Pump

A **pump** is a device used to move fluids, such as liquids, gases or slurries.

A pump displaces a volume by physical or mechanical action. Pumps fall into three major groups: **direct lift**, **displacement**, and **gravity** pumps.[1] Their names describe the method for moving a fluid.

A small, electrically powered pump

Types

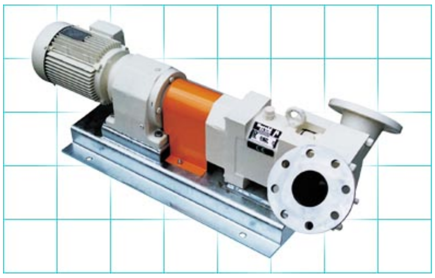
A large, electrically driven pump (electropump) for waterworks near the Hengsteysee, Germany.

Positive displacement pumps

A positive displacement pump causes a fluid to move by trapping a fixed amount of it then forcing (displacing) that trapped volume into the discharge pipe.

or

A positive displacement pump has an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation.



A lobe pump

A positive displacement pump can be further classified according to the mechanism used to move the fluid:

- **Rotary-type**, internal gear, screw, shuttle block, flexible vane or sliding vane, circumferential piston, helical twisted roots (e.g. the Wendelkolben pump) or liquid ring vacuum pumps.

Positive displacement rotary pumps are pumps that move fluid using the principles of rotation. The vacuum created by the rotation of the pump captures and draws in the liquid. Rotary pumps are very efficient because they naturally remove air from the lines, eliminating the need to bleed the air from the lines manually.

Positive displacement rotary pumps also have their weaknesses. Because of the nature of the pump, the clearance between the rotating pump and the outer edge must be very close, requiring that the pumps rotate at a slow, steady speed. If rotary pumps are operated at high speeds, the fluids will cause erosion. Rotary pumps that experience such erosion eventually show signs of enlarged clearances, which allow liquid to slip through and detract from the efficiency of the pump.


Mechanism of a scroll pump

Positive displacement rotary pumps can be grouped into three main types. Gear pumps are the simplest type of rotary pumps, consisting of two gears laid out side-by-side with their teeth enmeshed. The gears turn away from each other, creating a current that traps fluid between the teeth on the gears and the outer casing, eventually releasing the fluid on the discharge side of the pump as the teeth mesh and go around again. Many small teeth maintain a constant flow of fluid, while fewer, larger teeth create a tendency for the pump to discharge fluids in short, pulsing gushes.

Screw pumps are a more complicated type of rotary pumps, featuring two or three screws with opposing thread —- that is, one screw turns clockwise, and the other counterclockwise. The screws are each mounted on shafts that run parallel to each other; the shafts also have gears on them that mesh with each other in order to turn the shafts together and keep everything in place. The turning of the screws, and consequently the shafts to which they are mounted, draws the fluid through the pump. As with other forms of rotary pumps, the clearance between moving parts and the pump's casing is minimal.

Moving vane pumps are the third type of rotary pumps, consisting of a cylindrical rotor encased in a similarly shaped housing. As the rotor turns, the vanes trap fluid between the rotor and the casing, drawing the fluid through the pump.

- **Reciprocating-type**, for example, piston or diaphragm pumps.

Positive displacement pumps have an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation.

The positive displacement pumps can be divided into two main classes

- reciprocating
- rotary

The positive displacement principle applies whether the pump is a

- rotary lobe pump
- Progressive cavity pump
- rotary gear pump
- piston pump
- diaphragm pump
- screw pump
- gear pump
- Hydraulic pump
- vane pump
- regenerative (peripheral) pump

- peristaltic pump

Positive displacement pumps, unlike centrifugal or roto-dynamic pumps, will produce the same flow at a given speed (RPM) no matter what the discharge pressure.

- Positive displacement pumps are "constant flow machines"

A positive displacement pump must not be operated against a closed valve on the discharge side of the pump because it has no shut-off head like centrifugal pumps. A positive displacement pump operating against a closed discharge valve, will continue to produce flow until the pressure in the discharge line are increased until the line bursts or the pump is severely damaged - or both.

A relief or safety valve on the discharge side of the positive displacement pump is therefore necessary. The relief valve can be internal or external. The pump manufacturer normally has the option to supply internal relief or safety valves. The internal valve should in general only be used as a safety precaution, an external relief valve installed in the discharge line with a return line back to the suction line or supply tank is recommended.

