PDHonline Course M416 (3 PDH)

Mechanical Seals - Fundamentals

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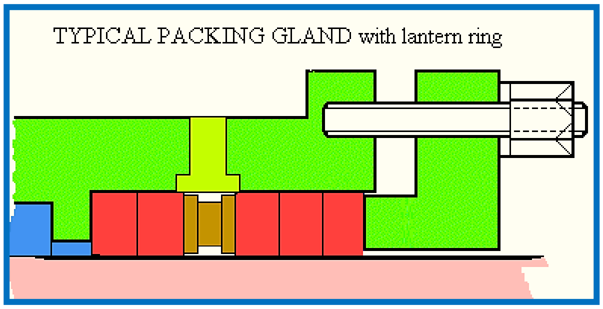
MECHANICAL SEALS – FUNDAMENTALS

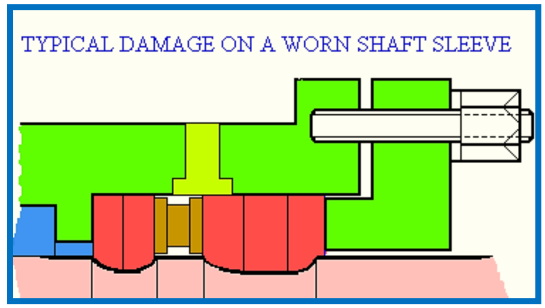
Contents:

I. INTRODUCTION:

The **conventional packed glands** are used primarily for **sealing pump shafts** and for shafts in both **axial** movement and **rotary** movement for a variety of process pumping fluids. The packed gland has provided a low convenient solution throughout the history of pumping engineering. In modern times the packed gland is being replaced by more technical solutions, such as the **mechanical seals**.

Years ago, most pump shafts were sealed by using rings of soft packing, compressed by a packing gland, but this type of shaft seal required a fair amount of fluid just to lubricate the packing and keep it cool.



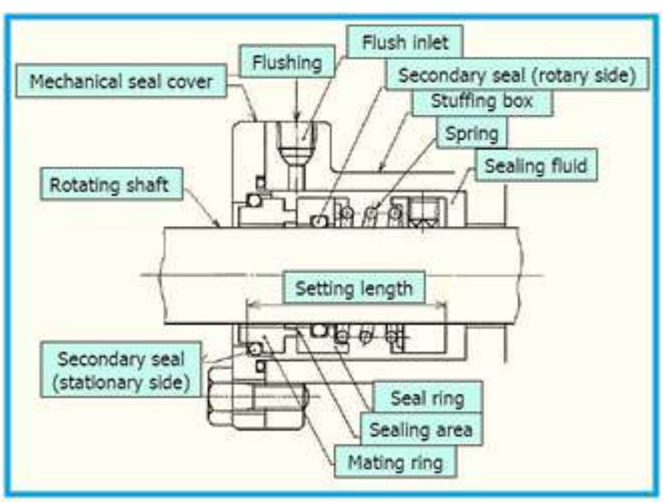


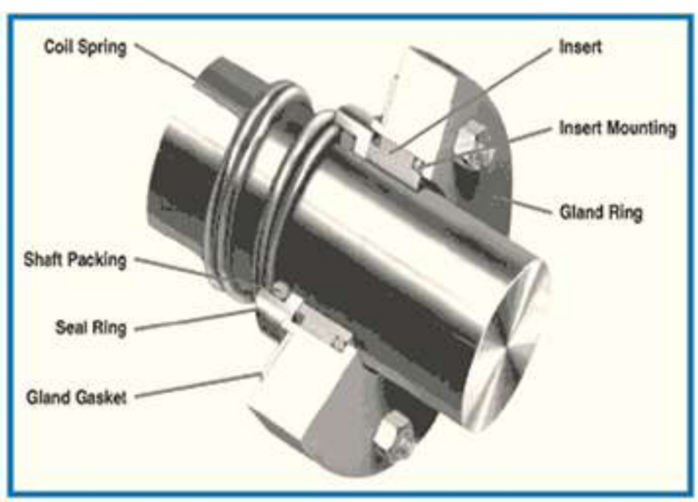
The modern development of "**mechanical seals**", accomplishes the work of restraining product leakage around the pump shaft with two very flat surfaces (one stationary and one rotating). Even though these mechanical seal faces also require some (very small) lubricating or cooling fluid across the faces, to form a hydrodynamic film, this system normally evaporates and is not noticeable. Most pump shafts today are sealed by means of mechanical seals.

