How to transfer hazardous chemicals



Most chemicals are either toxic, volatile, or highly corrosive and therefore must be handled with care. Chemicals can pollute and harm the environment, posing significant risks to human health. Due to these hazards, there is a great responsibility for the chemical industry to establish plants and processes absolutely safely. In this whitepaper, we will discuss the best practices for handling the pumping of hazardous chemicals.

In industrial processes, a wide variety of chemicals are utilized, both for manufacturing industrial and consumer goods. They are employed in various applications such as effluent treatment, chemical waste processing, pharmaceuticals, and wastewater treatment. Additionally, chemicals are used for finishing or treating products, such as in metal baths in the galvanic industry or in sanitary applications like CIP processes to clean hygienic equipment.

Many chemicals are considered compound chemicals, such as methylbenzene or toluene, which are often used as solvents in adhesive compounds. Inhalation of these solvents poses severe risks to the central nervous system and can lead to memory loss. Moreover, these substances are known carcinogens.

One of the most commonly used acids in the industry is sulfuric acid, utilized in the production of artificial fertilizers and found in automotive batteries as an electrolyte. Contact with sulfuric acid can result in serious skin burns, emphasizing the critical importance of organizing production processes with utmost safety, ensuring 100% exclusion of leaks.

Hydrochloric acid usage can lead to long-term health issues such as lung damage, tooth enamel erosion, and eye damage. Safety measures are of paramount importance when handling chemicals like acetone or hydrogen fluoride.

Chemicals are typically delivered to the factory in containers or barrels. From there, they are transported to the relevant part of the production line, such as storage tanks or reactors, where they are used.

Once in the production line, the chemicals may be mixed, diluted, or used as solids in suspension. After processing, it may be necessary to filter the residue. It is crucial to ensure that at this stage of the process, the risk of leakage is completely eliminated.



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Leak-free operation and total containment of fluids

The seal is a critical aspect for the safe operation of the pump. “A pump is only as good as its seal” is a well-known saying in the industrial pump world. The choice of seals is often limited by the pump type, which becomes immediately apparent when comparing sealless pumps with sealed pumps.

Shaft-sealed rotary pumps

Most shaft-sealed pumps, such as centrifugal pumps, gear pumps, lobe pumps, and vane pumps, require a seal between the shaft and the liquid being pumped.

Stuffing box packing (**see fig. 1**) can be utilized for this purpose. However, it has the disadvantage that the rings can become heated, posing a significant danger in ATEX environments. Additionally, these packings only function effectively if the medium serves as both a coolant and a lubricant. Maintenance of a stuffing box is extensive, and there is a high likelihood of eventual wear due to abrasion. This defect occurs more frequently when pumping crystallizing liquids, which can leak into the surrounding air.

A lantern ring or a quench can provide a solution (**see fig. 2**). However, liquid may still escape through the packing rings preceding the lantern. The quench liquid may also become significantly diluted. An alarm will sound if the fluid level in the barrier chamber rises, indicating pump failure. Such pumps are expensive to use when transferring hazardous chemicals, primarily due to the high maintenance and frequent replacement costs of barrier fluid and seals, as well as associated downtime costs.

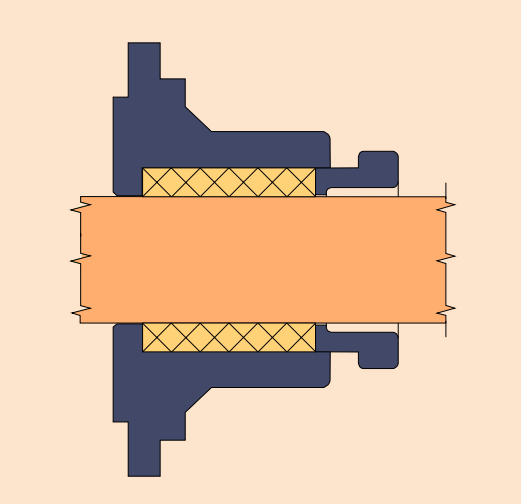


Fig. 1: Pumpshaft with packing gland containing 6 packing rings.

