RUHRPUMPEN

Specialist for Pumping Technology

Session 26 – Mechanical Seals and Sealing Systems

Simon Smith September 2023

Presenter Profile – Simon Smith

Simon graduated with an honours degree in Chemical Engineering from the University of Surrey in 1978 and began a long career in the engineered pump industry spanning 40 years (so far!) with Peerless Pump, BW/IP International / Flowserve, SPP Pumps, Ruhrpumpen and Ebara Cryodynamics.

Over his long career he has filled various roles as Applications Engineer / Manager, Project Manager, Key Account Specialist, Vertical Pump Product Specialist, International Sales Engineer / Manager / Director and he has considerable experience in Training & Mentoring young engineers.

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RuhRPumpen Short Courses

Here is a listing of all the previous courses.

- No 1 – API610 12th v 11th editions
- No 2 - Curve Shape
- No 3 – The Importance of System Curves
- No 4 - Selecting the Right Pump for the Application
- No 5 - NPSH & Nss
- No 6 - Mechanical Seals & Systems
- No 7 - Firepumps
- No 8 - BB5 Barrel Pumps
- No 9 - Pump Instrumentation
- No 10 – Non-Destructive Examination
- No 11 - Vertical Pumps (Part 1) Type VS1, VS2, VS3
- No 12 – Vertical Pumps (Part 2) Type VS4, VS5, VS6 & VS7
- No 13 – Performance Testing of Centrifugal Pumps; the What, the Why & the How
- No 14 – Testing & Inspection of API 610 Pumps
- No 15 – Start-Up, Commissioning & Troubleshooting Centrifugal Pumps
- No 16 – Introduction to Positive Displacement (Plunger) Pumps
- No 17 – Refresher Session
- No 18 – Overhung Process Pumps OH1 & OH2
- No 19 – Vertical Overhung Process Pumps OH3-OH6
- No 20 – New Developments in the VS6 Market
- No 21 – BB4 Multistage Pumps for the Power Industry
- No 22 – Coking Process and Hydraulic Decoking Equipment
- No 23 – Pumps for the Desalination Market
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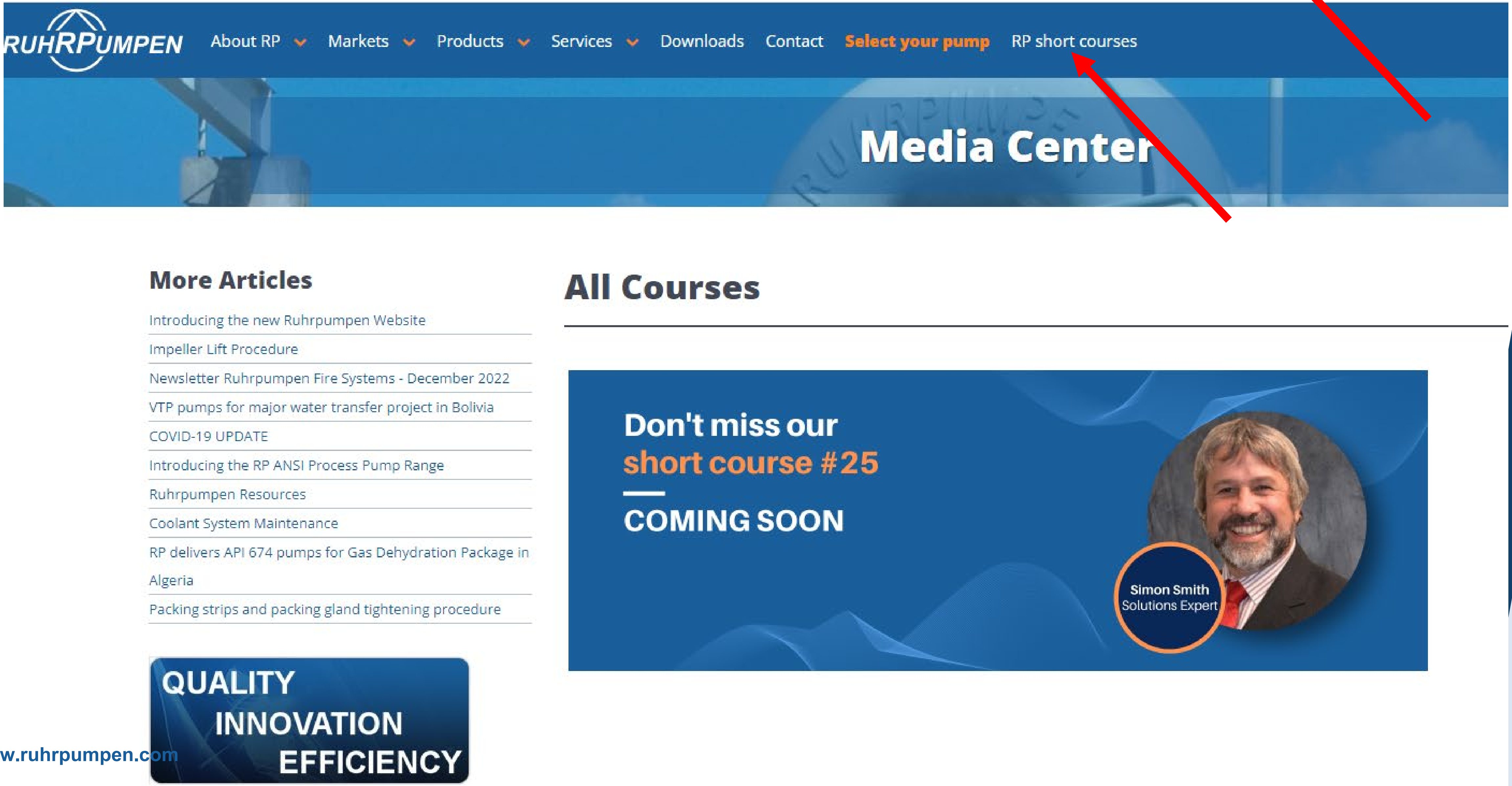

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SHORT COURSE 12

Vertical Pumps (VS4/5, VS6, VS7)

Full session.

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SHORT COURSE 13

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SHORT COURSE 15

Start-Up, Commissioning & Troubleshooting Centrifugal Pumps

Full session.

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SHORT COURSE 16

Introduction to Positive Displacement (Plunger) Pumps

Session part 1.

Session Part 2.

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Session 6 –
Mechanical Seals & Sealing Systems

Aimed at Process and Mechanical Engineers and Consultant Engineers specifying pumping equipment as well as Applications & Sales Engineers selecting and quoting them. Develop an understanding of the fundamentals of sealing technology, the types of seals available and their associated sealing support systems (piping plans).

Sealing the Gap:-

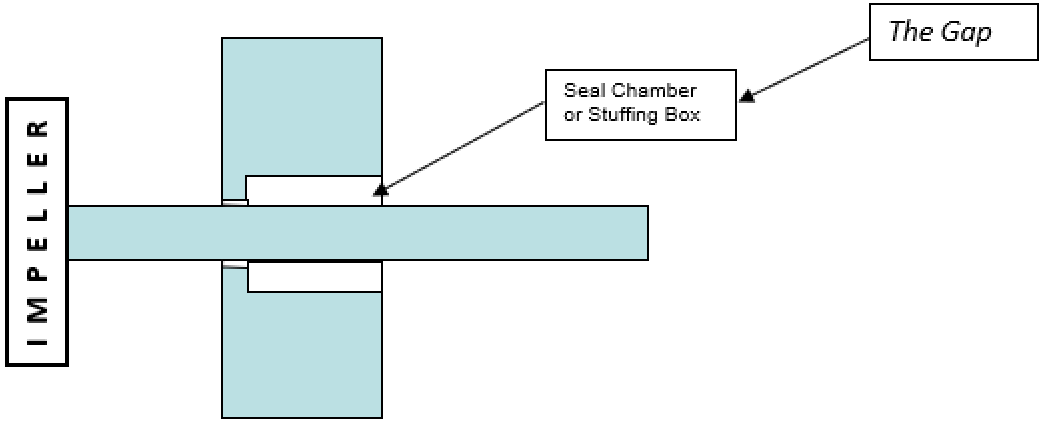
The pump Casing and Impeller are the means of producing the Head to drive the liquid Flow into the customers piping system.

It was always going to be a challenge designing a pump to pressurize a liquid by rotating an Impeller using a Shaft.

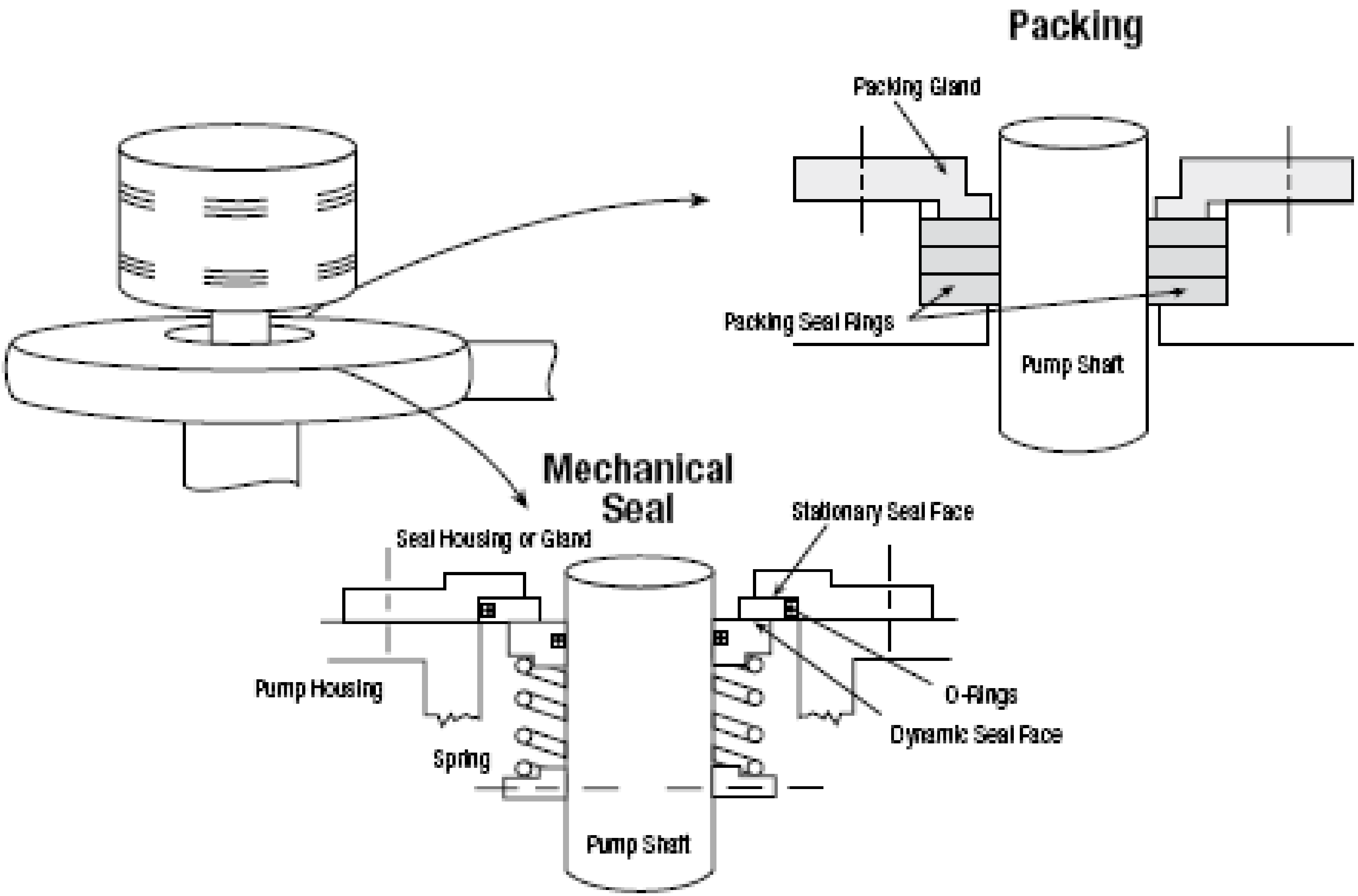
This Shaft has to cross the boundary from inside the pump to outside the pump, leading to the Motor. And this has to be accomplished in a way that prevents the liquid leaking out.

There will be a Seal Chamber gap between the rotating Shaft and the stationary Case which must be filled with something to stop the liquid leaking out.

The gap in the seal chamber is sealed by either Packing or Mechanical Seals.



Sealing the Gap:-



Packing

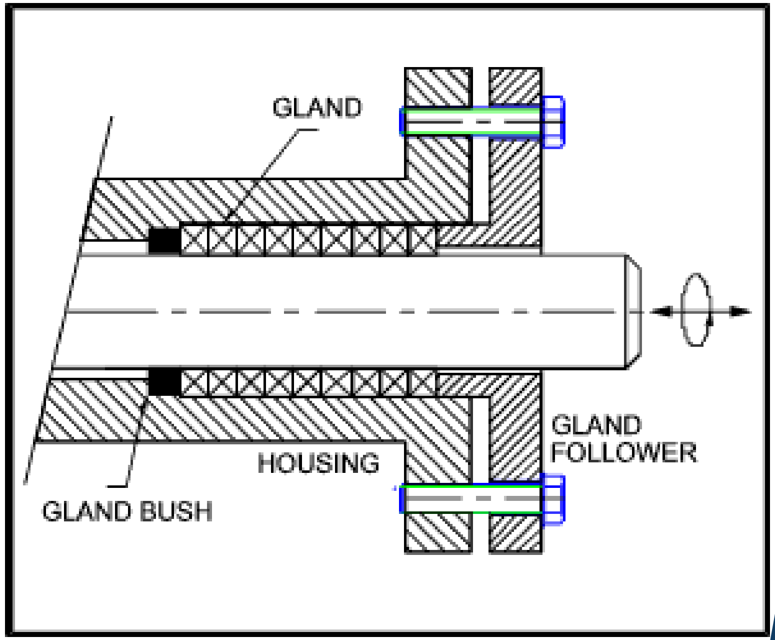
Packing

Packing is a compressible Braiding that is used to fill the gap between the stuffing box walls and the rotating shaft.

Aramid synthetic polyamide fibre impregnated with graphite or PTFE most commonly used.

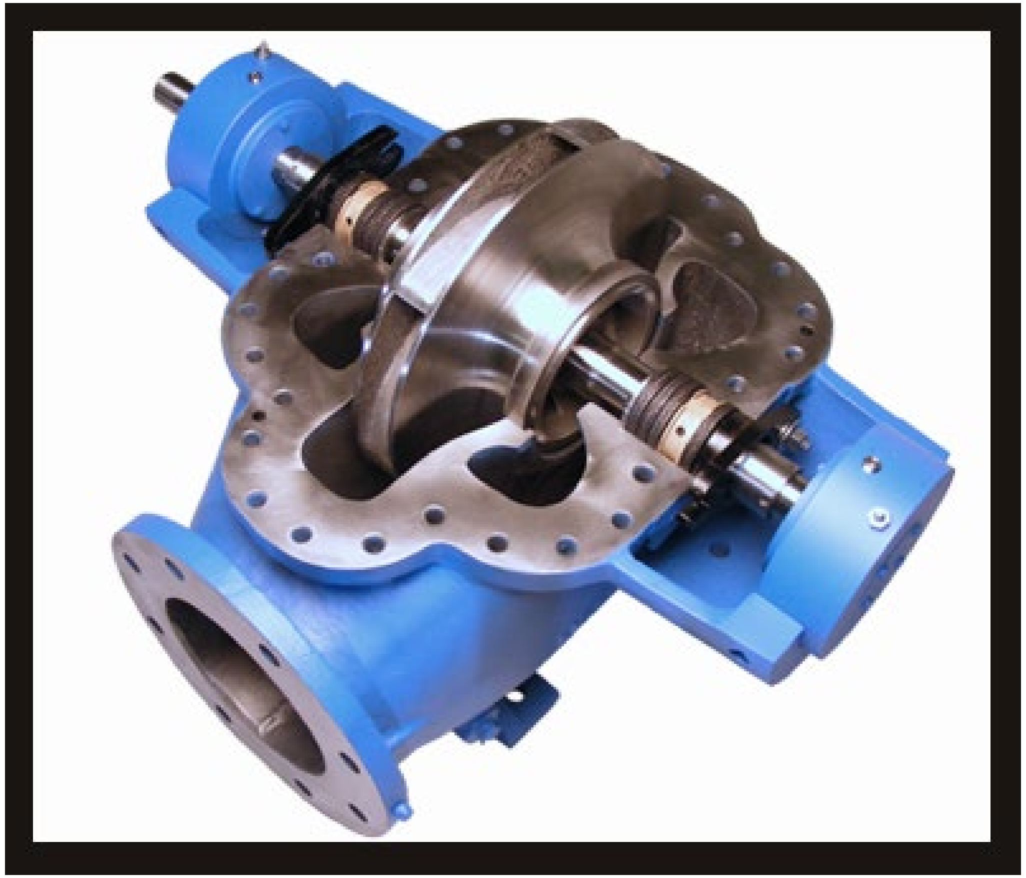
The Braiding is formed into rings that are radially split, then compressed in the stuffing box of the pump.
As the packing is tightened, it compresses against the shaft and Stuffing Box bore to create the seal. Yet it also needs a leakage between the packing and the shaft to limit friction and stop burnout and damage.

Usually there are 2 sets of Packing, and they are separated by a Lantern Ring. Which is a metal or plastic disk with holes, to allow the Packing Water Flushing to go through both Packing Rings.

