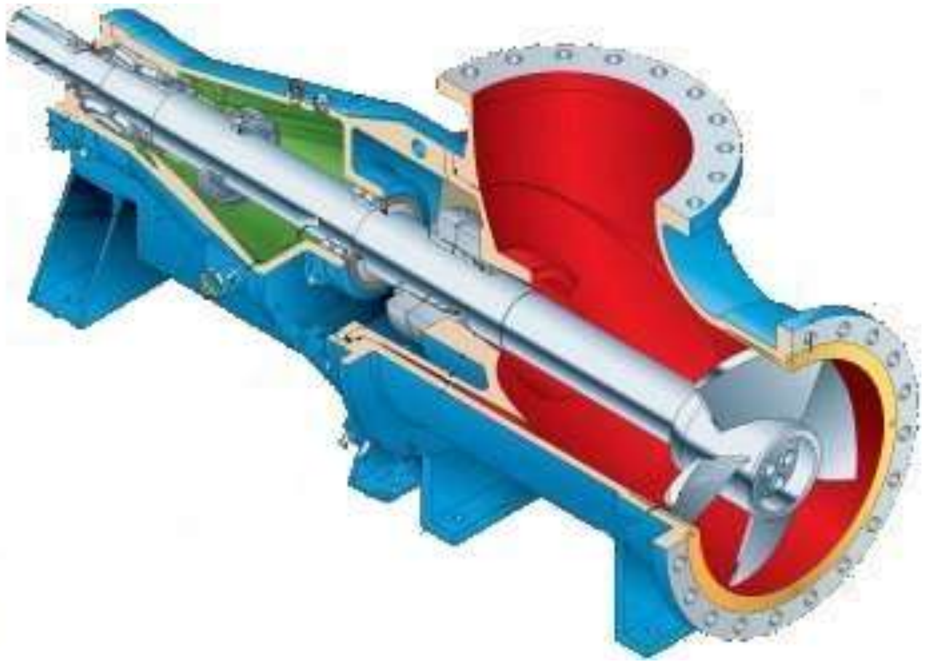
Submersible or Sump Pump

This is the typical submersible sump pump. They resemble a wet-pit volute pump except that the motor also is submerged. They are very popular for controlling water level in sumps in all types of industry. They are usually connected to a flexible hose and are usually easily removed for maintenance.

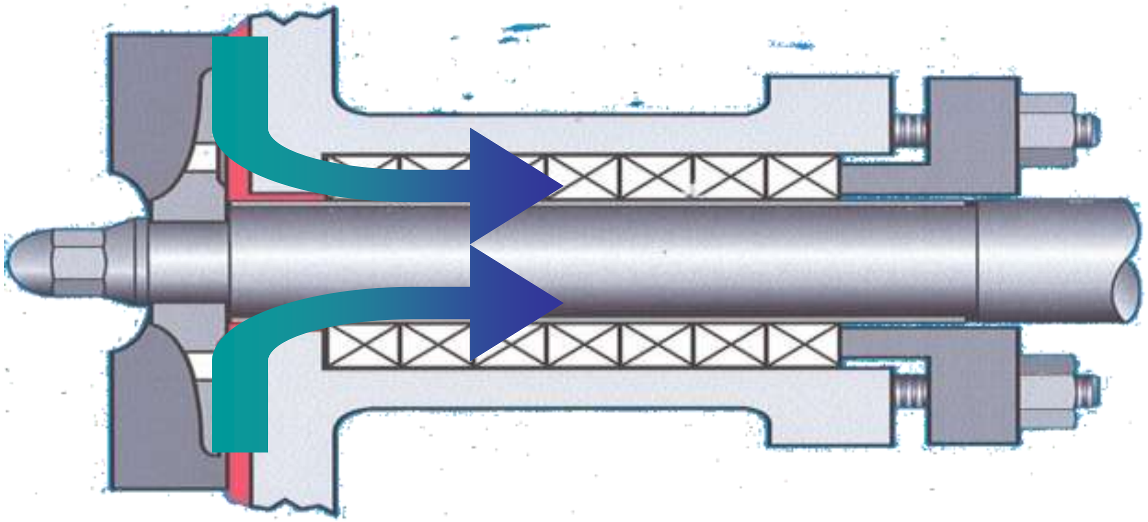


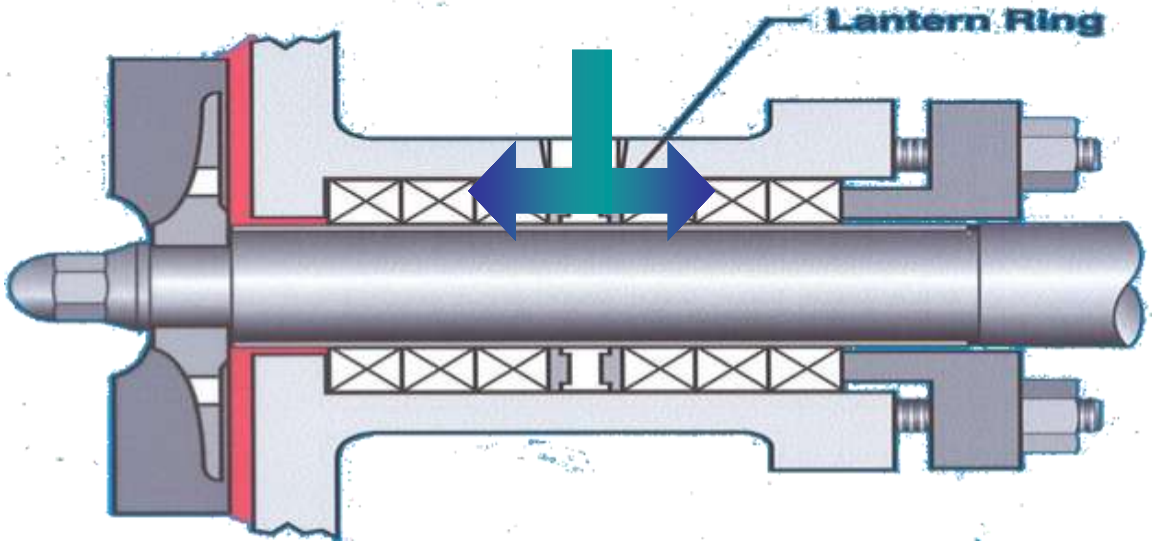
Axial Flow Jet Type Pump

This style of pump is used for high flow, low head purposes. Manly used in very special function in the chemical, mining, petroleum, pulp & paper and food general applications.

