PUMPING FLUID through piping systems

Pumps add hydraulic energy to a fluid, increasing fluid pressure at the pump discharge and creating flow through piping systems

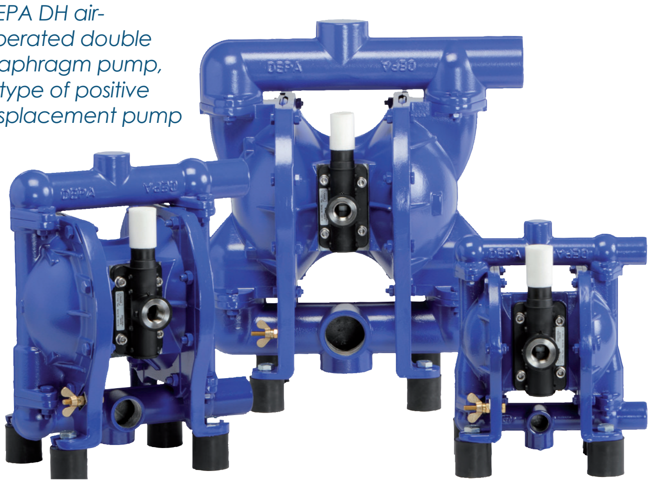
There are a wide variety of pump designs to aid flow through piping systems, but they fall into two general categories: kinetic and positive displacement.

Centrifugal pumps

Centrifugal pumps, which fall into the 'kinetic' category, are the most common in industrial applications.

A centrifugal pump is characterised by the use of a rotating impeller to increase the pressure and flow rate of a fluid, and is the most common type of pump used to move liquids through a piping system. Entering the pump impeller near the rotating axis, fluids are accelerated by the impeller, flowing outward or into a diffuser or volute chamber before exiting into the downstream piping system. Typically used for higher flow rates, centrifugal pumps are commonly utilised in water, sewage, petroleum, petrochemical and boiler feed applications, among others.

Among centrifugal pumps there exists a vast array of pump types, including submersible, end suction, split case and column pumps, for example. The varying designs handle different fluids, pressures, flow capacities and other system conditions, and the selection of a pump should take into account all of these factors.



DEPA DH air-operated double diaphragm pump, a type of positive displacement pump

Manufacturer's typically present pump head and capacity information in the form of a pump performance curve, which represents performance characteristics over the operating range of the pump. To properly select a pump and evaluate system performance, a number of factors should be considered, outlined below.

Centrifugal pump sizing and selection

Selecting the proper centrifugal pump for an application requires careful evaluation of the following criteria:

Pump curve: The pump curve is developed by testing the pump according to industry standards and consolidating the resulting head and flow rate data into a curve. Pump manufacturers often provide a performance curve for a single impeller size and speed, or multiple curves for a range of impeller sizes or speeds. Elements found on the pump curve include:

- *Total head:* The energy content of the liquid, imparted by the pump, expressed in feet of liquid
- *Pump efficiency:* The ratio of the energy supplied to the liquid to the energy delivered from the pump shaft
- *Shutoff head:* The head generated at the condition of zero flow where no liquid is flowing through the pump, but the pump is primed and running
- *Minimum flow:* The lowest flow rate at which the manufacturer recommends the pump be operated
- *Allowable operating region (AOR):* The range of flow rates recommended by the pump manufacturer in which the service life of the pump is not seriously reduced by continuous operation
- *Best efficiency point (BEP):* The flow rate on the pump curve where the efficiency of the pump is at its maximum. Operating near this point will minimise pump wear
- *Preferred operating region (POR):* A region around the BEP on the pump curve, defined by the user, to ensure reliable and efficient operation
- *Maximum flow rate:* The end of the manufacturer's curve for the pump, commonly referred to as 'run out'
- *Net positive suction head required (NPSHr):* The amount of suction head above the vapour pressure needed to avoid more than 3% loss in total head due to cavitation at a specific capacity.

Net positive suction head available: The net positive suction head available (NPSHa) refers to the head provided by the piping system to the pump suction. It is influenced by the configuration of the system and the properties of the fluid. Properly calculating the NPSHa is essential to ensure that it exceeds the manufacturer's NPSHr and prevents cavitation in the pump.

System variables can be optimised to increase NPSHa at the pump suction, including:

- *Pump location:* Lowering the pump suction in relation to the tank will increase NPSHa
- *Pump suction piping:* Minimising suction pipeline head loss will increase NPSHa. This head loss will be a factor of pipe size, pipe roughness and any components installed in the pipeline. In addition, as flow increases through the suction pipeline, head loss will increase, effectively reducing the NPSHa. For most pumps, NPSHr will increase with flow rate
- *Fluid properties:* Fluid properties such as vapour pressure, density and viscosity vary with temperature. The net effect of a change in fluid temperature on NPSHa should be evaluated
- *Supply tank:* An increase in supply tank pressure, elevation or liquid level will

increase the NPSHa
- *Atmospheric pressure:* Changes in atmospheric pressure can affect the NPSHa.

Viscosity corrections: Most published pump curves reflect the performance of the pump with water as the operating fluid. A more viscous fluid will lead to an increase in required power and a reduction in flow rate, head, and efficiency. Pump performance should be corrected for viscosity to obtain the most accurate representation of operation.

Pump affinity rules: Affinity rules predict pump performance in response to changes in impeller speed or diameter. For example, when a pump's rotational speed is changed, the head, capacity, and power for a point on the pump curve will vary according to the pump affinity rules.