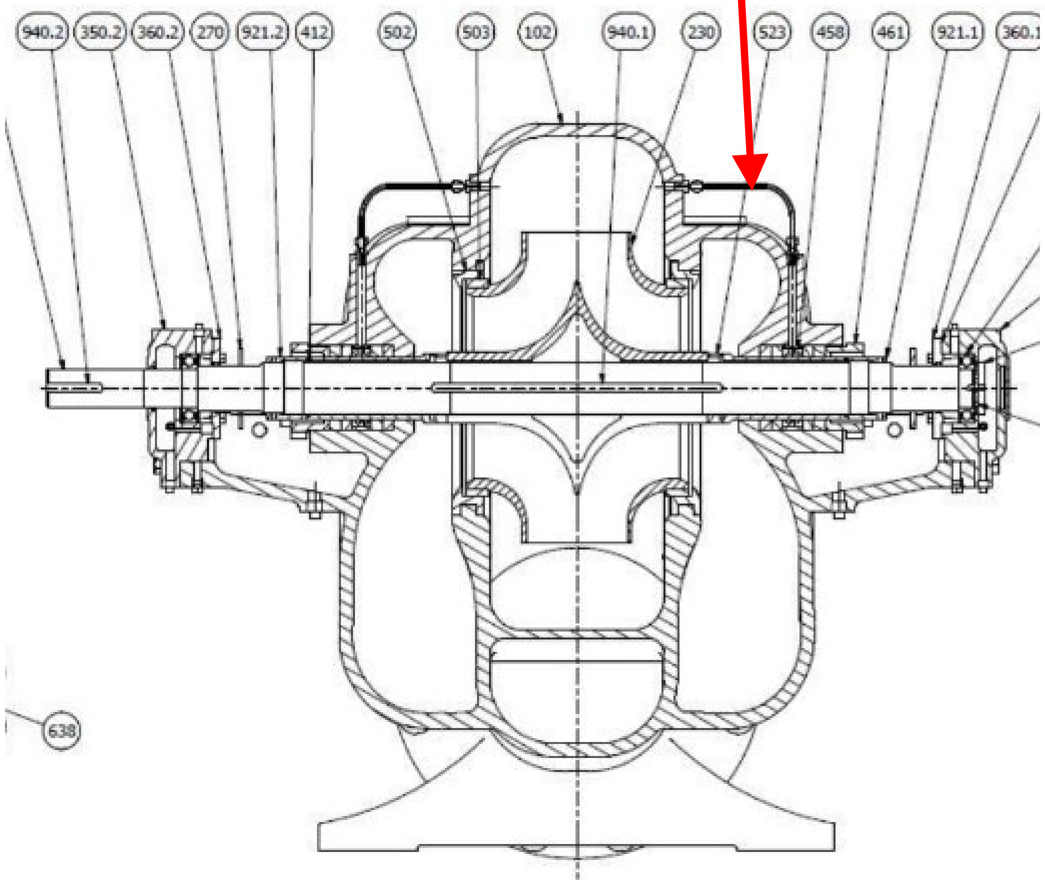


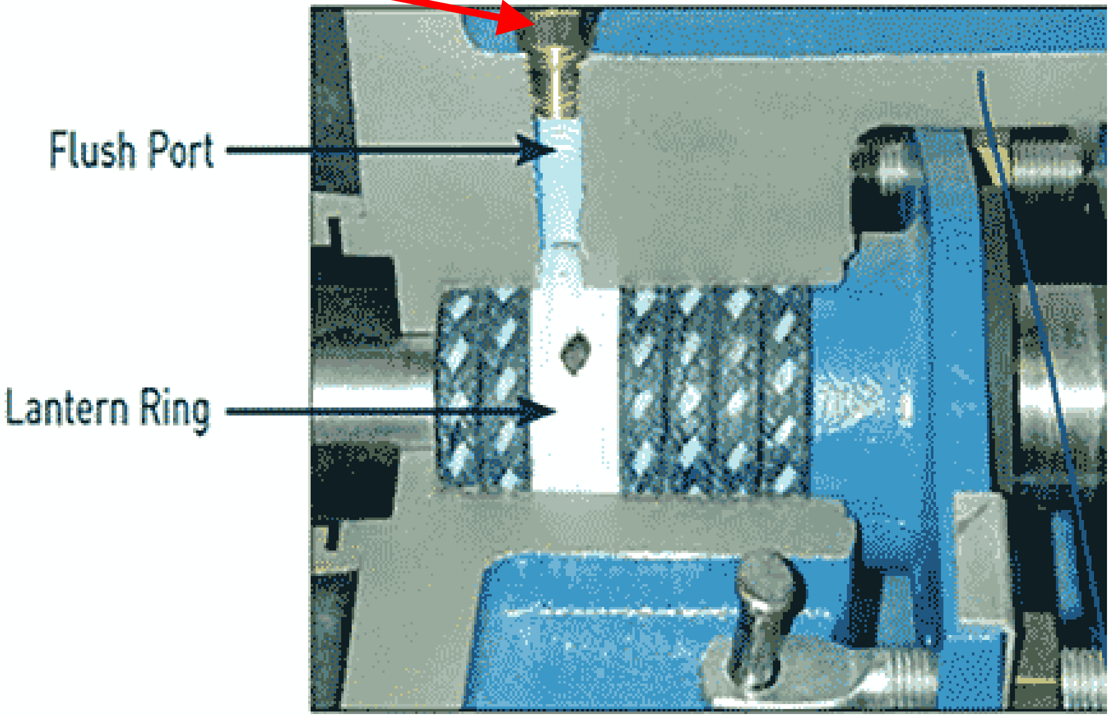
Packing

Packing



Packing – Flush to Lantern Ring





Packing

This method of sealing is low cost, economical and good for sealing Water as a safe liquid, and Low Pressure.

Requires lubrication either externally or by the liquid being pumped; this means packing must be allowed to leak slightly (weep).

Can damage the pump shaft, or the hardened (Stellite) Shaft Sleeve if adjusted too tightly.

Needs a regular maintenance routine to monitor leakage rates.

Mechanical Seals

There are basically 2 types of Mechanical seals, referred to by the design to be between the rotating Face and stationary Seat:-

1. Liquid supported Mechanical Seals.
2. Gas supported Mechanical Seals.

This presentation will concentrate on liquid seals

Liquid Mechanical Seals

The components are:-
1. **Seal Plate or Gland** to retain the stationary face or Seat, and bolt to the casing to retain the pressure. Also provide connections so that a pressurized liquid, like Plan-11, can pass near the sealing faces to cool and lubricate them.

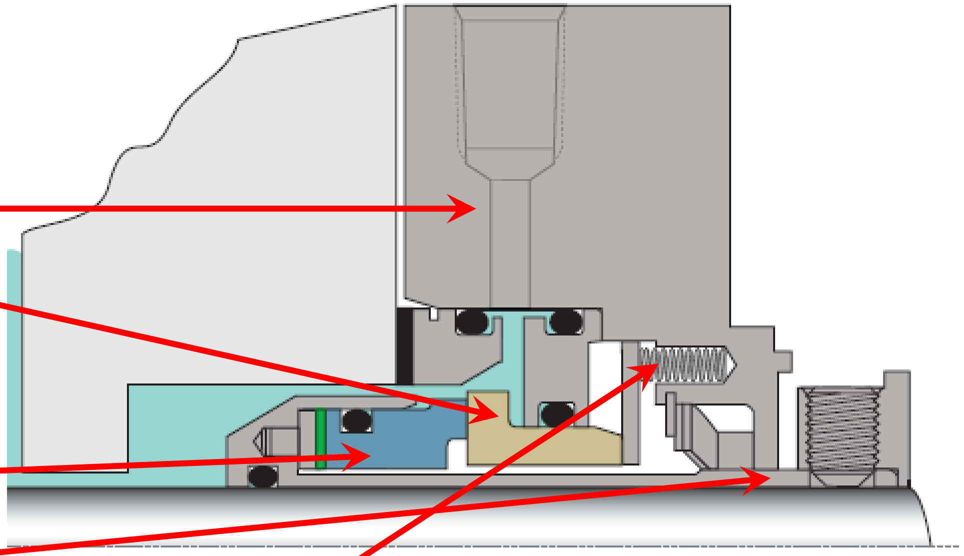
2.Stationary Face or Seat- Optically flat disc- first element of sealing. Usually made of Carbon,Silicon Carbide or Tungsten Carbide.

3.Rotating Face- Optically flat disc, driven by and connected to the Sleeve. Usually made of a very hard material, such as Silicon Carbide or Tungsten Carbide.

4.Sleeve & Drive Collar- Required for the cartridge seal assembly.

5. **Spring element**- The spring element is usually located behind the rotating face. The spring can be in the form of multiple small spring located within pockets, or a single larger spring. In the case of sealing high temperature liquids, the Mechanical Seal is connected to a Metal Bellows. The Metal Bellows act both as a pressure retaining component and a spring. The Spring element is NOT there to push the 2 faces together. The design of the sealing pressure areas ensure that the faces are together. The only reason for the spring is to allow the face assemblies to move together as they wear.

6. **Various O-Rings** and Gaskets are also provided to seal to the shaft and the casing.



Liquid Mechanical Seals

Liquid Mechanical Seals

Mechanical seals use highly polished faces (one stationary and one rotating) running against each other to form a seal.

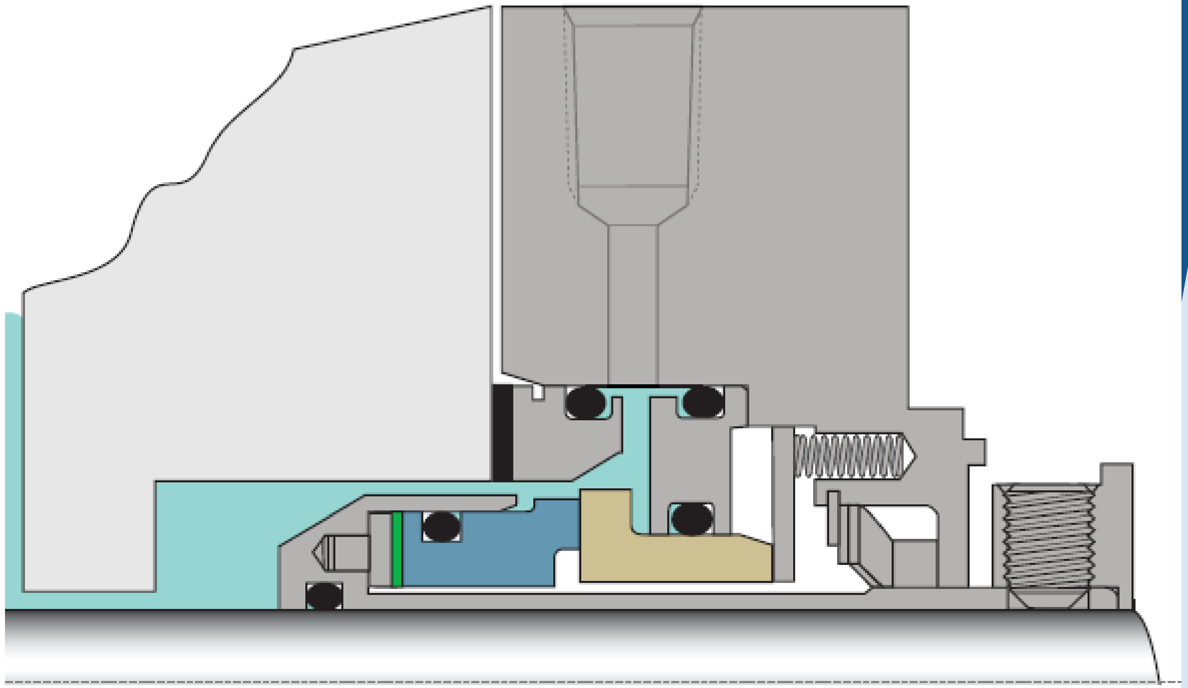
The seal faces are only in direct contact when at rest.

When rotating the faces are separated by an extremely thin film of the liquid being pumped, (or barrier fluid, or gas for Double or Tandem seals).

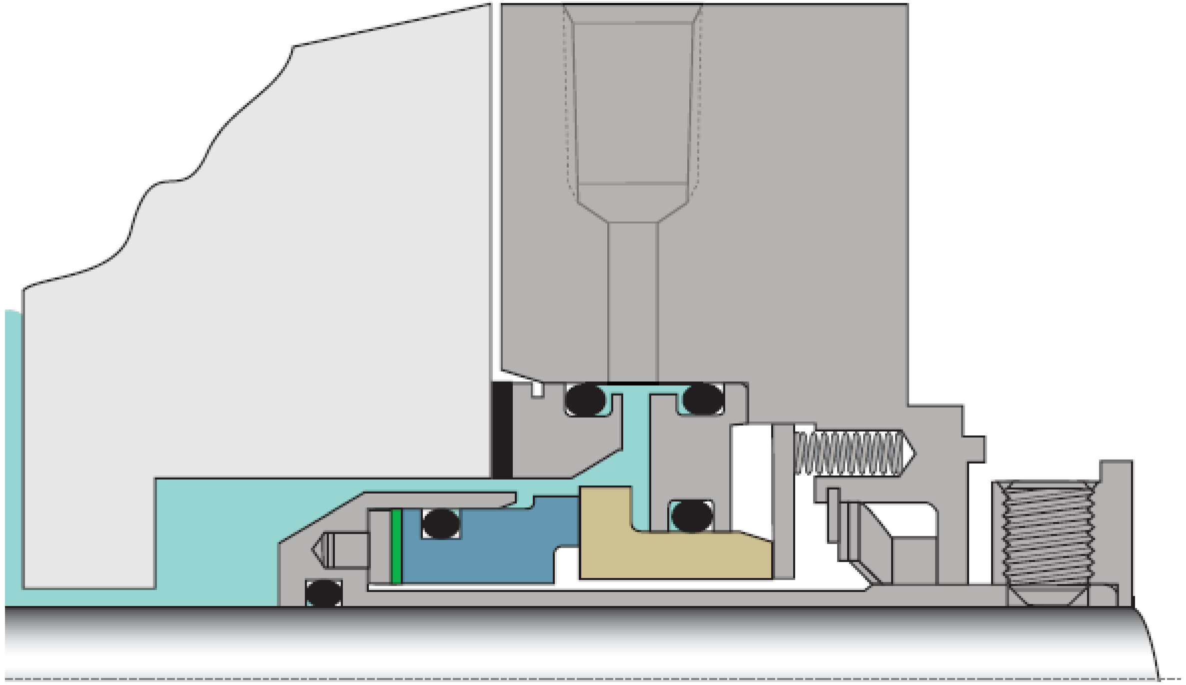
Mechanical seals come in a wide variety of designs and materials for nearly every application.

For dangerous, or other difficult to seal liquids, Double (back to back) or Tandem (face to face) are often used.

For these seals an external support vessel is usually provided, such as Plan 52, 53 & Plan 54.



Single Pusher Seal



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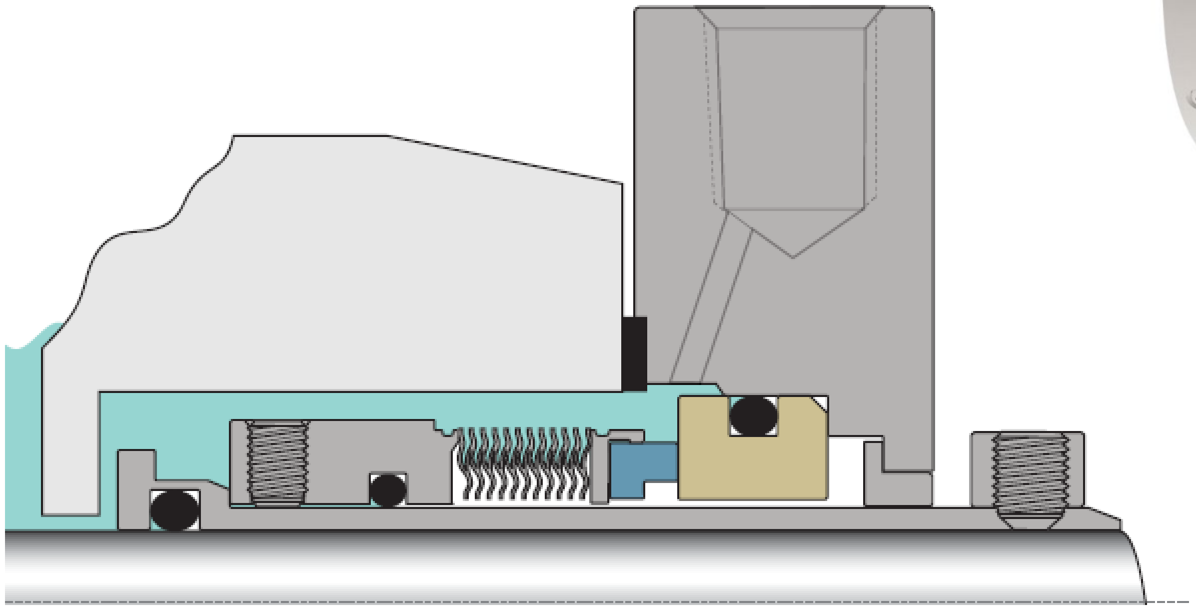
Single Bellows Seal

Generally used for high temperature fluids



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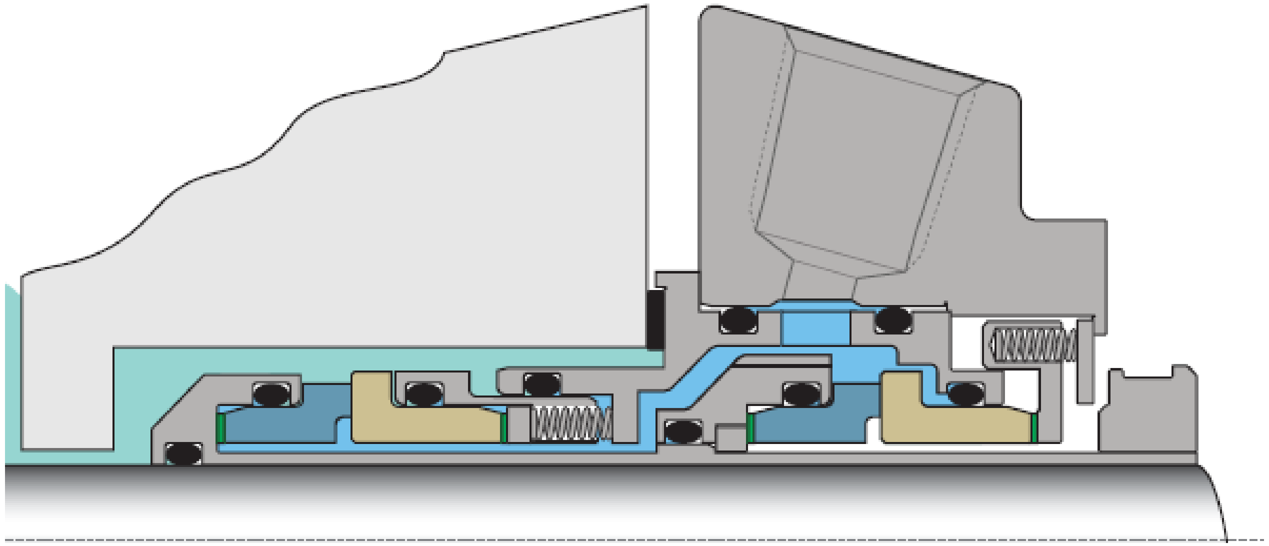
Dual Pusher Seal

