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MECHANICAL SEALING TECHNOLOGY USED IN MULTIPHASE PUMP APPLICATIONS

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ABSTRACT

Multiphase pumps have demonstrated their capability to operate successfully in pumping the product extremes, means 100% liquid up to 100% gas, as well as solids. This duty is difficult for a pump and thus even more difficult for its mechanical seals, which are a critical component of any pump.

Mechanical seals are readily available for liquid or gas applications. However, in a multiphase pump the mechanical seals are exposed to multiphase mixtures, sealing liquids like crude oil and formation/produced water, but also natural gas and solids like sand or all kind of debris or cracked hydrocarbon products. Consequently, special mechanical seals had to be developed to handle the product extremes under transient conditions, unpredictable flow composition and a (natural) gas content up to 100%.

The biggest challenge for a mechanical seal manufacturer is to design extremely stiff sliding seal faces with the ability to maintain acceptable liquid lubrication to avoiding contact and wear of the mechanical seal faces. Another challenge is the proper selection of the secondary sealing element materials, which are prone to extrusion, excessive wear and explosive decompression associated with sealing gases under high pressures.

In this tutorial, we share an overview about the most used multiphase pump technologies, like twin-screw pumps, progressive cavity pumps and helico-axial pumps. We would like to describe the challenges for its mechanical seals, as some pump types use only one mechanical seal, while other pump types require up to four mechanical seals.

We focus on a comprehensive overview about the different concepts sealing multiphase with single seals or with dual seal arrangements, handling density variations, viscosity variations, erosion and corrosion effects at high or extremely low temperatures in onshore, offshore and even subsea applications. We also describe specific seal face materials, like Diamond Face Technology, a new face material which offers specific benefits in these multiphase applications.

INTRODUCTION

Over the past 25 years, multiphase pumping undergone constant development and improvement. Multiphase pumping has become an accepted technology, and it is in the meantime one of the most important methods to enhance oil recovery rates from the well. Only one pump is necessary to transfer both, liquid and gas in a single pipeline without separation, so there is no need for phase separation process. This offers significant equipment cost reduction to the operators, which results in more cost-effective production systems.

Based on their working principle, multiphase pumps are generally subdivided into two types of pumps. These are positive displacement pumps and rotodynamic pumps. Well-known positive displacement multiphase pumps are twin screw pumps and progressive cavity pumps. Well-known rotodynamic pumps are the helico-axial type and the electric submersible pump type. All of them have their own benefits and limitations:

Twin Screw Multiphase Pumps

These multiphase pumps are the most common in the market as a real multiphase pump, as they can handle up to 100% gas. They work with a fixed displacement, where each pumping chamber is formed by the two counter-rotating meshing screws, delivering a constant volume from suction to discharge nozzle of the pump. This pump type could already handle Gas Void Fractions (GVF) up to 70%, so only minor improvements had to be made to handle up to 100% gas flow. Some key features are true dry running characteristics, suitable for high viscosity liquids and low suction pressures, and relatively low rotational speed, which is a big advantage for the low sliding velocity of their rotating parts, like the mechanical seals. As this kind of pump consists of two counter-rotating shafts, it has four shaft ends which must be sealed; hence four mechanical seals are needed in one pump.

Progressive Cavity Pumps

These multiphase pumps are widely used in shallow wells as an artificial lift option and have been adapted for multiphase pumping as well. They are single screw type, with a rotating rotor fitted within a rubber stator. This pump type is mainly used on surface applications where the pumped fluid may contain a considerable number of solids such as sand or dirt. This pump is effective for low flow rates and for low discharge pressures as it rotates in general at low rotational speed. This pump type has only one shaft and sealing is only required at the suction side, only one mechanical seal is needed in a pump.

Helico-axial Pumps

These multiphase pumps are rotodynamic pumps and the multiphase mixture flows through a series of pump stages, each consisting of a rotating helical-shaped impeller and a stationary diffusor. Each pump can have up to 15 stages or compression cells. The arrangement is similar to a Between-Bearing pump (BB) and can be orientated vertical or horizontal. One important feature is that it has open hydraulic channels which accommodate solids in the flow. So, they have the ability to pump fluid at any Gas Void Fractions (GVF) from 100% liquid up to 100% gas. These pumps are characterized by their mechanical simplicity and reliability and can create high discharge pressures. They are predominantly used in subsea applications. These pumps run in general with very high speed, up to 6000 rpm, which makes it difficult for its mechanical seals. As the pump arrangement looks like a between-bearing pump, one mechanical seal is located at the drive end and the second mechanical seal located at the non-drive end side.

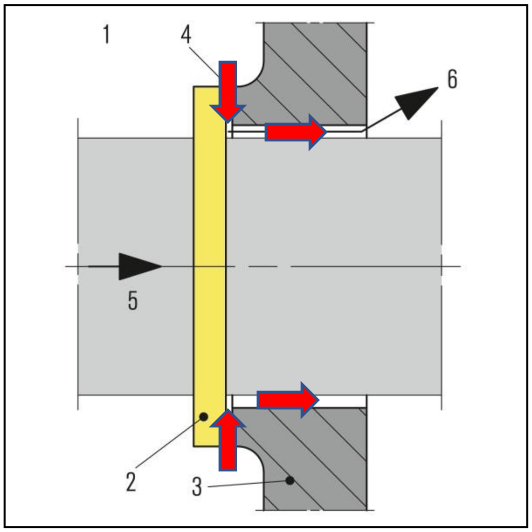
Electric Submersible Pumps

These multistage centrifugal pumps are rotodynamic pumps as they contain several rotating impellers within a single casing. These pumps are used as artificial lift pumps in oil wells. This pump type is submerged in the wellhead and pressurizes the fluid at the bottom of the well up to the surface. Recently, this pump type has been adapted for surface pumping and the ability to handle a significant amount of gas. A typical pump layout consists of a centrifugal pump unit, an electric motor and in-between a motor protector unit. This protector section prevents the well fluid from entering the motor. The protector section includes up to four mechanical seals (rubber bellows or metal bellows type), separating units and an axial trust bearing.

Multiphase pumps and their mechanical seals can encounter a large variation of operating conditions, such as changing process fluid composition, temperature variations, viscosity variations, high and low operating pressures and exposure to abrasive and erosive components. The major challenge is to select the appropriate mechanical seal arrangement, seal face and secondary sealing materials and an adequate support system (e.g. piping plans) to ensure long lifetime and overall efficiency.

SEALING ROTATING SHAFTS – AN INTRODUCTION IN BASIC SEALING TECHNOLOGY

A mechanical seal, as shown in Figure 1, essentially consists of two flat, annular sliding surfaces that are pressed together. One sliding surface is fixed to the stationary machine casing, while the other is fixed to the rotating shaft. The media to be sealed, which is generally in contact with the outer side of the sliding surface, penetrates into the gap between the two surfaces, forming a lubricating film, and emerges at the inner side as leakage. The pressure differential to be sealed is reduced in the radial direction. In its simplest form, a mechanical seal can consist of a collar arranged on and turning with the shaft. This collar is pressed axially against the machine casing, see Figure 1.



