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Pump sealing for low-temperature hydrocarbons and liquefied atmospheric gases

Pumping of low-temperature and cryogenic fluids requires specific and unique engineering technologies for the shaft sealing system. When correctly applied, these technologies provide the containment and reliability to meet pumping equipment operators' requirements.

Due to their extreme sub-zero temperatures, low-temperature hydrocarbons and liquefied atmospheric gases pose significant challenges to pumping, and particularly to the specification of their shaft sealing systems. To provide long-term reliability while ensuring that these pumped fluids are safely contained, the designs of the shaft seals used in cold-fluids pumps are often highly specialized.

For example, low temperatures have significant implications for the choice of materials used in the seal construction. Metals become increasingly brittle as the temperature is reduced; therefore, thermal constriction and expansion must be factored. The volatility and flammability of low-temperature hydrocarbons pose special challenges for the design of pump shaft seals, as well as for the release of hazardous emissions to the atmosphere. Liquefied oxygen, with temperatures much colder than these hydrocarbons, is a strong oxidizer and can cause certain materials to spontaneously combust.

Low-temperature hydrocarbons are typically pumped at sub-cryogenic temperatures, between –20°C and –140°C (–5°F to –220°F), although lower temperatures are occasionally encountered. They have high vapor pressures at ambient temperatures and are pumped at low temperatures to reduce the pumping pressures. These hydrocarbon fluids include ethylene, LNG, LPG, methane, butane and propylene.

Liquefied atmospheric gases include oxygen, nitrogen, argon and the noble gases. They are typically pumped at cryogenic temperatures ranging from –175°C to –198°C (–285°F to –325°F). Impeller inducers are often used, as they are frequently pumped with a low vapor pressure margin at the pump suction.

Pumping equipment for low-temperature and cryogenic fluids. Low-temperature hydrocarbons are commonly pumped with API 610 (VS6) vertical multistage double-casing pumps that feature a warming chamber, known as a cofferdam (**FIG. 1**), which thermally isolates the shaft seal from the cold pumped fluid. Cofferdams enable a greater range of shaft sealing solutions to be used on these pumps, utilizing traditional sealing technology.

A cofferdam is a chamber between the pump discharge and the mechanical seal that is connected to the pump suction, or the vessel from which the pump is drawing suction. Ambient heat surrounding the pump, together with energy from the shaft and bearings, causes the liquid in this chamber to vaporize into a gas, which forms an insulating barrier between the seal and the process fluid. Cofferdams can be incorporated only into vertical pump designs.

Although vertical arrangements are common, various horizontal pumps can also be used. In these types of pumps, the shaft seal is in direct contact with the cold-pumped fluid; therefore, selection of the seal materials for low-temperature operation becomes more critical.

Similar to pumping equipment for low-temperature hydrocarbons, pumps used for liquefied atmospheric gases have a combination of vertical multistage pumps, together with horizontal single-stage pumps. These systems generally do not follow API pump design standards.

However, as the temperatures of liquefied atmospheric gases are much colder than those at which hydrocarbons are pumped, cofferdams cannot be used on

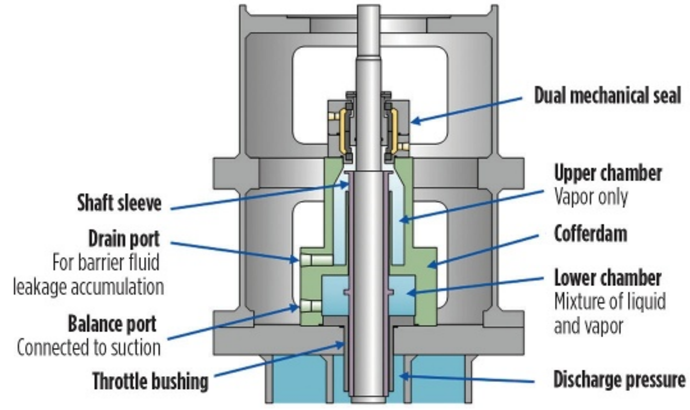

FIG. 1. A cofferdam thermally isolates a shaft seal from cold pumped fluid.

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these pumps. Although a mixture of vertical and horizontal pumps is commonly used at air liquefaction plants, mobile trailer truck unloading pumps are almost exclusively overhung single-stage pumps, either with direct-drive or speed-increasing gearboxes.