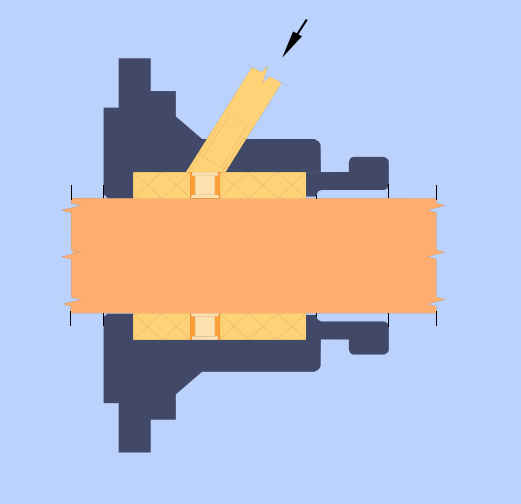


Fig. 2: Packing gland with 2 packing rings, lantern ring with quench and 3 packing rings



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Mechanical seals

A mechanical seal is much more common in process pumps because it is much safer (**see fig. 3 and 4**). A mechanical seal has a spring-loaded tension mechanism, and the sealing surface is cooled and lubricated by the liquid. However, the seal will exhibit abrasive wear quickly because it rotates against a stationary surface. A single mechanical seal is very sensitive to leaks, which can result in liquid dripping or evaporating and unnoticed vapors escaping into the ambient air, leading to dangerous situations.

Even with a double mechanical seal (**see fig. 5**), wear on the first seal will occur as described above. Although the sensitivity to leaks is reduced, the high maintenance costs associated with a single mechanical seal remain. Installing an alarm is also an absolute requirement for this type of seal. A double mechanical seal requires a thermo-siphoning system or an additional pump to maintain the pressure. Costs for spare parts and labor, such as maintenance, inspection, and installation, must also be considered. Mechanical seals can be very effective to contain liquids, a double mechanical seal require a barrier fluid to protect the seals and manage the risk to potential leaks or failures. The system is effective and require regular inspection and maintenance.

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Sealless pumps

Sealless pumps, interestingly enough, also have seals. These consist of O-rings, creating a static seal between the flange surfaces of the housing. The term “sealless” refers to the pumping action of a sealless pump. The static seal prevents wear by avoiding contact between moving pump parts. The liquid is fully contained, completely sealed within the pump chamber. Peristaltic pumps, mag drive pumps, and air-operated diaphragm pumps operate according to this principle.

As long as the wetted materials (the materials that come into contact with the medium) are chemically resistant to the liquid, there is total containment, ensuring a completely leak-free operation.