Several designed models of mechanical seals are being used increasingly on fluid pumps to replace packed glands and lip seals. Pumps with mechanical seals perform more efficiently and undoubtedly have much more reliable performance for extended periods of time.

II. MECHANICAL SEALS:

A mechanical seal is a **shaft sealing device**, which forms a running and dynamic seal between the rotating and stationary parts of a rotary equipment, developed to overcome the disadvantages of the traditional compression gland packing. Mechanical seals are **typically** used in applications for superior sealings. The effectiveness of **mechanical seals** is highly dependent on correct installation and a continuously clean operating environment.

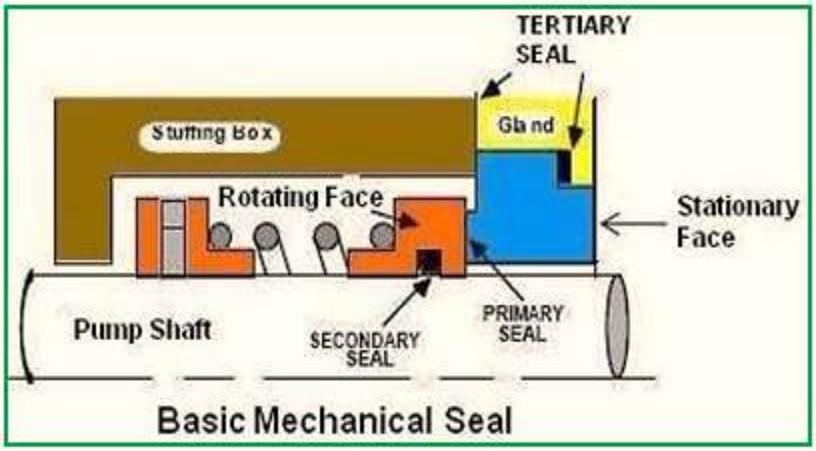




III. THE BASIC MECHANICAL SEAL:

All mechanical seals are constructed of **three basic sets of parts** as shown below:

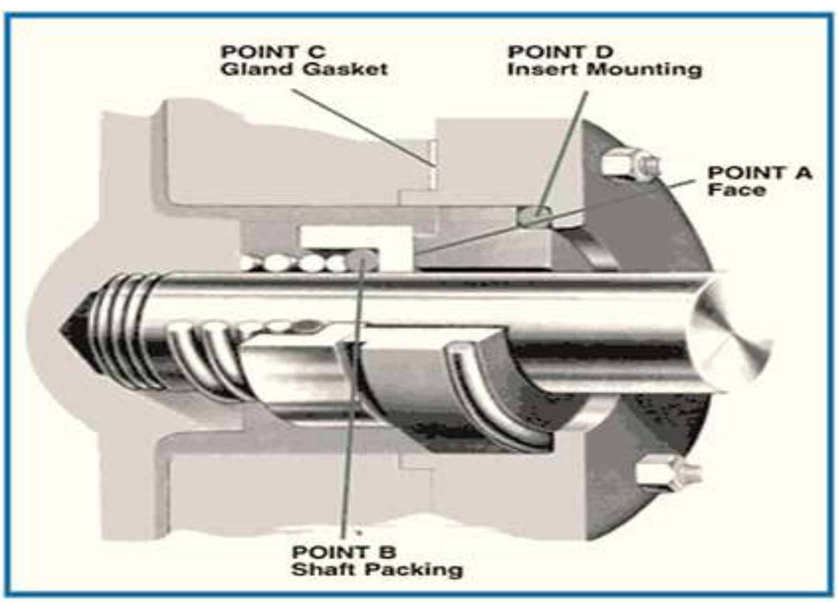
- A set of **primary** seal faces: one rotary and one stationary, a seal ring and an insert.
- A set of **secondary** seals known as shaft packings such as O´rings, wedges and V´rings.
- A set of **tertiary** seals including gland rings, collars, compression rings, pins, springs and bellows.



How A Mechanical Seal Works:

The primary seal is achieved by two very flat, **lapped faces**, which create a difficult **leakage** path perpendicular to the shaft. Rubbing contact between the two flat **mating** surfaces minimizes leakage. For all seals, one **face** is held **stationary** in a housing, and the **other** face **rotates** with the shaft. One of the faces is usually a **non-galling** material, such as **carbon-graphite**. The other is usually a relatively hard material like **silicon-carbide**.

