Accurately Quantifying Pump Failures During a PHA

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Are you overestimating the severity of a pump failure during your PHA? Pump failures are one of the most common scenarios analyzed during a Process Hazard Analysis (PHA) Study. There are a multitude of considerations that go into the determination of pump hazards, which may be confusing due to the wide range of pumps, process conditions, and failure mechanisms. Without proper preparation, these scenarios can be easily overestimated to conservatively cover a hazard that may be less severe than determined by the available PHA team. The goal of this TechTip is to provide a helpful way to approach these scenarios to ensure that your systems and personnel are being properly protected.

Understanding the traditional pump hazards and what considerations go into them. Before being able to properly analyze a scenario within the PHA, it's important to first ask what the pump hazard is. A loss of suction scenario can be developed if the upstream vessel is no longer being provided its process flow. During this event, the insufficient suction pressure can result in seal failure and a limited inventory vessel vapor release. It is important to ensure that the elevation between the pump and associated vessels is considered when analyzing the inventory to be released at the loss of containment (LOC) location. The most common safeguard to consider during this scenario is a low-level alarm/function. A slight variation to this scenario would be in the event where an upstream valve is closed resulting in a blocked suction case. The immediate closure of an upstream valve would result in an insufficient suction pressure for the pump and lead to cavitation, pump damage, and a possible LOC. The inventory released during this scenario should be limited to the volume of the suction piping; however, downstream flow may be reversed and released through the LOC location for some pump designs. The most common safeguard to consider during this scenario is a low-flow alarm/function. A severe pump hazard can be developed due to a downstream closure of a valve, traditionally referred to as a blocked discharge scenario. During this event, the pump will continue to build pressure as it reaches its deadhead pressure resulting in the overpressure of its discharge piping or failure of the pump itself. The new concern with this pump hazard is that the buildup of pressure can also lead to overheating of the pump. This can lead to a decomposition of the process material and thermal degradation of the pump casing/internals. Additionally, due to the location of the blocked flowpath, a LOC scenario can result in a much larger inventory of release that should be taken into consideration when determining the severity during the PHA. The most common safeguards to consider during this scenario are a low-flow alarm/function or a minimum flow recirculation.

Aside from these scenarios developed due to causes independent of the pump, there are a few cases emerging from the pump itself. A common failure mode can be if the pump shuts off during normal operation, which can lead to pump back spinning and reverse flow through the pump. Without proper reverse flow protection, this can lead to detrimental impacts both upstream and downstream of the pump. The most common way to provide this reverse flow protection is through multiple inline dissimilar check valves. For dual-pump configurations,

TECH TIP

an important scenario to investigate is the event when a standby pump is inadvertently activated. This can lead to the drainage of upstream vessels and a vapor release that can be more severe than the LOC of the previous scenarios investigated.

How various pump types will affect your pump hazards within the PHA. The next important question to ask is what type of pump you are analyzing. Different pump designs may alter the credible scenarios to investigate during a PHA and can change the severity of the pump hazards previously mentioned.

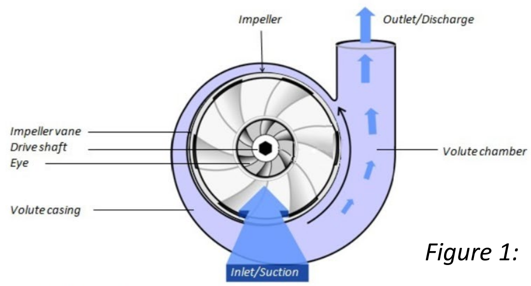

Figure 1: Centrifugal Pump

Centrifugal pumps are utilized for the transportation of lower viscosity fluids where the rotation of the pump's impeller is utilized to draw fluid and force into the discharge of the pump. Due to the impeller providing the pressure, this can significantly increase the severity of a loss of suction/blocked suction scenario. As the impeller rotates, the vaporized liquid can result in significant impeller damage resulting in seal/bearing failure and an LOC.