In-Line Configuration (Tandem)



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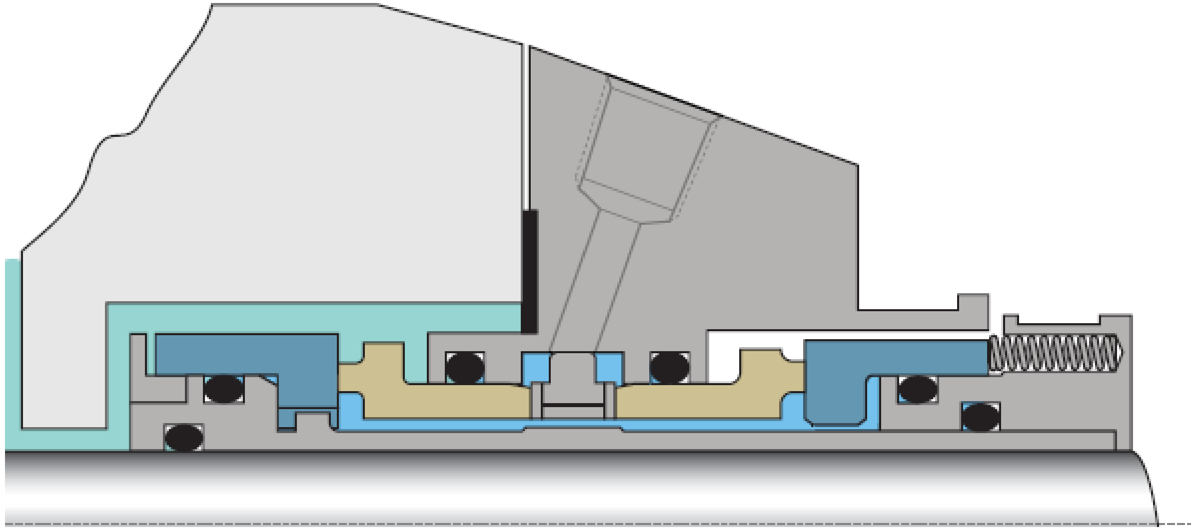
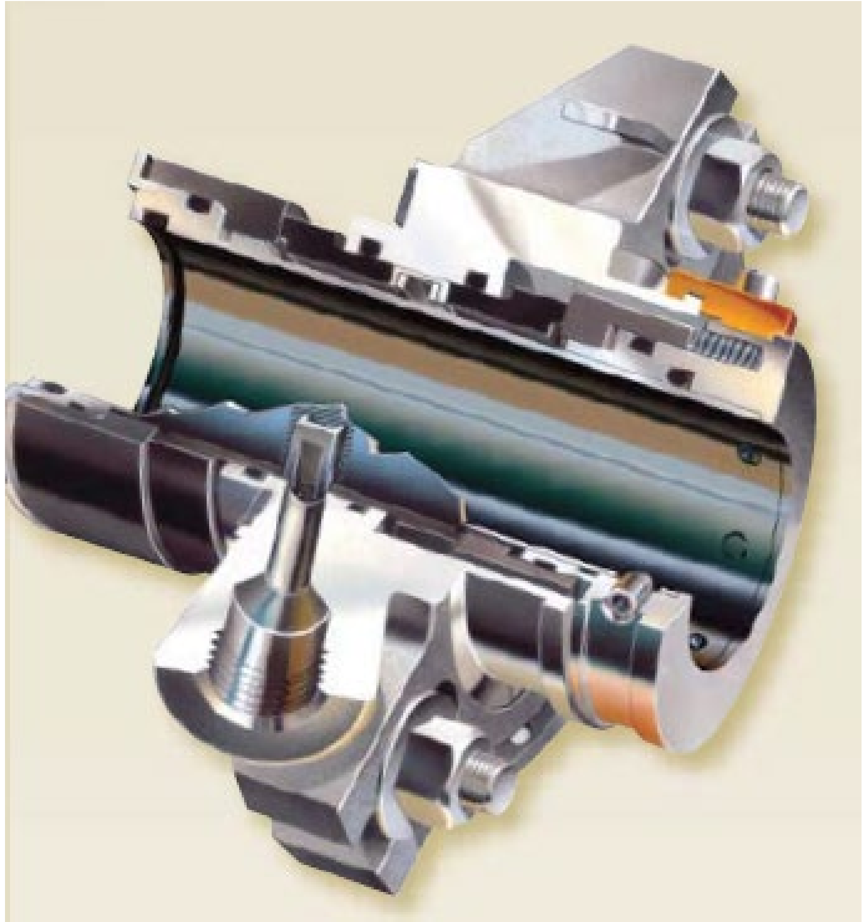
Dual Pusher Seal

Back-to-Back Configuration (Double)





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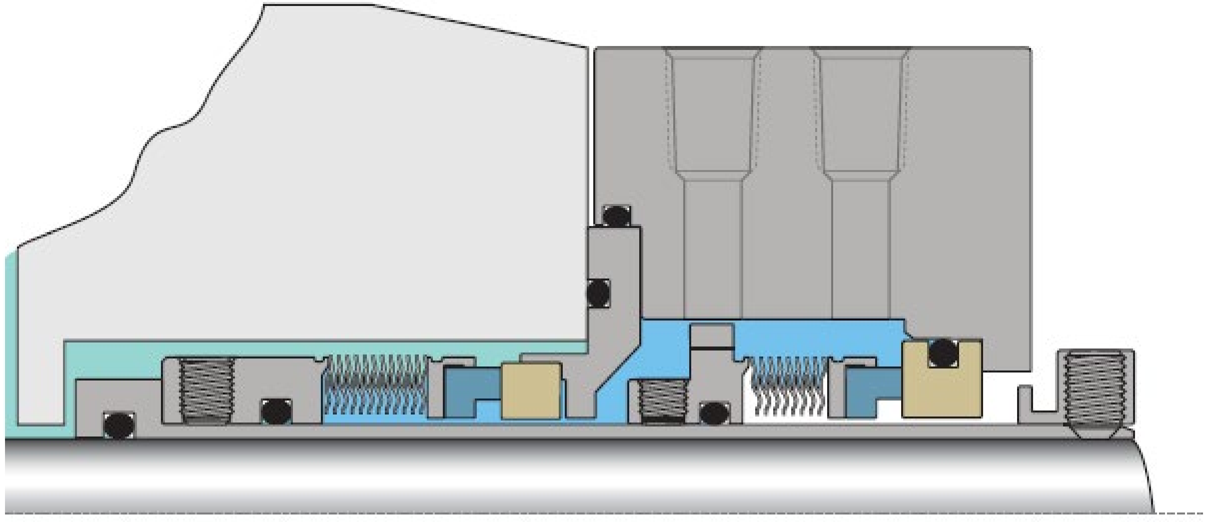
Dual Bellows Seal

Generally used for high temperature fluids



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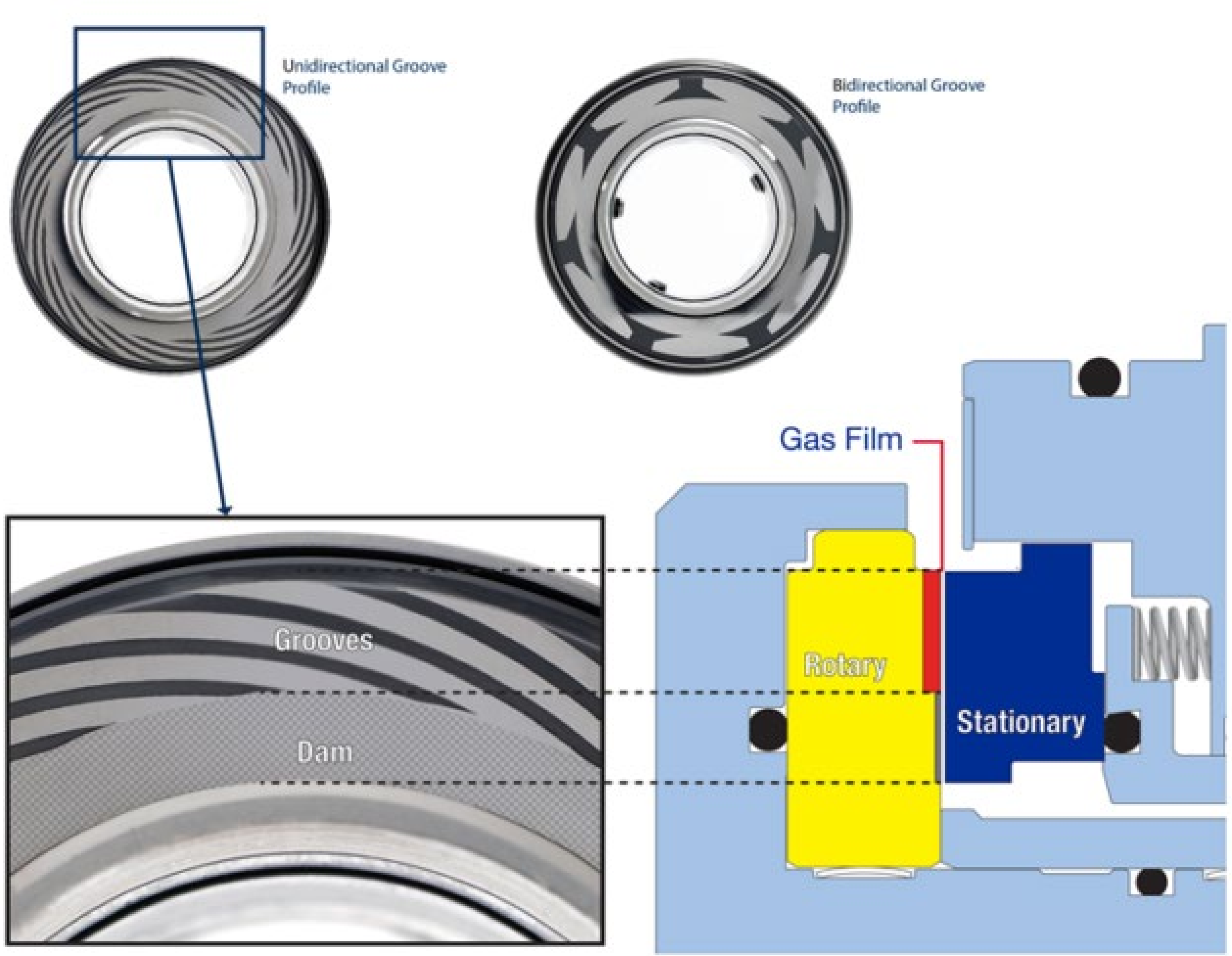
Dry Running Gas Seal

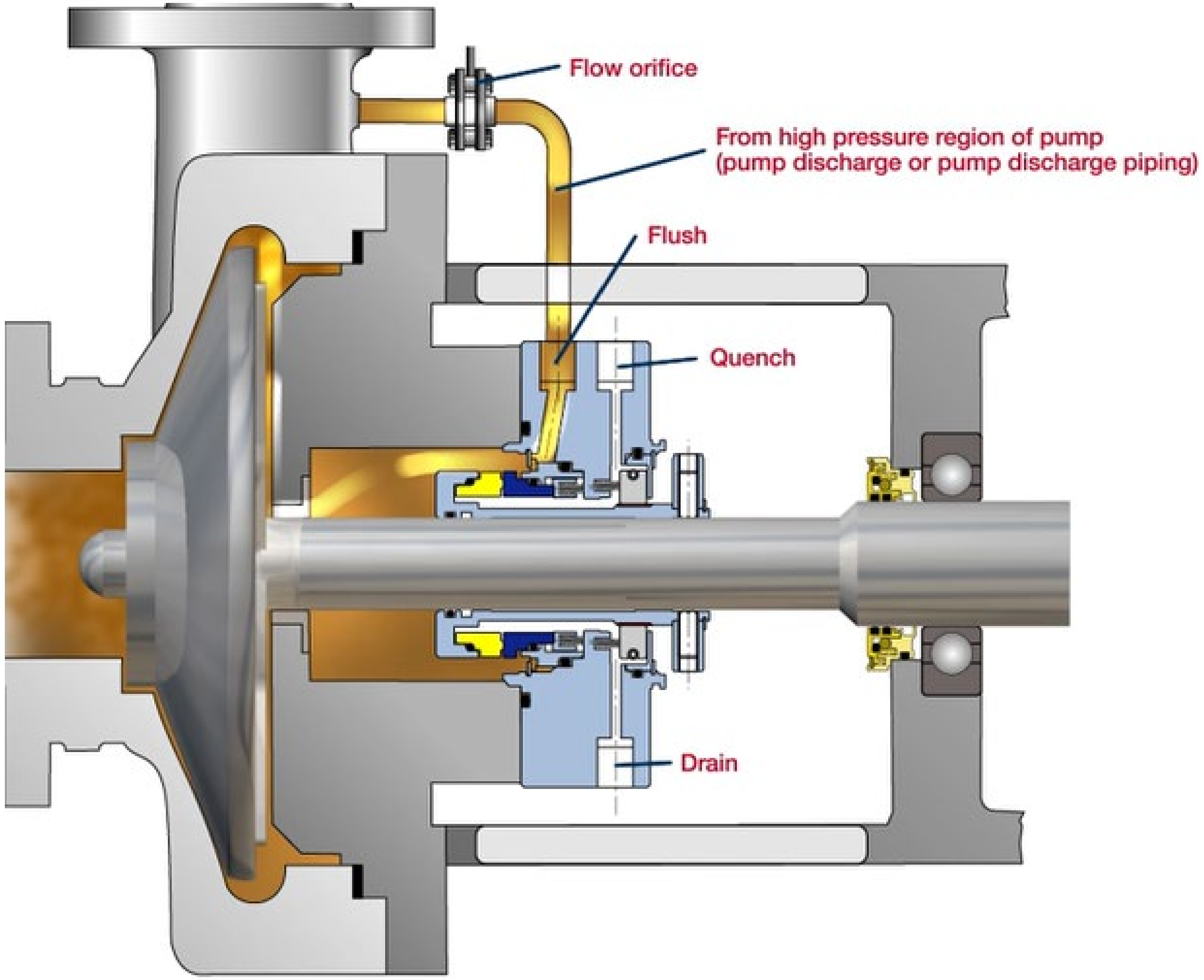
Frequently used as a secondary seal



API Plan 11

- Plan 11 is the most common flush plan. This plan takes fluid from the pump discharge (or from an intermediate stage for a Multi-Stage Pump) through an orifice(s) and directs it to the seal chamber to provide cooling and lubrication to the seal faces.

- If the Mechanical Seal needs a pressurized Seal Piping, then Plan-11 is effective if the Pumped Liquid does not have Particles & is Clean.



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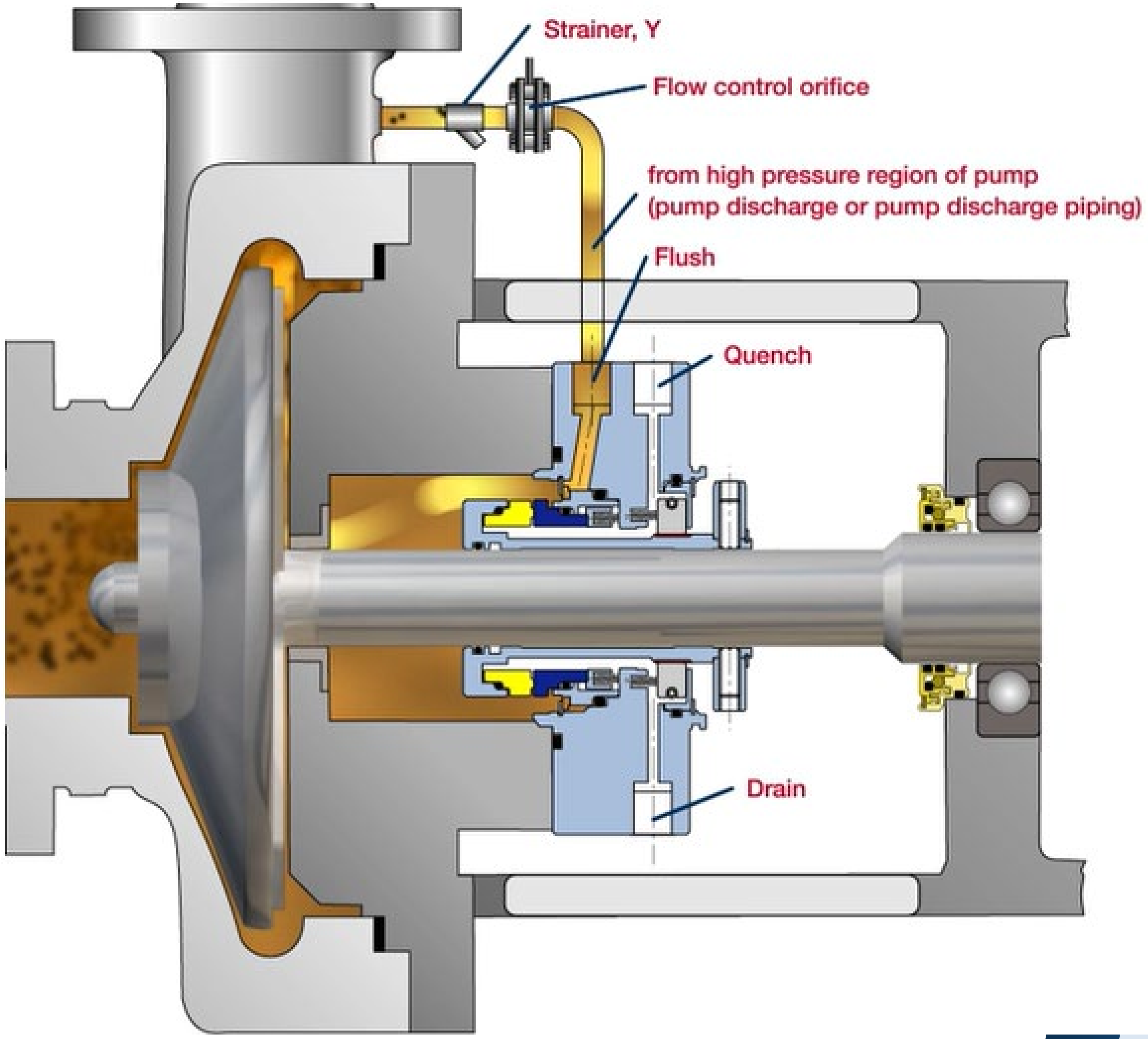
API Plan 12