Reciprocating pumps

Typical reciprocating pumps are

- plunger pumps
- diaphragm pumps

A plunger pump consists of a cylinder with a reciprocating plunger in it. The suction and discharge valves are mounted in the head of the cylinder. In the suction stroke the plunger retracts and the suction valves open causing suction of fluid into the cylinder. In the forward stroke the plunger pushes the liquid out of the discharge valve.

With only one cylinder the fluid flow varies between maximum flow when the plunger moves through the middle positions, and zero flow when the plunger is at the end positions. A lot of energy is wasted when the fluid is accelerated in the piping system. Vibration and "water hammer" may be a serious problem. In general the problems are compensated for by using two or more cylinders not working in phase with each other.

In diaphragm pumps, the plunger pressurizes hydraulic oil which is used to flex a diaphragm in the pumping cylinder. Diaphragm valves are used to pump hazardous and toxic fluids.

An example of the piston displacement pump is the common hand soap pump.

Gear pump

This uses two meshed gears rotating in a closely fitted casing. Fluid is pumped around the outer periphery by being trapped in the tooth spaces. It does not travel back on the meshed part, since the teeth mesh closely in the centre. Widely used on car engine oil pumps. it is also used in various hydraulic power packs..

Progressing cavity pump

Widely used for pumping difficult materials such as sewage sludge contaminated with large particles, this pump consists of a helical shaped rotor, about ten times as long as its width. This can be visualized as a central core of diameter x, with typically a curved spiral wound around of thickness half x, although of course in reality it is made from one casting. This shaft fits inside a heavy duty rubber sleeve, of wall thickness typically x also. As the shaft rotates, fluid is gradually forced up the rubber sleeve. Such pumps can develop very high pressure at quite low volumes.

Roots-type pumps

The low pulsation rate and gentle performance of this Roots-type positive displacement pump is achieved due to a combination of its two 90° helical twisted rotors, and a triangular shaped sealing line configuration, both at the point of suction and at the point of discharge. This design produces a continuous and non-vorticuless flow with equal volume. High capacity industrial "air compressors" have been designed to employ this principle, as well as most "superchargers" used on internal combustion engines, and even a brand of civil defense siren, the Federal Signal Corporation's Thunderbolt.

Peristaltic pump

A **peristaltic pump** is a type of positive displacement pump used for pumping a variety of fluids. The fluid is contained within a flexible tube fitted inside a circular pump casing (though linear peristaltic pumps have been made). A rotor with a number of "rollers", "shoes" or "wipers" attached to the external circumference compresses the flexible tube. As the rotor turns, the part of the tube under compression closes (or "occludes") thus forcing the fluid to be pumped to move through the tube. Additionally, as the tube opens to its natural state after the passing of the cam ("restitution") fluid flow is induced to the pump. This process is called peristalsis and is used in many biological systems such as the gastrointestinal tract.

Reciprocating-type pumps

Reciprocating pumps are those which cause the fluid to move using one or more oscillating pistons, plungers or membranes (diaphragms).

Reciprocating-type pumps require a system of suction and discharge valves to ensure that the fluid moves in a positive direction. Pumps in this category range from having "simplex" one cylinder, to in some cases "quad" four cylinders or more. Most reciprocating-type pumps are "duplex" (two) or "triplex" (three) cylinder. Furthermore, they can be either "single acting" independent suction and discharge strokes or "double acting" suction and discharge in both directions. The pumps can be powered by air, steam or through a belt drive from an engine or motor. This type of pump was used extensively in the early days of steam propulsion (19th century) as boiler feed water pumps. Reciprocating pumps are now typically used for pumping highly viscous fluids including concrete and heavy oils, and special applications demanding low flow rates against high resistance.

Hand-operated, reciprocating, positive displacement, water pump in Košice-Ťahanovce, Slovakia (walking beam pump).

Compressed-air-powered double-diaphragm pumps

One modern application of positive displacement diaphragm pumps is compressed-air-powered double-diaphragm pumps. Run on compressed air these pumps are intrinsically safe by design, although all manufacturers offer ATEX certified models to comply with industry regulation. Commonly seen in all areas of industry from shipping to processing, SandPiper, Wilden Pumps or ARO are generally the larger of the brands. They are relatively inexpensive and can be used for almost any duty from pumping water out of bunds, to pumping hydrochloric acid from secure storage (dependent on how the pump is manufactured - elastomers / body construction). Lift is normally limited to roughly 6m although heads can reach almost 200 Psi..