1 Medium to be sealed
2 Shaft collar
3 Machine casing
4 Sealing gap
5 Axial force
6 Leakage path (red arrows)

Figure 1: Simplified version of an axial shaft seal

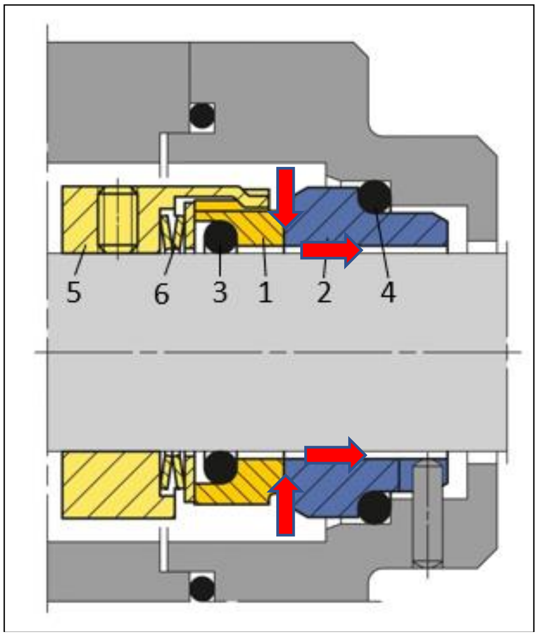
Thus, a mechanical seal essentially consists of an axial throttle that reduces the pressure of the media to be sealed – generally to atmospheric pressure – via the sealing gap. We distinguish between liquid-lubricated and gas-lubricated mechanical seals according to the physical state of the media to be sealed.

The sealing gap is delimited by two sliding faces and is perpendicular to the shaft being sealed. These sliding seal faces are ring-shaped and are wholly or partly separated from each other by the liquid lubricating film.

The main components of a mechanical seal

A rotating mechanical seal is shown in Figure 2 and illustrates its most important elements. The rotating seal ring and the stationary seat, also called mating ring, are the most important elements since they form the sliding surfaces. In the next illustration, the seal unit (in yellow color) is connected to the rotating shaft and the stationary mating ring (in blue color) to the pump casing. The sliding surfaces must be pushed together in the axial direction. In this example, this necessary force is generated by a single spring. Alternatively, several small springs distributed around the circumference (multiple springs), could be used.

The rotating seal ring and stationary mating ring must be sealed towards the adjacent pump elements. The mating ring is sealed to the pump casing by a static sealing element, while the rotating seal face is sealed to the shaft by a dynamic sealing element. This sealing element is “dynamic” because it can be moved axially on the shaft to compensate shaft displacements, vibration and wear of the sliding surfaces. These sealing elements, also called *secondary* elements are round sealing rings, well-known as O-rings. In addition to their sealing function, these secondary seals also act as retainers: Thus, this dynamic sealing element holds and centers the rotating seal ring on the shaft, while the static sealing element fixes the mating ring in the opening of the pump casing.



1 Seal Ring
2 Mating Ring
3 Dynamic secondary seal (O-ring)
4 Static secondary seal (O-ring)
5 Drive collar with set screws
6 Single spring

Figure 2: Typical mechanical seal components (yellow color shows the rotating parts and blue color shows the stationary parts), red arrows show the leakage path

Effective forces

The rotating seal face is pressed against the stationary mating ring by the mechanical force of the compressed spring and by the hydraulic force generated by the pressure to be sealed. Taken together, these forces are known as the closing force. In the unpressurized state, only the spring force keeps the sliding surfaces in contact. As the shaft rotates, the media itself penetrates into the sealing gap between the sliding faces, reducing the pressure to be sealed to ambient pressure. At the same time, the pressure of the lubricating film builds up the gap (opening force) that counteracts to the closing force and finds its equilibrium in continuous operation.

Torque transmission

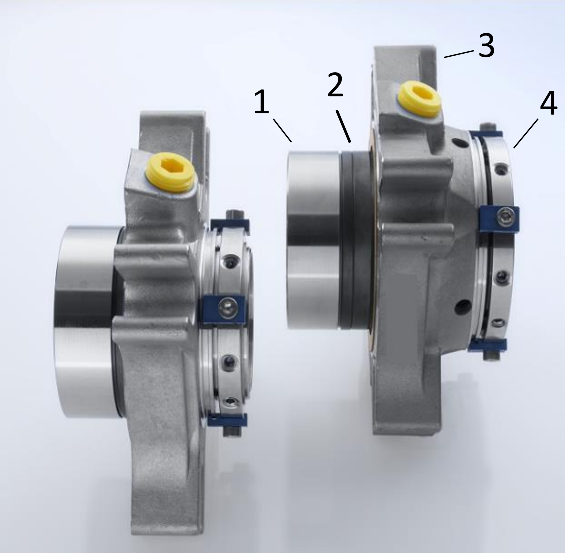
The relative movement between the sliding surfaces causes a moment of friction, partly due to the friction in the lubricating film and partly due to the direct contact between the materials to the sliding surfaces. This drag moment has to be transferred to the adjacent machine elements, i. e. from the rotating seal to the shaft and from the stationary seat to the machine casing. In the rotating part of the mechanical seal this is due to the positive fit, very similar to a key-drive. In the stationary part, it is due to the adhesive friction between the O-ring and the machine casing and by an anti-rotation pin, as shown in Figure 2 in grey color.

Cartridge mechanical seals

Mechanical seals assembled directly on the pump shaft and into the pump casing are called component seals, as shown in Figure 2. The term “cartridge seal” is used to describe all those kinds of seals that form a single ready-to-assemble unit, which comes together with the seal shaft sleeve and cover or seal gland plate. Cartridge seals should be given preference since they have the following advantages:

- easy and quick to assemble and disassemble on site without mistakes — even by untrained personnel,
- can be tested at the factory by the manufacturer by applying a hydrostatic pressure test, for example,
- sensitive elements such as sliding surfaces and secondary sealing elements are protected against damage during transportation and assembly. During transportation and assembly, the so-called assembly fixtures create a mechanical connection between the stationary part and the rotating part of the seal. Assembly fixtures are removed after seal installation and before the shaft of the machine starts turning.

According to the mechanical seal standard API682, only cartridge seals should be used in the petroleum and chemical industry.