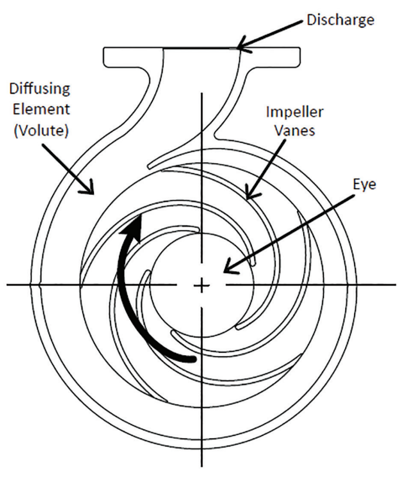
Trimming an impeller will change the vane angle, thickness and impeller clearance. Although these changes will impact pump performance, they are not accounted for by the affinity rules. Therefore, the affinity rules should be used only for small changes in impeller diameters, as increased inaccuracies may occur with larger changes. Interpolation between two known impeller diameters on the pump curve typically provides more accurate results.

Pump power calculations: Pump horsepower can be used to appropriately size a motor for the pump and calculate operating costs based on pump and motor efficiencies.

Positive displacement pumps

A positive displacement pump differs from a centrifugal pump in that it moves fluid by trapping a fixed volume in a cavity and then forcing it out into the discharge pipe. Liquid flows into the pump as the cavity on the suction side expands, and it flows out as the cavity collapses. This maintains a constant volume through each cycle of operation.

The two main categories of positive displacement pumps – reciprocating and rotary – add this energy in a periodic, rather than continuous, fashion. Reciprocating pumps use reciprocal motion such as pistons or diaphragms to directly displace fluid, while rotary pumps employ a variety of designs including peristaltic, screw and gear pumps to displace fluid through the application of rotary motion.



Cross section of a standard centrifugal pump

Positive displacement pump applications: The fact that positive displacement pumps add energy by direct force on a fluid makes them a suitable choice for certain applications. They impart little shear force to the fluid, making them suitable for fluids with high-viscosity and low-shear requirements, as well as for fragile solids. By directly moving a volume of fluid, they can meet high-pressure/low-flow, and precise fluid delivery requirements, as well as offer efficient pumping of two-phase fluids.

Positive displacement pump curve: Positive displacement pump curves are not limited to a flow-versus-head relationship. Flow-versus-speed and flow-versus-discharge graphs are also commonly used. With the exception of slip, capacity in a positive displacement pump varies directly with speed, independent of head. Positive displacement pumps typically exhibit slip, which is fluid leakage from the high-pressure side to the low-pressure side of the pump. At higher pressures and/or lower viscosities, this will result in an increasing loss of capacity through the pump.

Centrifugal vs. positive displacement pumps

While centrifugal pumps are the more common of the two pump types, there are a number of reasons to choose a positive displacement pump in specialised situations:

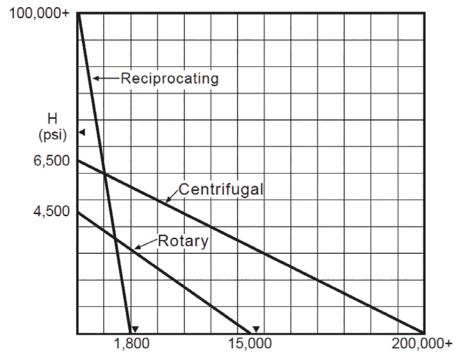
Highly-viscous solutions: As mentioned above, positive displacement pumps are the better choice when handling high-viscosity fluids, as these will affect the flow rate and efficiency of a centrifugal pump and can result in increased energy costs.

High-pressure applications: While pressure limits can vary with the design of individual pumps, positive displacement pumps are often better able to produce extremely high pressure than centrifugal pumps, especially at low flow rates, even when operated in series.

Variations in pressure and viscosity: Debris, pipe corrosion and even modest changes in valve operation or pressure can greatly affect the efficiency of a centrifugal pump, whereas positive displacement pumps are able to maintain their flow rate.

Shear-sensitive fluids: As pump speed increases, so does the tendency to shear liquids. Therefore, high-speed centrifugal pumps are typically not the ideal option for shear-sensitive liquids, and positive displacement pumps offer a better solution.

Operating away from the middle of the curve: Centrifugal pumps have a specific range on the pump curve at which they operate with maximum efficiency – the greater the deviation from this range, the greater the risk of cavitation, deflection and pump failure. Positive displacement pumps, however, are able to more efficiently accommodate operating conditions at any point on the curve.



Head vs. flow for centrifugal, rotary and reciprocating pumps

Pump selection process

The process of pump selection can be broken down into a series of distinct steps:
- *Determine pump capacity:* This is the desired pump flow rate, usually in gallons per minute
- *Determine head requirements:* The pump must overcome the static and dynamic head losses of the system
- *Find NPSHa:* This can be calculated by hand
- *Select the pump:* Typically, a selection chart is consulted to create a short list of pumps for evaluation, the curves are then individually considered to find the best fit
- *Correct for fluid density and viscosity:* Both of these will impact the shape of the pump performance curve and need to be adjusted for the fluid being pumped
- *Find the pump horsepower:* Curves for horsepower may be included on the published pump curve, if not it can be calculated using equations.

Whether your application requires a centrifugal or positive displacement pump, there are myriad factors to consider in ensuring that a system is compatible with the selection and able to operate with maximum efficiency and minimum costs.

The information contained within this article has been gathered from Crane's Technical Paper No. 410, first published in 1942 and continuously updated to reflect the evolution of the fluid handling industry, with the most recent revision having been completed in 2009. Visit: www.flowoffluids.com.