



Mechanical Seals for Product Pipeline Pumps

Application Guide

Introduction

This guide will address the application of mechanical seals in product pipeline pumps, covering the transmission of crude oil and refined products such as fuel oils, gasolines and natural gas liquids (NGL), for example propane and ethane. Included in this discussion will be pipeline systems that transport multiple products through the same pipeline as well as mixtures of NGL. These batched product pipelines present difficult sealing applications because the pumped products can range from light NGL products to heavier gasoline products. Additionally, some of these same pipeline systems can also be used to transport crude oils.

Characteristics of the Service

- Suction pressure can range from low to >1500 psig (103 bar)
- NGL product vapor pressures can be high (ideal) or near the pump suction pressure (challenging)
- Pump speeds are normally two pole motor speed (3000 or 3600 rpm) but can be much higher
- Intermittent or continuous service
- Temperature is usually ambient
- Product viscosity may be low
- Refined products may contain MTBE or other additives and contaminants
- Varied fluid properties of viscosity and pressure for batched product pipelines
- Crude oil may contain sand, salt, pipe scale or other erosive agents

Application Considerations

Product pipeline pumps are subject to varying pipeline system pressures. Typically, the seal chamber pressure on most between-bearing, double suction, single stage and multistage pipeline pumps will be equal to the suction pressure of the pump. While this pressure can be as low as the discharge pressure of a booster pump, mainline pumps piped in series will have seal chamber pressures equal to the discharge pressure of the preceding pump. In parallel operation, the seal chamber pressure will equal the suction pressure. However, standby pumps in parallel operation can be subject to full pipeline pressure if they are not blocked in properly. Because of the high seal chamber pressures, cartridge mechanical seals must be positively locked to the pump shaft to ensure that they are not forced out of the seal chamber due to the hydraulic forces.

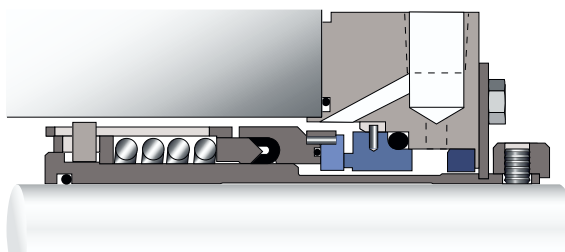
Crude Oil Pumpage and the Presence of Solids

Crude oil transported through pipeline systems may contain dirt, pipe scale and other erosive agents. Mechanical seals installed in crude oil pipeline pumps must be designed to operate in these abrasive conditions. The use of two hard seal faces is the typical method promoted for handling the abrasives common to crude oil pipeline applications. High quality, hard seal faces have been proven in many abrasive sealing environments and withstand the blistering that occurs during high viscosity sealing.

The use of cyclone separators to remove sand and other solid particles from dirty crude oil is a common, effective practice. They are especially effective during start-up situations or when a pig is sent through the system to clean the pipeline.

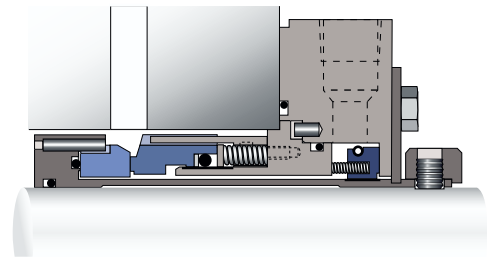
Cyclone separators can provide a cleaner flush for the mechanical seal. Considerations with the use of cyclone separators: together with a crude oil's high viscosity, the cyclone separator can reduce the seal flush rate because of the increased friction losses. Cyclone separators, with their small diameter passages, can even become plugged with particles whereby reducing or cutting off the seal flush entirely. This situation can easily be avoided by reviewing the flowrate and keeping a balance between the particle weight and the fluid weight. A cyclone separator's efficiency is related to the size and density of the abrasives in the crude oil. Smaller, suspended solids will not separate as well and may pass through the separator to the seal chamber. Additionally, the constant erosive action within the cyclone separator can eventually wear out the cyclone body.