Shaft sealing systems: Low-temperature hydrocarbons. Due to the volatility and flammability of low-temperature hydrocarbons, dual mechanical seals are almost exclusively used.

For pump designs where the mechanical seal is immersed in the pumped fluid, the vapor pressure margin in the seal chamber becomes critical. Where the vapor pressure margin is low, the heat energy from the mechanical seal faces can vaporize the fluid around the seal and in the seal interface, resulting in dry running of the seal. In this situation, a dual-pressurized seal is required. A dual-pressurized seal provides a stable barrier fluid to lubricate the seal faces, thereby negating the effect of vaporization of the pumped liquid at the seal faces.

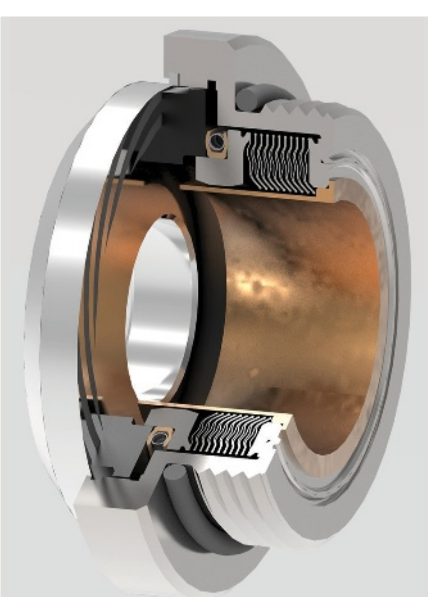

FIG. 2. 3D diagram of a vaporizing liquid gas seal with threaded housing.

API Plan 53B and 53C barrier systems are commonly selected for dual-pressurized seals to provide a source of warm, clean and stable barrier fluid to the mechanical seal. When an API Plan 53C system is selected, extra care should be taken to ensure that the pressure-amplifying piston and rod seals are insulated from exposure to cold temperatures.

The availability of suitable barrier fluids becomes limited at low temperatures, as the viscosity of many fluids becomes too high at the seal chamber operating temperatures. Mono- and di-ethylene glycol mixtures with water can be used down to temperatures of –29°C (–20°F). Alcohols, such as propanol (propyl alcohol), are suitable for even colder temperatures reaching –70°C (–95°F). Synthetic oils can also be used; however, careful consideration to their pour point is required, and a heating system may be needed to warm the barrier fluid to maintain a suitable viscosity.

When sufficient vapor pressure margin exists within the seal chamber, a dual-unpressurized seal can be selected. Typically, these designs feature a dry-sliding containment seal fitted with API Plan 76, or a combination Plan 72 and 76. These seal arrangements have the advantage of removing the low-temperature limitation of barrier fluid selection.

Pump designs utilizing a cofferdam require a dual-pressurized mechanical seal, as the seal chamber contains no liquid to lubricate the mechanical seal faces.

Icing, due to condensation of atmospheric humidity, can create a problem for sealing systems handling cold hydrocarbons. Since condensing water expands as it freezes, it can interfere with the operation of the mechanical seal if it reaches the seal's operating mechanism. Extra protection should be applied to equipment exposed to atmospheric elements, such as rain. An API Plan 62 using a dry nitrogen quench can displace atmospheric humidity, thereby protecting the mechanical seal from these effects.

Liquefied atmospheric gases. In applications handling liquefied atmospheric gases, pump seal reliability takes precedence when selecting a shaft sealing system. Unlike hydrocarbons, emissions of gases to the environment by liquefied atmospheric gases pose relatively minor hazards and, therefore, are not as critical a factor as seal reliability.

Two commonly employed shaft sealing technologies are used in pumps handling liquefied atmospheric gases: single mechanical seals and segmented bushings.

Single mechanical seals. The most common solution for pumps used in air liquefaction plants and mobile-transportation unloading pumps is the single mechanical seal. The major difference between the two is that the mobile unloading pumps tend to be smaller and often use non-cartridge seals. Cartridge seals are commonly found in larger machinery at air liquefaction plants. Single mechanical seals fall into two sub-categories: contacting wet seals and vaporizing liquid gas seals.