There are **four** main sealing points within an end face mechanical seal. The **primary** seal is at the seal face, indicated below as **Point A**. The leakage path at **Point B** is blocked by either an O´ring, a V´ring or a wedge. Leakage paths at **Points C and D** are blocked by gaskets or O´rings.



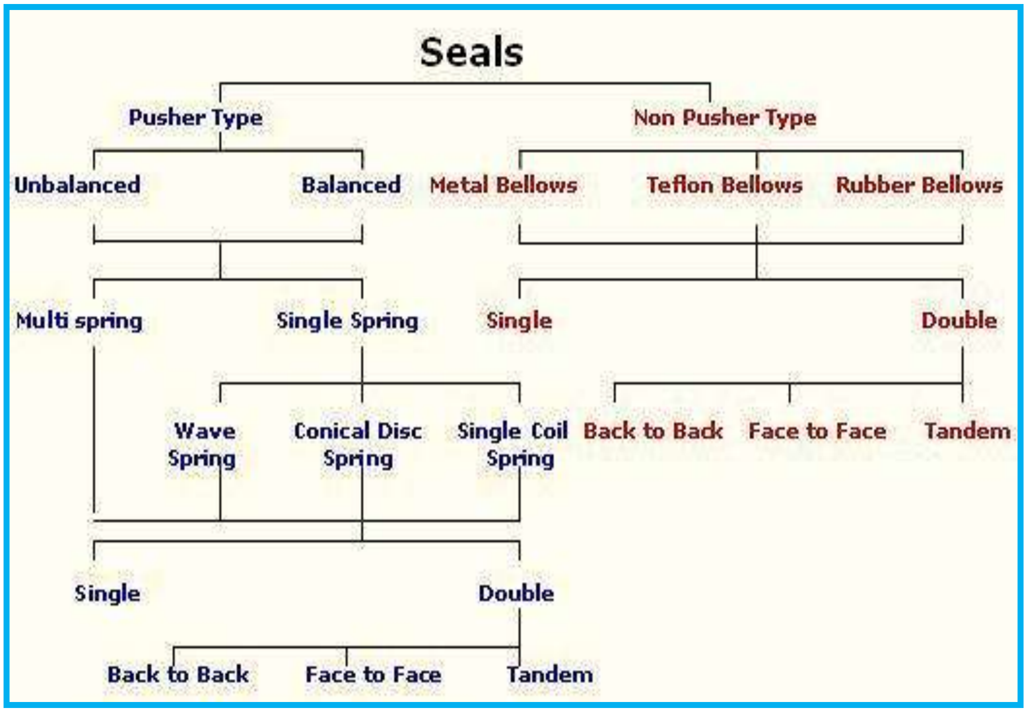
Dissimilar **materials** are usually used for the stationary **insert** and the **rotating** seal ring face, in order to **prevent** adhesion of the two faces. The softer face usually has **smaller** mating surface and is commonly called the **wear nose**.

The mechanical seal works through the use of **two** very flat (generally within 3 light bands flat) **lapped faces**, which make it **difficult** for leakage to occur (beyond a vapor). One face is **stationary** and the other **rotates** with the shaft.

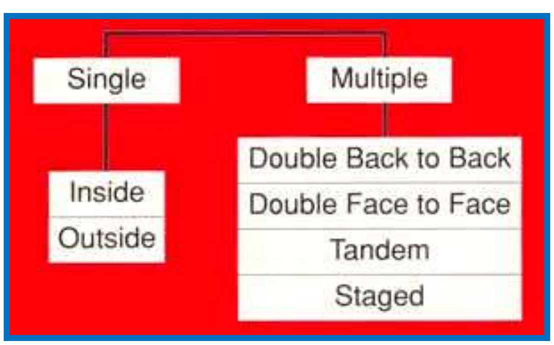
One of the two faces is usually a **non-galling material** such as **carbon-graphite**. The other will be a **harder** material providing dissimilar materials making contact and allowing one to be a **sacrificial**.

The **softer** mechanical seal face usually has a **smaller** mating surface and is commonly called the "**wear nose**" of the mechanical seal. In systems with **highly corrosive fluids**, are recommended mechanical seals with external **springs**.