The use of multiple springs, flexible rotor pusher type mechanical seal for sealing a wide range of fluids is well known and generally successful. However, because they employ small diameter pocket springs within a compact spring holder, they may be prone to packing up with solid particles and other contaminants when directly exposed in the crude oil flush stream. This increases the likelihood of these contaminants accumulating around the dynamic seal components. If the motion of the dynamic seal face is inhibited, leakage and/or seal failure may eventually occur. In comparison, a large single coil spring has been shown to perform well under the same conditions. Single coil spring seals with a thick cross section spring and large slotted openings in the spring holder allow the crude oil and any contaminants to circulate through the dynamic seal parts.



UO Seal - large cross-section, single spring design

When stationary mechanical seals are required, the use of a large, single coil spring seal is typically not possible because of seal chamber space constraints. Here, the use of maximized diameter multiple springs located in the gland away from the crude oil flush or behind the seal faces has proven to be a very successful design.



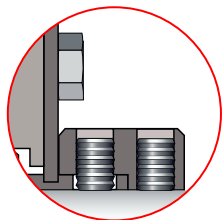
HSH Seal - multiple spring, stationary design

Collar Design

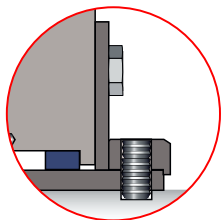
Cartridge sleeve collars must be designed to hold the hydraulic forces of the entire operating regime. This may include full discharge pressure and typically a higher maximum allowable working pressure (MAWP).

Several methods for accomplishing this include:

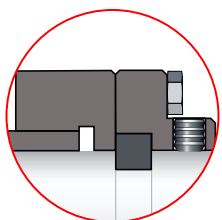
1. Larger diameter, hardened set screws capable of higher axial loads.
2. Double row set screw drive collar utilizing hardened steel set screws.
3. Spot drilling the shaft under the drive collar set screws. This allows the set screws to engage into the shaft, guaranteeing a fixed location for the cartridge seal.
4. A two piece, split ring arrangement utilizing a groove machined in the shaft.
5. A shrink disc assembly that imparts a radial compressive force at the end of the shaft sleeve.



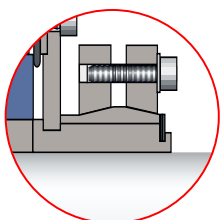
Double row set screw drive collar



Spot drilled drive collar



Split ring drive collar with key



Shrink disk drive collar

If the chosen drive arrangement requires additional axial space outside the seal chamber or modification to the pump shaft, the pump manufacturer or owner should be consulted as to the most desirable design.

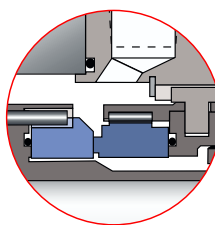
Pipeline systems often employ variable speed drives and flow control devices to increase or decrease pump flow rates and pressures, resulting in changes to seal face surface speeds and seal chamber pressures. With large shaft diameters and pumps operating at maximum speeds, the surface speed of the seal faces can exceed the limits set for rotating, flexible element mechanical seals. These same conditions necessitate the use of heavy duty drive keys and lugs. Drive keys and lugs are typically constructed from a non-galling material to eliminate the potential for hanging up the dynamic seal face. With variable shaft speeds and fluctuating system pressures, a clear understanding of the pipeline operation is required.

Mechanical seals selected for product pipeline pumps must be capable of handling the full range of conditions to which they will be subjected.