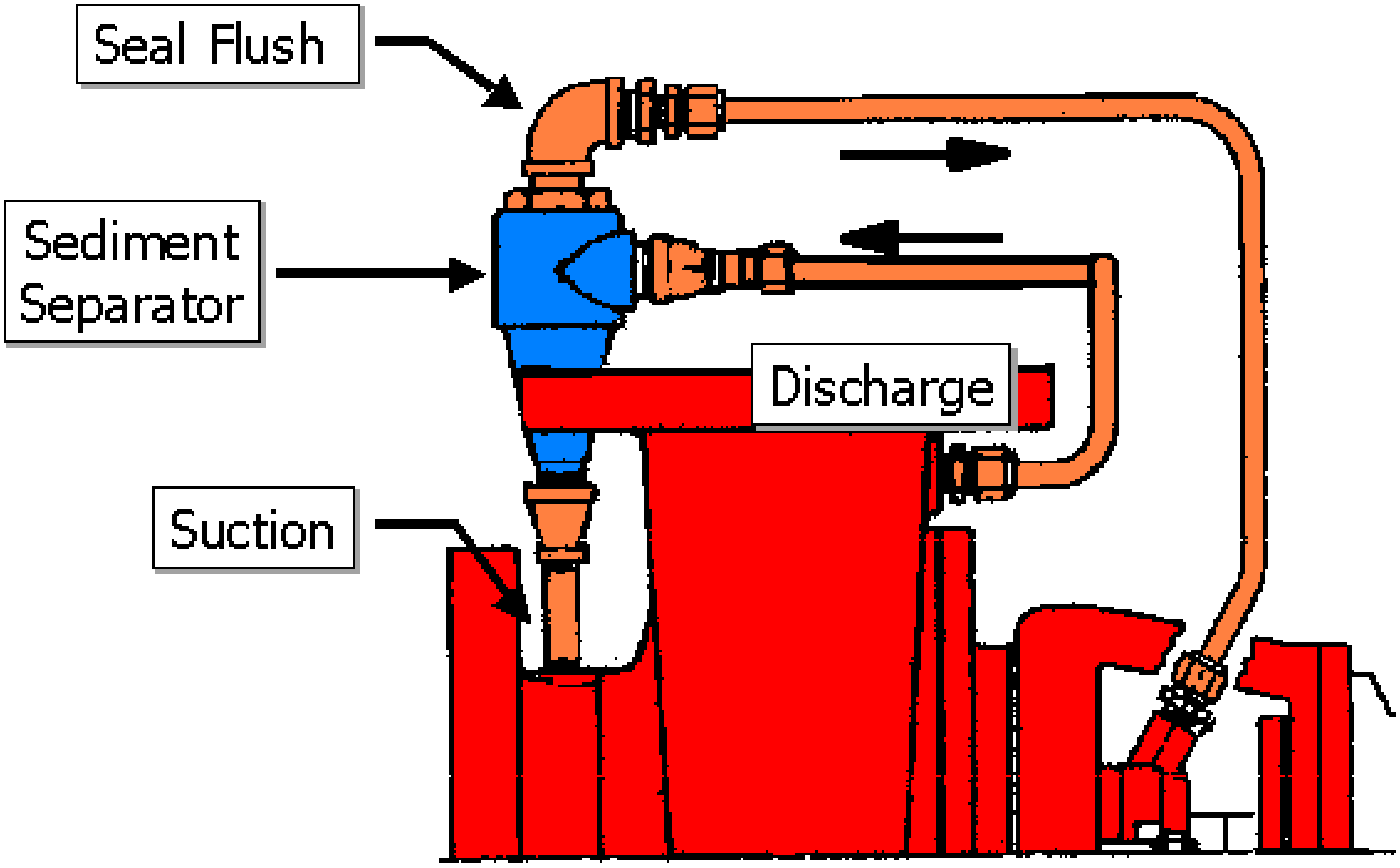


Packing Installation





Liquid-Abrasives Separator



Main Causes pump failure

CAVITATION

LACK OF FLUID

REVERSE ROTATION

CYCLING

COUPLING MIS-ALIGNMENT

IMBALANCE

CLOSED HEAD OPERATION

CAVITATION

Symptoms

1. The pump sounds like it is pumping rocks!
2. High Vacuum reading on suction line
3. Low discharge pressure/High flow
4. Power draw not as per manufacturers curve

CAVITATION

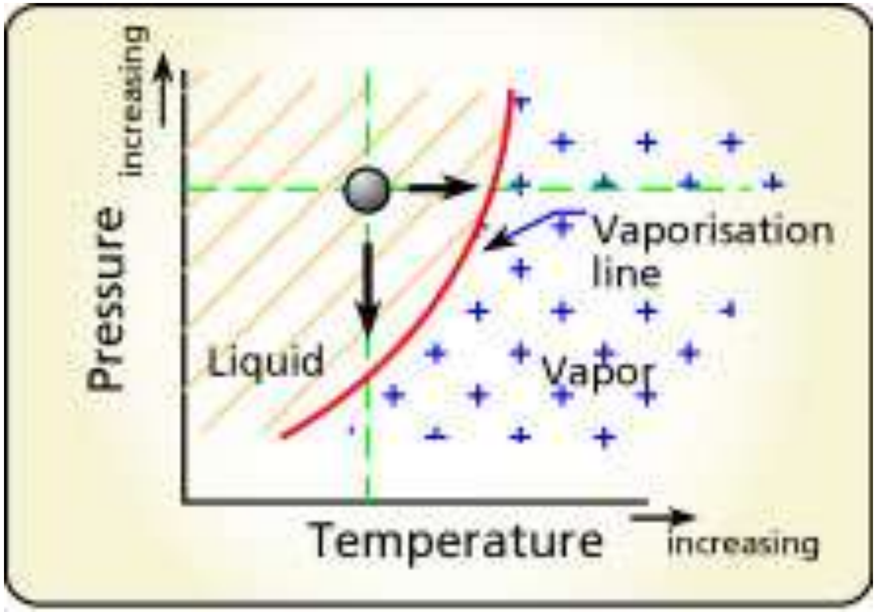
Causes

1. Clogged suction pipe
2. Suction line too long
3. Suction line diameter too small
4. Suction lift too high
5. Valve on Suction Line only partially open
6. Discharge pressure too low

CAVITATION

Beware of suction line problem such as vortex forming around the suction filter

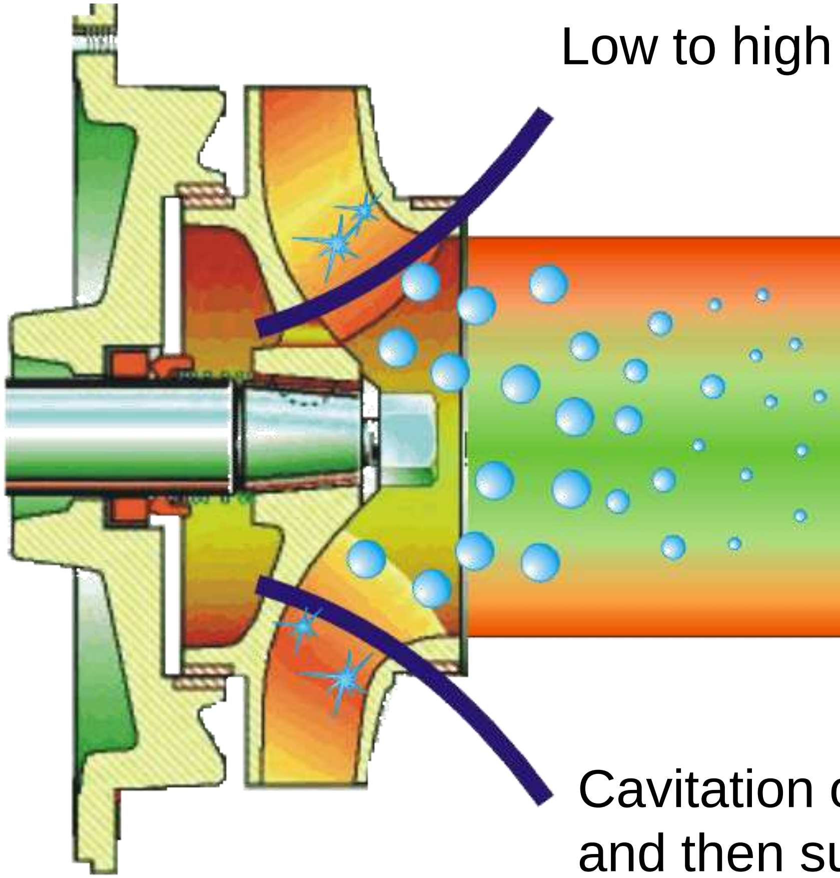
Suction Cavitation occurs when the pump suction is under a low pressure/high vacuum condition where the liquid turns into a vapour at the eye of the pump impeller.



