Triangle Pump Components Incorporated
Since 1919

Reciprocal Pump Cavitation

Understanding Reciprocal Pump Cavitation

Cavitation involves the formation and collapse of vapor bubbles within a pump. These bubbles are created when the fluid pressure drops below a prescribed value. The bubbles, when collapsing, generate high-speed jets of fluid, which hit the metallic parts, thereby causing micro fractures and, over time, degrading the mechanical structure of the equipment and reducing pump performance.

Occurring in all types of pumps and often experienced in reciprocal plunger pump applications, cavitation can cause serious damage to pumps over time, resulting in pump erosion, noise, erratic power consumption, and vibration. Often, unchecked cavitation also damages the pump components and eventually leads to the complete failure of the plunger pump.

Vapor Pressure in Pump Cavitation

To fully understand cavitation, it's essential to understand vapor pressure. Usually, a liquid, such as water, turns into vapor at normal atmospheric pressure when the temperature exceeds its boiling point. (In the case of water, this would be 100 °C). However, liquids can also turn into vapor if, at any given temperature, their pressure drops below a certain value. This value of pressure is referred to as vapor pressure — the pressure exhibited by the vapor present above the liquid surface at hand. In a pump, if the pressure of the liquid drops below the vapor pressure at any point, the liquid in that area vaporizes and forms bubbles.

These bubbles will continue to move through the pump along with the rest of the liquid and collapse inward when they reach a region of higher pressure. In the process, a high-velocity micro stream of fluid is released, which may impel on the pump components, causing damage. In general, cavitation requires the fluid pressure to drop below the vapor pressure. Therefore, in a plunger pump, cavitation is most common at the suction and discharge valves and on the end of the plunger, where there is the highest chance of turbulence and pressure variation due to improper piping design, clogging of filters, and blockages. These problems can lead to the formation of low-pressure pockets near the pump valves, which in turn leads to the formation and accumulation of vapor bubbles.

Causes of Cavitation

Cavitation can cause several major issues in pumps. While multiple factors can lead to cavitation, improper system design – specifically, improper pump selection or incorrect pipe size – is the most common.

For example, a pump that is too large would require more net pressure suction head than is available. Design flaws can cause fluid pressure within the system to drop below the vapor pressure, in turn causing bubbles to form. As an example, if an elbow is located just before the intake, it creates a turbulent flow into the pump and ultimately causes cavitation. Or, if the inlet temperature of the fluid is higher than the design value, cavitation is likely to occur, as the vapor pressure decreases as temperature increases. In addition, dissolved gaseous impurities or components with a low flash point in the fluid can also contribute to bubble formation, increasing the severity of cavitation.

Finally, cavitation can also be caused by pipe corrosion buildup or sediment accumulation within tanks or vessels that feed suction piping; both of these problems reduce the pipe's interior diameter and therefore limit flow.

One of the most noticeable symptoms of cavitation is the knocking noise associated with it; the pressure shocks produced by the collapse of many bubbles result in a knocking sound. The pressure shocks produce vibrations that can eventually loosen the flange bolts from the pump, letting in air and causing aeration. The shock waves are often severe enough to damage the crank shaft itself. The most characteristic damage of cavitation, however, is erosion and pitting in areas where pressure variation is highest, such as the suction and discharge valves. And because vapor occupies a much larger volume than liquid, cavitation also leads to a reduced pump capacity.

Spray metal plunger showing damage caused by severe cavitation.

Valve disc showing pitting caused by cavitation.

NPSH, NPSHA, and NPSHR

As discussed, cavitation is caused when the pressure at a certain location drops below the vapor pressure of the circulating fluid; therefore, cavitation can be prevented by ensuring an adequate pressure inside the system such that the fluid pressure never drops below the vapor pressure. This can be achieved by maintaining a sufficient net positive suction head (NPSH). NPSH is essentially the difference between the pressure at the suction side of the pump and the vapor pressure of the operating liquid, expressed as a height of the liquid column.

There are actually two different NPSH quantities to consider, NPSH Available (NPSHA) is the actual difference between the suction inlet pressure and the lowest pressure level inside the pump. In essence, NPSHA is the measured NPSH of a pump.