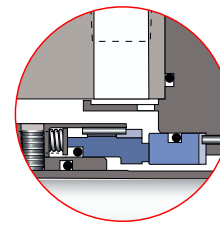
Seal Flush Piping

In order to remove the heat generated at the seal faces on product pipeline pumps, a reliable and sufficient seal flush must be maintained. Because many of the refined products transported in product pipelines are ‘flashing hydrocarbons’ (products that have a vapor pressure greater than 14.7 psia [1 bar]), any vapors formed at the faces must be carried away. Because vapors are not a good conductor of heat, these

vapors will isolate the seal faces and prohibit face cooling. A good rule of thumb is to maintain a 25 to 50 psi (1.7 - 3.44 bar) margin between the seal chamber pressure and the product vapor pressure. For NGL products, this margin should be 50 psi (3.44 bar) minimum. Since the seal chambers will operate at or near the suction pressure, a Plan 11 flush, piped from the discharge volute (single stage pump) or from an intermediate stage discharge (multistage pump), is suggested. While it is common on multistage pumps to take the discharge flush from the first stage discharge, consideration must be given to throttle bushing wear on the crossover end of the pump which can change the seal chamber pressure and seal flush rate.



Single port flush

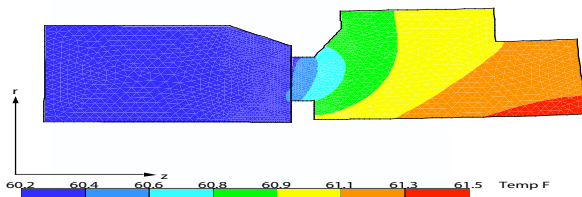


Multiport flush

Seal face cooling can be greatly enhanced with the use of a multiport flush. Flushing ports drilled around the circumference of the mating seal faces provide uniform cooling while sweeping away any vapor bubbles that may appear due to flashing. The seal flush rate should be a minimum of 2 gpm per inch (7.57 lpm) of seal diameter for flashing NGL applications. The flush rate can be controlled with the use of an orifice or multiple orifices. It should be noted that the flush rate will be affected by variable speed drives, flow and pressure controlling devices and batched by fluid-specific gravity and viscosity differences. Multiport injection is not recommended for cold crude applications due to the increase in viscosity of the cold product and tendency for flow to decrease significantly in these situations leading to plugging of the ports.

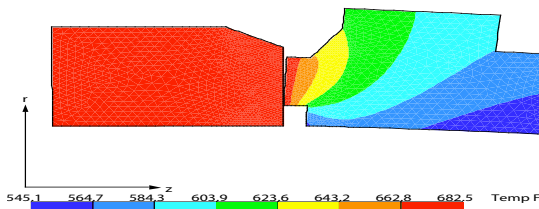
Seal Face Design

Paramount to the performance of mechanical seals in product pipeline pumps is the seal face design. Seal faces will undergo deformation due to the fluid pressure within the seal chamber. Hard seal face materials, such as silicon carbide or tungsten carbide, will experience less deformation compared to carbon seal faces. A carbon seal face run against a hard face has proven to be the optimal face combination for refined products such as gasolines and NGLs. Carbon will deform under higher pressures in a negative (concave) coning, producing outer diameter face contact. This contact, while desirable in static conditions, tends to cut off the fluid film lubricating the faces during operation. If the hydraulic pressure was the only force acting on the seal faces, there would be little leakage and the faces would run hot and eventually be destroyed.



Total deflection with film thickness

Pressure deformation is counteracted by the deformation that takes place due to the heating of the seal faces in operation. Heat is generated from the shearing of the liquid between the seal faces as well as from the contacting surface asperities on the seal faces. The faces will open as they are heated because the temperature increase at the face contact area causes the face material to expand. Because the face is hottest at the contact area and is gradually cooler as the distance from the contact area increases, it expands the most at the contact area. The result is that the face will distort in a curved shape at the mating area and this allows liquid to enter the gap between the faces. The liquid provides cooling to the contact area so the process tends to be self regulating. The faces will quickly reach a point of equilibrium where the heat generation will be balanced by the cooling effect of the liquid.