This vapour is carried over to the discharge side of the pump where it no longer sees low pressure and is compressed back into a liquid by the discharge pressure. This imploding action occurs violently and attacks the face of the impeller.

High pressure

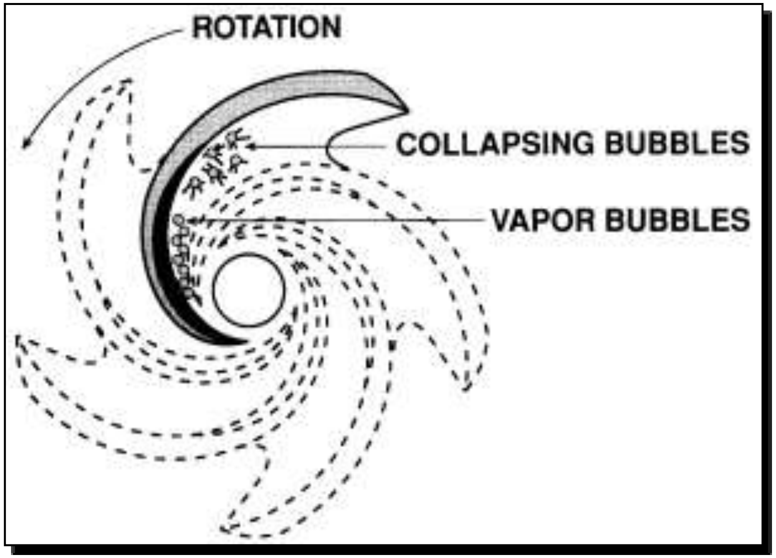
Low to high pressure transition



Low Pressure

Cavitation occurs when vapour bubbles form and then subsequently collapse as they move along the flow path of the impeller.

Implosion of gas or vapor bubble



Can be caused by gas or air entrained in the pumped liquid or by a phase change due to pressure fluctuations as the liquid passes through the impeller

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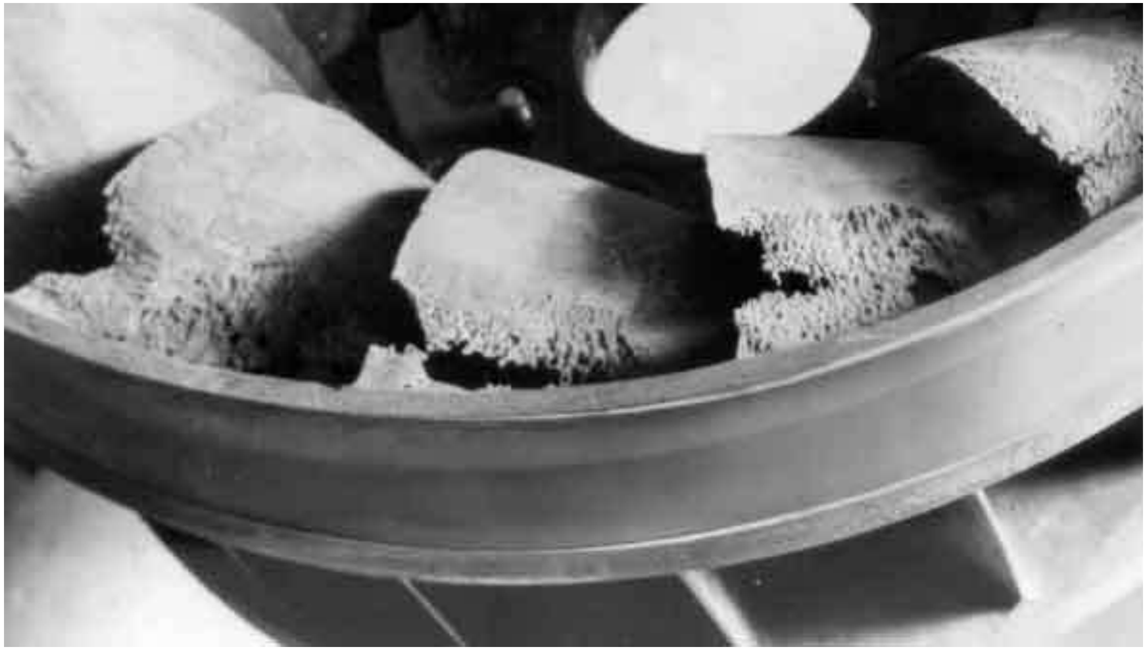
An impeller that has been operating under a suction cavitation condition has lost a lot of material from its impellor this will always lead to premature failure of pump



Examples Of Cavitation

Vertical multistage pumps with pressed impellers do not exhibit the same failure mode as cast components.

Typical failure is bearing and shaft failure

CAVITATION REMEDIES

1. Remove debris from suction line
2. Move pump closer to source tank/sump
3. Increase suction line diameter
4. Decrease suction lift requirement
5. Install larger pump running slower which will decrease the Net Positive Suction Head Required by the pump(NPSHR)
6. Increase discharge pressure
7. Fully open Suction line valve

Centrifuge Pump Commissioning Procedure

1. Ensure the bearing arrangement has an oil supply
2. Check that all auxiliary feeds are working (seal or gland flush, bearing oil heating/cooling feeds)
3. Fully open the suction valve making sure any suction filters are clear.
4. Prime the pump by flooding the volute case and venting any gas.
5. Ensure the discharge valve is throttled in to no more than ¼ open.

Commissioning Procedure Continued

6. Start the pump and ensure it turns in the correct direction (note; - if the electric motor wiring has been changed and the motor is running in the wrong direction, the pump will still pump but with a greatly reduced performance)
7. Slowly open the discharge valve to fully open while monitoring the discharge pressure increase.
8. Check for any leakage, undue noise, vibration and signs of overheating and adjust any shaft glands very carefully as required.

Positive Displacement or Volumetric Pumps

Positive Displacement Reciprocating Pumps

For each pump revolution a fixed amount of liquid taken from one end and positively discharged at other end

If pipework is blocked pressure will rises that may damage the pump

Used on a variety of fluids

Reciprocating pump displacement by reciprocation of piston plunger.

Used mainly for viscous fluids and have a precise metering capability.

They can vary their delivery rate by changing the speed of the drive or altering the crank displacement length.

