Self-Priming Centrifugal Pumps

The ability to self-prime can be a cost effective solution for many applications.

BY TERRY W. BECHTLER

With greater global competition and increased environmental regulations, modern industrial applications over the years have evolved into sophisticated operations, demanding more control over their liquid handling processes. This is particularly evident on the "dirty" liquid side of a plant's manufacturing process, in the drainage, filtration/pollution control/wastewater areas. Self-priming centrifugal pumps are important in meeting this demanding challenge.

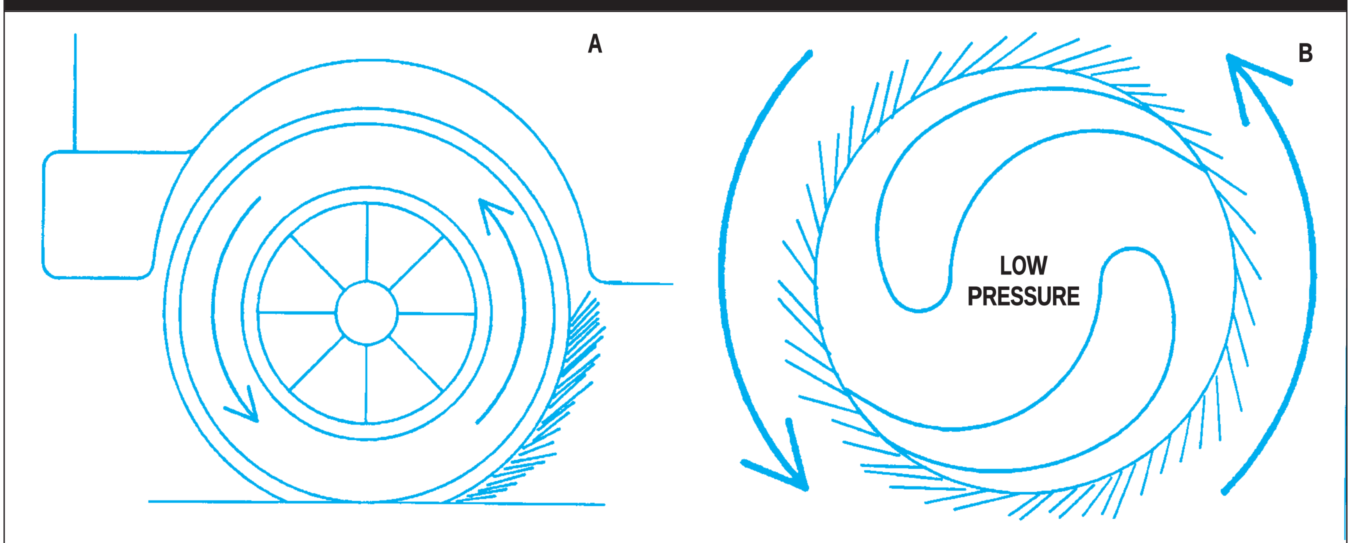
Single stage end suction centrifugal pumps may be divided by their designs into conventional or standard centrifugals and self-priming centrifugals. Centrifugal pumps incorporate a simple design with minimum moving parts - impeller, shaft and bearings. They are reliable, durable and relatively easy to maintain. To better understand the working principle of a self-priming centrifugal pump, let's first examine the centrifugal force principle and a standard or conventional centrifugal pump.

All centrifugal pumps incorporate the centrifugal force principle, which may be illustrated by a car running on a wet road (Figure 1). The tires pick up water and throw it by centrifugal force against the fender. Centrifugal pumps incorporate the same principle, but the tire is replaced by an impeller with vanes and the fender is replaced by the casing (Figure 1b). The liquid enters the center or eye of the impeller. As the liquid reaches the impeller vane, its velocity is greatly increased. Centrifugal force, created by the impeller blades or vanes, directs the liquid towards the outside diameter of the impeller. Once the liquid reaches the tip of the impeller vane it leaves the impeller at its greatest velocity. As the liquid leaves the impeller, its direction is controlled by the pump casing (the most common casing shapes are spiral or volute and circular).