Impulse pumps

Hydraulic ram pumps

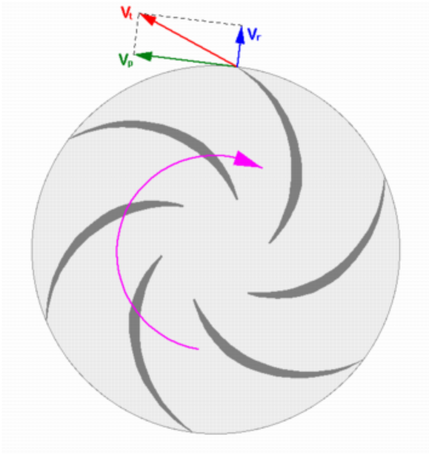
A hydraulic ram is a water pump powered by hydropower.

It functions as a hydraulic transformer that takes in water at one "hydraulic head" (pressure) and flow-rate, and outputs water at a higher hydraulic-head and lower flow-rate. The device utilizes the water hammer effect to develop pressure that allows a portion of the input water that powers the pump to be lifted to a point higher than where the water originally started.

The hydraulic ram is sometimes used in remote areas, where there is both a source of low-head hydropower, and a need for pumping water to a destination higher in elevation than the source. In this situation, the ram is often useful, since it requires no outside source of power other than the kinetic energy of flowing water..

Velocity pumps

Rotodynamic pumps (or dynamic pumps) are a type of velocity pump in which kinetic energy is added to the fluid by increasing the flow velocity. This increase in energy is converted to a gain in potential energy (pressure) when the velocity is reduced prior to or as the flow exits the pump into the discharge pipe. This conversion of kinetic energy to pressure can be explained by the First law of thermodynamics or more specifically by Bernoulli's principle. Dynamic pumps can be further subdivided according to the means in which the velocity gain is achieved.[2]



A centrifugal pump uses a spinning "impeller" which has backward-swept arms

These types of pumps have a number of characteristics:

1. Continuous energy
2. Conversion of added energy to increase in kinetic energy (increase in velocity)
3. Conversion of increased velocity (kinetic energy) to an increase in pressure head

One practical difference between dynamic and positive displacement pumps is their ability to operate under closed valve conditions. Positive displacement pumps physically displace the fluid; hence closing a valve downstream of a positive displacement pump will result in a continual build up in pressure resulting in mechanical failure of either pipeline or pump. Dynamic pumps differ in that they can be safely operated under closed valve conditions (for short periods of time).

Centrifugal pump

A **centrifugal pump** is a rotodynamic pump that uses a rotating impeller to increase the pressure and flow rate of a fluid. Centrifugal pumps are the most common type of pump used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward or axially into a diffuser or volute chamber, from where it exits into the downstream piping system. Centrifugal pumps are typically used for large discharge through smaller heads.

Centrifugal pumps are most often associated with the radial flow type. However, the term "centrifugal pump" can be used to describe all impeller type rotodynamic pumps[3] including the radial, axial and mixed flow variations.

Radial flow pumps

Often simply referred to as centrifugal pumps. The fluid enters along the axial plane, is accelerated by the impeller and exits at right angles to the shaft (radially). Radial flow pumps operate at higher pressures and lower flow rates than axial and mixed flow pumps.

Axial flow pumps

Axial flow pumps differ from radial flow in that the fluid enters and exits along the same direction parallel to the rotating shaft. The fluid is not accelerated but instead "lifted" by the action of the impeller. They may be likened to a propeller spinning in a length of tube. Axial flow pumps operate at much lower pressures and higher flow rates than radial flow pumps.

Mixed flow pumps

Mixed flow pumps, as the name suggests, function as a compromise between radial and axial flow pumps, the fluid experiences both radial acceleration and lift and exits the impeller somewhere between 0-90 degrees from the axial direction. As a consequence mixed flow pumps operate at higher pressures than axial flow pumps while delivering higher discharges than radial flow pumps. The exit angle of the flow dictates the pressure head-discharge characteristic in relation to radial and mixed flow.