- Description: Plan 12 is similar to Plan 11, except that a strainer or filter is added to the flush line, if the Pumped Liquid has Particles.
- So the Liquid Particles are removed from the Seal Flush Piping with the Strainer or Filter, which keeps the Plan 12 clean to the Seal.
- General: If the seal is setup with a distributed or extended flush, the effectiveness of the system will be improved. This plan should be equipped with a differential pressure indicator or alarm to show when the filter or strainer is being blocked. Which would reduce the Pressure and Flow-rate to the Mechanical Seal.
- Filters remove Particles that smaller than 0.0016" (40 microns). Strainers remove larger Particles that are larger than 0.0016" (40 microns



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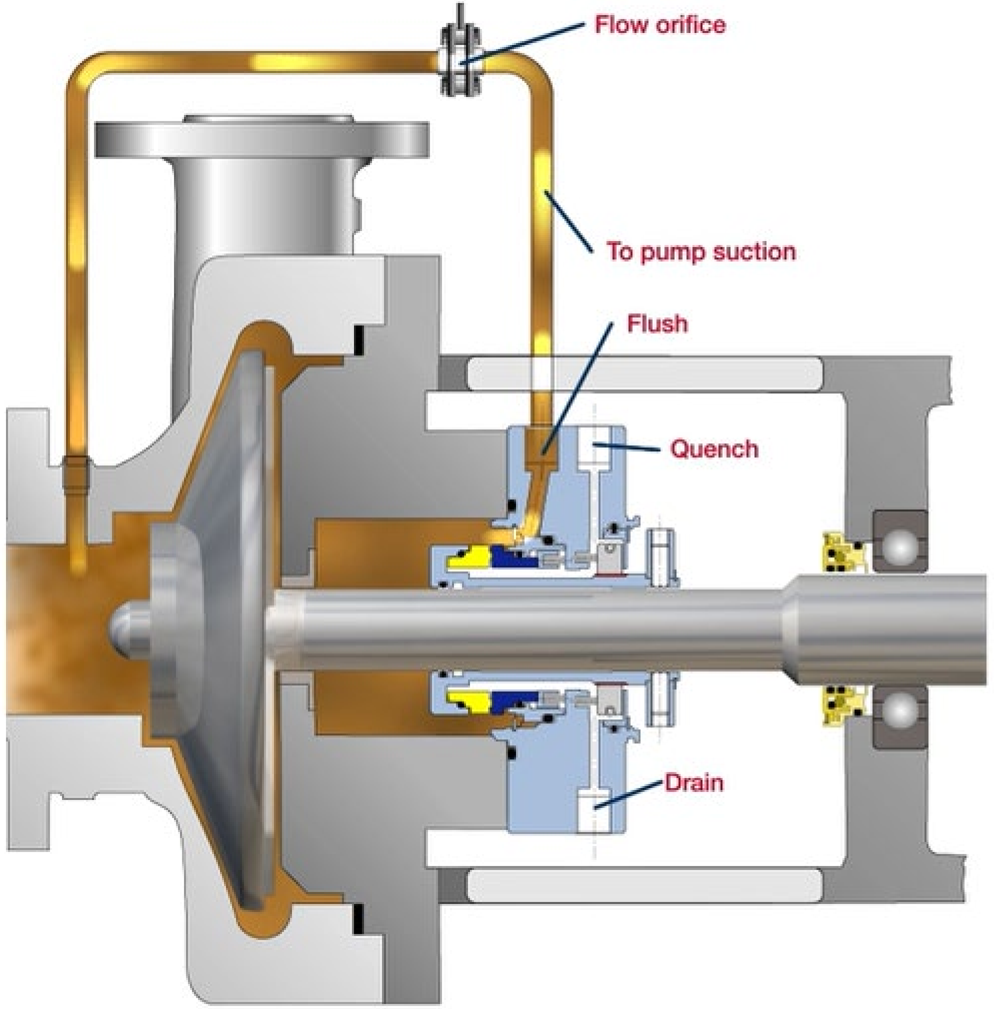
API Plan 13

- If an API610 Pump has a very high Suction Pressure, causing high thrusts. Then the Impeller back Wear Ring & Balance holes would be removed to reduce the Thrusts. So Plan-13 must be used. As it allows discharge pressure flow to enter the Stuffing Box Throat Bushing. In a Plan 13, the flow exits the seal chamber through an orifice and is routed back to Pump Suction.
- Advantages: With a Plan 13, it is possible to increase or decrease seal chamber pressure with proper sizing of the orifice and throat bushing clearance.
- General: Typically Plan 13 is used on vertical turbine pumps since they have the discharge at the top of the pump where the seal is located. Because of the difference in flow patterns, Plan 13 is not as efficient in removing heat as a Plan 11 and thus requires a higher flow rate.



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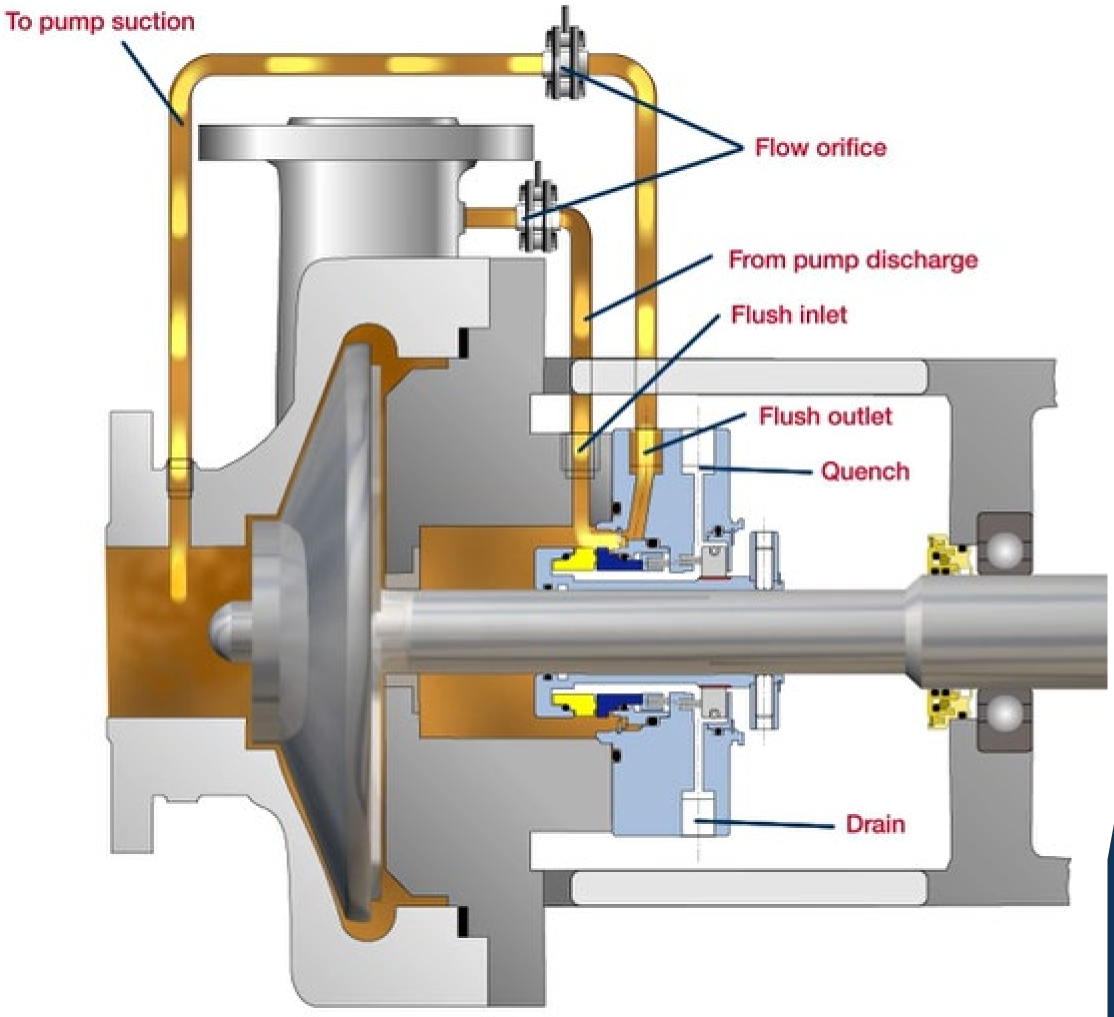
API Plan 14

- Description: Plan 14 is a combination of Plans 11 and 13. Flush is taken off of pump discharge, sent to the seal chamber, and piped back to pump suction.

- Advantages: Cooling can be optimized with the flush directed at the seal faces. Plan allows for automatic venting of the seal chamber.

- General: Often used on vertical pumps to provide adequate flow and vapor pressure margin independent of throat bushing design.



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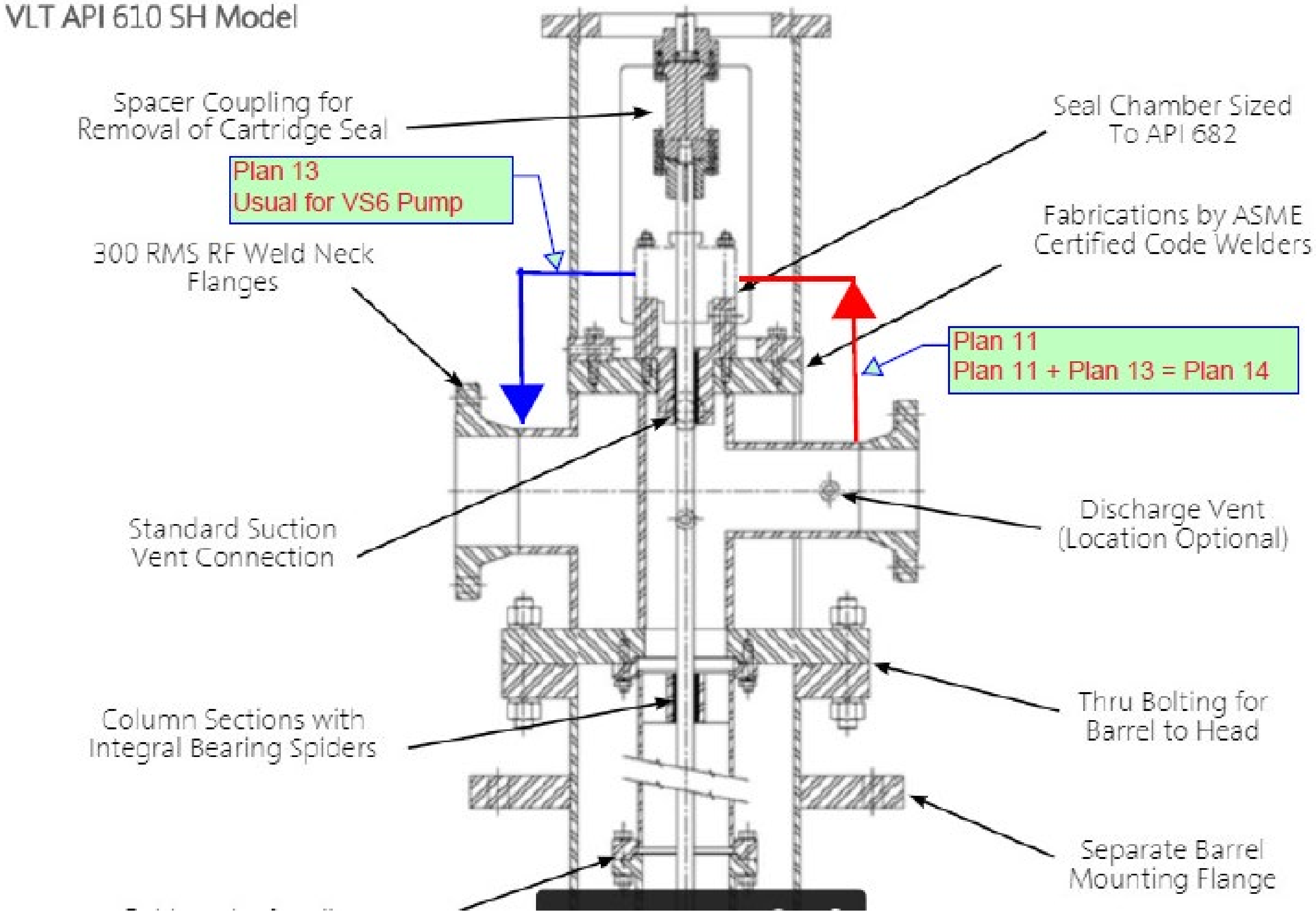
Seal Piping Plans

API Plan 14

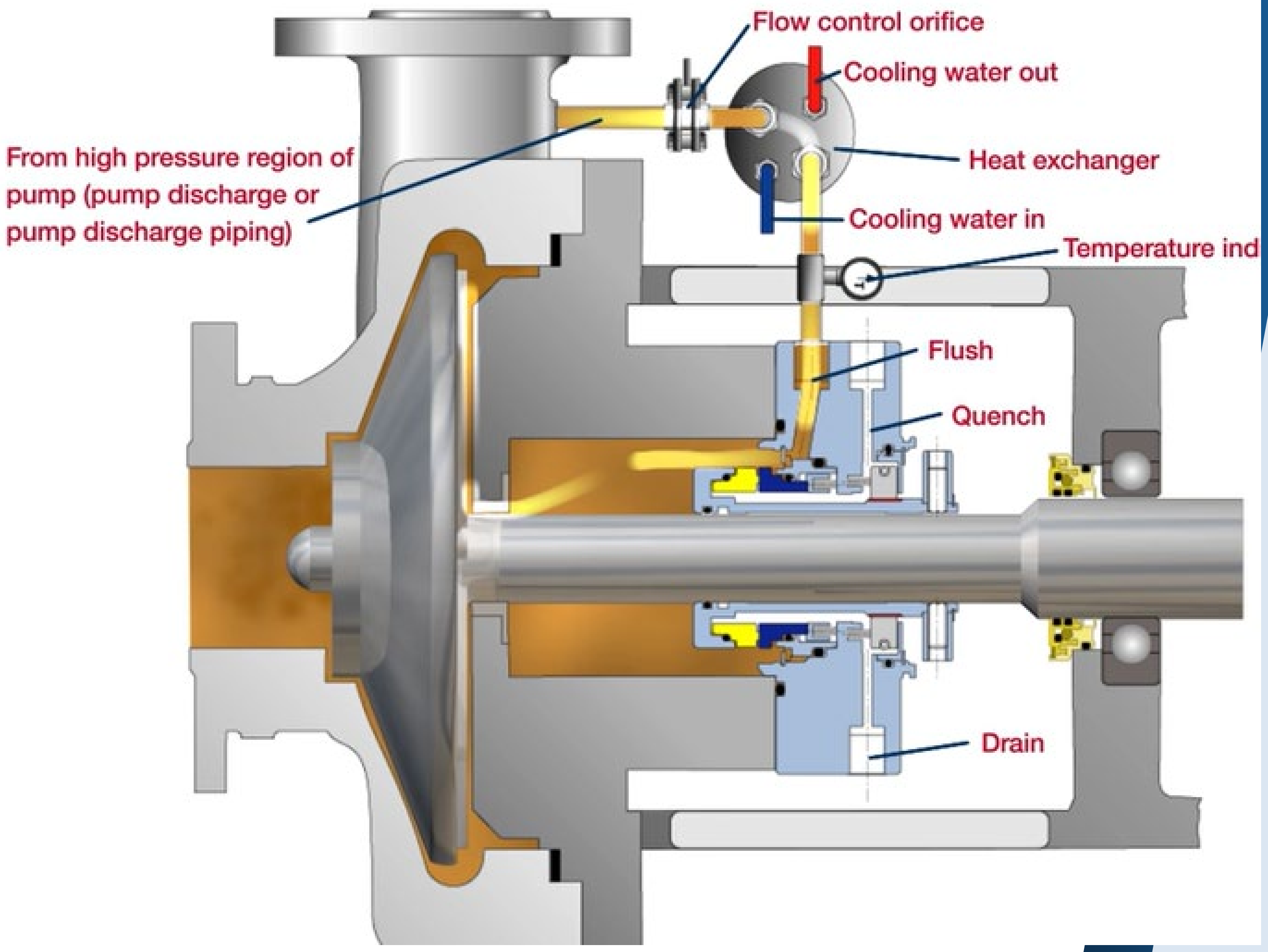


API Plan 21

- Plan 21 is a cooled version of Plan 11. The High Temperature Liquid from pump discharge is directed through an orifice, then to a heat exchanger (Cooler) to lower the temperature before being introduced into the seal chamber to the Seals.

- Advantages: Process fluid cools and lubricates the seal. Cooling improves Seal lubrication, and reduces the possibility of vaporization in the seal chamber & across the Seal Faces.

- General: Plan 21 is not a preferred plan, either by API or many users, due to the high heat load put on the heat exchanger, and the fact that cooled product is injected back into the process. A Plan 23 is preferred.