Seal faces in operation with pressure applied

Seal Face Materials

High quality seal face materials are a requirement for sealing demanding refined product pipeline applications. There are many grades of carbon graphite available but only a few can meet the requirements of product pipeline services. Experience and testing have shown that metallized, or antimony impregnated, carbon offers excellent performance in low specific gravity products and other common refined products. Metallized carbon is a better conductor of heat and is stronger than resin impregnated carbons so it will withstand mechanical and thermal deformations better.

As the preferred choice for the hard seal face in light hydrocarbon services, silicon carbide offers superior performance. Not only is silicon carbide harder than other commercially available seal faces, it is also a better conductor of heat. Sili-

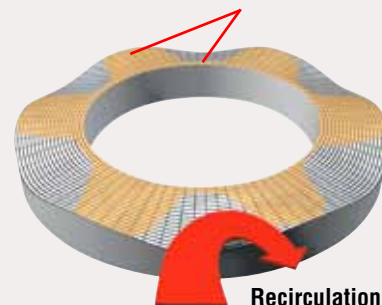
con carbide, when paired with carbon, offers the lowest coefficient of dry friction of any face material combination. Because of this, silicon carbide will generate less heat and the heat that it does generate will be conducted away more quickly. This quality is very important in sealing low specific gravity pipeline products operating at or near their vapor pressure.

While two hard faces may be better suited to handle the mechanical and thermal properties of difficult services including crude oil, a hard versus hard seal face configuration can be carefully applied in refined services. Tungsten carbide is used when toughness is required and provides a hard surface that easily withstands low viscosity and the presence of solids. However, a tungsten against tungsten combination is not recommended and tungsten in conjunction with silicon carbide should be used for the best possible sealing solution; tungsten having the wear nose. These face materials also offer an advantage for sealing higher pressure services. The strength of these materials makes them less likely to deform in these conditions, allowing the faces to remain flat without closing off the lubricating film between them.

Precision Face Topography

When application conditions push the boundaries of contacting seal face performance, Precision Face Topography can change the sealing dynamics directly on the surface of the seal faces. Smooth, sinusoidal, bi-directional waves are one technology that augments the load support of the seal faces, reduces heat generation and increases reliability. Flowserve can apply Precision Face Topography to many of our seal designs and extend performance in mixed phase or poor lubrication applications.

Seal faces contact lightly at wave peaks and seal dam.



Fluid enters wave valleys to increase load support and reduce heat generation.

Recirculation effect minimizes fouling for high reliability.

O-ring Selection based on Application Temperature

Consideration of O-ring and gasket selection must be based on the properties of the process fluid. These parameters would include chemical composition and process temperature. Based on these aspects, a recommendation of elastomers can be made.

Material	Description	Min Temp F (C)	Max Temp F (C)
Viton A	Fluoroelastomer	-20 (-29)	482 (250)
FKM Type 1	Fluoroelastomer	-15 (-26)	482 (250)
FKM Type 3	Fluoroelastomer	-40 (-40)	400 (204)
FFKM	Perfluoroelastomer	-22 (-30)	621 (327)
FVMQ	Fluoroelastomer	-99 (73)	392 (200)
EPDM**	Ethylene Propylene	-67 (-55)	302 (150)
FEPM	TFE/P	-18 (-28)	482 (250)
NPR	Nitrile	-76 (-60)	325 (163)
CR	Neoprene	-60 (-51)	257 (125)
VMQ	Silicone	-175 (-115)	482 (250)
IIR	Butyl	-74 (-59)	250 (121)

* Information obtained from Engineering Standards Documents GMS-04.01
 ** Material may be attacked in oil applications

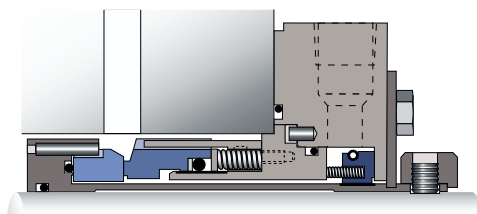
Single Seals

Performance may drive the selection of single seals and, in some cases, it is driven by the available axial and radial space. Certain considerations must be made when applying a single seal in the pump.