Volumetric Pumps

Piston Pumps

Plunger Pumps

Diaphragm Pumps

Piston reciprocating pumps may be single or double acting

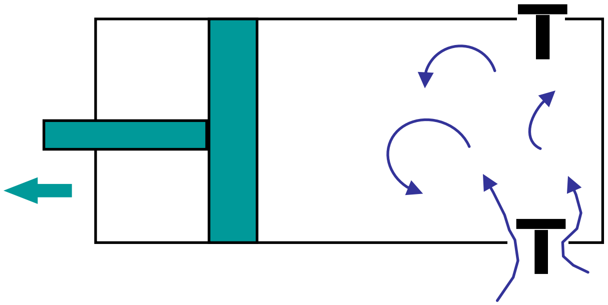
Alternating Volumetric Pumps

Types :

double or single acting

Plunger or diaphragm

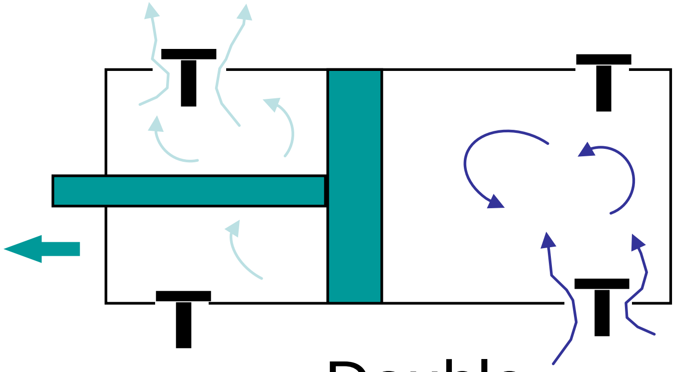
Single



All work on a linear or alternating movement

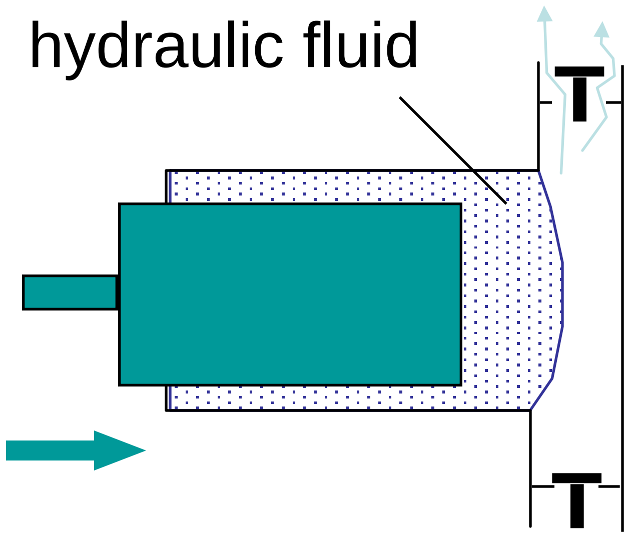
simple & sturdy

can pump high viscosity liquids at high pressures



Double

Alternating Volumetric Pumps

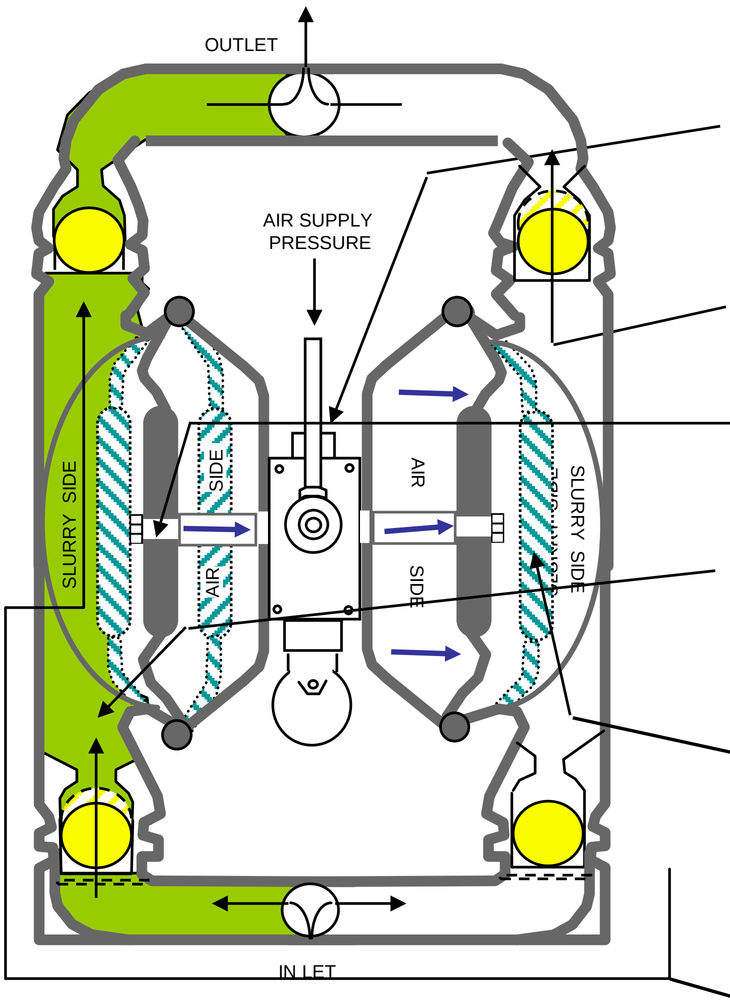


Disadvantages:

Big & cumbersome compared to centrifugal pumps

They give a pulsed flow can create dangerously high pressures if the discharge is restricted

The Diaphragm Pump



One-moving-part air valve directs air supply to back side of diaphragm

Fluid is pushed out of liquid chamber through pump outlet

Opposite diaphragm is pulled in by connecting shaft

Suction draws liquid chamber through pump inlet

When the diaphragm reaches end of its stroke, air valve shifts air to the opposite diaphragm