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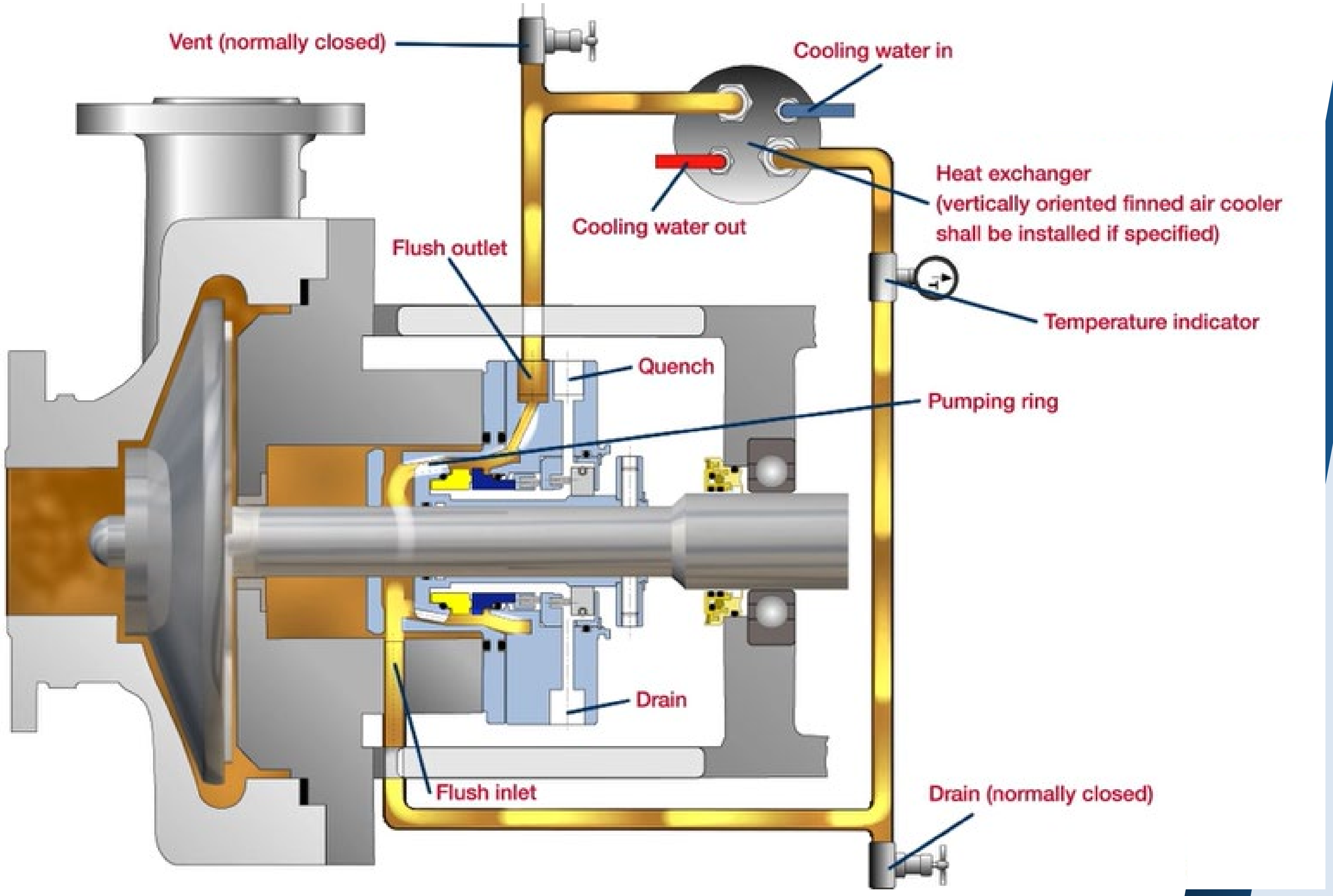
API Plan 23

- Description: Plan 23 is a closed loop system from the Stuffing Box, using a Seal Pumping Ring to circulate product through a heat exchanger (Cooler) and back to the seal chamber. Plan 23 is also used when there is Discharge Pressure behind the Impeller. Similar to Plan 13, but Plan 23 is used for high Pumping Liquid Temperatures.
- Advantages: More efficient than a Plan 21 and less chance of heat exchanger fouling. Reduced temperature improves lubricity and improves vapor pressure margin.
- General: Preferred plan for hot applications. Close clearance throat bushing is recommended to reduce mixing of hot product with cooler closed loop system fluid.



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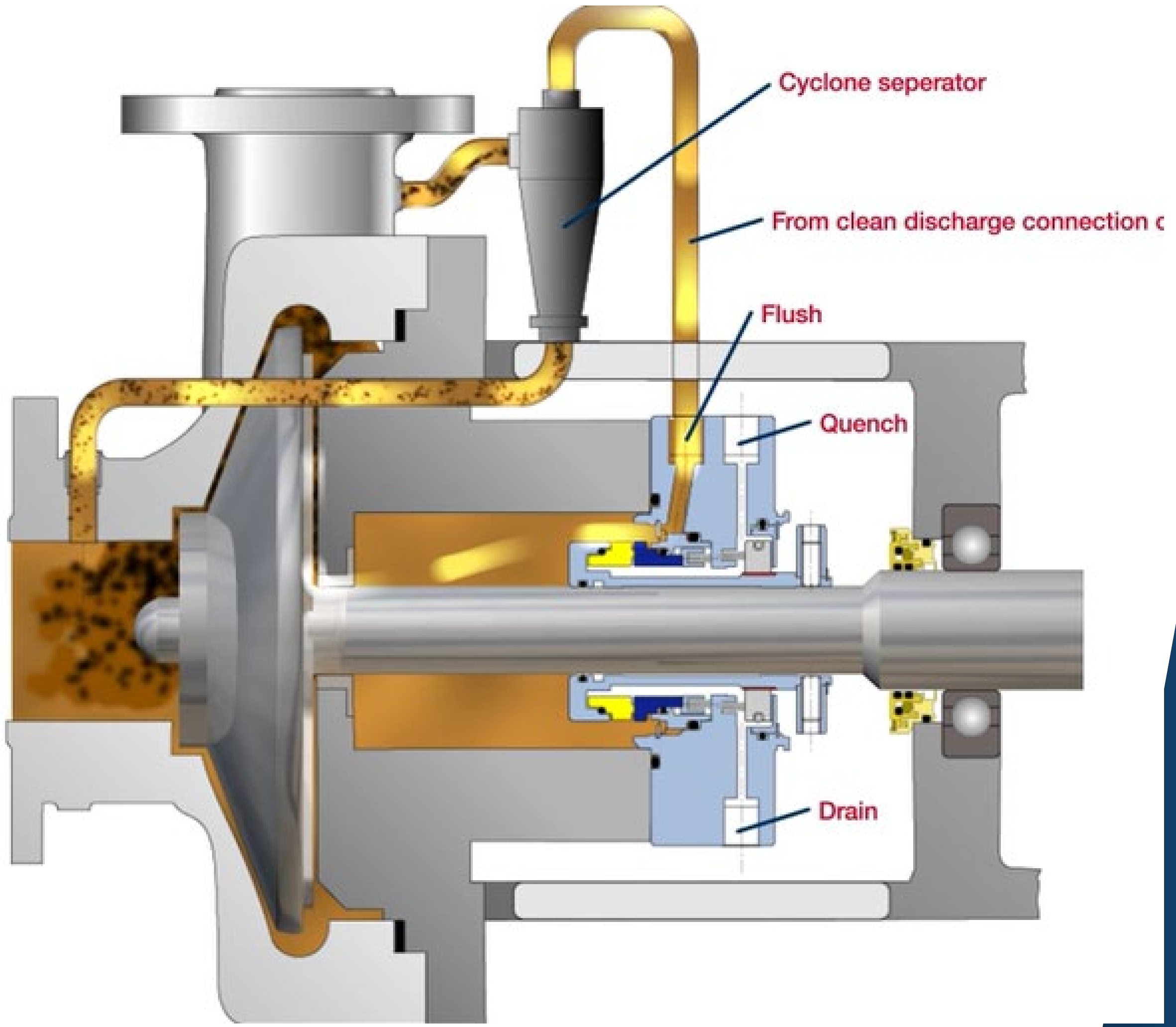
API Plan 31

- Plan 31 is a variation of Plan 11, where a liquid particle Cyclone Separator is added to the flush line. In this plan, the product is introduced to the abrasive Cyclone Separator from the discharge of the pump. Clean flush is piped from the separator to the seal chamber and solids are returned to the pump suction, from the bottom of the Cyclone Separator.

- Advantages: Unlike a strainer or filter, the Cyclone Separator does not require cleaning. Solids are removed from the flush liquid keeping the seal Stuffing Box clean.

- This Plan 31 should be used for services containing solids that have a specific gravity at least twice that of the process fluid. Typically the Cyclone Separator requires a minimum pressure difference of 15 psi from the Top Clean Liquid to the Bottom of the Particle Liquid.



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API Plan 31 Liquid & Particle Limits

1-LIQUID LIMITS.

In order to ensure that the hydraulic Vortex forms effectively, the liquid cannot be too thick. So the maximum limit of the Liquid viscosity is 20cSt.   If the liquid was higher than this Viscosity, the hydraulic vortex would not form as effectively, so the Cyclone Separator would not separate the Particles from the Liquid effectively.

2-PARTICLE REQUIREMENTS.

There are several features that the Particles must meet in order to ensure they are effectively forced to flow down the Cyclone Separator internal hydraulic vortex.

The Particle sizes must not be smaller than 1 Micron.

To ensure the effect of the hydraulic vortex is to draw the Particles downwards to the dirty exit connection. The Particles must be heavier than the liquid.

The % content of the Particles must not be any higher than 10%, to ensure no Particles manage to flow out the clean top outlet connection.

3-PRESSURE REQUIREMENTS.

The top Clean and bottom Dirty outlets pressures should be as similar as possible, and no more than 10% different from each other.

In fact the Pressure Differences between the Inlet and the Clean and Dirty Cyclone Separator outlet connections should be very close to those required by the Cyclone Separator Manufactures requirements.

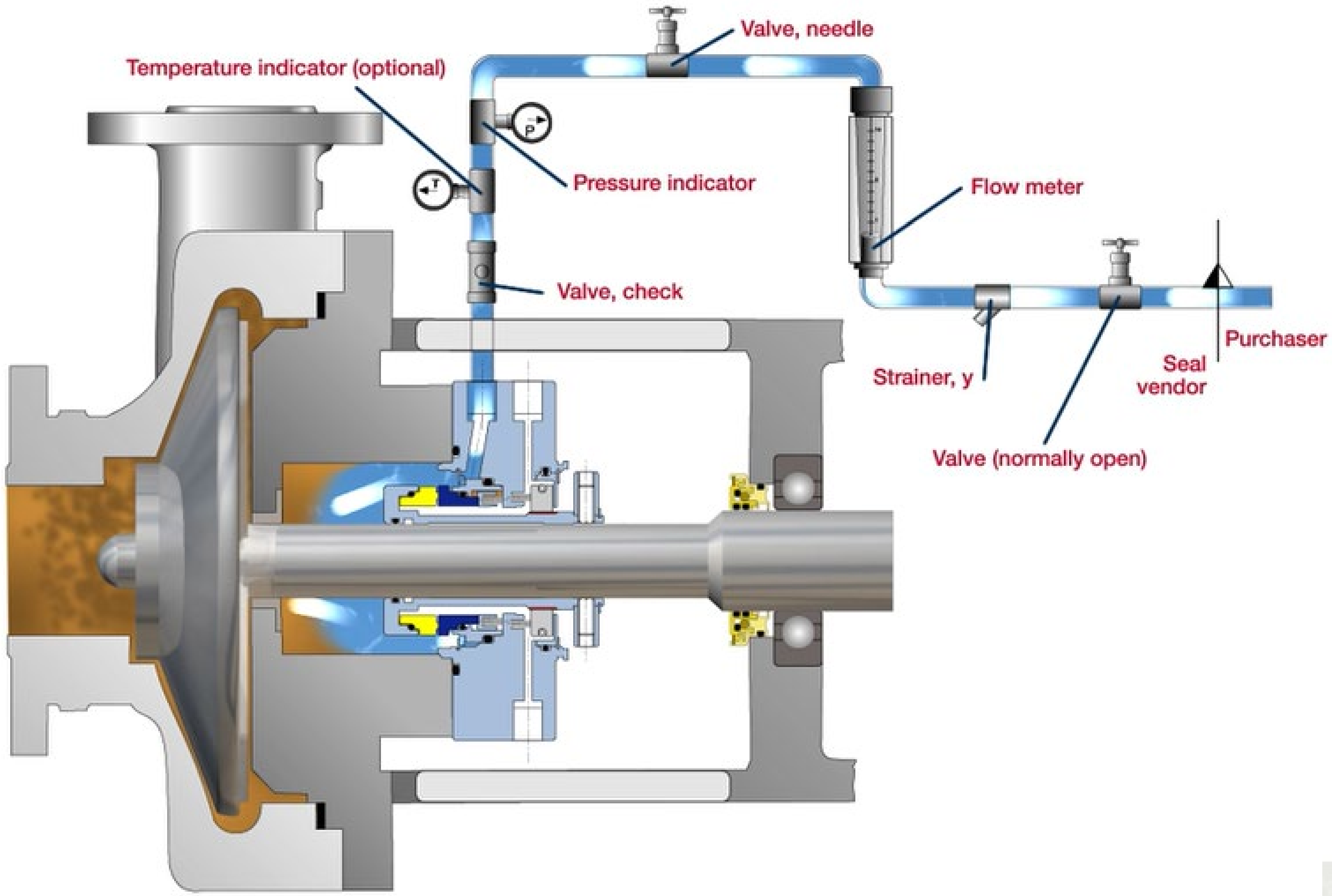
If the pressure differences are more than required, a possible solution would be to install a Flow Controller on the Dirty outlet line, to make the pressure differences closer.

API Plan 32

- Plan 32 uses a Clean External Flush Liquid brought in from an external source to the seal. This Plan 32 is almost always used in conjunction with a close clearance throat bushing.

- Advantages: The external flush fluid, when selected properly, can result in extending the Mechanical Seal life.

- General: When Plan 32 is used, the External Flushing Liquid is Clean. The Plan 32 pressure must be maintained a minimum of 15 psig above maximum seal chamber pressure. So it will flow out the Throat Bushing at the end of the Stuffing Box, to behind the Impeller



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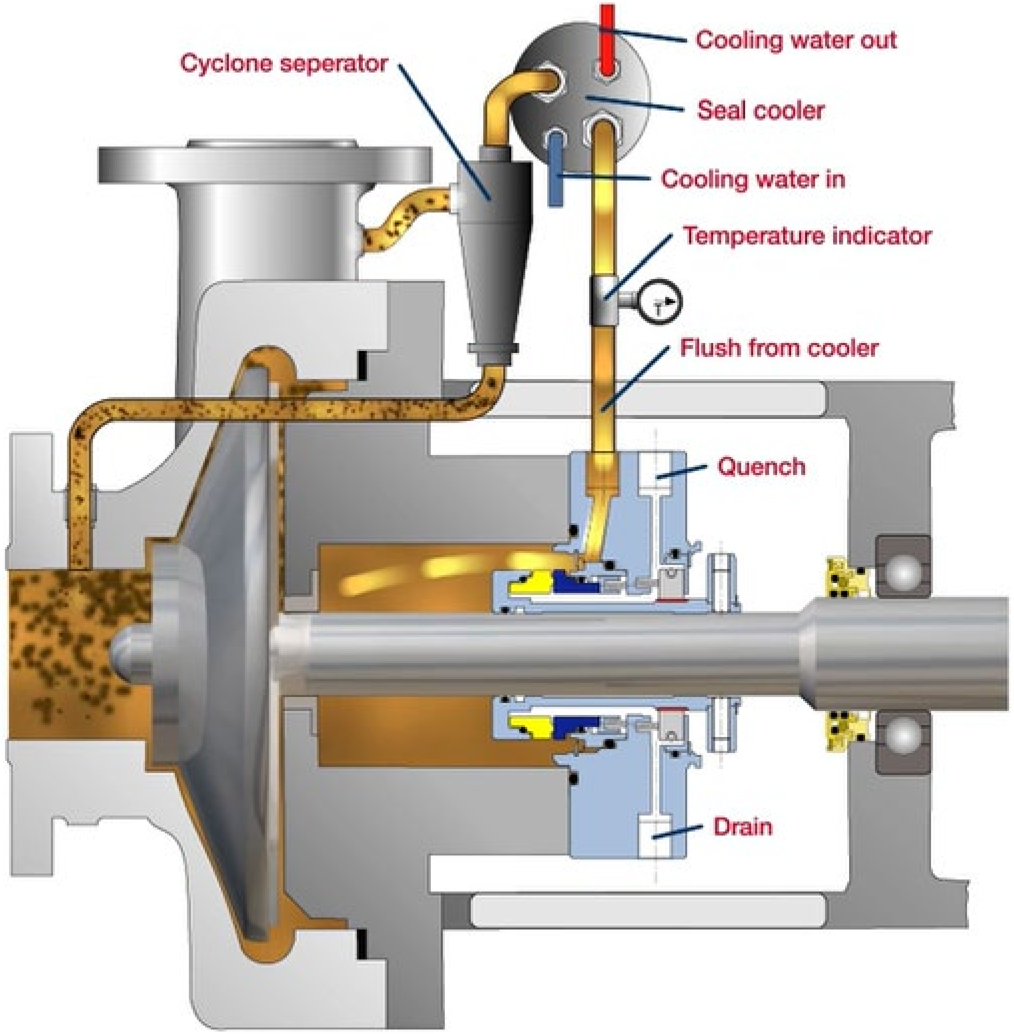
API Plan 41

- Description: Plan 41 is a combination of Plan 21 and Plan 31. In Plan 41,the pumped Liquid with Particles, will flow from the pump discharge is first put through a Cyclone Seperator, and then to the heat exchanger before being introduced to the seal chamber.

- Advantages: Solids are removed and product temperature is reduced by the Cooler, to cool the seal's Stuffing Box.

- **General: Plan 41 is typically used on hot services with solids;** however, depending on the temperature of the process, operating costs can be high. This plan should be used for services containing solids that have a specific gravity at least twice that of the process fluid.