The second quantity, NPSH Required (NPSHR), is the pressure head specified by the manufacturer so as to avoid cavitation. In practice, if the NPSHA of a pump is greater than the NPSHR at 3-5 lbs/ in^2, then cavitation can be avoided. The idea here is that if the inlet pressure is sufficiently high, then, for a given set of operating conditions, the lowest pressure that occurs within the pump will be higher than the vapor pressure of the fluid, thereby preventing any vapor bubble formation.

However, when factors such as poor plumbing design, high fluid inlet temperature, and placement of the pump above certain heights — which reduces the atmospheric pressure and adds to the inlet pressure — can reduce the inlet pressure below the design value and reduce the NPSHA below NPSHR, thereby causing cavitation.

Successful System Design

A well-planned system design is the best way to eliminate cavitation. For example, the NPSHA of a system, which is not based on an individual pump, should be calculated, and a pump with a lower NPSHR, which is a design characteristic of a pump, should be chosen.

In addition, the suction valve should be designed in a way that any gas bubbles in the fluid have sufficient time to escape. The suction piping and suction line pipe valves should not have a strainer or filter unless there is provision for regular maintenance, as a blocked pipe valve can starve the pump, causing low pressure and, eventually, cavitation.

Manipulating the Pressure Gradient

In addition to proper system design, it is possible to manipulate the pressure gradient in a pump so as to avoid cavitation. This can be achieved either by lowering the NPSHR or by raising the NPSHA. The NPSHR can be lowered by placing the pump at a lower height or, if necessary, by replacing the existing pump with a pump with a lower NPSHR value.

Reducing the operating speed can also effectively reduce the NPSHR. However, lowering the NPSHR by reducing speed can cause the pump to operate below its designed efficiency. Increasing NPSHA is more easily achieved by raising the height of liquid column at intake — effectively increasing the pressure at intake — or by cooling the fluid before suction. NPSHA can also be increased by optimizing the fittings at the suction line in order to reduce any pressure loss due to friction.

Steps to Reduce Cavitation Beyond Proper Suction and Discharge System Design

Cavitation is most commonly the result of a pump on the suction side of a system not receiving enough working fluid, which means the pump cannot operate at ideal pressures. This issue can often be remedied with the addition of a booster — also referred to as a charging pump — at suction side, or the use of an appropriate dampener.

Cavitation in Reciprocating Pumps

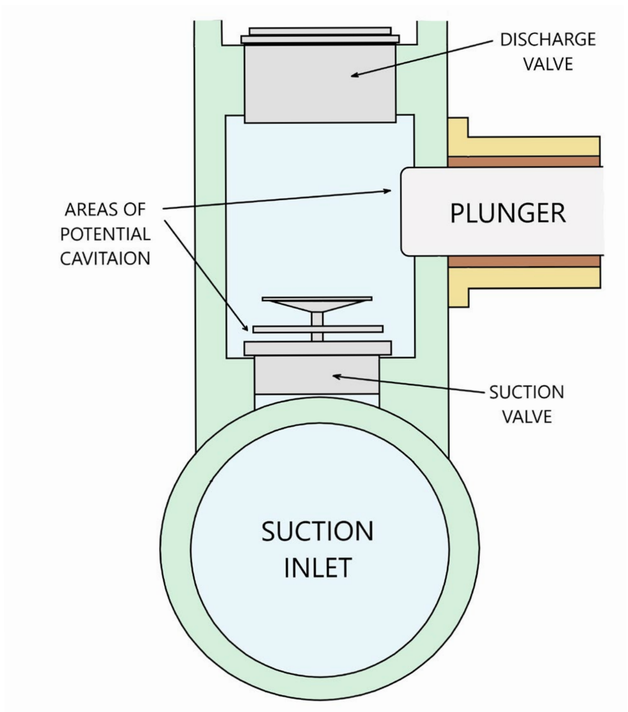
Although cavitation can occur in all types of pumps, the effect is often a greater concern in reciprocating pumps, which are used to deliver pressurized liquid that can be used to power a number of different industrial applications.