1 Seal sleeve
2 Mechanical seal faces
3 Mechanical seal gland plate
4 Set ring

Figure 3: Cartridge seal samples, pre-assembled units, which include a seal sleeve and the seal gland plate

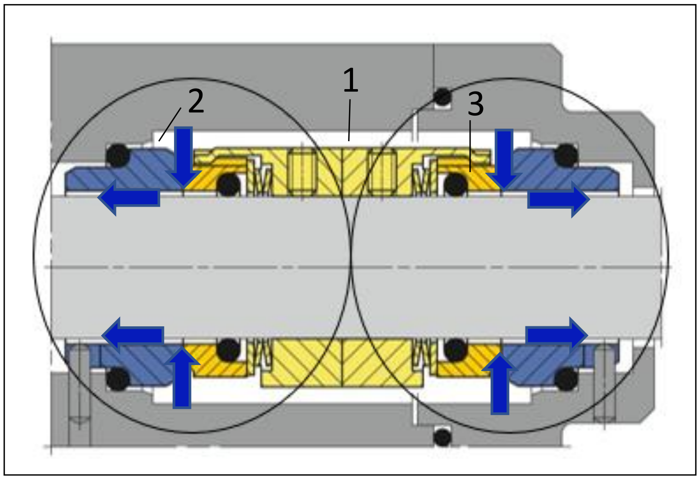
Mechanical Seal Arrangements - Single and multiple mechanical seal arrangements

In a single seal arrangement, as shown in Figure 2, the pumped media itself penetrates into the gap between the sliding faces, lubricates the sliding surfaces and thus largely prevents them from touching each other. This means that a single seal will only work satisfactorily if the pumped media has the necessary penetration capacity and lubricity.

This seal arrangement is still widely used in the industry. However, single mechanical seals have their limitations, for example if the pumped media

- has a high solids content,
- is harmful to the environment or explosive,
- has a high vapor pressure and a low density, thus poor lubricating properties,
- does not lubricate the faces properly, like multiphase mixtures (crude oil, formation water, gas).

Media of these types are therefore predominantly sealed with a dual mechanical seal arrangement, shown in Figure 4, lubricated by a so-called barrier fluid. In this case, two mechanical seals attached on each other and acting in different directions (known as a back-to-back or face-to-face arrangement) form a sealing chamber, that is filled with a pressure-overlaid barrier fluid. The barrier pressure is typically 10 percent higher than the pressure of the pumped media. The mechanical seal on the media side is pressurized by the clean barrier fluid and prevents the media from penetrating into the sealing gap between the sliding surfaces. The mechanical seal on the atmosphere side releases the barrier fluid in the form of leakage from the barrier pressure to atmospheric pressure. The barrier fluid acts like a barrier between the pumped media and the atmosphere.



1 Barrier fluid cavity
2 Sealing gap process side seal
3 Sealing gap atmosphere side seal

Figure 4: Dual mechanical seal in a back-to-back arrangement (two single seals installed in opposite directions), leakage path of barrier fluid shown as blue arrows

Figure 4 shows such a dual seal and requires a necessary barrier fluid supply system, which provides the fluid in order to lubricate and cool the seal faces. It essentially consists of a closed loop system filled completely with the liquid fluid and includes a vessel, which will be pressurized. This vessel stores the barrier fluid to compensate for leakage from the dual seal. The required pressure overlay, in the form of a Nitrogen gas cushion for example, also takes place in this vessel. An additional heat exchanger integrated into the closed loop can be used to dissipate the frictional heat from the two mechanical seals.

Supply systems can be simple pressure vessels, like thermosiphon vessels or very complex pressure distribution systems. In barrier pressure systems, for example, a pressure booster pump integrated into the circuit generates the necessary barrier pressure. It also forces the circulation of the barrier fluid. Even more complex barrier pressure systems and monitoring components may be required. The technical complexity required for dual seals is always substantially larger than for a single mechanical seal arrangement.

Sealing media of different properties

Sealing media containing solids

In this kind of pumped media, the type, particle size and concentration of the solids in the pumped fluid affect the design of the mechanical seal. Hard seal face material pairings, ideally silicon and tungsten carbides, are generally used for media containing solids. Hard particles in the range of micrometers, in particular, can easily penetrate the sealing gap, and can damage soft sliding surfaces due to the high abrasion. It has also been observed that hard solid particles become embedded in a soft face material such as artificial carbon and can then be grounded into a hard-opposing surface made from tungsten carbide, for example.

Sealing media containing a significant amount of gas

In case the pumped fluid contains significant amounts of gas, then a pressure-overlaid dual seal is recommended. The sealing chamber between the two seals is filled with a barrier fluid, the pressure is higher than the pressure of the pumped media. The barrier fluid must be compatible with both, the process media and the environment, because there is leakage in both directions. On the other hand, the pumped media cannot leak out into the environment. The significant advantage of this sealing solution is that the sliding surfaces on the media side seal are lubricated by the barrier fluid and not the pumped media.

SPECIFIC SEALING SOLUTIONS FOR MULTIPHASE APPLICATIONS

Multiphase pumps can pump mixtures of crude oil, formation water and gas and transport them successfully over long distances in a single pipeline prior to separation. Therefore, separation of the oil from the gas and the associated flaring of the off-gas is not required near the well head. Multiphase pumps are used on ground and offshore as well as in subsea applications.

The pump types most frequently used in this service are progressive cavity, twin screw and helico-axial pumps. Mechanical seals must simultaneously seal liquid and gas. One of the challenges in this application is that the composition of the moved media fluctuates continuously between 100 percent gas and 100 percent liquid. Transient operating conditions are critical for the pump and its mechanical seals, not to mention the fact that the pumped media frequently contains waxes and sand, which may have considerable adhesive and abrasive properties.

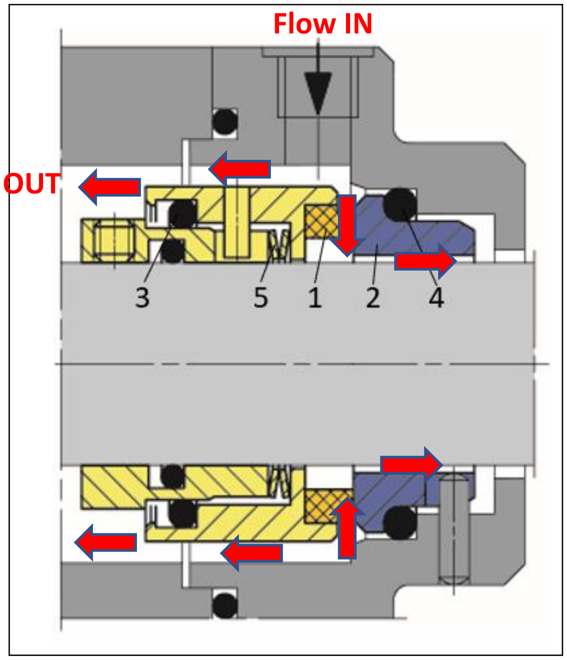
For this kind of service robust mechanical seals with extremely hard sliding materials are recommended, which have already become standard in many multiphase pumps offered by the leading manufacturers. The range includes different types of single seals up to dual seal arrangements with pressurization via different kind of supply systems, like barrier fluid circulation and cooling systems.