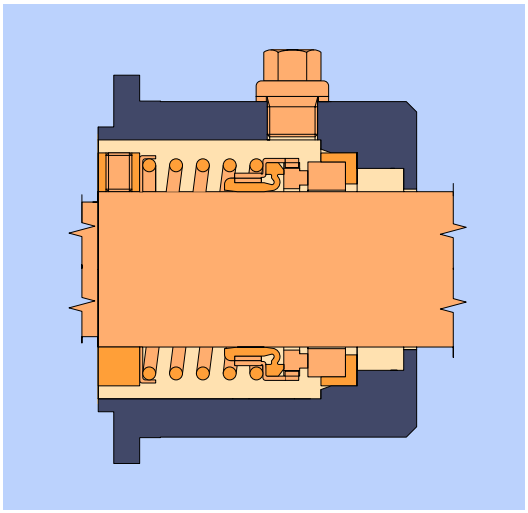


Fig. 3: Single mechanical seal

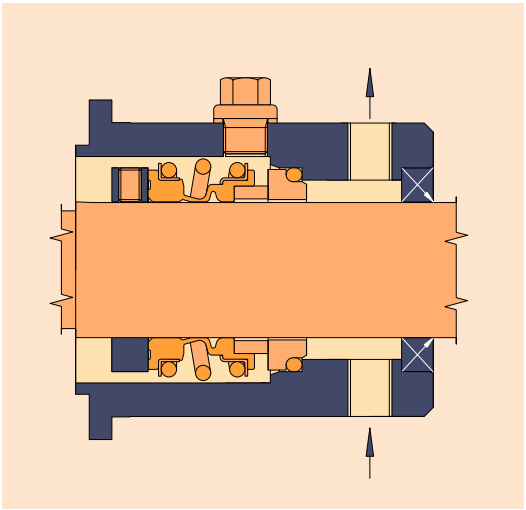


Fig. 4: Single mechanical seal + quench

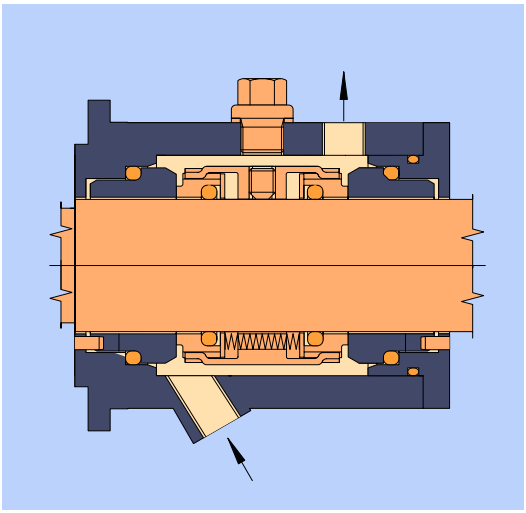


Fig. 5: Shaft equipped with double mechanical seal

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The mag drive system

Parts of the pump that come into contact with the medium are generally made of non-metallic, metal-lined, or stainless steel materials. An ETFE-sealed pump provides additional security against corrosive media but does not have the strength and robustness of a steel pump housing. Many mag drive pumps work for decades without any downtime. This robust pump principle normally operates without any problems. Magnetic drive pumps does not have any mechanical seals or bearings, bearings are replaced with wear rings depending on the choice op pump material a magnetic drive pump excel in the safe and reliable containment and liquid transfer. The technology has limitations to high density liquids or liquids containing solids.

The reliability of mag drive pumps makes them prescribed as standard in many refineries and chemical-producing industries. However, mag drive pumps are not suitable for viscous liquids (> 250 cPs) or when the liquid contains solid particles. In such cases, there is too much load on the magnets and bearings. When the fluid has a higher viscosity, it will not flow adequately in a mag drive pump. Mag drive pumps are also unsuitable for media with solid, hard particles, as the pumps will be damaged and will fail when pumping larger solid particles. A positive displacement pump is a better choice for these applications, such as in the manufacture of paints and lacquers, where poisonous cyanide compounds can be formed by the viscous resins.

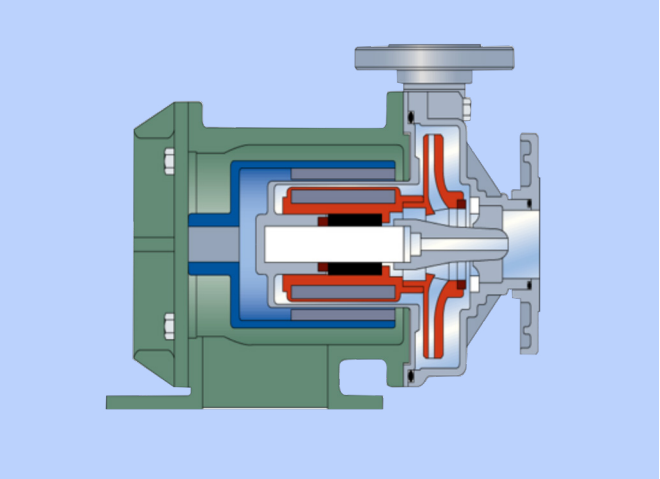


Fig. 6: Working principle of a magnetic driven centrifugal pump

Positive displacement pumps: a good alternative

A peristaltic pump operates on a simple yet ingenious principle and does not have any liquid seals. The heart of the pump consists of a flexible tube or hose fitted inside a circular pump casing. As the rotor turns, rotor shoes or rollers compresses the tube, creating a vacuum that draws fluids through. This mechanism ensures that the liquid is contained within the tube/hose and does not come into contact of any metal or moving parts of the pump, effectively minimizing the risk of contamination or chemical reaction. The chemical compatibility is limited to and option of available hose and tube materials.

The liquid isolation is particularly advantageous when transferring volatile, corrosive, or hazardous chemicals, which require stringent safety measures to protect both the machinery, and the personnel involved. Hydrofluoric acid (HF) when in human contact penetrate human skin and cause internal tissue and skeleton damage. Hydrochloric acid (HCl) and some chlorines are important chemicals used in the manufacturing, pharmaceutical, rubber and water treatment industries, the liquids turn into a gas that is harmful to environmental exposure, liquid containment is therefore extremely important.

Industrial peristaltic pump options include a choice of a shoes and rollers, a distinct difference between the options is, shoe pumps contain a pump casing lubricant to reduce friction between the hose surface and the shoe whereas roller pumps is a dry casing with no lubricant. It is noteworthy to understand the risk in the event of hose failure or maintenance, the lubricant in hose pumps should be chemical compatible with the transferred liquid. Secondly, the liquid dilutes the chemical and remains contained within the pump casing to be drained and disposed in a controlled manner. The corrosive risk in dry casings is higher than in lubricated casings.