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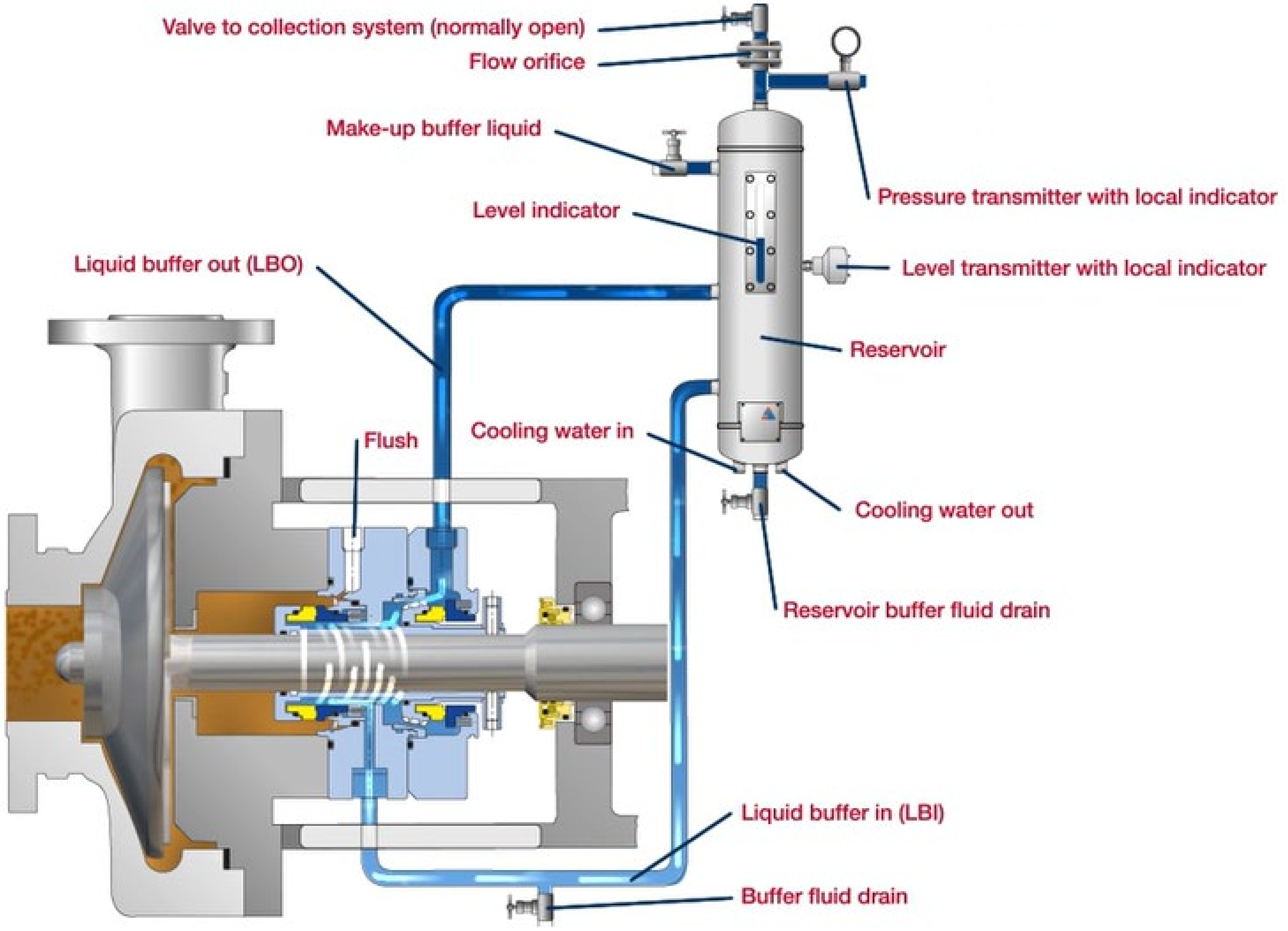
API Plan 52

- Plan 52 uses an external reservoir to provide buffer fluid for the outer seal of an Unpressurized Double seal arrangement.

- Advantages: In comparison to single seals, Dual Unpressurized Seals can provide reduced net leakage rates as well as redundancy in the event of a primary seal failure.

- General: Cooling coils in the reservoir are available for removing heat from the buffer fluid. Plan 52 is often used where the process fluid cannot be affected with the buffer fluid.



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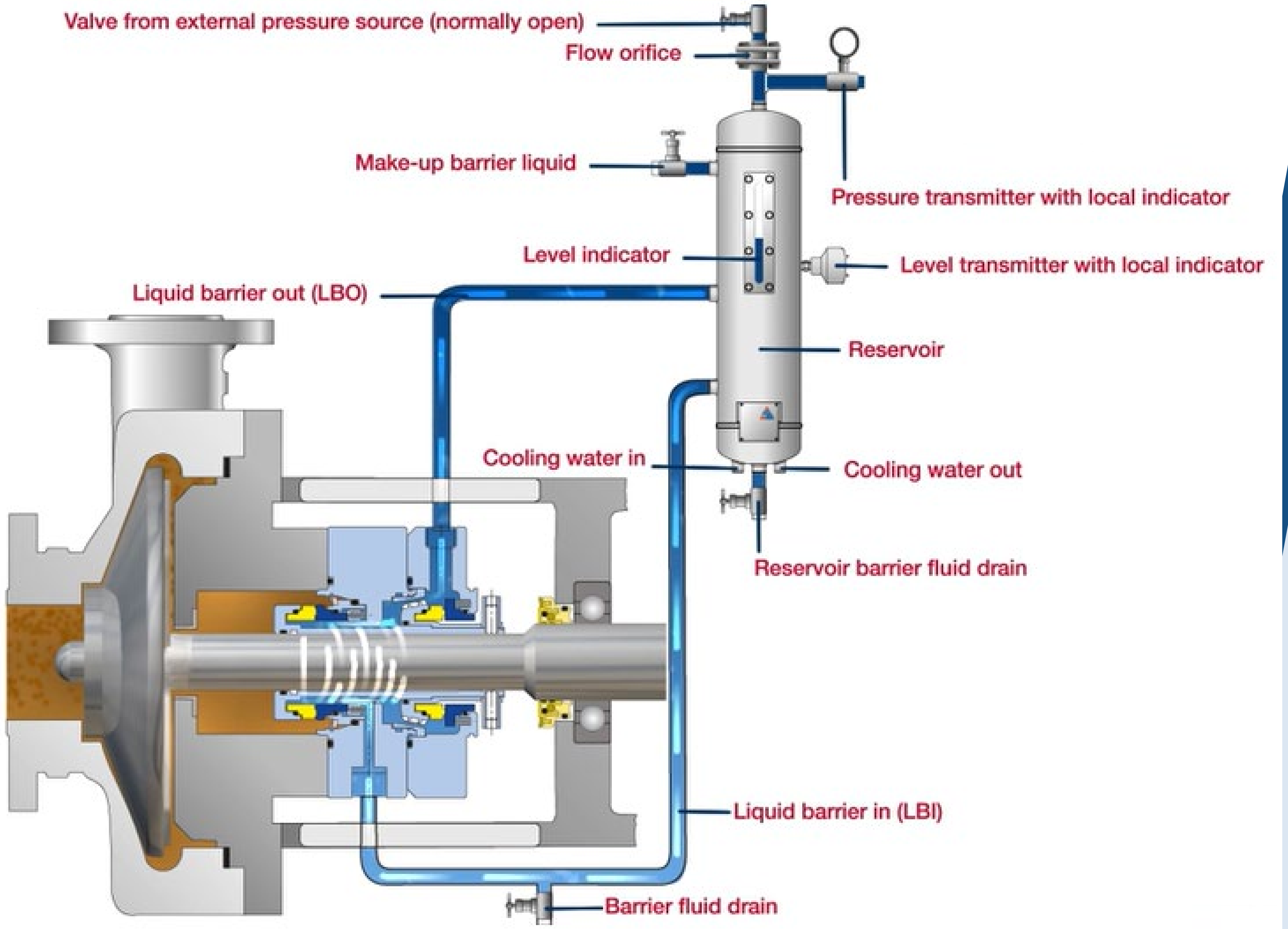
API Plan 53A

- Plan 53A uses an external reservoir to provide a pressurized barrier fluid for a pressurized Double seal arrangement. Reservoir pressure is produced by a gas, usually nitrogen. Flow is induced by a pumping ring within the Seal Gland.

- Advantages: Reservoir size can be optimized dependent on flow rate. Wear particles settle to bottom of reservoir and don’t get recirculated.

- General: Heat is dissipated by reservoir cooling coils. Barrier fluid is subject to gas entrainment at pressures/temperatures above 300 psi/250F 20 Bar/120C.



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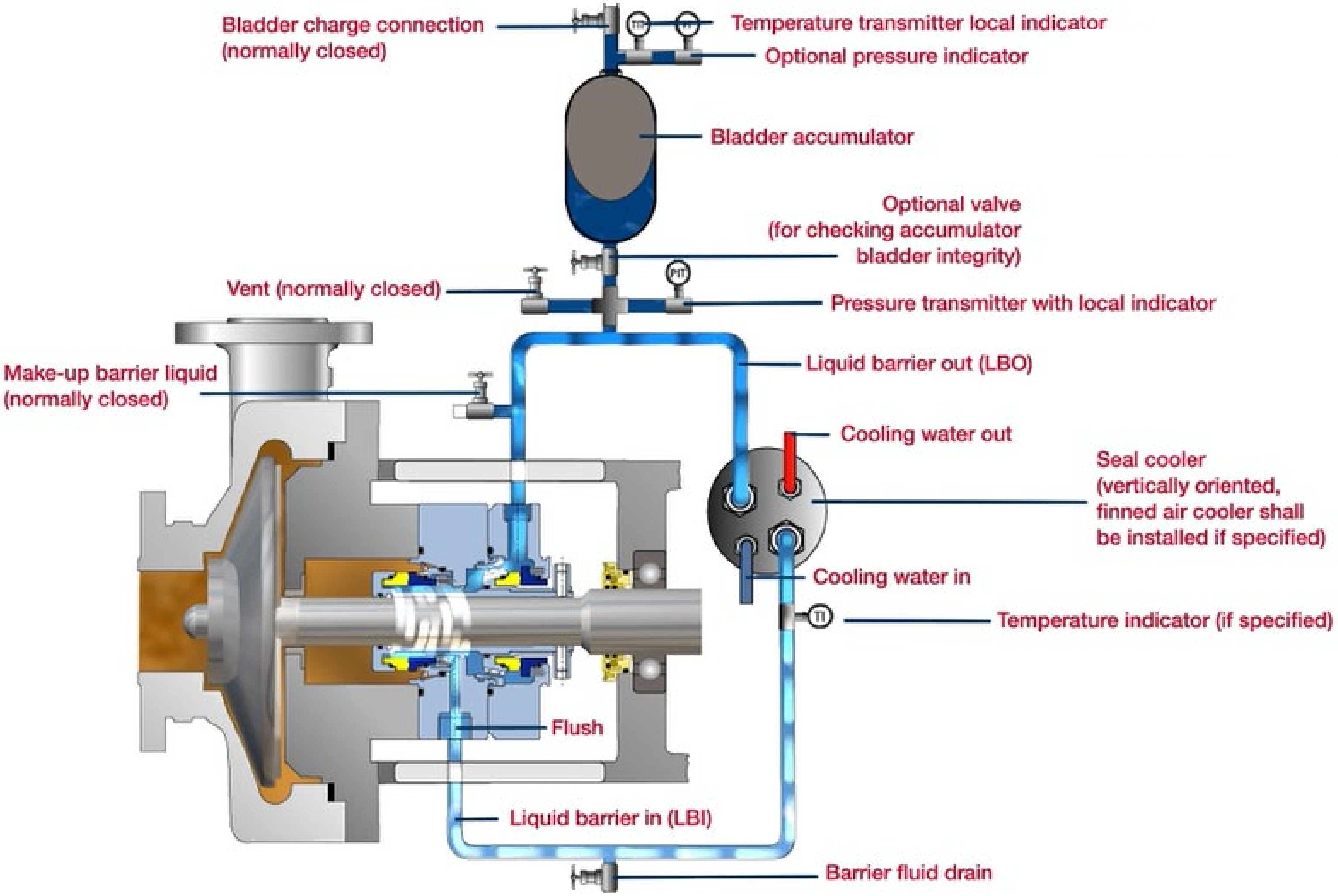
API Plan 53B

- Plan 53B, previously termed 53 Modified, uses an accumulator to provide the pressurizing gas and the barrier fluid. A heat exchanger is included in the circulation loop to cool the barrier fluid. Flow is induced by a pumping ring in the Seal Gland.

- Advantages: If the loop is contaminated by the Pumped Liquid for any reason, the contamination is contained within the closed circuit. The make-up system can supply barrier fluid to multiple dual pressurized sealing systems, on between bearing Pumps with 2 Stuffing Boxes & 2 sets of Mechanical Seals.

- General: The bladder accumulator isolates the pressurizing gas from the barrier fluid to prevent gas entrainment. The heat exchanger can be a water-cooled unit, an air-cooled unit, or utilize finned tubing based upon the system heat load.



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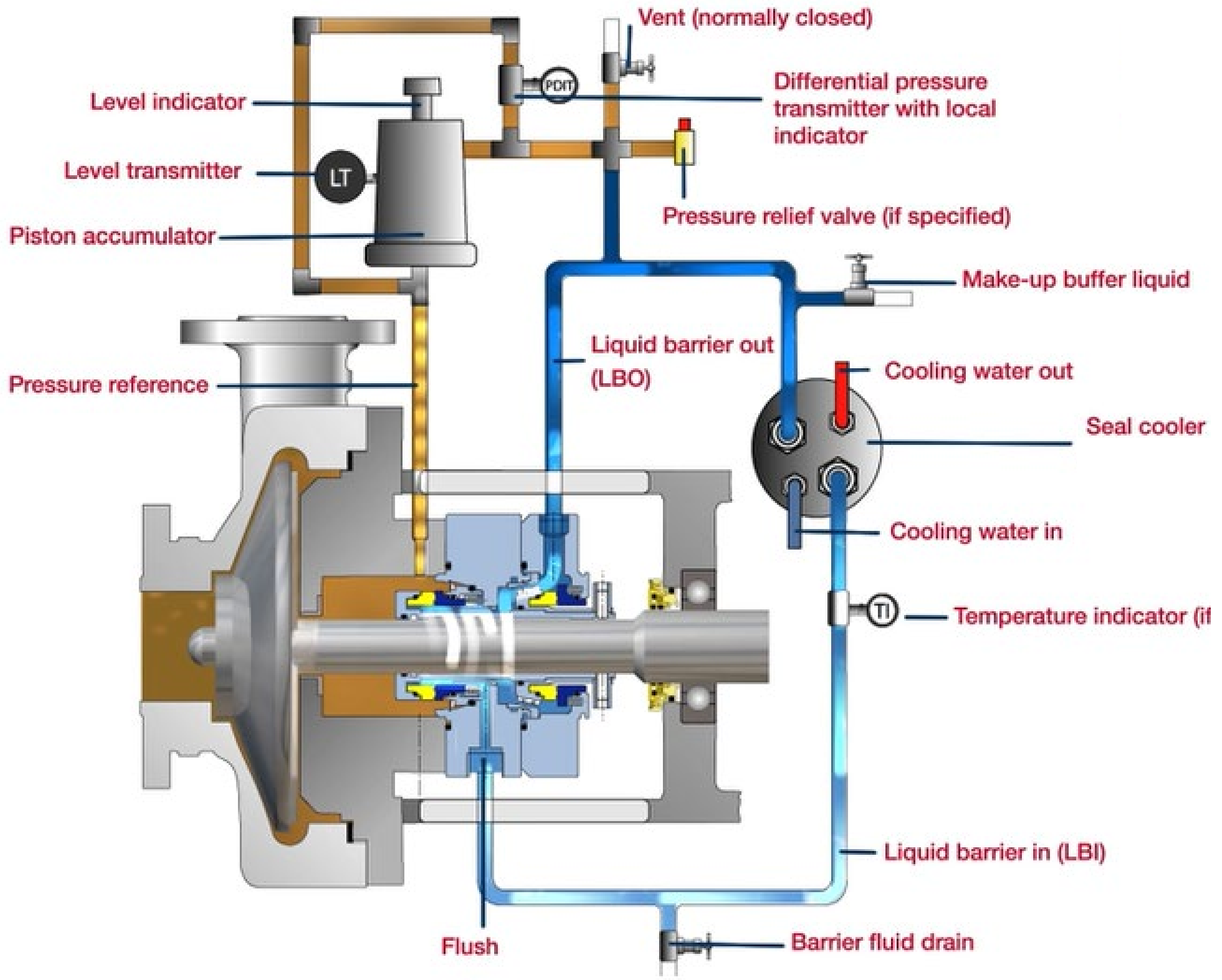
API Plan 53C

- Plan 53C uses a piston accumulator to provide pressure to the system. It uses a reference line from the seal chamber to provide a constant pressure differential over the seal chamber's pressure. A water- or air-cooled heat exchanger provides for barrier fluid cooling. Flow is induced by a pumping ring in the Seal Gland.

- Advantages: Provides a tracking system to maintain barrier pressure above seal chamber pressure.

- General: The heat exchanger can be a water-cooled unit, an air-cooled unit, or utilize finned tubing based upon the system heat load. The reference line to the accumulator must be tolerant of process contamination without plugging.



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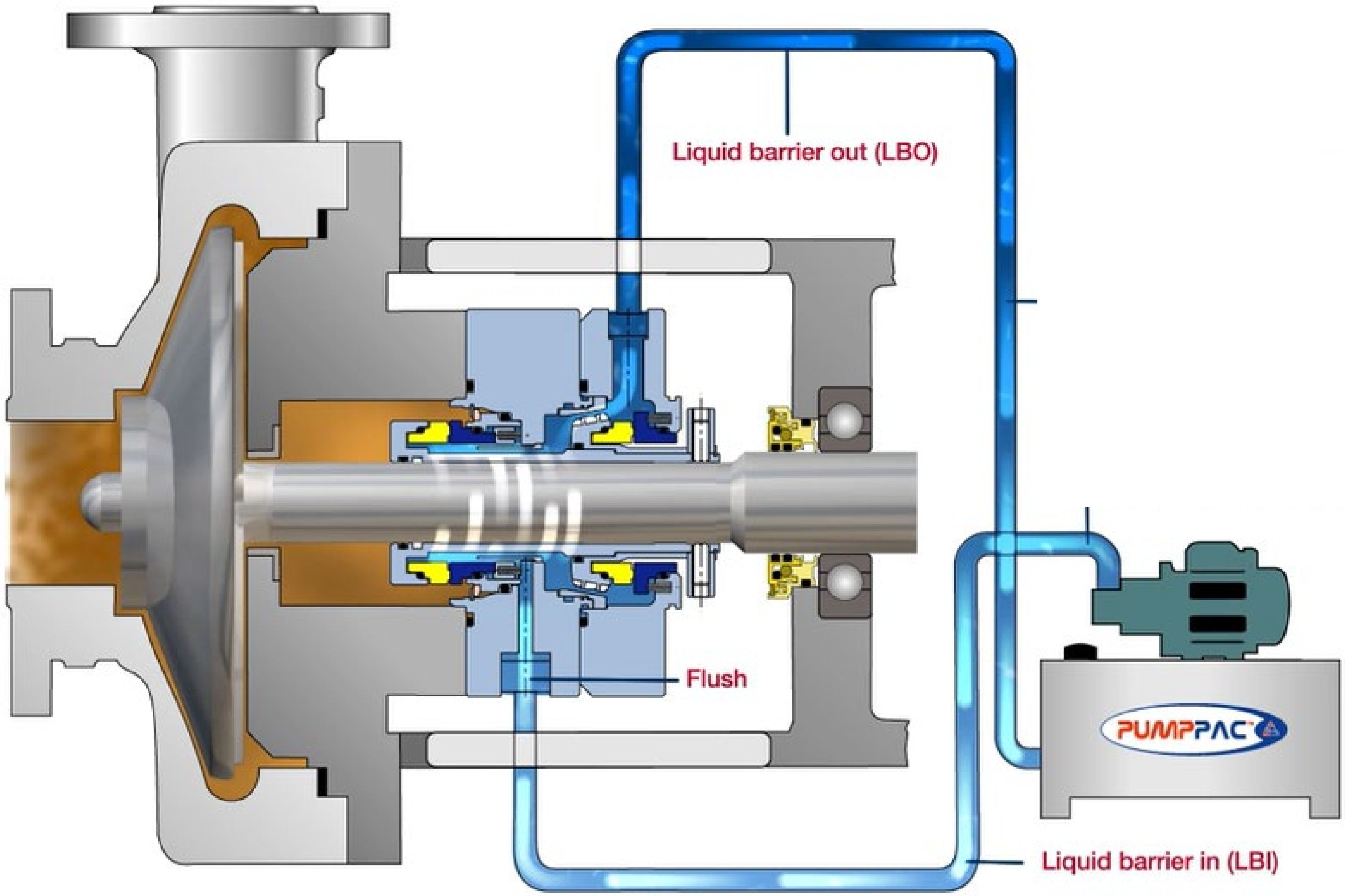
API Plan 54

- Plan 54 utilizes an external source to provide a clean pressurized barrier fluid to the Double seals.
- Advantages: Can provide pressurized Flow to multiple seal installations of Double Bearing Pumps with 2 Stuffing Boxes, to reduce costs.
- General: Plan 54 systems can be custom engineered to suit application or specific plant requirements. Systems can range from the direct connection from other process streams.