Single seal solutions for Multiphase Applications

As mechanical seals need liquid, which clearly means “wet” lubrication, single seal arrangements in combination with specific measures are required sealing multiphase, which is always a mixture of liquid and gas, and possibly pure gas slugs for a short period of time. This is the main reason why sealing multiphase with a single seal arrangement is so difficult. The typical additional measures in this industry are for example an external liquid Flush and Quench system. According to API 682 they are called Piping-Plans 32 and Piping Plan 62, which provides the required liquid lubrication film. Piping Plans are explained in the next section of this tutorial.

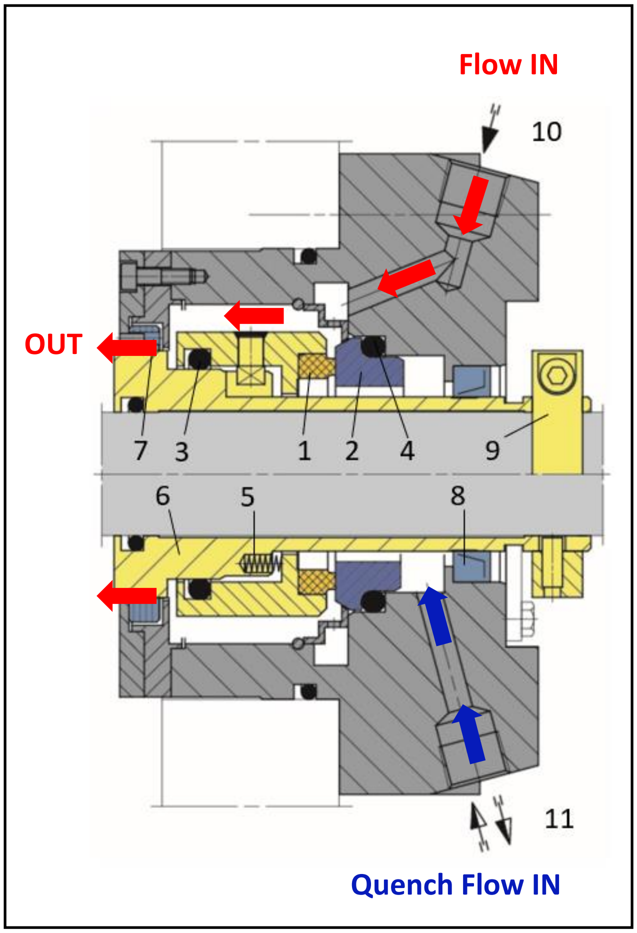
This sealing solution results in a single seal embedded in a permanent liquid-flooded seal environment. It is accomplished through a pressurized injection of clean liquid into the seal chamber from an external source (defined as API 682 Piping Plan 32). The required flush source must be continuous and reliable even during start-up and shutdown of the pump. A close clearance throat bushing downstream of the seal is added, which isolates the pumped media from the seal chamber and controls the flow rate of the injected liquid flush into the pumped media. A typical example is shown in Figure 6., item 7 is the respective throat bushing.

In addition to this injected flush, a simple unpressurized quench system (according API682 Piping Plan 62) in combination with laser textured hydrodynamic grooves at the inner diameter of the stationary mating ring ensure that a lubricating film is always present in the sealing gap even in the case of poor flush availability and / or vacuum conditions and helps to overcome the gas phase/slugs for a substantial period of time. As multiphase mixtures may contain solids, the spring/springs of the seal is/are located on the atmospheric side of the seal, so are not product wetted, see item 5 in Figure 5. This sealing solution is mainly used in twin screw pumps and is available as a component seal, see Figure 5 or a full cartridge design, see Figure 6.



1 Seal ring
2 Mating ring
3 Dynamic secondary seal (O-ring)
4 Static secondary seal (O-ring)
5 Single spring, not product-wetted

Figure 5: Component mechanical seal, directly assembled on a pump shaft, red arrows show the pumped media and leakage path



1 Seal ring
2 Mating ring
3 Dynamic secondary seal (O-ring)
4 Static secondary seal (O-ring)
5 Multiple springs, not product-wetted
6 Shaft sleeve
7 Throat bushing
8 Lip seal
9 Set ring with set screws
10 Piping connection for Plan 32
11 Piping connection for Plan 62

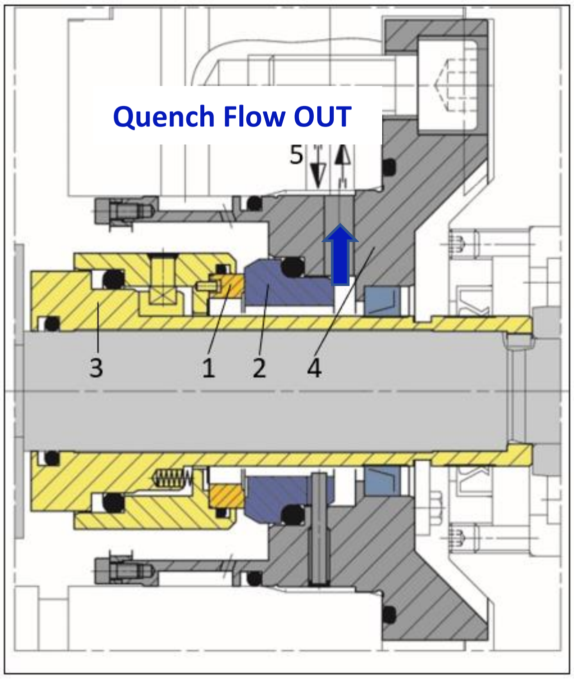
Figure 6: Cartridge mechanical seal, which includes a seal sleeve and a seal gland, a pre-assembled mechanical seal unit. The throat bushing, item 7 and the lip seal, item 8 are included in the seal cartridge. Yellow color shows all rotating parts and blue and grey color shows all stationary parts of this seal.

Red arrows show the Flush flow (Piping Plan 32) and blue arrows show the Quench flow (Piping Plan 62).

A unique technical sealing solution for multiphase application is the next one, a single seal arrangement with specific seal face materials. This solution is provided, in case a clean flush fluid (as per Piping Plan 32) cannot be supplied by an external source as it is simply not available, like in dessert or remote jungle installations.