The spiral or volute casing surrounds the impeller, beginning at the point where the liquid leaves the impeller. The liquid enters the casing and follows the rotation of the impeller to the discharge. Within the casing there is a section called the throat or cutwater.

The cutwater, also called the tongue, is a cast section of the volute casing, near the discharge that is positioned close to the maximum impeller diameter. As the liquid

FIGURE 1



reaches the cutwater it is diverted into the pump's discharge opening (Figure 2).

SELF-PRIMING

Self-priming centrifugal pumps incorporate all the above standard centrifugal pump design features and add the following internal modifications:

- A casing design that surrounds the volute and impeller and enables the pump to retain liquid in a built-in reservoir, or priming chamber. This reservoir is filled during the initial prime of the pump, and when the pump completes a pumping cycle and shuts down, the reservoir retains liquid for the next priming cycle.

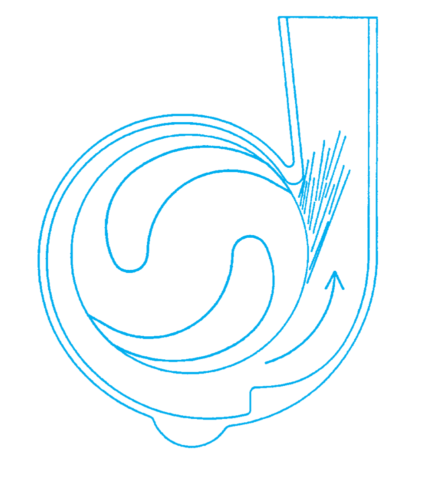
- An internal recirculation channel or port. This channel connects the pump's discharge cavity back to the suction reservoir internally, allowing the continuous recirculation of liquid from discharge back to suction during the priming, usually to the peripheral portion of the impeller (Figure 2B).

These two internal design features, the priming chamber and internal recirculation channel, are what distinguishes a self-priming centrifugal pump from a standard centrifugal pump. Self-priming can also be accomplished by a diffuser design centrifugal pump that is used primarily for clear liquids.

HOW IT WORKS

Self-priming centrifugal pumps can be placed above the liquid level of the source (Figure 3). Only the suction pipe enters the liquid being pumped. The pump is initially primed by adding liquid to the pump casing through a priming port, normally located near the discharge. The liquid fills the discharge reservoir, traveling into the eye of the impeller through the pump's recirculation channel. The suction line, itself, is not filled. A check valve is usually located just inside the suction reservoir. All connections must be airtight. During initial start-up, the impeller rotation causes the liquid

FIGURE 2



in the pump reservoir to be directed to the discharge cavity via centrifugal force. Simultaneously, a lower pressure is formed in the suction reservoir. This draws the liquid from the discharge cavity back into the suction reservoir through the pump's internal recirculation channel. This is a continuing action during the priming cycle. While this is occurring, the air in the suction line is drawn by the lower pressure into the eye of the impeller with the priming liquid and travels through the volute into the discharge cavity. At this point velocities decrease, allowing the air and liquid mixture to separate. The air flows up and is ejected, and the priming liquid recirculates back into the impeller.

This process continues to draw all the air from the submerged suction line. In applications where the liquid level is at atmospheric pressure, that pressure on the liquid surface, coupled with the lower pressure in the suction pipe due to the evacuation of air, serves to push the liquid in the sump into the pump. When all air is evacuated liquid pumping automatically begins.

Note that the diffuser design self-prime principle incorporates an impeller rotating in a stationary multi-vane diffuser (Figure 4). During priming, the diffuser separates the air from the pumped liquid until priming is completed.

This priming action might seem somewhat complicated or mysterious, but it is actually a very easy task for a correctly installed self-priming centrifugal pump, and it happens automatically in a relatively short time (20 - 30 seconds for a normal 15 foot suction lift).