Liquid is pushed out of the chamber through pump outlet

Positive Displacement Rotary Pumps

Rotary pump displacement by rotary action of gear, cam or vanes

Several sub-types

Used for special services in industry

Rotary Types

Lobe Pumps

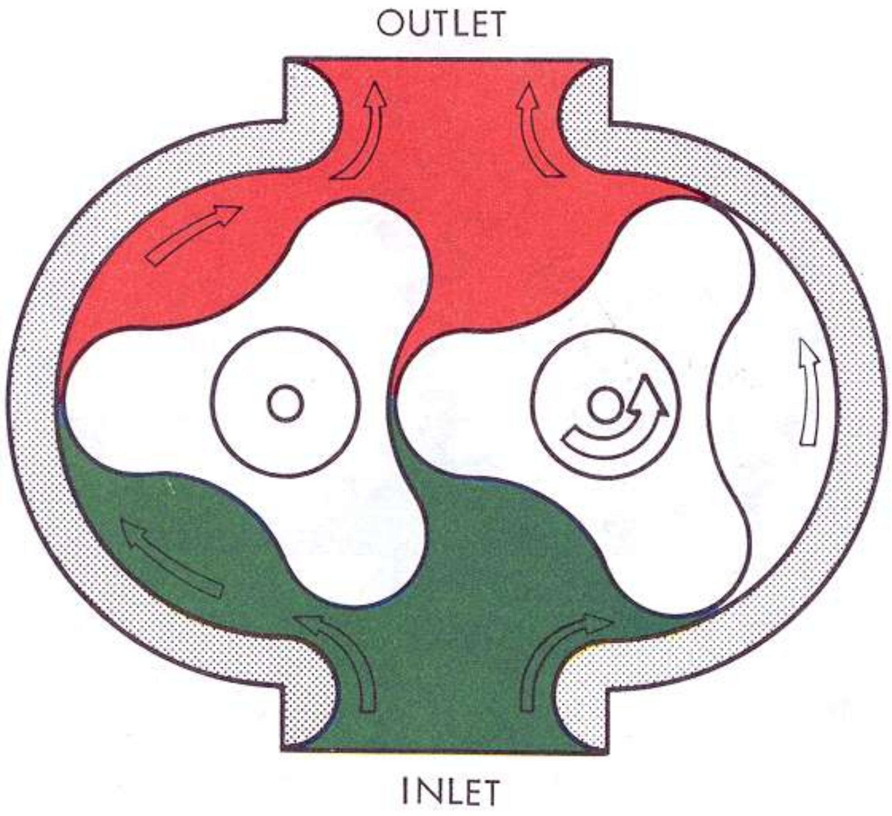
Gear Pumps

Sliding Vane Pumps

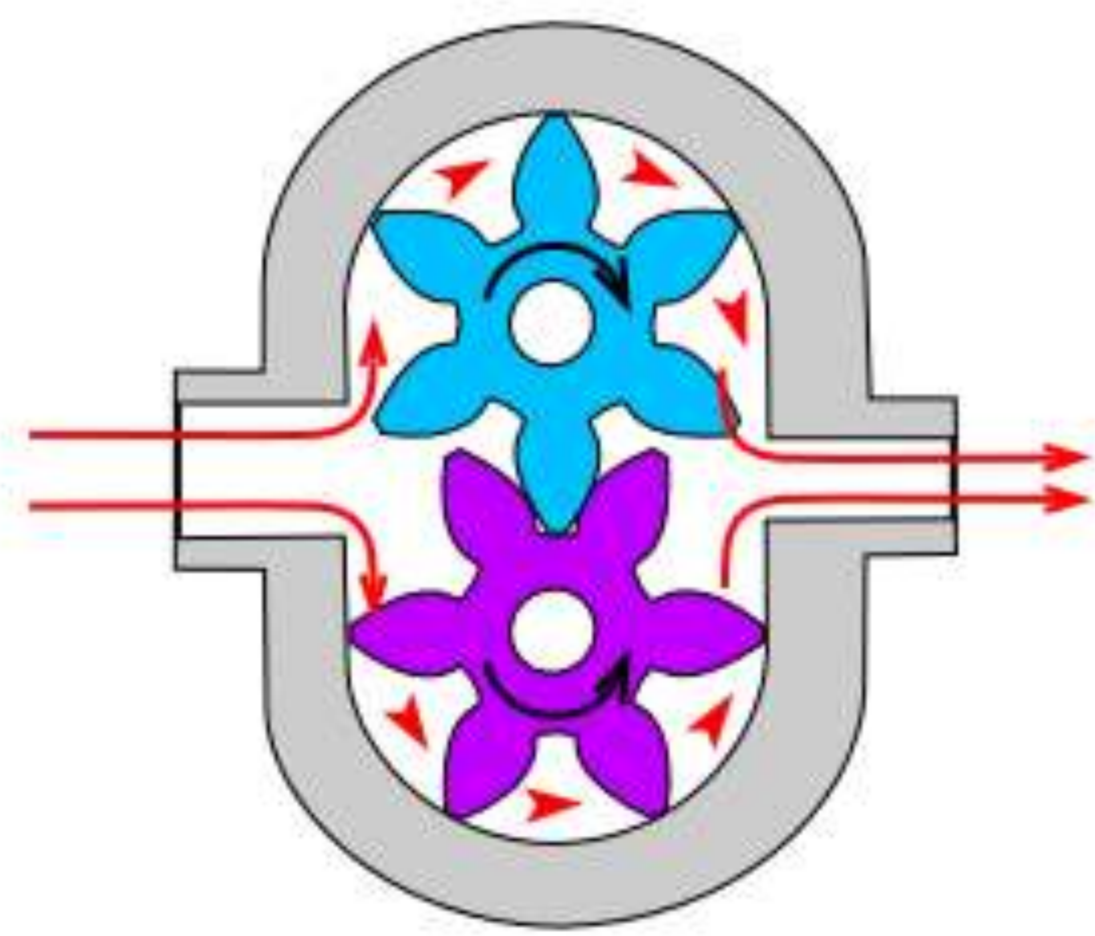
Screw Pumps

Lobe Pumps and screw pumps require an external gearbox to drive the components - they cannot come into contact

Lobe Pump



GEAR PUMP



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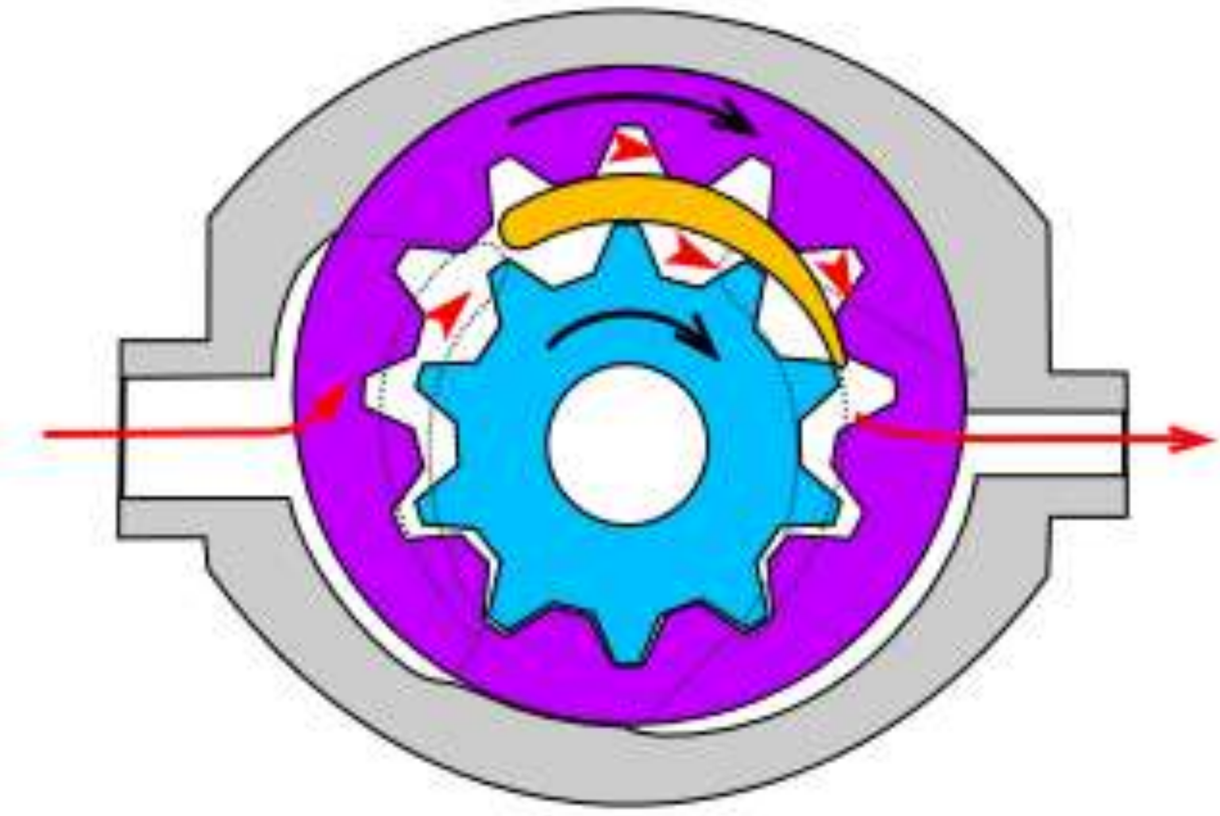
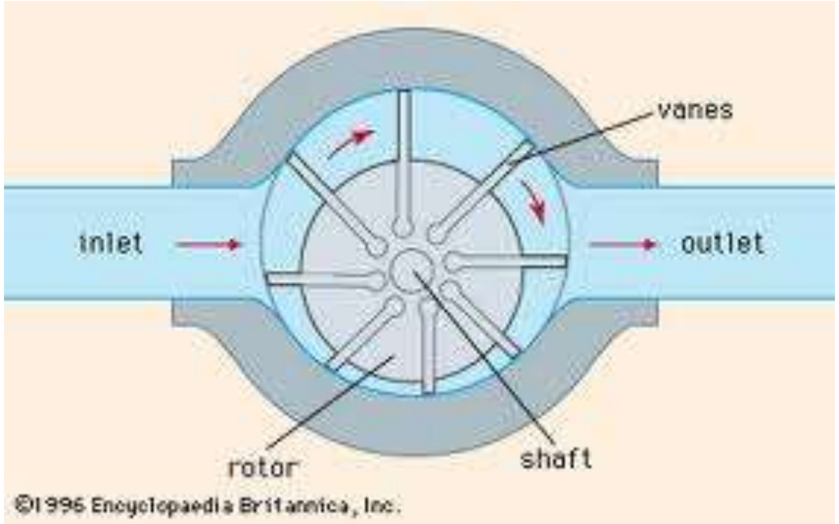