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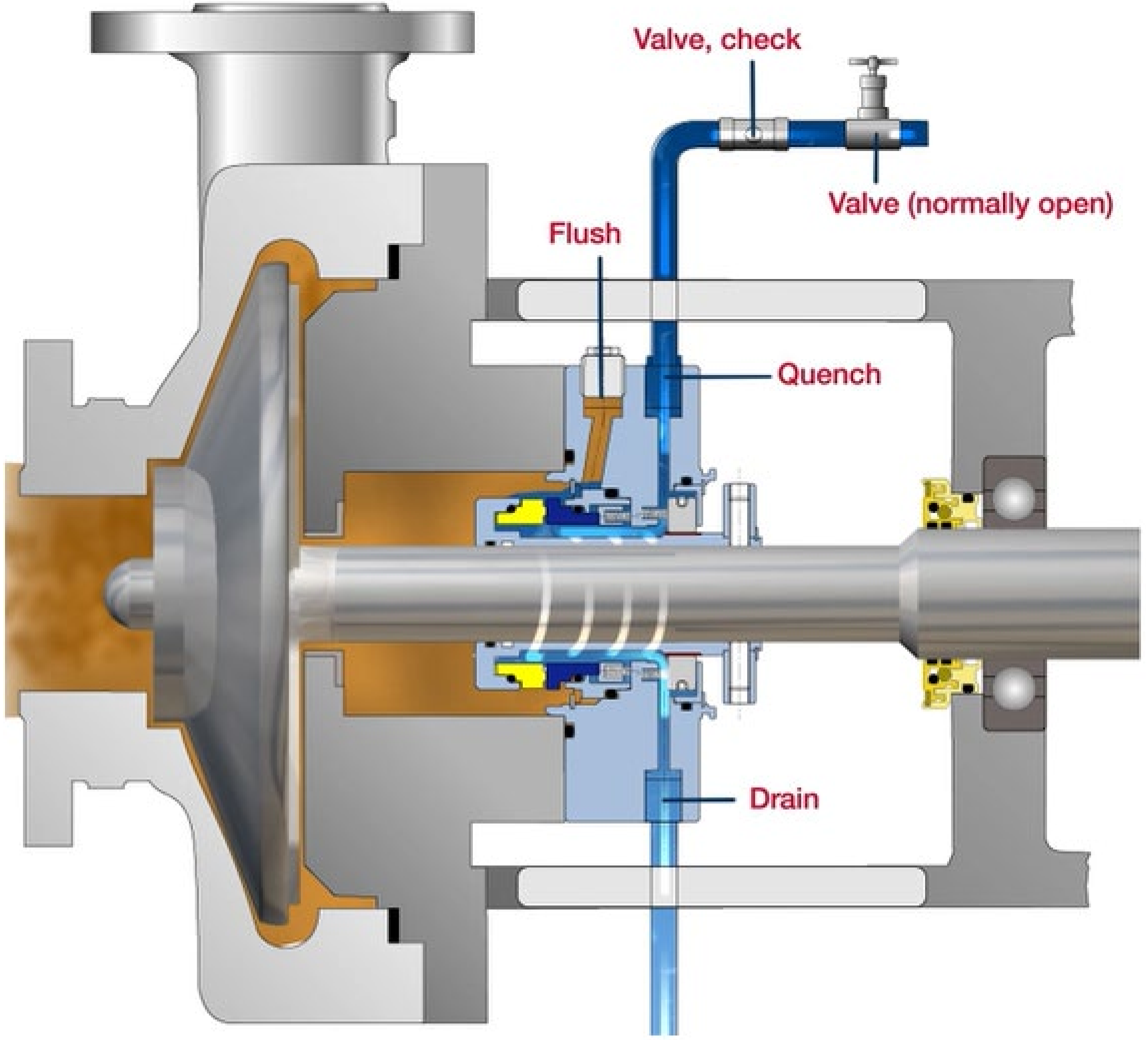
API Plan 62

- Plan 62 is a common plan to improve the environment on the atmospheric side of single seals by quenching with steam, nitrogen or water.
- An example of the purpose for Quench, is if you are pumping NaOH (Sodium Hydroxide). Which on the atmospheric side of the Seal face, forms crystals which would damage the seal faces. So the Quench liquid flushes the crystals away and protects the Seal.
- Advantages: Plan 62 is a low cost alternative to Tandem seals. The quench prevents or retards product crystallization or coking. Quenches can also provide some cooling.
- General: Typical applications include; steam quenches on hot services to retard coking; nitrogen quenches on cold or cryogenic service to prevent icing; or water quench to prevent crystallization or accumulation of product on the atmospheric side of the seal.



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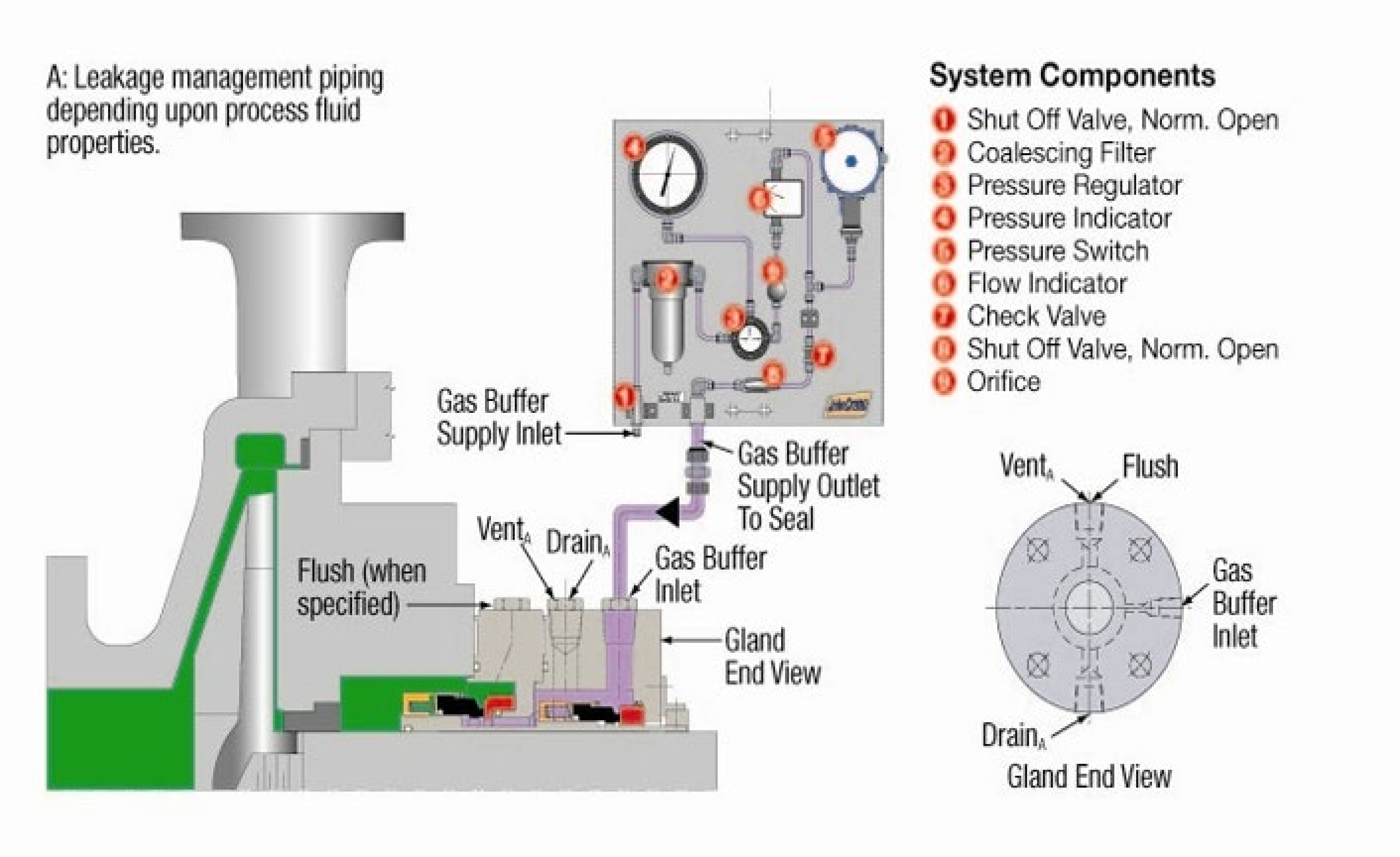
API Plan 72

- Plan 72 for secondary containment uses an external low pressure buffer gas, usually nitrogen, regulated by a control panel that injects it into the outer seal cavity.

- Advantages: Introduction of a buffer gas like nitrogen reduces fugitive emissions, prevents icing on cold applications, and provides for some cooling to the outboard seal.

- General: Plan 72 is normally used with Plan 75 for primary seal leakage that is condensing, or with Plan 76 for non-condensing leakage.



API Plan 75

- Plan 75 is a collection system used with Secondary Containment Seals for process fluid that will condense at lower temperatures or is always in a liquid state.

- Advantages: The collection reservoir contains a pressure gauge and a high pressure switch to indicate a build up in pressure from excessive primary seal leakage or failure.

- General: Plan 75 can be used in conjunction with a gas purge from Plan 72. Typically dry-running, contacting Secondary Containment Seals are used with this plan.

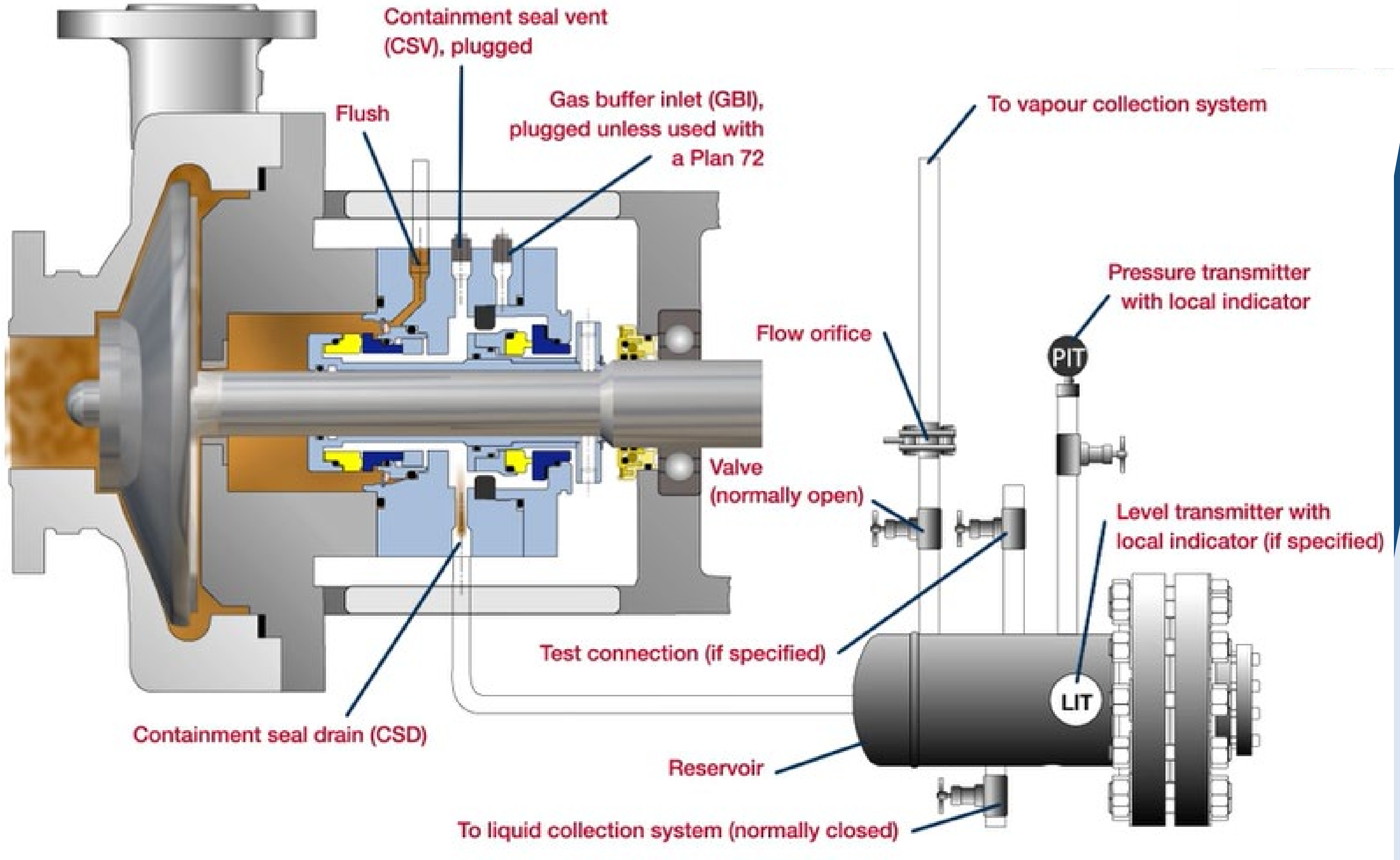


Image borrowed from AES Seals

API Plan 76

- Plan 76 is a system to divert non-condensing primary seal leakage to a flare or vapor recovery system.
- Advantages: Lower initial and maintenance costs than dual unpressurized seals using a Plan 52.
- General: Plan 76 can be used in conjunction with a gas purge from Plan 72. Can be used with dry-running, contacting or non-contacting Secondary Containment Seals.

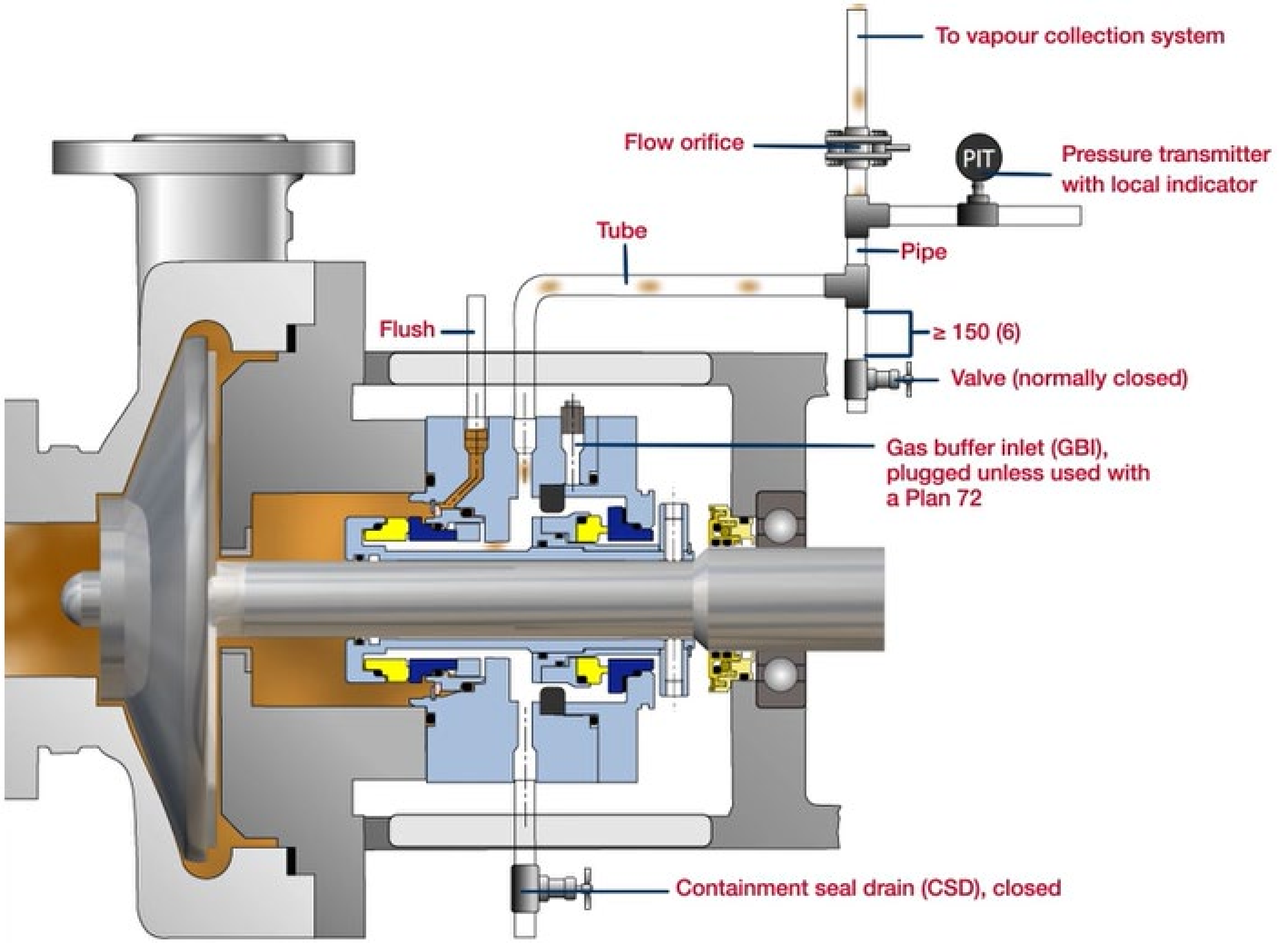
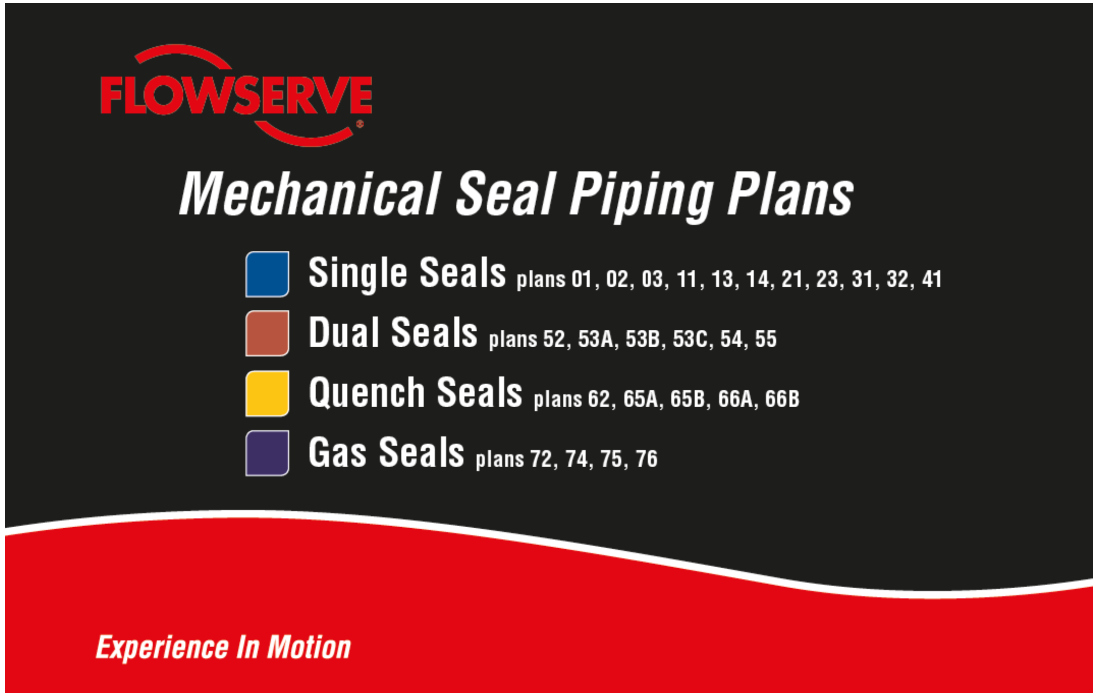