It's this feature that differentiates self-priming centrifugal pumps from standard centrifugal models. On a suction lift condition, a standard centrifugal pump, with only air in the casing and having no ability to separate air and liquid to create a vacuum, would have an impeller that simply spins, acting as a fan, because it has no way to lower the suction line pressure. By placing a foot valve on the end of a suction line and filling the pump and suction line with liquid, a standard centrifugal pump can be made to operate and pump in a conventional mode.

If the foot valve leaks and air enters the suction, such as under a shutdown condition, a standard centrifugal pump stands the risk of losing its prime and becoming air bound. Under suction lift conditions, self-priming centrifugal pumps are ideal for unattended use.

Standard centrifugal pumps are sometimes fitted with priming systems to fill the pump and suction line with liquid prior to starting. In such cases, a control device tells the pump when all air is evacuated and the unit is liquid filled to start.

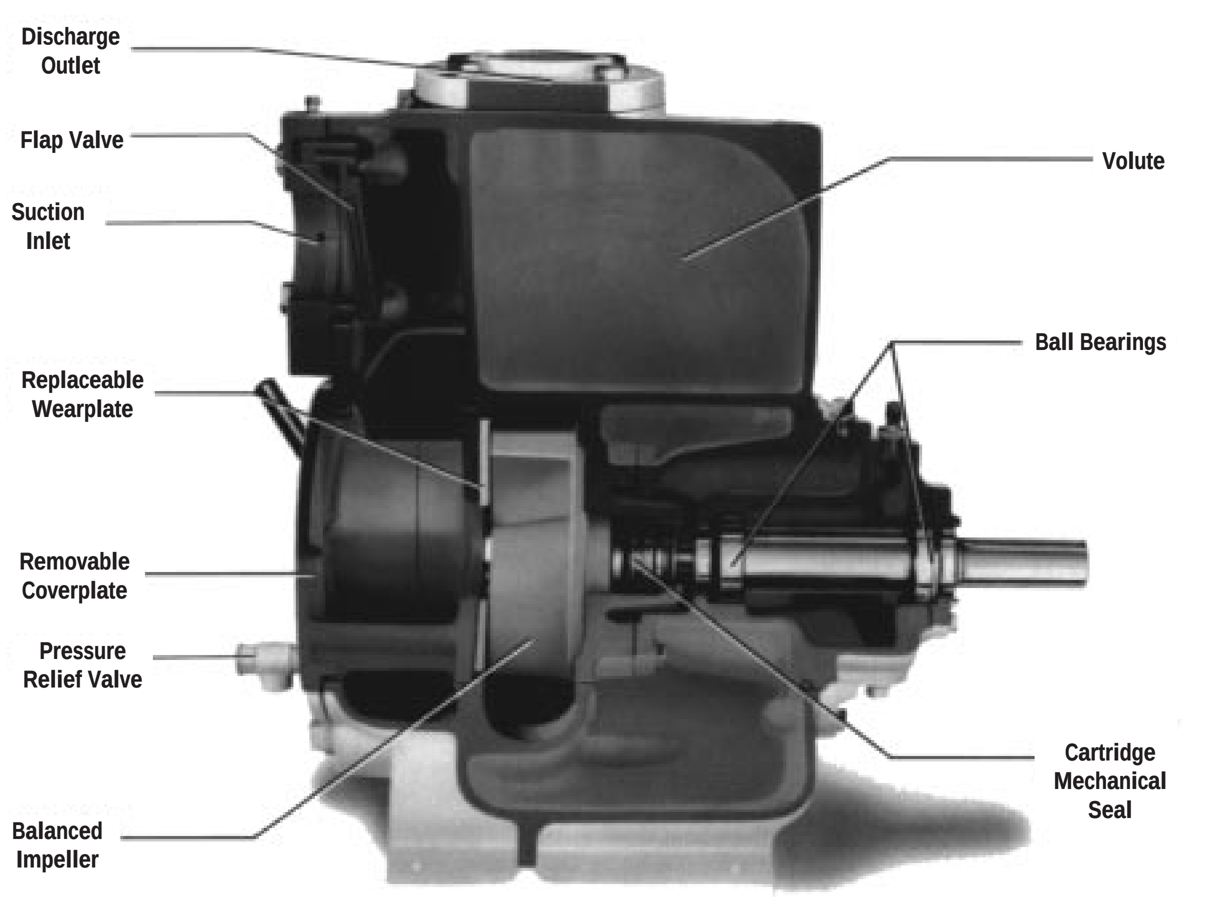
STYLES

Self-priming centrifugal pumps are usually classified into two groups: basic self-priming pumps and trash-handling self-priming pumps.

Basic self-priming pumps usually come with different impeller configurations, including fully enclosed and semi-open. Like all centrifugal pumps, the pressure developed is dependent on the impeller diameter and rpm.

- Fully enclosed impellers allow self-priming pumps to develop medium to medium-high discharge pressures, up to about 110 psi or 254 ft total dynamic head (TDH). Normal pump sizes range from 1 in. through 6 in. suction and discharge. Pumps with a fully enclosed impeller have a very limited solids handling capa-

FIGURE 2B



A cut-away view of a self-priming centrifugal pump designed to handle solids-laden liquids and slurries