Eductor-jet pump

This uses a jet, often of steam, to create a low pressure. This low pressure sucks in fluid and propels it into a higher pressure region.

Gravity pumps

Gravity pumps include the syphon and Heron's fountain - and there also important qanat or foggara systems which simply use downhill flow to take water from far-underground aquifers in high areas to consumers at lower elevations. The hydraulic ram is also sometimes referred to as a gravity pump.

Steam pumps

Steam pumps are now mainly of historical interest. They include any type of pump powered by a steam engine and also pistonless pumps such as Thomas Savery's pump and the Pulsometer steam pump.

Valveless pumps

Valveless pumping assists in fluid transport in various biomedical and engineering systems. In a valveless pumping system, no valves are present to regulate the flow direction. The fuid pumping efficiency of a valveless system, however, is not necessarily lower than that having valves. In fact, many fluid-dynamical systems in nature and engineering more or less rely upon valveless pumping to transport the working fluids therein. For instance, blood circulation in the cardiovascular system is maintained to some extent even when the heart’s valves fail. Meanwhile, the embryonic vertebrate heart begins pumping blood long before the development of discernable chambers and valves. In microfuidics, valveless impedance pump have been fabricated, and are expected to be particularly suitable for handling sensitive biofuids.

Pump Repairs

Examining pump repair records and MTBF (mean time between failures) is of great importance to responsible and conscientious pump users. In view of that fact, the preface to the 2006 Pump User's Handbook alludes to "pump failure" statistics. For the sake of convenience, these failure statistics often are translated into MTBF (in this case, installed life before failure).[4]

In early 2005, Gordon Buck, John Crane Inc.'s chief engineer for Field Operations in Baton Rouge, LA, examined the repair records for a number of refinery and chemical plants to obtain meaningful reliability data for centrifugal pumps. A total of 15 operating plants having nearly 15,000 pumps were included in the survey. The smallest of these plants had about 100 pumps; several plants had over 2000. All facilities were located in the United States. In addition, considered as "new," others as "renewed" and still others as "established." Many of these plants—but not all—had an alliance arrangement with John Crane. In some cases, the alliance contract included having a John Crane Inc. technician or engineer on-site to coordinate various aspects of the program.

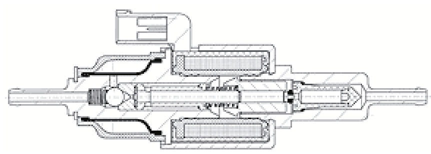
Not all plants are refineries, however, and different results can be expected elsewhere. In chemical plants, pumps have traditionally been "throw-away" items as chemical attack can result in limited life. Things have improved in recent years, but the somewhat restricted space available in "old" DIN and ASME-standardized stuffing boxes places limits on the type of seal that can be fitted. Unless the pump user upgrades the seal chamber, only the more compact and simple versions can be accommodated. Without this upgrading, lifetimes in chemical installations are generally believed to be around 50 to 60 percent of the refinery values.

It goes without saying that unscheduled maintenance often is one of the most significant costs of ownership, and failures of mechanical seals and bearings are among the major causes. Keep in mind the potential value of selecting pumps that cost more initially, but last much longer between repairs. The MTBF of a better pump may be one to four years longer than that of its non-upgraded counterpart. Consider that published average values of avoided pump failures range from $2600 to $12,000. This does not include lost opportunity costs. One pump fire occurs per 1000 failures. Having fewer pump failures means having fewer destructive pump fires.

As has been noted, a typical pump failure based on actual year 2002 reports, costs $5,000 on average. This includes costs for material, parts, labor and overhead. Let us now assume that the MTBF for a particular pump is 12 months and that it could be extended to 18 months. This would result in a cost avoidance of $2,500/yr—which is greater than the premium one would pay for the reliability-upgraded centrifugal pump.[4] [5] [6]

Applications

Pumps are used throughout society for a variety of purposes. Early applications includes the use of the windmill or watermill to pump water. Today, the pump is used for irrigation, water supply, gasoline supply, air conditioning systems, refrigeration (usually called a compressor), chemical movement, sewage movement, flood control, marine services, etc.