Contacting wet seals utilize a metal bellows to provide elastomer free-axial flexibility. Seal face materials typically include filled tetrafluoroethylene running against a tungsten carbide or hard-coated, stainless steel mating ring.

Vaporizing liquid gas seals (**FIG. 2** and **FIG. 3**), similar in construction to contacting wet seals, feature engineered seal-face topography that allows the controlled vaporization of the pumped atmospheric gas to produce a highly reliable seal that exhibits controlled, low-level leakage rates.

Segmented bushings. A segmented bushings sealing configuration is often found in vertical multi-stage pumps at air liquefaction plants. The design provides a controlled leakage by breaking down the sealed pressure over a series of tightly controlled bushing clearances. Leakage rates are higher than those of mechanical seals; however, these leakage rates are often considered acceptable by this industry.

Sealing materials: Low-temperature hydrocarbons. As mentioned, low temperatures have significant implications for the choice of materials used in the seal construction. This is especially true for elastomers applied in seals for pumps handling low-temperature hydrocarbons. Depending on the material grade used, elastomers have a variety of minimum temperature limits, but none can survive dynamic operation at true cryogenic temperatures.

Engineered polymer seals are an option at temperatures below the limits of elastomers; however, many of these designs will not function with pressure reversals applied to the sealing ring, which may be required in the mechanical seal design when support system failures occur.

Elastomers can survive at significantly lower temperatures below their operational limits when the seals are not in operation (i.e., static); however, they must be warmed up prior to operation. Commissioning of shaft seals containing elastomers must be completed carefully to ensure that equipment is at the correct temperatures before startup. Blowdown—the rapid depressurization of a vessel/pipeline—is one situation that can create excessively low temperatures for mechanical seal elastomers.

Thermal expansion and contraction are also considerations. The cavities in which elastomers or engineered polymer seals are installed will change with decreasing temperatures, as well as the dimensions of sealing elements installed in these cavities. Additionally, clearances between dissimilar materials, such as bushings, will require review. Mechanical seal manufacturers take these factors into consideration during the design of the mechanical seal for these cold services.

Since metals become increasingly brittle as the temperature is reduced, as a general rule of thumb, martensitic and ferritic stainless steels should be avoided in preference to austenitic stainless steels.

Liquefied atmospheric gases. Since pumping equipment is often used interchangeably between different atmospheric gases, sealing of liquefied atmospheric gases presents some unique challenges to the selection of materials.

Liquefied oxygen is a strong oxidizer and can cause certain materials to spontaneously combust. Additionally, any organic contaminates on the seal can lead to spontaneous combustion, including metal cutting fluids, fibers from cleaning rags, and even oils from human fingerprints. To meet oxygen service requirements on seals, stringent cleaning specifications must be employed to ensure that the seal is free of any contaminates that may create a fire hazard while in service.

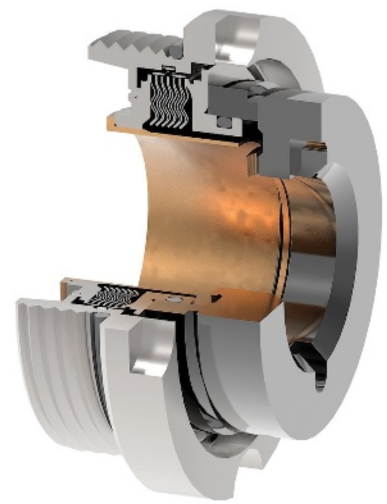

FIG. 3. A vaporizing liquid gas seal exhibits controlled, low-level leakage rates.

Additionally, the materials of construction must include materials that are compatible for use in oxygen service.

Aluminum alloys should be avoided, as they can become hazardous when their protective oxide film is stripped from the material, such as when abrasion occurs. Lubricants used in the assembly and operation of the mechanical seal must be free of hydrocarbons and compatible for use in oxygen service. Packaging of the seal should also be suitable to preserve the cleanliness of the seal prior to installation into the pumping equipment, which must be performed in a suitably clean environment.

Reliability. Of the many pump mechanical seal applications in use throughout various industries, those that deal with low-temperature and cryogenic processes rank among the more challenging.

It is critical to keep these seals, which handle low-temperature hydrocarbons and liquefied atmospheric gases, in optimal operating condition to ensure that the pumped fluids are safely contained, while providing long-term reliability. HP

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