bility, with sizes from 1 1/32 in. through 5/8 in. in diameter, depending on the size of the pump. This configuration is excellent for handling clear liquids, including processed hydrocarbons, along with general wash-down pressure applications.

- Semi-open multi-vane impellers are usually designed for slightly lower head conditions than fully enclosed impellers, but they have greater solids handling capabilities. Pump sizes usually range from 3/4 in. through 12 in. suction and discharge, with capacities to more than 5,500 gpm. Spherical solid sizes range from 3/4 in. through 3 in. in diameter, depending on the size of the pump. Basic self-priming pumps with semi-open impellers are sometime referred to as general-purpose self-priming pumps. They are excellent for handling dirty, contaminated liquids. Applications include extensive use in industrial filtration operations and a wide range of engine-driven models that serve the construction market.

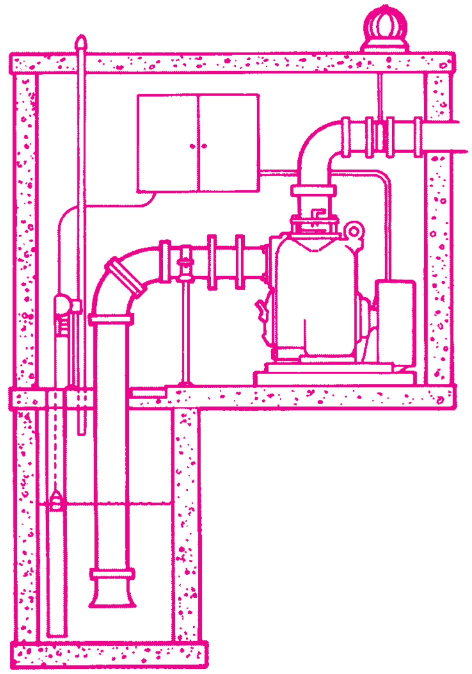
Trash handling self-priming pumps generally use a trash-type, semi-open, two-vane impeller that allows the pump to pass larger spherical solids.

- Trash handling self-priming pumps generate medium discharge pressures in the area of 62 psi or 145 ft TDH on electric motor drives and discharge pressures upwards of 75 psi or 173 ft TDH on engine-driven configurations, with capacities upwards of 3,400 gpm. Normal pump sizes range from 1-1/2 in. through 10 in. suction and discharge. The impeller design allows for excellent solids handling capability, ranging from l in. to 3 in. spherical solids diameter, depending on the pump size.

Trash handling self-priming pumps are often referred to as the workhorse of centrifugal pumps due to their rugged design and large solids handling capabilities. These pumps can be found on some of the most severe pumping applications within plants or on construction sites.