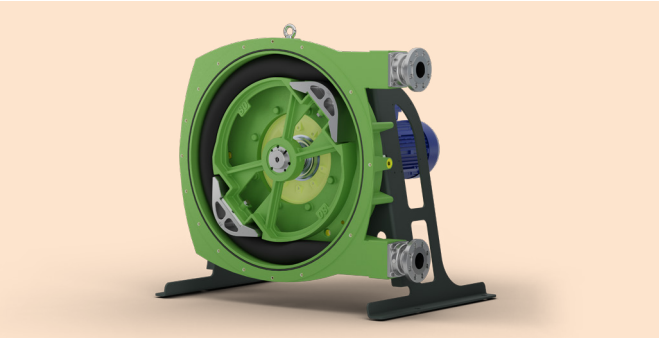


Fig. 7: Working principle of a peristaltic pump

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Air and electric operated double diaphragm pumps

Air and electric operated double diaphragm pump (AODD/EODD pumps) are manufactured as standard from injection-molded plastics such as PVDF, polypropylene, or metals. These materials are resistant to solvents. However, for some chemicals, the standard materials are not ideal due to factors like temperature limitations, chemical resistance, or purchase costs.

Injection-molded (non-metallic) AODD/EODD pumps have a temperature limit of +90 °C, so a non-standard material for the diaphragm is often required. PTFE is a good choice for solvents and chemicals, as it ensures that the liquid cannot enter the air chambers.

Pumps with PVDF pump chambers often have either a metal or a polypropylene center section. In case of diaphragm failure, the medium will enter the center section and damage it. A leak detection sensor can be placed in the air section to alert for diaphragm rupture, but this is only a partial solution because the sensors are attached to the air side of the pump. The alarm will only sound if the rupture has already occurred, meaning the medium has already escaped to the air side. Liquid may have already leaked into the atmosphere before the pump is stopped.



Fig. 8: A machined double diaphragm pump

Solid machined double diaphragm pumps

For the transport of aggressive and corrosive media in hazardous environments, double-acting diaphragm pumps have been developed that are manufactured from a single piece of solid pure PTFE. For applications where safety is crucial, these pumps are the safest solution. They are available in both air and electric driven execution (AODD/EODD).

Pure PTFE is chemically inert, meaning it is chemically neutral and does not react with chemicals. Unfortunately, virgin PTFE cannot be injection molded. The pumps must be machined from a solid pure block of PTFE. With this type of pump, all chemicals and solvents can be pumped without any corrosion or risk of leaks. In potentially explosive areas (ATEX environments), the pump can be manufactured from solid PTFE material with a small amount of carbon added to it. This modified material retains the same chemical properties, and the added carbon ensures that the PTFE becomes electrically conductive. This makes the pump suitable for use in accordance with ATEX 2014/34/EC guidelines.

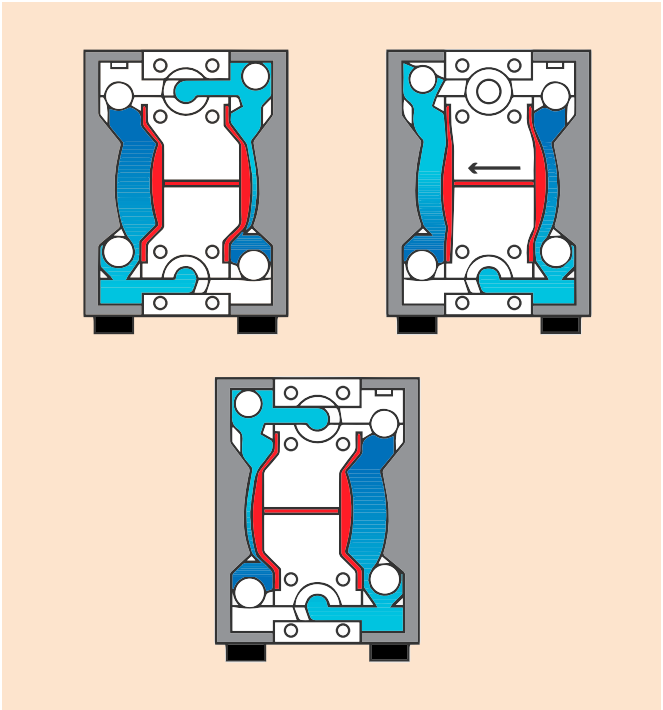


Fig. 9: Working principle of a double diaphragm pump

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Additional safety measures

Although these pumps are manufactured from a single block of solid PTFE and offer extra safety, the diaphragm remains susceptible to wear and rupture. In case of diaphragm failure, the pumped liquid can enter the air chamber and leave the pump via the muffler. Because this pump is machined, it is cost-efficient to easily add accessories, such as leak detection, drains and barrier chambers. These additions provide even better protection for staff and the environment.