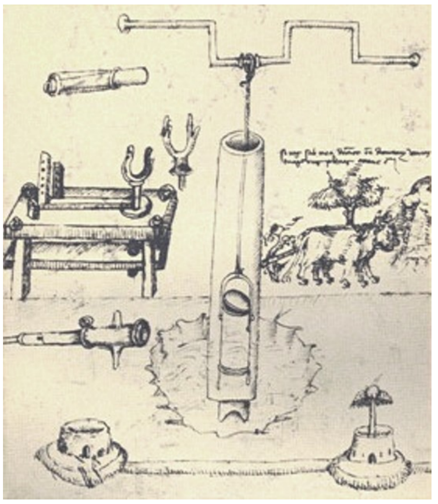
Metering pump for gasoline and additives.

Because of the wide variety of applications, pumps have a plethora of shapes and sizes: from very large to very small, from handling gas to handling liquid, from high pressure to low pressure, and from high volume to low volume.

Priming a pump

Liquid and slurry pumps can lose prime and this will require the pump to be primed by adding liquid to the pump and inlet pipes to get the pump started. Loss of "prime" is usually due to ingestion of air into the pump. The clearances and displacement ratios in pumps used for liquids and other more viscous fluids cannot displace the air due to its lower density.

Pumps as public water supplies



First European depiction of a piston pump, by Taccola, c.1450.[7]

One sort of pump once common worldwide was a hand-powered water pump, or 'pitcher pump'. It would be installed over a community water well that was used by people in the days before piped water supplies.

In parts of the British Isles, it was often called "**the parish pump**". Although such community pumps are no longer common, the expression "parish pump" is still used. It derives from the kind of the chatter and conversation that might be heard as people congregated to draw water from the community water pump, and is now used to describe a place or forum where matter of purely local interest is discussed.[8]

Because water from pitcher pumps is drawn directly from the soil, it is more prone to contamination. If such water is not filtered and purified, consumption of it might lead to gastrointestinal or other water-borne diseases.

Modern hand operated community pumps are considered the most sustainable low cost option for safe water supply in resource poor settings, often in rural areas in developing countries. A hand pump opens access to deeper groundwater that is often not polluted and also improves the safety of a well by protecting the water source from contaminated buckets. Pumps like the Afridev pump [9] are designed to be cheap to build and install, and easy to maintain with simple parts. However, scarcity of spare parts for these type of pumps in some regions of Africa has diminished their utility for these areas.

Sealing Multiphase Pumping Applications

Multiphase pumping applications, also referred to as tri-phase, have grown due to increased oil drilling activity. In addition, the economics of multiphase production is attractive to upstream operations as it leads to simpler, smaller in-field installations, reduced equipment costs and improved production rates. In essence, the multiphase pump can accommodate all fluid stream properties with one piece of equipment, which has a smaller footprint. Often, two smaller multiphase pumps are installed in series rather than having just one massive pump.

For midstream and upstream operations, multiphase pumps can be located onshore or offshore and can be connected to single or multiple wellheads. Basically, multiphase pumps are used to transport the untreated flow stream produced from oil wells to downstream processes or gathering facilities. This means that the pump may handle a flow stream (well stream) from 100 percent gas to 100 percent liquid and every imaginable combination in between. The flow stream can also contain abrasives such as sand and dirt. Multiphase pumps are designed to operate under changing/fluctuating process conditions. Multiphase pumping also helps eliminate emissions of greenhouse gases as operators strive to minimize the flaring of gas and the venting of tanks where possible.[10]

Types and Features of Multiphase Pumps

Helico-Axial Pumps (Centrifugal) A rotodynamic pump with one single shaft requiring two mechanical seals. This pump utilizes an open-type axial impeller. This pump type is often referred to as a "Poseidon Pump" and can be described as a cross between an axial compressor and a centrifugal pump.

Twin Screw (Positive Displacement) The twin screw pump is constructed of two intermeshing screws that force the movement of the pumped fluid. Twin screw pumps are often used when pumping conditions contain high gas volume fractions and fluctuating inlet conditions. Four mechanical seals are required to seal the two shafts.

Progressive Cavity Pumps (Positive Displacement) Progressive cavity pumps are single-screw types typically used in shallow wells or at the surface. This pump is mainly used on surface applications where the pumped fluid may contain a considerable amount of solids such as sand and dirt.