Sliding Vane Pump

A sliding vane pump is a positive-displacement pump that consists of vanes mounted in a rotor that rotates inside of a cavity

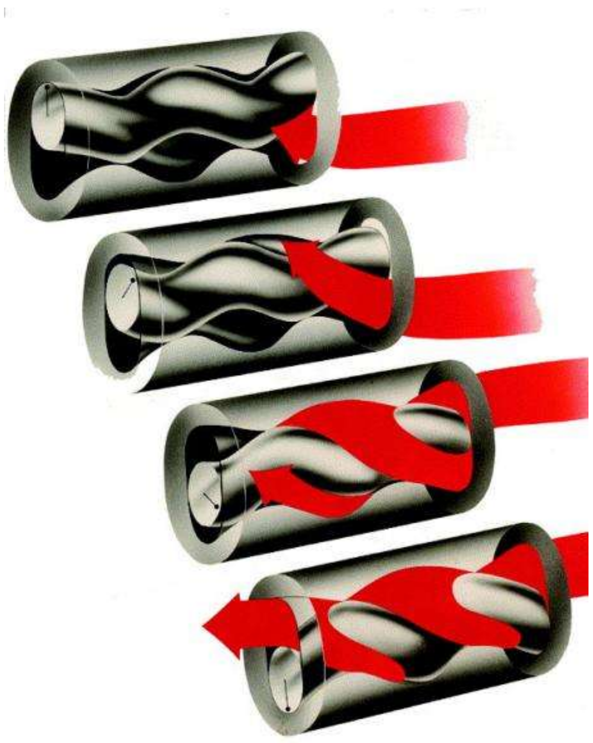


Progressive cavity pump

The progressive cavity pump consists of a helical rotor and a twin helix rubber stator

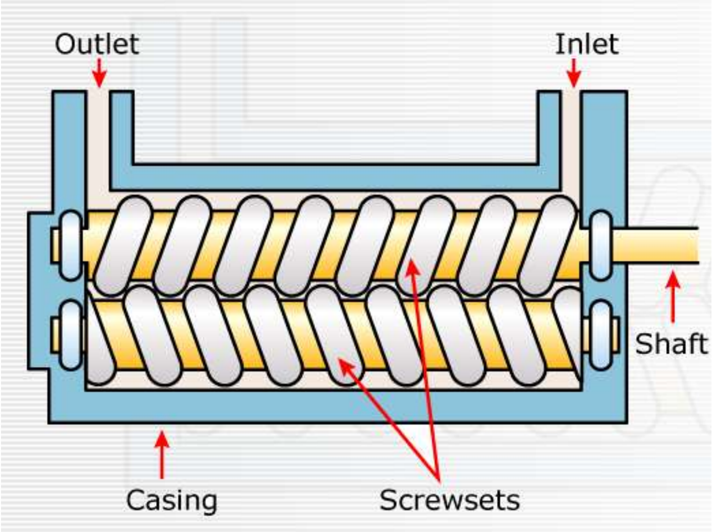
Progressive cavity pump

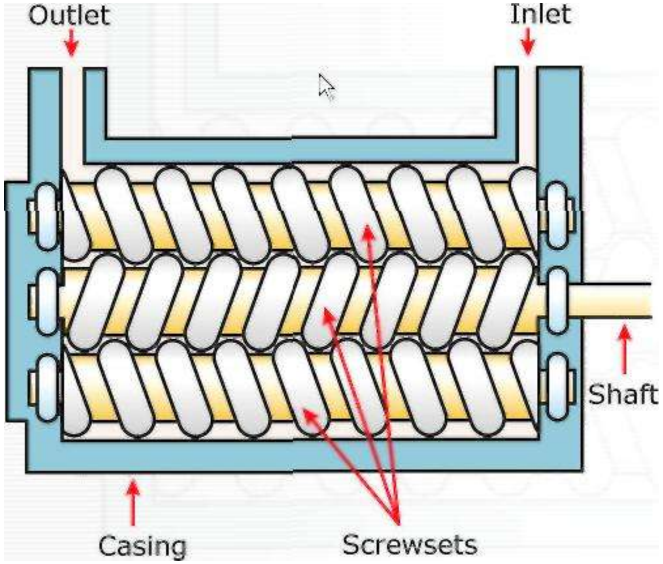
It is a progression of sealed cavities that pass along the pump flexible stator as the rotor turns



Screw Pumps

The screw pump designs are generally capable of high flow rates for the size of the pump and high discharge pressures, they can two or three screwsets.