Image borrowed from AES Seals

Flowserve Pocket Guide to Seal Piping Plans

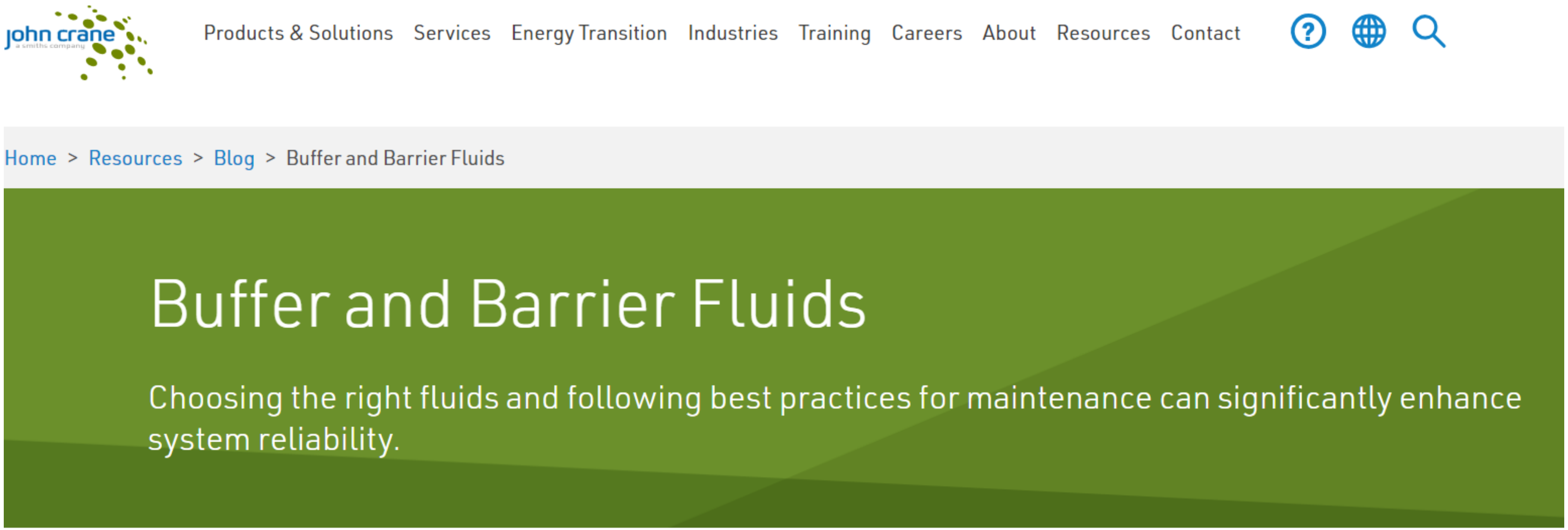
www.flowserve.com/sites/default/files/2017-11/FTA160eng_Rev_9-17_LR.pdf



John Crane Buffer & Barrier Fluids

Here is a link to a John Crane page on Buffer/Barrier fluids which may be helpful

https://www.johncrane.com/en/resources/blog/2012/buffer-and-barrier-fluids



Coming Attractions ☺

"The Importance of Using System Curves in Pump Selection and Successful Pump Operation"

Thurs 19th Oct – 08.00 (UK BST+1) (Eastern Hemisphere) & 17.00 (UK BST+1) (Western Hemisphere)

Aimed at Process and Mechanical Engineers and Consultant Engineers specifying pumping equipment as well as Applications Engineers selecting and quoting them. Develop an understanding of how the System Curve works with the Pump H/Q Curve to determine how a pump will operate in the field.

Will cover such topics as parallel operation, steep vs shallow curves, and "hooked" curves

Future subjects in preparation include:

– *NPSH*

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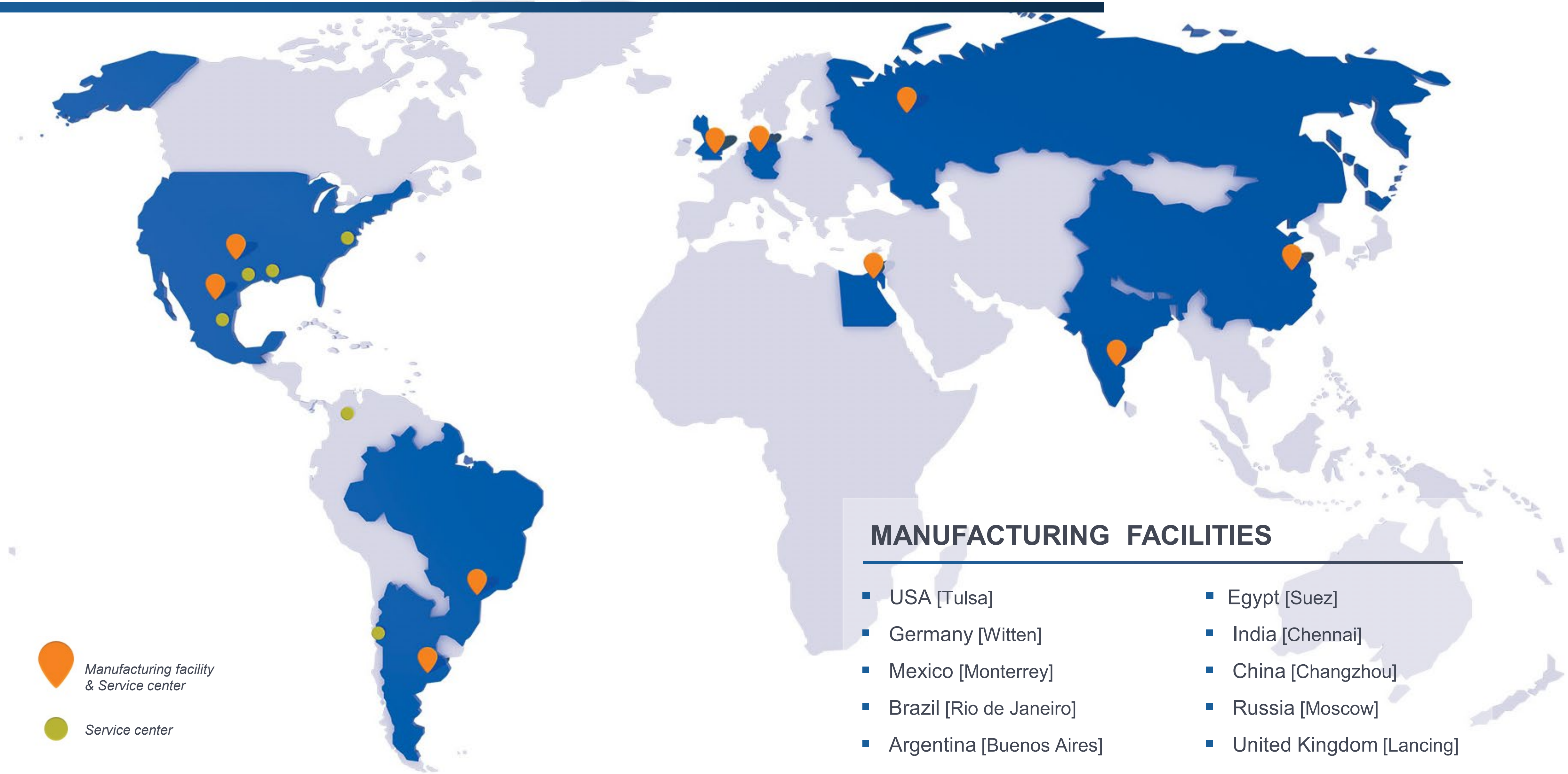

MANUFACTURING FACILITIES

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- Germany [Witten]
- Mexico [Monterrey]
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- Argentina [Buenos Aires]
- Egypt [Suez]
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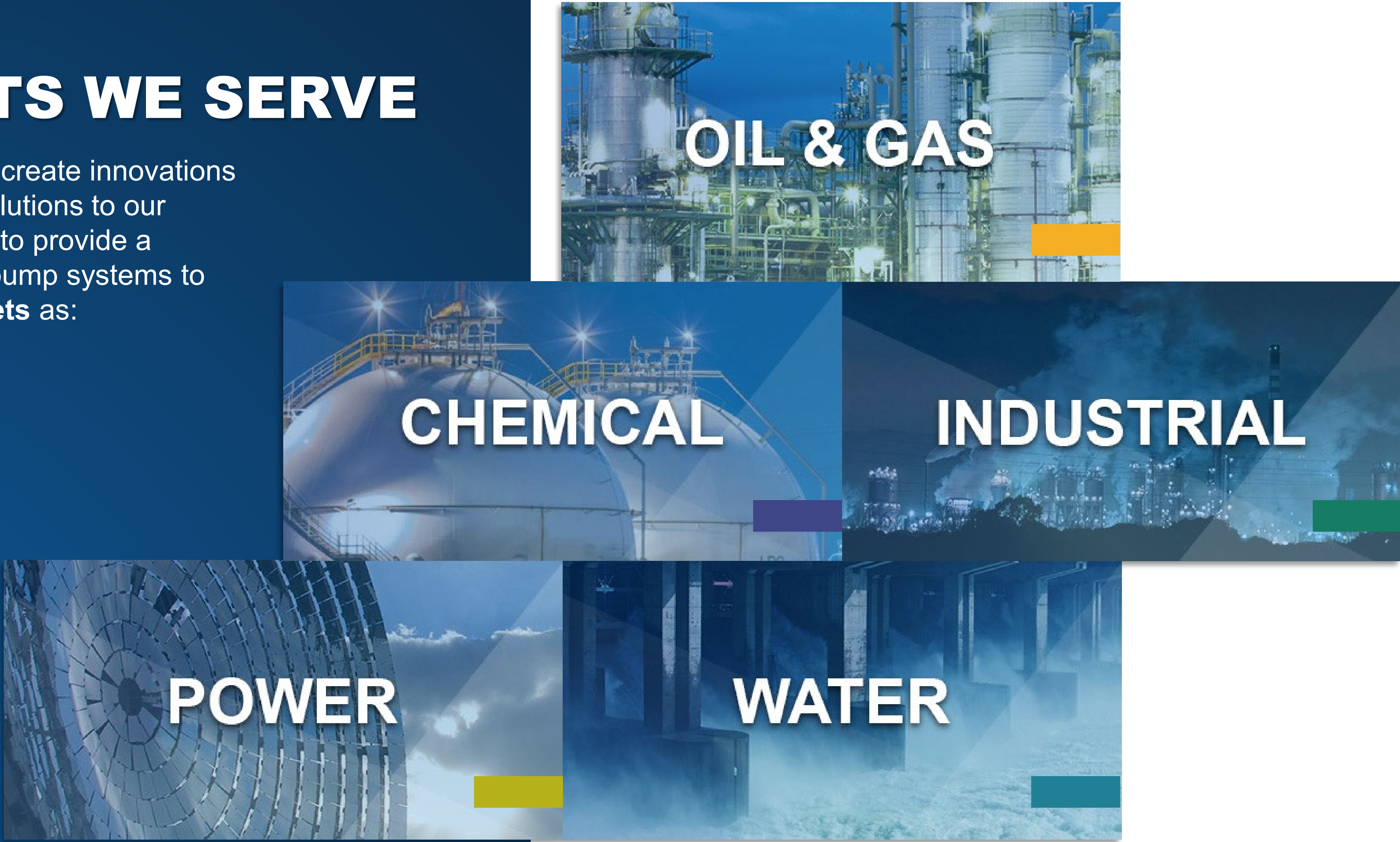
- China [Changzhou]
- Russia [Moscow]
- United Kingdom [Lancing]

MARKETS WE SERVE

Our commitment to create innovations that offer reliable solutions to our customers allow us to provide a complete range of pump systems to support **core markets** as:



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OUR PUMP LINES

Ruhrpumpen offers a broad range of highly engineered and standard pumping products that meet and exceed the requirements of the most demanding quality specifications and industry standards.

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Products include:

- Single Stage Overhung Pumps
- Between Bearings Pumps
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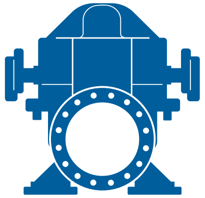
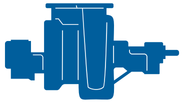
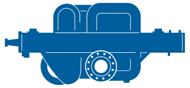
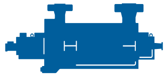
- Vertical Multi-Stage Pumps
- Vertical Mixed Flow & Axial Flow Pumps
- Positive Displacement Pumps
- Full Range of Industrial Pumps
- Submersible Pumps
- Magnetic Drive Pumps
- Decoking Systems
- Packaged Systems
- Fire Systems

OVERHUNG PUMPS

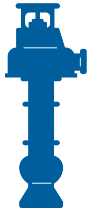
CATEGORY	RP MODEL	DESIGN STANDARD
Sealless Magnetic Drive Pumps	**CRP-M / CRP-M-CC**	ISO 2858 & 15783 HI design (OH11)
	SCE-M	API 685
Foot Mounted OH1 and General End Suction Pumps	**IPP**	HI design (OH1)
	CPP / CPP-L	HI design (OH1) ANSI B73.1
	CPO / CPO-L	HI design (OH1) ANSI B73.1
	CRP	HI design (OH1) ISO 2858 & 5199
	GSD	HI design (OH0)
	SHD / ESK / SK / SKO SKV / ST / STV	HI design (OH1)
	SWP	HI design (OH3A)
Centerline Mounted	**SCE**	API 610 (OH2)
Vertical In-Line Pumps	**SPI**	API 610 (OH3)
	IVP / IVP-CC	HI design (OH4 / OH5)
	IIL	HI design (OH5) Dimensionally compliant with ANSI B73.2
	SPN	API 610 (OH5)



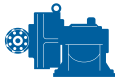
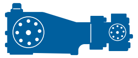

BETWEEN BEARING PUMPS

CATEGORY		RP MODEL	DESIGN STANDARD	
1 and 2 stage	Axially split	HSC / HSD / HSL HSR / ZW	HI design (BB1)	
		HSM	HI design (BB3)	
		ZM / ZMS ZLM / ZME	API design (BB1)	
	Radially split	HVN / J	API design (BB2)	
		RON / RON-D	API design (BB2)	
Multi-stage	Axially split	SM / SM-I	API design (BB3)	
		JTN	API design (BB3)	
	Radially split *single casing*	GP	API design (BB4)	
	Radially split *double casing*	A LINE	API design (BB5)	

VERTICAL PUMPS

CATEGORY		RP MODEL	DESIGN STANDARD	
Single casing	Diffuser	**VTP**	HI & API 610 (VS1)	
		VCT	HI & API 610 (VS1)	
		HQ	HI & API 610 (VS1)	
		VLT	HI & API 610 (VS1)	
	Volute	**DSV / DX**	HI & API 610 (VS2)	
	Discharge through column – Axial flow	**VAF**	HI & API 610 (VS3)	
	Separate discharge line	**VSP / VSP-Chem**	HI & API 610 (VS4)	
Double casing	Diffuser	**VLT / VMT**	HI & API 610 (VS6)	
	Volute	**DSV / DX**	HI & API 610 (VS7)	
Submersible pumps		**SMF**	HI design (OH8A)	
		VLT-Sub / VTP-Sub	HI design (VS0)	

SPECIAL SERVICE PUMPS

CATEGORY	RP MODEL	DESIGN STANDARD	
Pitot tube pumps	**COMBITUBE**	HI design	
Reciprocating pumps	**RDP**	API 674 ISO 13710	
Vertical turbine generator	**VTG**	HI design (VS6)	
Barge	**LS BARGE**	HI design	
Floating dock pumps	**ZVZ**	HI design	
	LVZ	HI design	
Cryogenic pumps	**SVNV**	-	
	VTG Cryogenic	-	
	VLT Cryogenic VLTV	-	
Pre-packaged fire pump systems	Fire systems incorporate pumps, drivers, control systems and pipework in a single container. They can be skid mounted, with or without enclosure and supplied with electric motor or diesel engine.	**NFPA-20-850** UL and FM approved components