For these demanding installations a single seal arrangement with special seal face materials, so called “Diamond seal face technology” is selected. This is an innovative sliding face material technology, characterized by using Silicon Carbide seal faces with a thin layer of micro-crystalline diamonds. This sophisticated material enables the use of single seals in multiphase applications without additional external measures.
This new material technology for the sliding surfaces is characterized by its extreme hardness, high wear resistance, excellent thermal conductivity and low friction coefficient. These special seal faces can handle dry running (due to gas content in multiphase fluids and the possible gas slugs) for a substantial period of time.
Thus, it enables the seal faces to cope with the transient conditions on the multiphase pump inlet conditions where the mechanical seals are generally located. Due to its unique hardness, this material can also handle the solids as sand or cracked hydrocarbon debris, successfully.

A typical seal design is shown in figure 7, a single seal only supported by an unpressurized Quench system, Piping Plan 62, their connection ports are shown as item 5.



1 Seal ring
2 Mating ring
3 Seal sleeve
4 Gland plate
5 Piping connection for Plan 62

Figure 7: Single cartridge mechanical seal with specific seal face materials, item 1 and 2, known as Diamond face material technology

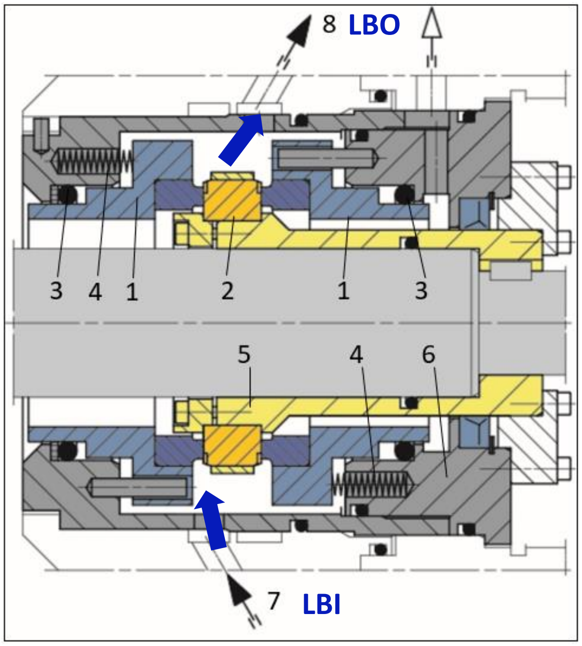
Dual mechanical seal solutions for Multiphase Applications

In case the operating conditions or the design limits of a single seal are exceeded, dual mechanical seal solutions are used. This arrangement offers specific benefits in case the pumped media does not offer any lubrication properties for instance, or an external flush source is simply not available on site. For these multiphase pump applications, dual seal cartridge designs with pressurized barrier fluid systems (API 682 Piping-Plan 53 and 54) are used.

After many years of experience, the stationary dual pressurized seal cartridge design in a face-to-face arranged seal faces was developed especially for high pressure applications. Stationary design means, that the seal faces, the spring-loaded units are arranged stationary and only the mating ring/rings are rotating with the shaft. This specific design results in a compact seal design with identical seal faces and mating rings inboard and outboard. The seal usually has only one rotating mating ring between the two stationary seal faces in order to provide a high-performance seal with a short axial length suitable particularly for small seal chambers like in twin screw pumps.

The cooling and lubrication of the seal is ensured in any operating condition of the pump by its own supply system. This measure protects the seal if there is a high risk of dry-run or for any high duty applications.

This type of seal design is commonly used even in low duty applications in regions such as the Middle East or Africa where the practicality of using a single seal with an external flush (API Piping Plan 32) is very limited or even impossible.



1 Seal rings
2 Mating ring
3 Dynamic secondary seal (O-ring)
4 Multiple springs
5 Seal sleeve
6 Gland plate
7 Piping connection for Plan 53 / 54 Liquid Barrier Fluid IN (LBI)
8 Piping connection for Plan 53 / 54 Liquid Barrier Fluid OUT (LBO)

Figure 8: Cartridge dual mechanical seal in face-to-face arrangement, stationary seal faces shown in blue color, rotating mating ring and seal sleeve shown in yellow color.

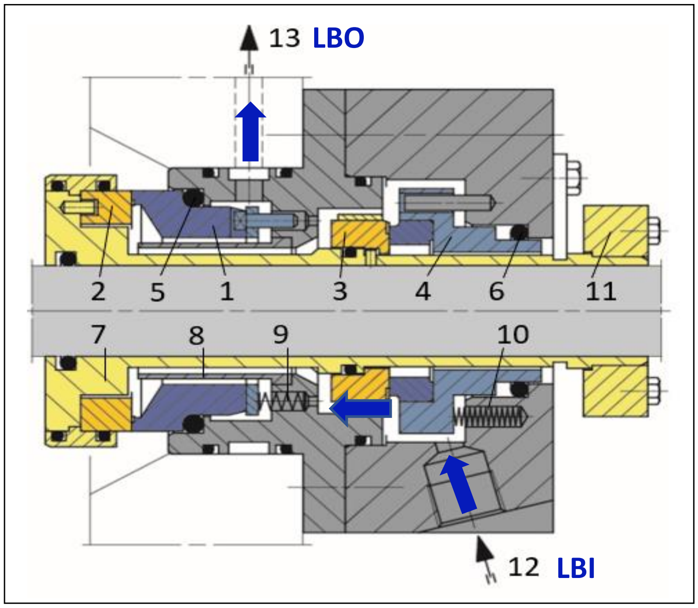
Dual seal arrangement solutions for extreme applications and for demanding subsea services

For specific applications with extreme demands on high sealing pressures or unknown transient conditions in a foreign environment engineered mechanical seals solutions are strongly recommended. These engineered solutions are designed for multiphase mixtures with high gas void fractions and unknown content of solids, for high or fluctuating operating pressure from the well or high sliding velocities due to big shaft diameters and high-speed pumps.

This specific dual seal design in a face-to-back arrangement can handle high amounts of solids and debris because of the conical-open inboard seal design and the inside pressurization of the product side seal. With an internally pressurized mechanical seal design, both the pressure and the barrier fluid are present at the internal sliding surface diameter. The leakage moves radially from inside to outside. Additionally, the barrier fluid is under higher pressure at the inner sliding surface diameter, this type of seal design prevents any solids or debris penetrating between the sliding faces.

This is the significant advantage and well-known from other applications in the industry, like slurry pumps which handle a high number of solids anyway. It finally leads into a longer lifetime, thus higher robustness of the mechanical seal.

The proper cooling and lubrication is ensured via a pressurized supply system (typically API-Piping-Plan 53 or 54), which is described on page 15 and 16.