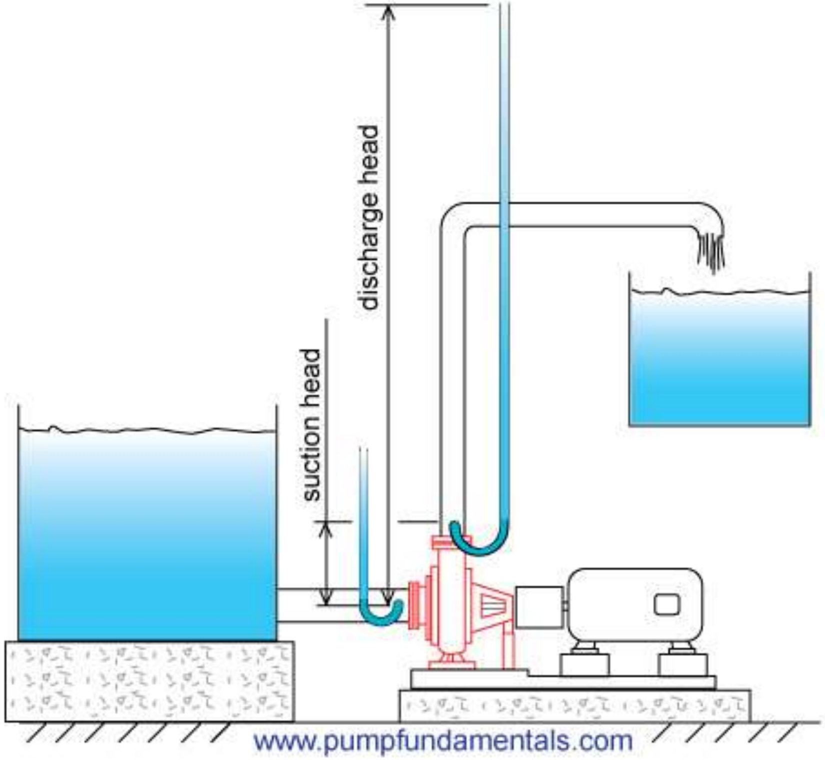




Pump Performance Flow and Pressure

Pump Head

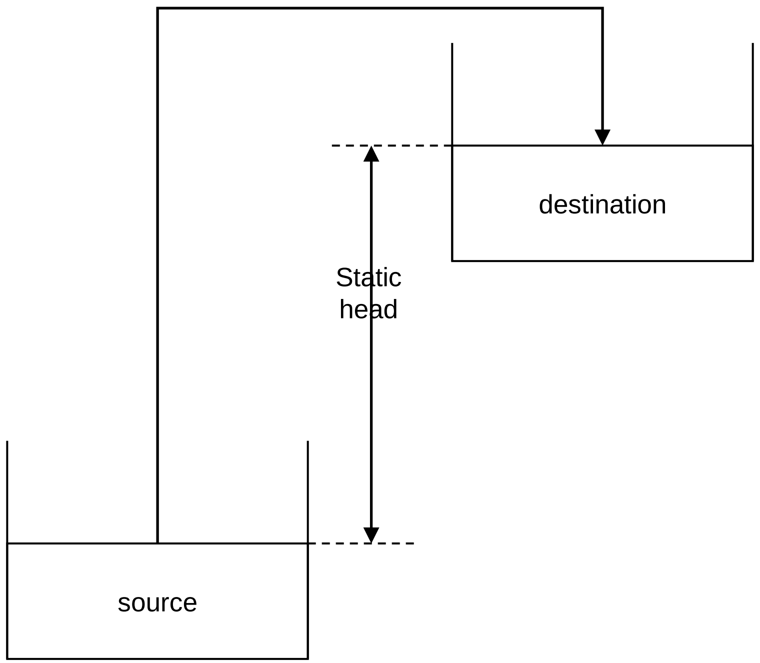
The height at which a pump can discharge a liquid too.



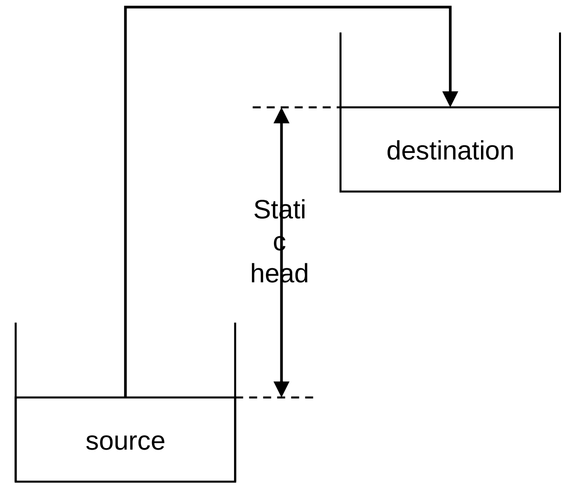
Head

Resistance of the system

Two types: static and friction

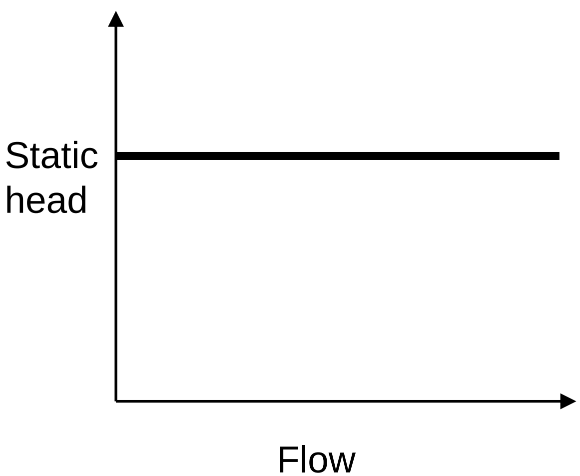


Static head



Difference in height between source and destination

Independent of flow



Static head consists of

Static suction head (hS): lifting liquid relative to pump center line

Static discharge head (hD) vertical distance between centerline and liquid surface in destination tank

Static head at certain pressure

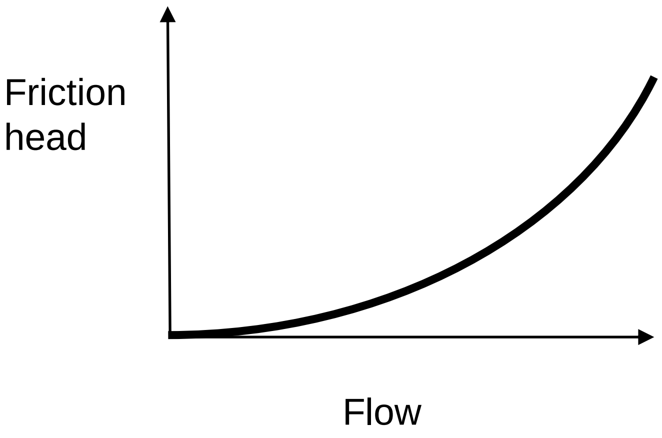
$$\text{Head (in feet)} = \frac{\text{Pressure (psi)} \times 2.31}{\text{Specific gravity}}$$

Friction head

Resistance to flow in pipe and fittings

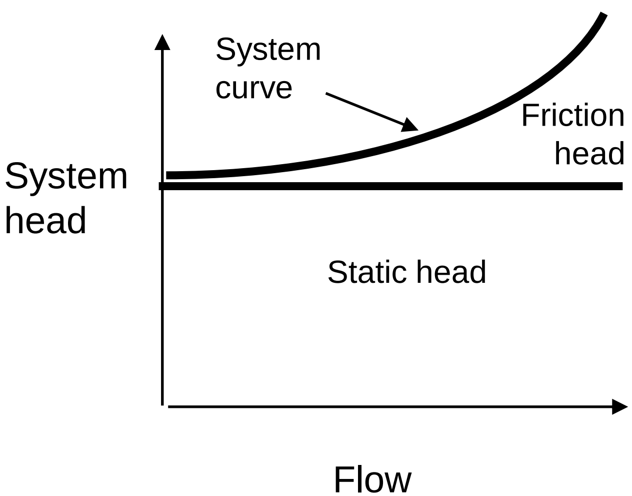
Depends on size, pipes, pipe fittings, flow rate, nature of liquid

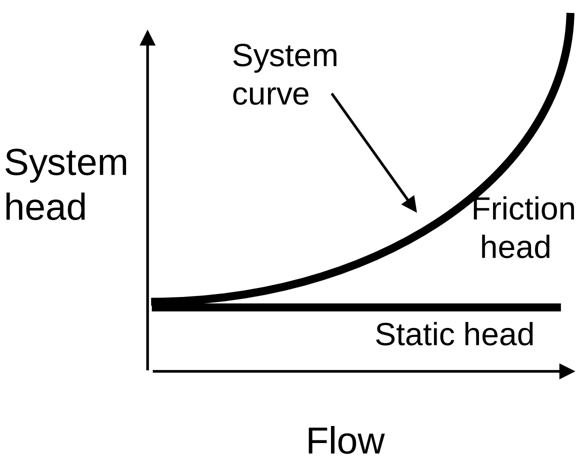
Proportional to square of flow rate



In most cases:

Total head = Static head + friction head





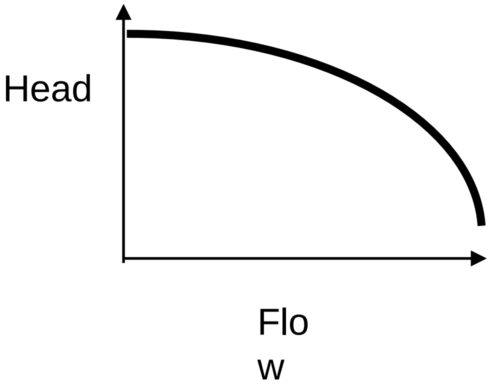
Pump performance curve

Relationship between head and flow

Flow increase
System resistance increases

Head increases
Flow decreases to zero

Zero flow rate: risk of damage to pump

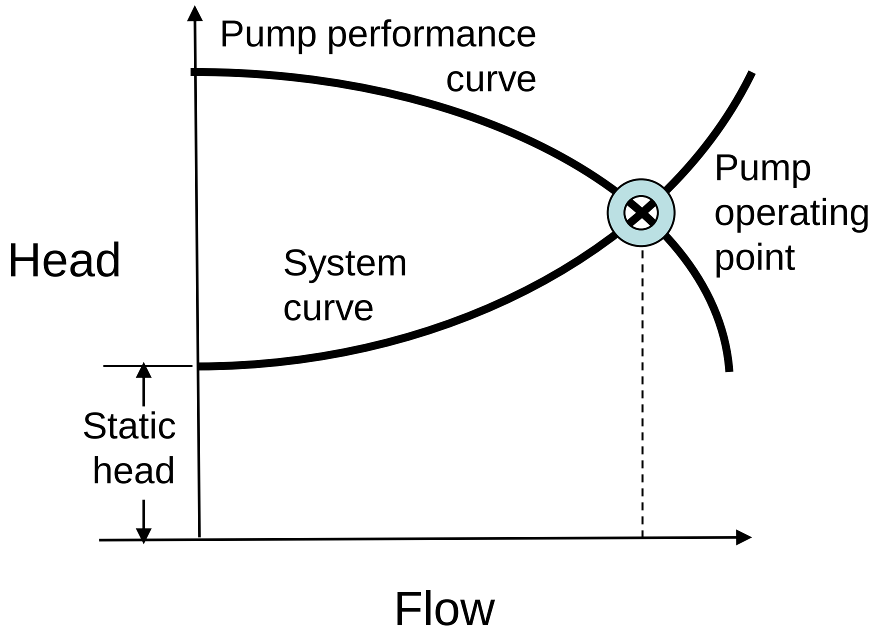


Performance curve for centrifugal pump

Pump Operating Point

Duty point: rate of flow at certain head

Pump operating point: intersection of pump curve and system curve usually at 75% to 85% of the total pump capacity.



N.P.S.H.A.

NPSHA means Net Positive Suction Head Available

NPSHA is a measure that corresponds to the level of pressure at the pump suction. The higher the pressure, the higher the NPSHA and the better the pump will operate

Pump Performance

The Affinity Laws state that (1) flow will change directly when there is a change in speed or diameter, (2) heads will change as the square of a change in speed or diameter, and (3) HP will change as the cube of a change in speed or diameter. As formulae, Affinity Laws are expressed as follows:-

$$\frac{q_1}{q_2} = \frac{N_1\, r_1^3}{N_2\, r_2^3}$$

$$\frac{H_1}{H_2} = \frac{N_1^2\, r_1^2}{N_2^2\, r_2^2}$$

$$\frac{HP_1}{N_1^3\, r_1^5} = \frac{HP_2}{N_2^3\, r_2^5}$$

q = Capacity, Gallons per Minute

H = Discharge Head usually in Feet

HP = Horsepower

N = Pump Speed, RPM

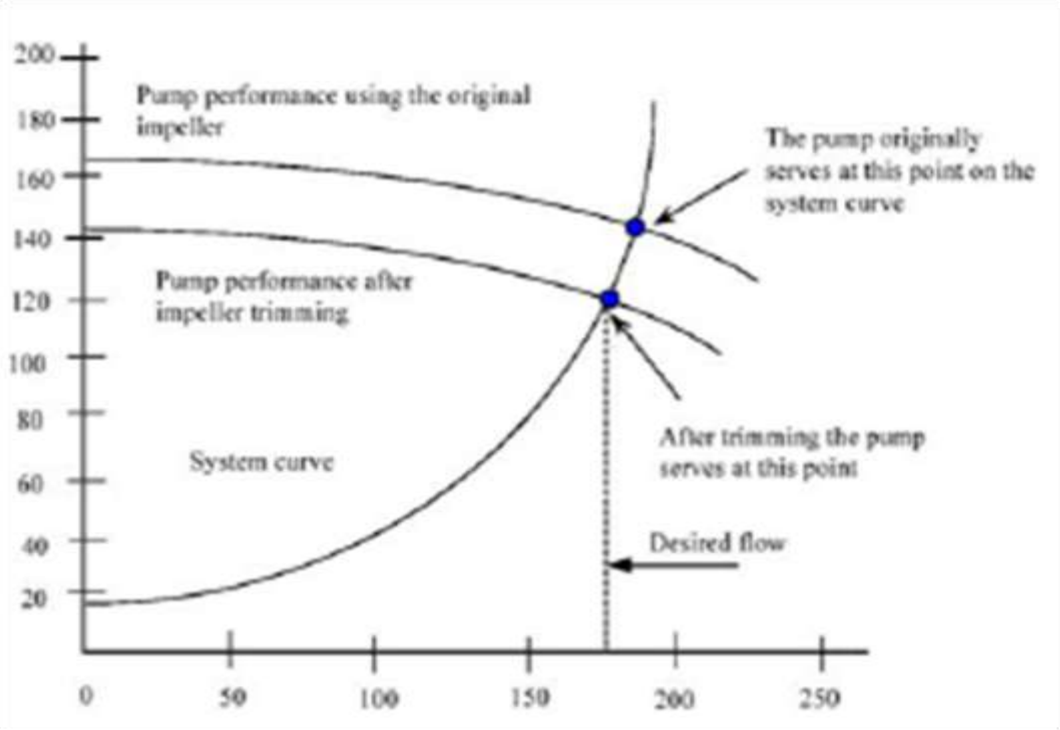
Adjusting Pump Performance

Impeller Trimming

Changing diameter = change in velocity

Changing the impeller diameter is an energy efficient way to control the pump flow rate

Impeller trimming and centrifugal pump performance



The following table compares three options to improve energy efficiency in pumps:
Changing the control valve, trim the impeller and variable frequency drive.

The VFD clearly reduces power most, but a disadvantage is the high costs of VFDs.

Changing the control valves should at all times be avoided because it reduces the flow but not the power consumption and may increase pump maintenance costs.

Comparing Energy Efficiency Options

Parameter	Change control valve	Trim impeller	VFD
Impeller diameter	430 mm	375 mm	430 mm
Pump head	71.7 m	42 m	34.5 m
Pump efficiency	75.1%	72.1%	77%
Rate of flow	80 m3/hr	80 m3/hr	80 m3/hr
Power consumed	23.1 kW	14 kW	11.6 kW

Therefore if a change in a centrifugal pump performance is required, this can be achieved by altering the suction head if possible, increasing the impellor speed, or increasing the impellor diameter if the volute case will permit this.

The End

Any Questions?