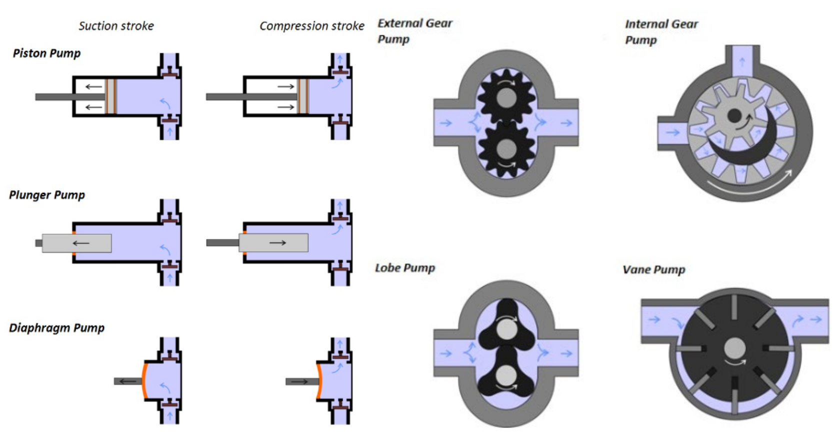

Figure 2: Positive-Displacement Pump

The other most common pump-style within a facility is a positive-displacement (PD) pump, which are typically operated under lower-flow conditions and with higher viscosity fluids. These pumps can be separated into two classifications: reciprocating and rotary. Reciprocating pumps include piston, plunger, and diaphragm pumps which rely on the repeated back-and-forth movement, also known as strokes. This movement creates pulses in the discharge of the pump and accelerates the fluid during its compression phases and decelerates during the suction phase. This can lead to vibrations within the pump system and why the seal selection for these pumps is highly critical to its mitigation of potential leaks. Additional considerations to your pump configuration can include the integration of dampeners to reduce the impact of these vibrations and overpressure protection on the discharge of the pumps to account for the high pressure generated during the pumping cycle of this pump style. On the other hand, rotary pumps are utilized to transfer fluids through the rotation of cogs or gears that creates a liquid seal with the pump casing to create the suction at the pump inlet, where fluids flow into the pump and its rotating elements transfer the fluid to the discharge of the pump to be

TECH TIP

transferred as designed. The vice associated with this style of pump is that the rotating elements must be properly lubricated due to the low tolerance between rotating elements and can lead to severe pump damage in the event of a loss of flow through the pump. An additional consideration worth noting for this style of pump is also the fluid selection when using rotary pumps. If a feed contains abrasive materials, this can cause excessive wear on the rotary elements and increase the frequency of the failure of the valves and seals for this style of pump.

How can you be more prepared to analyze scenarios during a PHA? The most valuable individual to assist with gauging the severity of pump hazards is a rotating equipment subject matter expert (SME). The only issue is that they are rarely available to attend the entirety of your PHA. One way to combat this is through the preparation phase of the PHA. Prior to performing the PHA study, preparing a Request-For-Information (RFI) several weeks prior to the study can lead to a more consistent and accurate study. The parameters to include within this document are process conditions (pressure, temperature, composition), maximum deadhead pressures, seal plans, and the minimum flow requirements for all pumps within the scope of your PHA. Following this request, the SME should be able to provide you with severity and timing estimates for safety and financial impacts associated with the previously mentioned pump hazards. The most valuable item to receive from this request is the timing associated with these failure modes. A common overestimation within a PHA is assuming that the seals/discharge piping will fail within a short period of time following the loss of feed or closure of upstream/downstream valving surrounding the pump. With the SME's insight, the conclusions drawn from your PHA scenarios will be far more credible, getting the most value out of your study.

Resources

Figure 1 : Centrifugal Pumps
Figure 2 : Positive-Displacement Pumps

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