1 Seal ring inner seal
2 Mating ring inner seal
3 Mating ring outer seal
4 Seal ring outer seal
5 Dynamic O-ring inner seal
6 Dynamic O-ring outer seal
7 Seal sleeve
8 Guide sleeve
9 Multiple springs inner seal
10 Multiple springs outer seal
11 Shrink disk
12 Piping connection Liquid Barrier Fluid IN (LBI)
13 Piping connection Liquid Barrier Fluid OUT (LBO)

Figure 9: Cartridge mechanical seal, the inboard seal (on the left side) is inside pressurized

Specific Seal Support Systems – Flush Systems and Piping Plans used in Multiphase Applications

In multiphase pump services, the following support system concepts are used successfully:

Supply Systems for **single seals** are

- Flush arrangements, defined as API682-Piping-Plan 32, and
- Quench arrangements, defined as API682-Piping-Plan 62

Supply Systems for **dual seals** are

- Closed loop systems, according to API682-Piping-Plan 53, or
- Open loop systems, according to API682-Piping-Plan 54

The simplest solution is a **single seal arrangement** in a perfectly liquid-flooded environment, for which a "Flush" is required. The API-Plans 11 and 32 are typically used Flush plans/Piping plans.

API-Piping Plan 11 M (M for modified) takes the liquid fluid, only the liquid from the pump discharge and directs it to the seal chamber to provide liquid lubrication and cooling to the seal faces, this results in a simple recirculation system. Liquid is separated from the multiphase mixture in a liquid/gas separator and used as the flush fluid.

API-Piping Plan 32 uses a Flush stream brought in from an external source to the seal. Source pressure must be maintained above "maximum" seal chamber pressure. As the flush source, water or any kind of clean liquid available on site could be used. This piping plan is almost always used in conjunction with a close clearance throat bushing, which is isolating the pumped media from the seal chamber.

API-Piping Plan 62, a simple Quench system is used to improve the seal environment on the atmospheric side by quenching the seal faces with liquid like potable water or hydraulic oil. The quench provides additional cooling and prevents product crystallization of the pumped media (as formation water may contain salt) passing the sealing gap and builds up agglomeration in the seal area.

API Piping Plan 11 as per API 682 4th edition Standard:

In Piping Plan 11 there is recirculation from a high-pressure region of the pump (typically the pump discharge or the pump discharge piping) through a flow control orifice to the seal. With purchaser approval, the flow control orifice may be omitted if it is not needed to achieve the required flush flow rate.

Piping Plan 11 is the most used seal flush plan for all Arrangement 1 and 2 seals. In Piping Plan 11, product is routed from the pump discharge to the seal chamber to provide cooling for the seal and to vent air or vapours from the seal chamber. Fluid then flows from the seal chamber back into the process stream. It is the most commonly used flush plan for clean general service equipment. Calculations are required to determine the proper orifice and throat bushing dimensions to assure adequate seal flush flow. In pumps with low differential head or pumping high-viscosity fluids, the required flow rate for the piping plan may be achieved without the flow control orifice. Care shall be taken when using this plan with polymerizing fluid that may plug the orifice and connecting piping. (© API Standard 682 4th edition, Figure G.6)

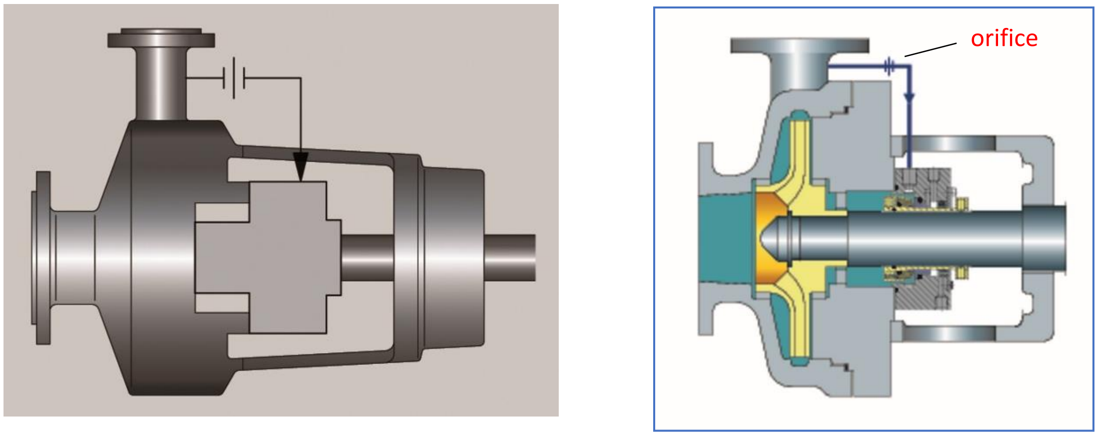


Figure 10: API-Piping-Plan 11 (schematic view and cross-sectional drawing)

API Piping Plan 32 as per API 682 4th edition Standard:

In Piping Plan 32, flush is injected into the seal chamber from an external source. Piping Plan 32 is used in services containing solids or contaminants, in which a suitable cleaner or cooler external flush will improve the seal environment. It is also used to reduce flashing across the seal faces by providing a flush that has a lower vapour pressure or that will raise the seal chamber pressure to an acceptable level.

In Piping Plan 32, the flushing product is brought from an external source to the seal. The external flush should be continuous and reliable even during start-up or shutdown. Care shall be exercised in choosing a Piping Plan 32 flush fluid. Since the fluid will flow into the process, it shall be chemically compatible with the process and not degrade the quality of the process fluid. In high-temperature applications, the user should consider the effects of the potential for the Piping Plan 32 flush fluid to flash under pump conditions and degrade pump performance.

This plan is almost always used in conjunction with a close-clearance throat bushing. The bushing can function as a throttling device to maintain an elevated pressure in the stuffing box or as a barrier to isolate the pumped product from the seal chamber. Piping Plan 32 is not recommended for cooling only, as the energy costs can be very high. Product degradation costs should also be considered when using a Piping Plan 32.
(© API Standard 682 4th edition, Figure G.14)

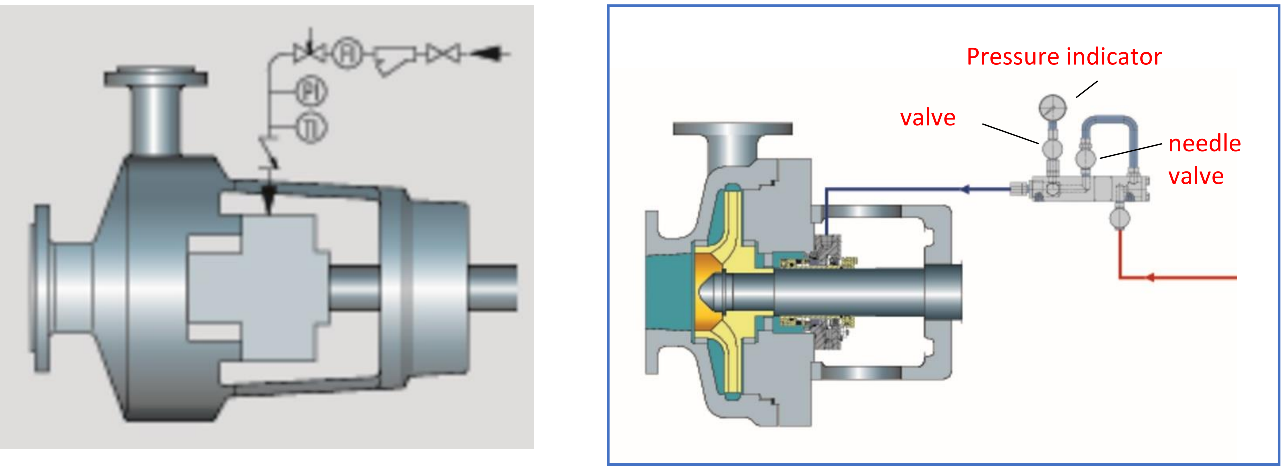


Figure 11: API-Piping-Plan 32 (schematic view and cross-sectional drawing), with filter, flow indicator, control valve, pressure indicator, temperature indicator and check valve