A desirable design feature of a trash handling self-priming pump is a removable cover plate, located

FIGURE 3



directly in front of the impeller on the suction side of the pump. Trash handling self-priming pumps may be applied in waste sump applications where they are exposed to various size solids. Any pump may clog trying to pump larger solids than it was designed to pass. The removable cover plate allows quick access to the suction side of the pump, expediting the removal of blockage. Some designs allow removal of the cover plate without disturbing the suction and/or discharge line.

SELECTION

As discussed, self-priming centrifugal pumps have a broad design range that allows them to serve a wide variety of applications. Many metallurgical choices and shaft seal configurations are available to best serve particular services.

Mechanical shaft seals can be single, double, or tandem. They are available as double grease lubricated for general purpose applications, oil lubricated with silicon carbide faces for industrial applications with abrasives, carbon against Ni-Resist faces for clean water or refined hydrocarbon applications, or Teflon fitted with carbon/ ceramic faces for chemical applications. Alloys available for pump construction also offer the same diversity. Cast iron and ductile iron are used for general purpose and refined hydrocarbons, hardened austempered ductile iron (ADI) is employed for abrasive applications, CD4MCu SS serves in corrosive and abrasive applications, and 316 SS, Alloy 20 SS, Hastalloy B, and Hi-Resin Epoxy Plastic are used for other special chemical applications.

APPLICATION GUIDELINES

The principal application area for self-priming pumps is where their ability to self-prime is a cost effective solution; and when it is more convenient and desirable to locate a pump ”high and dry“ above the liquid. Some general guidelines are in order:

The liquid being pumped should be of low viscosity (550SSU or less). Horsepower and efficiency corrections are needed for liquid viscosity above 550 SSU. If subjected to liquid freezing temperatures, the pump must be protected against freezing to avoid damage.

The vapor pressure of the liquid and the presence of high levels of entrained air are serious considerations in suction lift application.

The NPSHA (net positive suction head available) must exceed the manufacturer’s published NPSHR (net positive suction head required) by a margin that accounts for the liquid properties.

Repriming time increases with suction lift. Suction lifts with water as the liquid at normal ambient temperature should be limited to 15 to 18 ft. best efficiency range, although maximum practical lifts are obtainable to 25 feet. For other liquids or liquid mixtures, the vapor pressure of the liquid or the most volatile components of a mixture must be considered. Reducing the speed of operation (rpm) significantly reduces the NPSHR. Suction line piping should be sized to velocities in the 5 to 7 ft. range at design flow. For self-priming pumps it is recommended that the suction piping should be the same size as the pump’s suction inlet.

The self-priming centrifugal pump offers a unique solution to many pumping applications. ■

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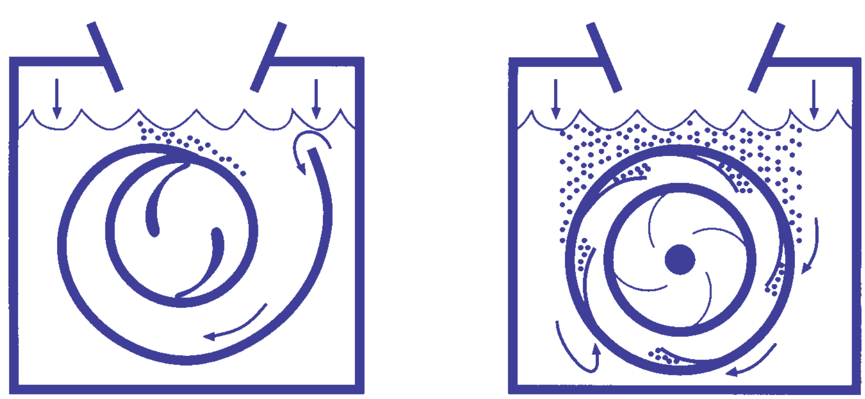
FIGURE 4



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