- What process fluid or fluids are being pumped?
- Why is there a need for a single seal to be used?
- Is there a limitation of axial space?
- Is cost of a dual seal a concern?
- Can a secondary containment device be used?

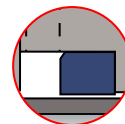
Leakage is one concern and a variety of containment devices may be used.

Single seal with a containment device and drain connection in the gland

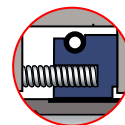


HSB seal with floating bushing

Fixed bushings provide basic, economical leakage containment. Use with Plan 65 leak detection. Bushing clearance is typically 0.090 inch (2.29 mm).



Floating bushings create a self-centering, close-clearance restriction. Use with Plan 65 leak detection. Bushing clearance is typically 0.040 inch (1 mm).



Custom containment devices per customer preference. Use with Plan 65 leak detection. Axial lip seals, radial lip seals or combinations with bushings can be included.



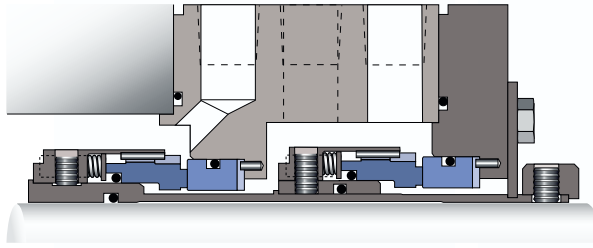
Dual Seals

Because sealing applications on product pipeline pumps are critical to pipeline operation, the use of dual (tandem, double or dry running secondary) seals should be considered. Dual seals can maintain low leakage rates while providing improved safety. A tandem seal is two seals operating in series with the secondary seal usually of the same configuration as the primary seal. An unpressurized seal reservoir, Plan 52, is required to support the operation of the secondary seal. A double seal is usually two seals sealing in opposite directions. This seal is usually supported with a pressurized seal reservoir, Plan 53A but other pressurized piping plans are also available (Plans 53B, 53C and 54). Dry running secondary seals operate in tandem arrangement without the seal reservoir required for liquid tandem arrangements. A discussion of piping and system requirements for these three arrangements can be found in the last section of this document.

Liquid tandem seals provide stable face operation for high pressure NGL pipeline services. Here, the buffer fluid maintains a more steady inboard seal face temperature differential that helps minimize flashing of the product. The outboard seal acts as a spare seal in the event that the inboard seal fails, and provides low leakage rates during normal and upset conditions. Leakage can be contained within the reservoir system and transferred to a vapor recovery system. Additionally, the volume of gas leakage (assuming that the product is a flashing hydrocarbon) can be reduced by pressurizing the Plan 52 flush system. This improves the performance of the secondary seal while protecting against pumping ring cavitation. To ensure reliable operation, the inboard seal should be double balanced in this situation.

Dry running secondary seals provide the same safety and containment as liquid tandem seals and are useful for both liquid and gas containment. Consideration must be given to the anticipated leakage pressure or seal chamber pressure in the event of a primary seal failure. The API 682 expectation for containment seals is that they must tolerate 8 hours operation when running as the primary seal before the pump is shut down.

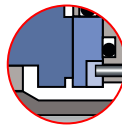
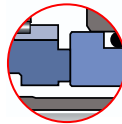
Dual seals with a pressurized or unpressurized support system



Tandem QB arrangement

Dual wet seals provide zero process emissions when pressurized with 53A, 53B, 53C or 54 support systems. When an unpressurized Plan 52 is used, the outboard seal acts as an installed spare.

GSL containment seals run dry until taking over as a wet backup seal. Use with Plans 75 or 76 vent and drain systems.