API Piping Plan 62 as per API 682 4th edition Standard:

API-Piping-Plan 62 is used to improve the seal environment on the atmospheric side by quenching the seal with water or hydraulic oil. The quench provides additional cooling an prevents leakage crystallization.

In Piping Plan 62, a quench stream is brought from an external source to the atmospheric side of the seal faces. The quench stream can be low-pressure steam, nitrogen, or clean water. It is used in selected single seal applications to exclude the presence of oxygen to prevent coke formation (for example, hot hydrocarbon services) and to flush away undesirable material build-up around the dynamic seal components (for example, caustic and salt services).

Piping Plan 62 is most effective when used with a close clearance bushing or containment device in the seal gland. This bushing not only contains the quench in the seal gland but also provides protection for the operator if a high-temperature quench is used. The drain port outlet should be larger than the quench port inlet. The drain port shall be sized to allow drainage of the quench medium.
(© API Standard 682 4th edition, Figure G.24)

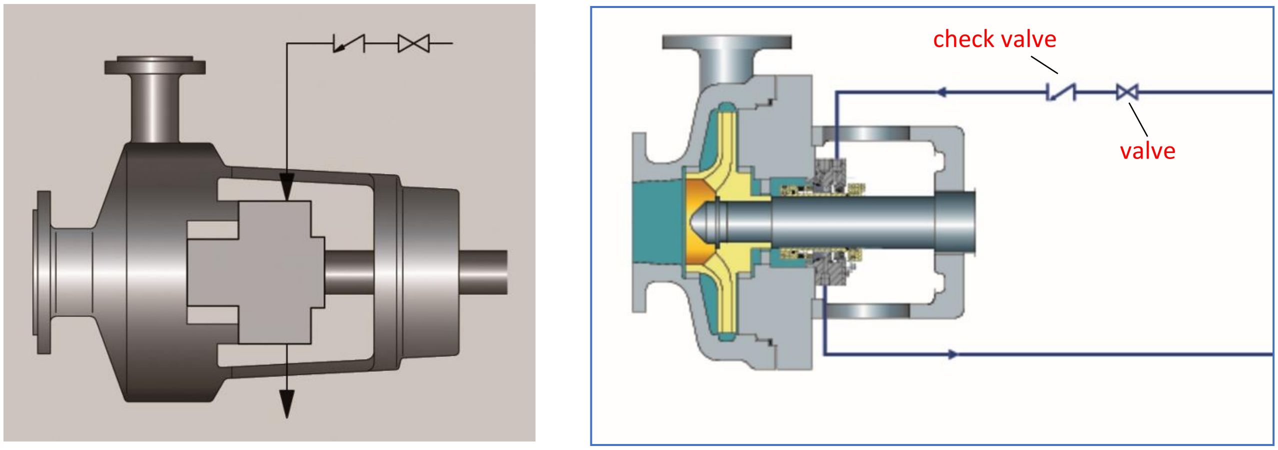


Figure 12: API-Piping-Plan 62 (schematic view and cross-sectional drawing), with check valve and valve

Supply Systems for dual mechanical seals distinguish two basic types:

In a **closed circuit** all components are kept at the same pressure, typically these supply systems are called Piping Plan 53 A, B or C. Plan 53B, the probably most used option of the Plan 53 family, is what has been designated in the past as a “Plan 53 modified” and is very popular in Europe. This Piping Plan incorporates a bladder type accumulator along with a heat exchanger in a closed piped loop. The accumulator is pressurized by gas, in general nitrogen and maintains the correct barrier pressure within the loop. Forced circulation is induced by a pumping device (pumping ring), which is part of the mechanical seal. Piping Plan 53’s are usually less complex and less expensive in comparison to a Piping Plan 54 system.

API682 4th edition Standard Piping Plan 53B:

In Piping Plan 53B, there is an external barrier fluid system pressurized by a bladder accumulator supplying clean liquid to the barrier fluid seal chamber. The accumulator and barrier liquid are maintained at a pressure greater than seal chamber pressure!!!

Barrier liquid is circulated through the system by means of an internal circulating device. To maximize barrier liquid circulation, the piping losses should be minimized. Piping Plan 53B is used with an Arrangement 3 liquid seal and differs from Piping Plan 53A in that pressure is maintained in the barrier liquid system through the use of a bladder-type accumulator. The use of an accumulator prevents contact between the pressurization gas and the barrier liquid. This prevents gas absorption into the barrier liquid and allows for high-pressure operation. The accumulator is pre-charged prior to filling the system with barrier liquid and is brought to operating pressure by compressing the bladder in the accumulator as the system is filled with barrier liquid. Leakage past the inner and outer seals results in a decrease in the barrier system pressure. This requires that the barrier system be pressurized to a higher initial pressure and allowed to “leak” down to the minimum allowable system pressure. At this time, the system would be refilled to restore the maximum working barrier liquid volume. Seal performance is therefore monitored by pressure decrease and not by barrier liquid level as in Piping Plan 53A.
(© API Standard 682 4th edition, Figure G.19)