Electric Submersible Pumps (Centrifugal) These pumps are basically multistage centrifugal pumps and are widely used in oil well applications as a method for artificial lift. These pumps are usually specified when the pumped fluid is mainly liquid.

Buffer Tank A buffer tank is often installed upstream of the pump suction nozzle in case of a slug flow. The buffer tank breaks the energy of the liquid slug, smoothes any fluctuations in the incoming flow and acts as a sand trap.

As the name indicates, multiphase pumps and their mechanical seals can encounter a large variation in service conditions such as changing process fluid composition, temperature variations, high and low operating pressures and exposure to abrasive/erosive media. The challenge is selecting the appropriate mechanical seal arrangement and support system to ensure maximized seal life and its overall effectiveness.[10] [11] [12]

Specifications

Pumps are commonly rated by horsepower, flow rate, outlet pressure in feet (or metres) of head, inlet suction in suction feet (or metres) of head. The head can be simplified as the number of feet or metres the pump can raise or lower a column of water at atmospheric pressure.

From an initial design point of view, engineers often use a quantity termed the specific speed to identify the most suitable pump type for a particular combination of flow rate and head.

Pump material

Pump material can be of Stainless steel (SS 316 or SS 304) , cast iron etc. It depend upon the application of pump. In water industry for pharma application, SS 316 is normally used. As at high temperature stainless steel give better result.

Pumping power

The power imparted into a fluid will increase the energy of the fluid per unit volume. Thus the power relationship is between the conversion of the mechanical energy of the pump mechanism and the fluid elements within the pump. In general, this is governed by a series of simultaneous differential equations, known as the Navier-Stokes equations. However a more simple equation relating only the different energies in the fluid, known as Bernoulli's equation can be used. Hence the power, P, required by the pump:

$$P = \frac{\Delta P Q}{\eta}$$

where ΔP is the change in total pressure between the inlet and outlet (in Pa), and Q, the fluid flowrate is given in m^3/s. The total pressure may have gravitational, static pressure and kinetic energy components; i.e. energy is distributed between change in the fluid's gravitational potential energy (going up or down hill), change in velocity, or change in static pressure. η is the pump efficiency, and may be given by the manufacturer's information, such as in the form of a pump curve, and is typically derived from either fluid dynamics simulation (i.e. solutions to the Navier-stokes for the particular pump geometry), or by testing. The efficiency of the pump will depend upon the pump's configuration and operating conditions (such as rotational speed, fluid density and viscosity etc).

$$\Delta P = \frac{(v_2^2 - v_1^2)}{2} + \Delta z g + \frac{\Delta p_{\mathrm{static}}}{\rho}$$

For a typical "pumping" configuration, the work is imparted on the fluid, and is thus positive. For the fluid imparting the work on the pump (i.e. a turbine), the work is negative power required to drive the pump is determined by dividing the output power by the pump efficiency. Furthermore, this definition encompasses pumps with no moving parts, such as a siphon.

Pump efficiency

Pump efficiency is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump. Its value is not fixed for a given pump, efficiency is a function of the discharge and therefore also operating head. For centrifugal pumps, the efficiency tends to increase with flow rate up to a point midway through the operating range (peak efficiency) and then declines as flow rates rise further. Pump performance data such as this is usually supplied by the manufacturer before pump selection. Pump efficiencies tend to decline over time due to wear (e.g. increasing clearances as impellers reduce in size).

One important part of system design involves matching the pipeline headloss-flow characteristic with the appropriate pump or pumps which will operate at or close to the point of maximum efficiency. There are free tools that help calculate head needed and show pump curves including their Best Efficiency Points (BEP).[13]

Pump efficiency is an important aspect and pumps should be regularly tested. Thermodynamic pump testing is one method.

Pump selection is done by performance curve which is curve between pressure head and flow rate. And also power supply is also taken care of. Pumps are normally available that run at 50 hz or 60 hz.

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Further reading

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External links

- www.pumpschool.com (http://www.pumpschool.com)—Pump education devoted primarily to rotary positive displacement pumps
- Parish Pumps of Eastern Essex in the UK (http://www.essex-family-history.co.uk/parishpump.htm)
- Pump sizing calculator (http://www.enggcyclopedia.com/welcome-to-enggcyclopedia/fluid-dynamics/calculationspumps_sizing_calculator) Calculate nPSHA, suction, discharge, differential pressure and power required for any pumping system.

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