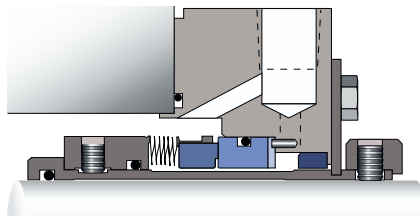


Seal Recommendations

BX Seal

The BX seal is an inherently balanced, flexible rotor, welded metal bellows seal suitable for low pressure applications. The design of the BX seal, with no dynamic secondary seals, eliminates the potential for seal face hang up and fretting of the shaft sleeve. The self cleaning effect of the rotating BX seal also reduces the possibility of clogging the bellows core. The BX seal will match a silicon carbide rotating face against a silicon carbide stationary face or carbon stationary face for lighter services.

Standard materials of construction are 316 stainless steel bellows and other metal parts. Optional alloy materials are available for maximum resistance to corrosive crude oils. The BX seal is rated for seal chamber temperatures up to 400°F (204°C) pressures up to 400 psig (27 bar) and surface speeds up to 75 feet per second (23 m/s).

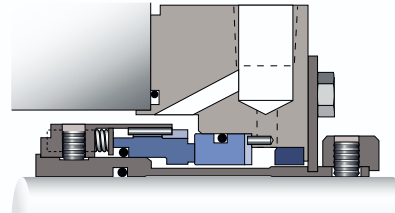


BX Seal

QB Seal

The QB seal is a balanced, multiple spring seal suitable for general service applications. The compact design of the QB

seal makes it a good choice when liquid tandem seals are a requirement. The QB seal will match a carbon rotating face against a silicon carbide stationary face as standard with optional hard faces.

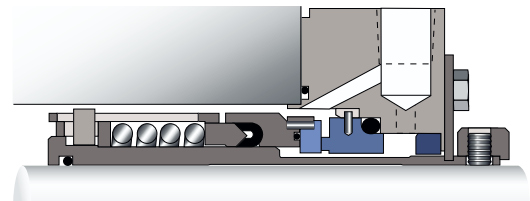


QB Seal

Standard materials of construction are 316 stainless steel metal parts with alloy C-276 springs. A complete range of secondary sealing materials is available for use with this seal. An optional high balanced carbon face (QBQ) is available to help meet low emission requirements of light hydrocarbons. The QB seal is rated for seal chamber pressures up to 750 psig (52 bar) and surface speeds up to 75 feet per second (23 m/s).

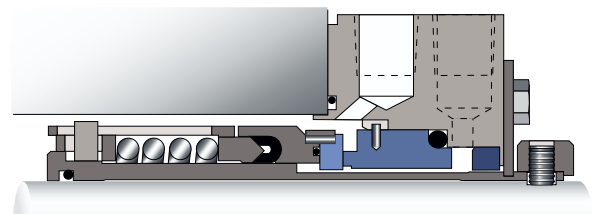
UO Seal

The standard UO seal is a balanced, single spring seal for general service that utilizes a multi-component silicon carbide rotating face with a carbon stationary face. The materials of construction are 316 stainless steel metal parts with a 316 stainless steel large cross-section spring. Fluorelastomer secondary seals are available as are most other chemically compatible secondary sealing materials. The UO seal is recommended for seal chamber pressures up to 1000 psig (69 bar).



UO Seal

The UOP seal shares a few features plus an optimized stationary seal face to withstand pressures beyond 1000 psig, up to 1500 psig (69 bar up to 103 bar). The maximum surface speed for UO and UOP seals is 75 feet per second (23 m/s).

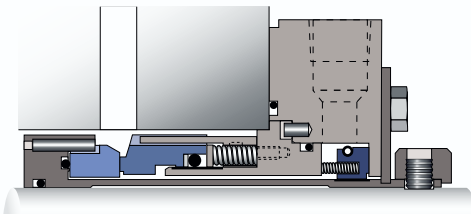


UOP Seal

HSH Seal

The HSH seal is a balanced, flexible stator, multiple spring seal designed to fit narrow seal chambers and offer a floating throttle bushing as standard. The design of the HSH seal allows higher pressures and provides robust seal face drive features especially in high torque, low viscous oil services.