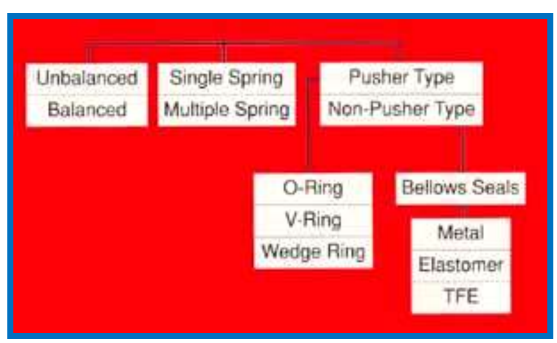
IV. CLASSIFICATION:



Mechanical seals classified by **Arrangement:**



Mechanical seals classified by **Design:**



1. Mechanical Seal Types:

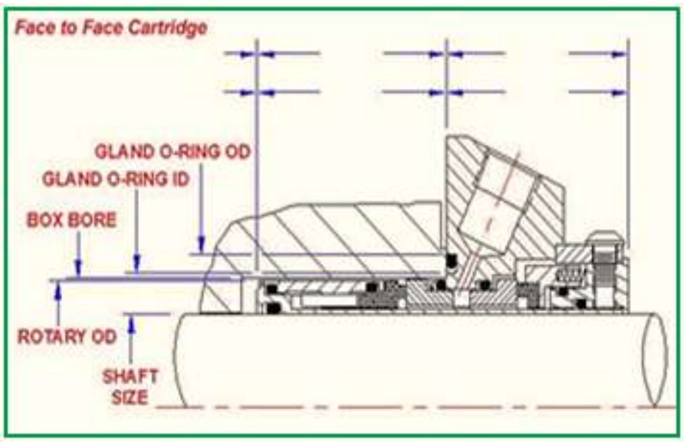
There are **multiple** designs available for mechanical seal configurations. Understanding how they work will help the professionals to select the appropriate type and their correct application.

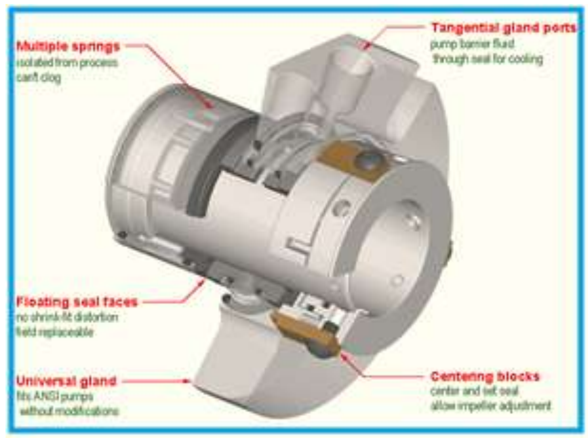
The common types are: **Cartridge; Conventional; Pusher; Non-pusher; Balanced and Unbalanced**.

a) Cartridge Seals:

Cartridge seals are all types that don't require **complicated** settings during the installation, as required by the conventional seals. This helps **reducing** errors associated with seal setting and eventually also reduces the maintenance required.

The **easiest** seals for a mechanic to install are the **cartridge** types, only required to **slide** onto the pump shaft and **bolt** to the pump gland, the cartridge seal **cannot** be miss installed.