In reciprocating pumps, the need for appropriate suction makes them more design-intensive than centrifugal pumps. Improper design, especially at the suction, can lead to low pressures within the system, resulting in cavitation. Cavitation will typically first manifest as vibration and noise, which can present a nuisance, but over time, it will result in mechanical deformation and can even cause total system failure. The pulsation caused by cavitation can damage instrumentation, as well as critical system and pump components.

Timely, thorough maintenance is key for preventing system failure. With proper upkeep, these pumps can last for decades. Without it, they're very vulnerable to the effects of general wear and tear, resulting in increased downtime, extra expenditures, and increased labor needs.

How to Increase NPSHA

Cavitation can be prevented by ensuring the fluid pressure inside of a system does not fall below the vapor pressure of the working fluid. This is done by maintaining a sufficient pressure head at the suction side.



Net positive suction head (NPSH) refers to the difference between the pressure at suction and vapor pressure of the operating liquid, expressed as a height of the liquid column. While the specific design of a system will determine NPSH, the head may be lost due to friction loss. Therefore, NPSHA is the sum of atmospheric pressure and height separation between the liquid storage tank and pump centerline, minus the vapor pressure for the operating temperature and any losses due to friction. If this NPSHA is greater than the required NPSH (NPSHR) of the pump, the system will operate smoothly.

To properly maintain net positive suction head, users should ensure any increase in velocity is progressive, as this will reduce turbulence and pressure loss. Flow stability can also be improved so that streamlined flow is achieved and separation between the supply tank and suction is minimized.

Common Client Inquiries Regarding Cavitation

While cavitation is easily preventable, it's a common problem in all types of liquid pumping systems involving reciprocating pumps. Systems usually work fine in the beginning stages of cavitation, but serious damage can occur as the effect intensifies over time. This will result in hammering, vibrations, and ultimately, serious mechanical deformation of components.

When customers come to us for advice, they are usually unsure of the root cause, how to properly identify it and unclear of how this problem can be fixed. The most popular solution is a valve, disc, or spring replacement. But these components may not be causing the issue, so it's important to carefully inspect the system and have a full understanding of its various components.

Users should first check for any changes on the suction side, such as the development of a clog.

Diagnosing Cavitation Issues

To some extent, users can diagnose their own cavitation problems by using the basic checklist below and keeping a close eye on any system changes or out-of-the-ordinary occurrences. We usually advise clients to look at the basics first, and not overcomplicate the solution. As mentioned earlier, if the system was running well before, then something on the suction side of the pump has changed, and this should be assessed and remedied immediately before making any drastic decisions.

The checklist below will provide a good starting point for identifying the cause of an issue, but users should be sure to partner with a well-respected, knowledgeable service provider in the event of very serious issues or hard-to-diagnose situations.

CHECKLIST FOR CAVITATION DIAGNOSIS

- Does the full opening pipe valve in the suction line need repair or replacement? Is it sticking and no longer fully opening?
- Has corrosion developed in the suction piping over time, causing restricted flow?
- Have flanges and other pipe fittings worked loose, causing air to be drawn into the system?
- Has the pumped fluid changed? Has the temperature increased? Increased temperature requires more NPSH. Have contaminants been introduced into the pumped fluid that altered its vapor point?
- Has the fluid level in the feeder tank or vessel changed? Has sediment accumulated in the bottom of the feeder tank or vessel, partially blocking the suction outlet or decreasing the overall volume of fluid available in the tank? Is the kill switch, triggered by the fluid level in the tank, still working?
- Is there a filter or strainer in the system that needs cleaning or removal?
- Does the suction dampener need attention? Has it been charged, or has the bladder failed?

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About Triangle Pump Components

For over 100 years, Triangle Pump Components Inc. has been an industry leader in durable, dependable pump components. From our patented World War II-era **Durabla®** valve to our plate valves, **Resista®** abrasion resistant valves, patented **WG Sphera® Series** of spherical valves, plungers, packing, and **DynaRod®** extension rods, our entire product line is equipped to mitigate suction system failures for your pump.

We manufacture and sell reciprocal pump valves, plungers, packing, and a full line of stuffing box components. Our dependable products and dedicated staff are here to help resolve any suction system problems you may be experiencing.

To learn more about our diverse line of pump products, contact us today to speak with a Triangle Pump Components representative.

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