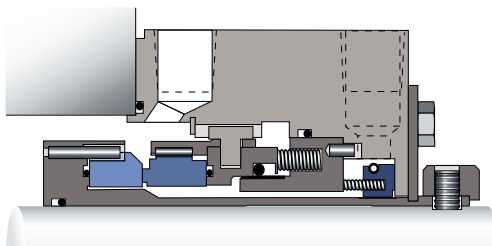
Standard materials of construction are 316 stainless steel metal parts with alloy C-276 springs. A complete range of secondary sealing materials is available for use with this seal. The HSH seal is rated for seal chambers pressures up to 1500 psig (103 bar) and surface speeds up to 75 feet per second (23 m/s).



HSH Seal

UHTW Seal

The UHTW seal is constructed with the same materials as the U seal, however, it utilizes large, robust cross section internal components and multiple coil springs. The stationary design of the UHTW seal locates these springs within the seal gland away from the product flush. The UHTW seal can be designed for pressures up to and beyond 3000 psig (27 bar) and can be provided in a dual seal configuration. The stationary design of the UHTW seal allows for surface speeds up to 250 feet per second (76 m/s).

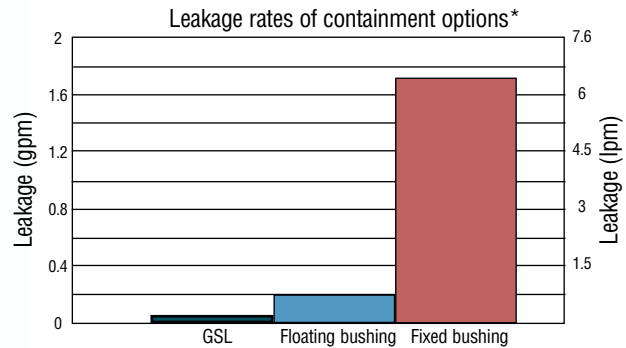


UHTW Seal

GSL Seal

The GSL seal is a non-contacting, bi-directional backup seal utilizing precision face technology. The non-contacting wavy face design of the GSL seal, utilizing rotating carbon and stationary silicon carbide seal faces, provides no measurable wear and long service life. The seal is rated for pressures up to 600 psig (41 bar) for both liquid and gas containment, however, higher limits may be attained with customer engineering. When combined in a tandem arrangement with any one of the primary seals discussed, the GSL seal provides the secondary containment required to help meet emission and leakage standards without the proper auxiliary equipment needed for traditional liquid tandem seals.

With a minimal amount of instrumentation and piping, the GSL seal provides condition monitoring with signal intelligence and feedback mechanisms. These mechanisms can be used to indicate excessive primary seal leakage. This feature allows for the application of the GSL seal in remote, unmanned pipeline stations.