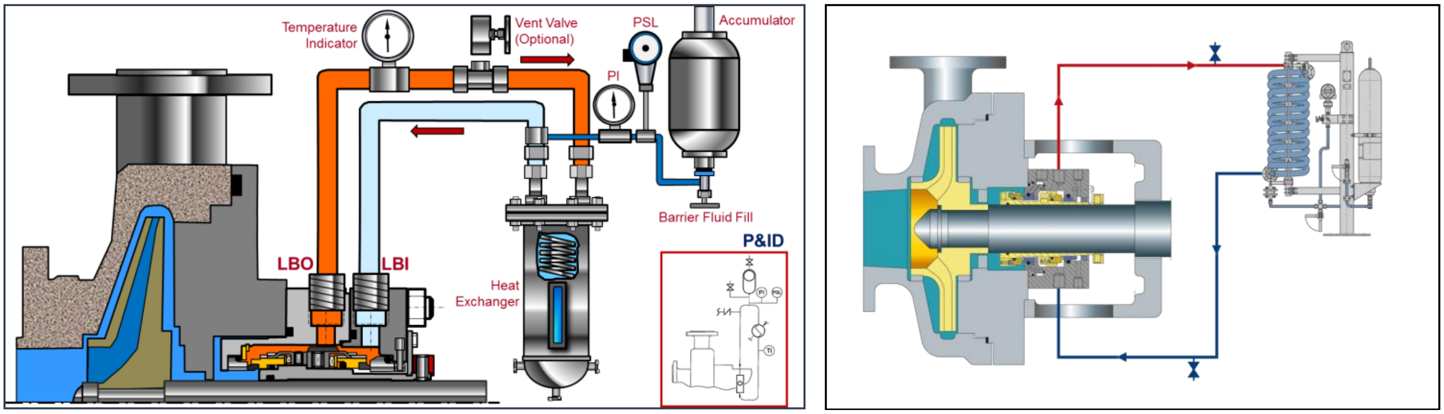


Figure 13: API 682 Piping Plan 53B, a closed loop system with a pressurized bladder accumulator and an integrated heat exchanger. Piping lines in blue show cold barrier fluid and piping lines in red show hot barrier fluid flow.

LBI – Liquid Barrier Fluid IN
LBO – Liquid Barrier Fluid OUT
PI – Pressure Indicator (or Transmitter)
PSL – Pressure Switch LOW Alarm (or Transmitter optional)

In the **open circuit**, barrier fluid is getting pressurized by an external pump, going to the mechanical seal and is then expanded back to atmospheric pressure after seal circulation via a simple pressure control valve. This open loop is defined as a Piping Plan 54. This API-Plan utilizes an external source to provide a clean pressurized barrier fluid. It can be as simple as a basic tank, a gear pump, a heat exchanger and a relief valve.

This kind of unit performs **all five duties of a supply system**:

- Pressurization of the barrier fluid
- Lubrication of the rotating seal faces
- Cooling
- Forced circulation
- Compensation of leakage

These units are very compact and can as well support multiple seal installations, like typically in multiphase applications, supporting 4 mechanical seals in a twin-screw pump.

API Piping Plan 54 in API 682 4th edition Standard:

In Piping Plan 54, there is a pressurized external barrier fluid system supplying clean liquid to the barrier fluid seal chamber. Piping Plan 54 is used with Arrangement 3 liquid seals and the barrier liquid is maintained at a pressure greater than seal chamber pressure. Barrier liquid is circulated by an external pump or pressure system. The design of the system including instrumentation, coolers, filters, and other components are outside the scope of this standard.

Piping Plan 54 systems are also pressurized dual-seal systems with inner seal leakage into the pumped product. In a Piping Plan 54, a cool clean product from an external source is supplied to the seal as a barrier liquid. The supply pressure of this product is at least 1.4 bar greater than the pressure the inner seal is sealing against. This results in a small leakage of barrier fluid into the process. This plan with an Arrangement 3 seal should never be used where the barrier liquid pressure is less than the sealed pressure. If it were, the failure of one inner seal could contaminate the entire barrier liquid system and cause additional seal failures.

Piping Plan 54 is often used in services where the pumped fluid is hot, contaminated with solids, or the internal flow inducer is unable to supply a sufficient flow rate. If Piping Plan 54 is specified, carefully consider the reliability of the barrier liquid source. If the source is interrupted or contaminated, the resulting seal failures are very expensive to rectify. A properly engineered barrier liquid system is typically complex and often expensive. Where these systems are properly engineered, they provide among the most reliable systems.
(© API Standard 682 4th edition, Figure G.21)

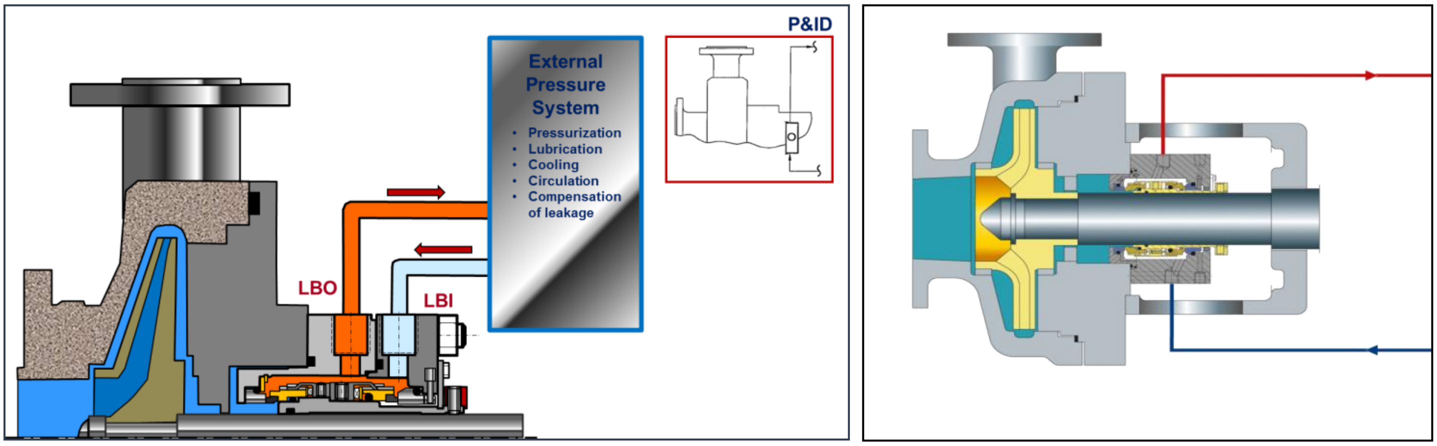


Figure 14: API 682 Piping Plan 54, an external barrier fluid system,
Piping lines in blue show cold barrier fluid and piping lines in red show hot barrier fluid flow.

LBI – Liquid Barrier Fluid IN
LBO – Liquid Barrier Fluid OUT

Conclusion

Mechanical seals have proven their ability to seal multiphase mixtures over a wide range of conditions in several applications all over the world. The described seal types and sliding face materials available today are capable to meet any technical demand.

Single mechanical seal arrangements handle multiphase mixtures by using current seal designs in combination with the API682 Piping Plan 32 and 62. As an option, diamond face materials are available for this arrangement and application, as these materials are capable to run without lubrication for a substantial period of time and can cope with solid particles.

In case a single seal arrangement could not be used, dual mechanical seal arrangements are the alternate solution. This arrangement is almost always used in combination with API-Piping Plan 53B or 54. Both have their advantages and limitations.

The correct installation and operation are key factors for long lifetime of the pump.

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