Barrier chambers

A barrier system (**see fig. 10**) consists of a double diaphragm in each liquid chamber. Between the double diaphragms, a neutral liquid is placed and monitored. When a diaphragm fails, the pumped liquid will enter the double chamber but will still be sealed from the atmosphere by the second diaphragm. Sensors in the barrier liquid detect the entry of the pumped liquid and trigger an alarm. If one of the diaphragms fails, one of the sensors will detect the rupture and will give an alarm.

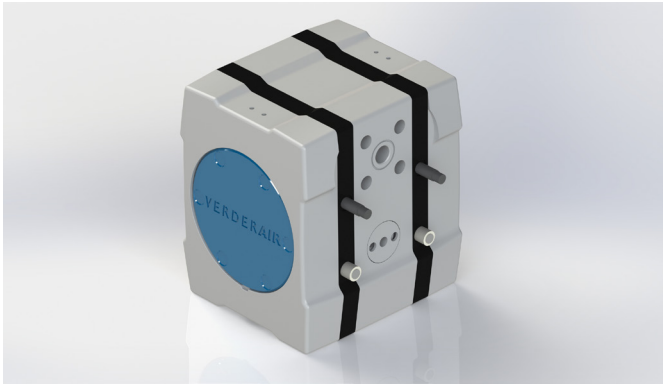


Fig. 10: A machined double diaphragm pump with barrier chambers + sensors

Drains

In a double diaphragm pump, one of the pump chambers will always be filled with the medium. Even when the pump is stopped, there will be liquid in one pump chamber because the ball valves, acting as non-return valves, prevent the liquid from draining out of the pump. If a pump is used for pumping several different liquids, it's crucial to carefully empty the pump chamber to prevent contamination with any remaining residues of the previously pumped medium. This is also important during maintenance when the engineer opens the pump.

A manual or pneumatic drain can be integrated into the pump through a bore on the side of the solidly manufactured pump without compromising the integrity of the housing (**see fig. 11**). This allows the pump to be drained for maintenance or when switching the liquid to be pumped.

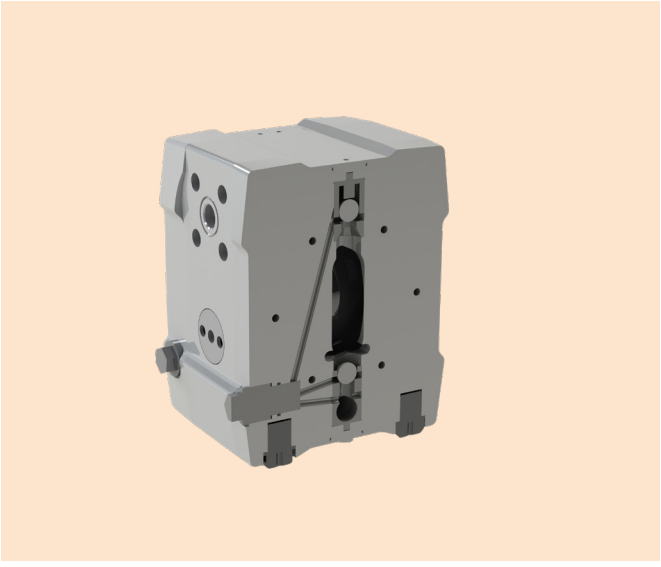


Fig. 11: Draining channels of an AODD pump



Conclusion

When choosing a pump for the transfer of dangerous chemicals, several important factors must be considered:
Leakage-Free Operation: It's essential to choose a pump that operates without any leakage to prevent environmental contamination and ensure the safety of personnel.
Chemical Resistance: The materials used in the pump must be highly resistant to the chemicals being handled to prevent corrosion or degradation, ensuring long-term reliability.
Ease of Safe Operation: The pump should be easy to operate safely, with clear controls and safety features to minimize the risk of accidents.
Installation, Inspection, and Maintenance: The pump should allow for safe and straightforward installation, inspection, and maintenance procedures to ensure continued reliability and safety.

Additionally, the choice of pump type should be based on factors such as volume and viscosity of the hazardous chemicals being transferred:
For mid-volume, low and mid-viscosity flows, solid machined double diaphragm pumps are typically suitable.
Large volume thin fluids are best handled by mag drive pumps.
Hose pumps are ideal for large volume mid-viscosity flows.
Progressing cavity pumps are well-suited for large volume high viscosity flows.

However, the most critical aspect is selecting the pump that best suits the fluid characteristics of your process and considering the operational requirements. For instance, 24/7 operation may require a different pump principle than a pump used only for emergencies or occasional use.



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