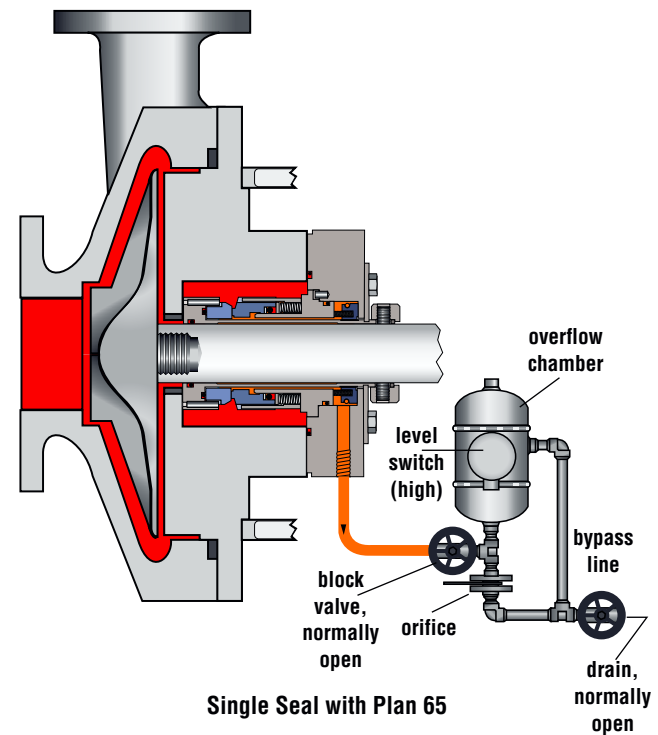


* Leakage data based on same design, speed, process fluid and standard clearance

Leakage Detection

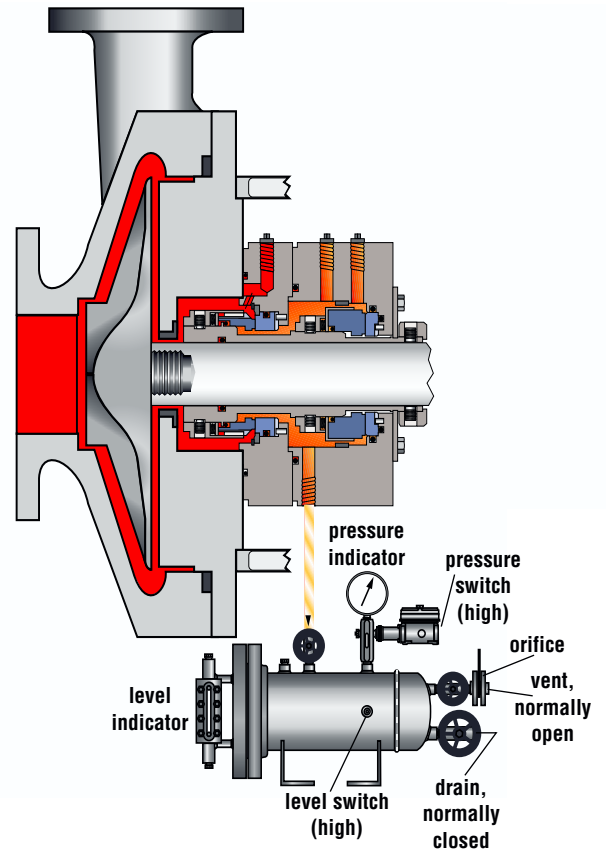
Plan 65 with Non-Vaporizing Products

Utilizing a Plan 65 in conjunction with a containment device, the leakage is contained and piped from seal gland to an external drain. Excessive leakage is restricted by a close-clearance throttle bushing on the atmospheric side of the seal to activate a safety indicator on the reservoir to detect failure. This system may be used in combination with a Plan 62 to consume leakage from the seal as a quench. The Plan 65 is a highly recommended option for single seal applications in remote locations and critical services.



Plan 75 with Vaporizing & Non-Vaporizing Products

Utilizing a Plan 75 in conjunction with a dual seal configuration and GSL serving as a containment seal, leakage is drained from the containment seal cavity to a liquid collector and vapor recovery system. A leakage collection and vapor recovery system ensures very low process emissions, satisfying environmental regulations. A safety indicator is used to signify increased pressure. Typical applications for a Plan 75 include sealing high vapor pressure fluids, light hydrocarbons, hazardous/toxic fluids and fluids that condense at ambient temperatures. Plan 75 applications may also be used with a Plan 72 low pressure purge on containment seals.



Dual Containment Seal with Plan 75

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USA and Canada

Kalamazoo, Michigan USA
Telephone: 1 269 381 2650
Telefax: 1 269 382 8726

Europe, Middle East, Africa

Roosendaal, The Netherlands
Telephone: 31 165 581400
Telefax: 31 165 554590

Asia Pacific

Singapore
Telephone: 65 6544 6800
Telefax: 65 6214 0541

Latin America

Mexico City
Telephone: 52 55 5567 7170
Telefax: 52 55 5567 4224