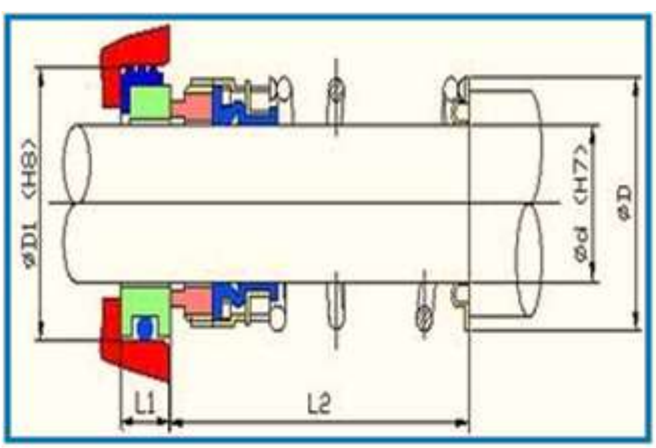


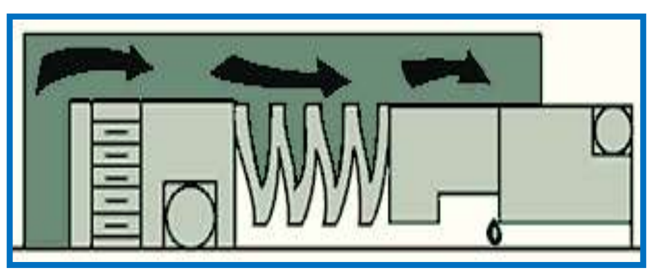


This mechanical seal is **pre-mounted** on a **sleeve** including the gland. The major benefit, of course, is there is no requirement for the usual seal setting **measurements** during installation. Cartridge seals lower maintenance costs and **reduce** seal setting errors.

b) Conventional Seals:

These seals types require **setting and alignment** of the seal (single, double, tandem) on the shaft or sleeve of the pump. The emphasis is on reducing maintenance costs, as the settings are relatively simple. This motive has increased preference for cartridge seals. Examples are Dura RO and Crane Type 1.

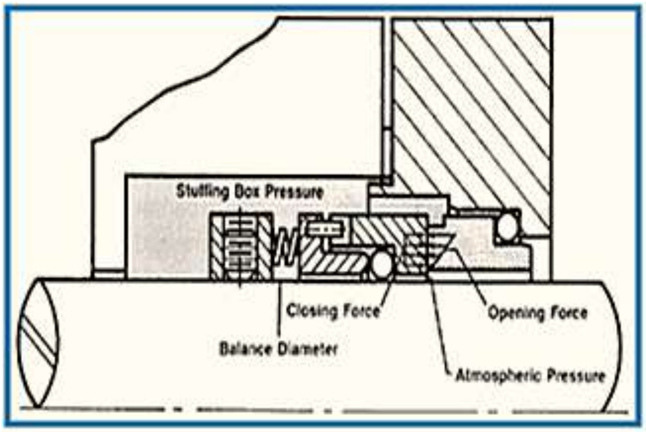


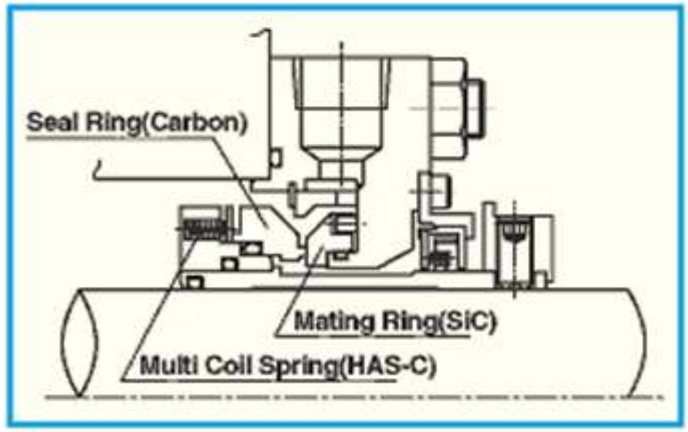


c) Pusher Seals:

Pusher seals are inexpensive and **commercially** available in a wide range of sizes and configurations. These types incorporate **secondary** seals that **move** axially along a shaft or sleeve to maintain **contact** at the seal faces.

This compensates the seal face **wear and wobble**, due to misalignment. Its disadvantage is that it's prone to a secondary seal **wear out** of the shaft or sleeve. Examples are Dura RO and Crane Type 9T.

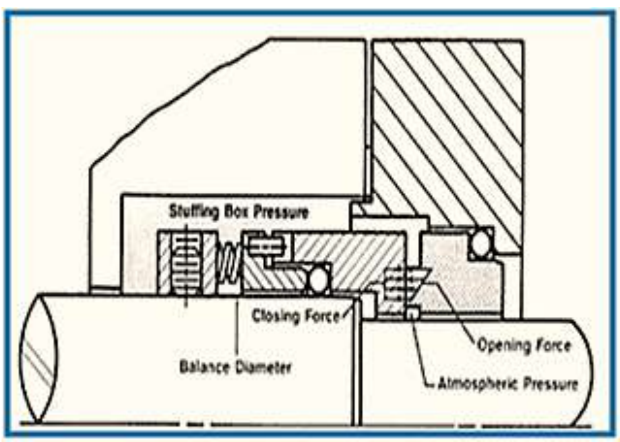


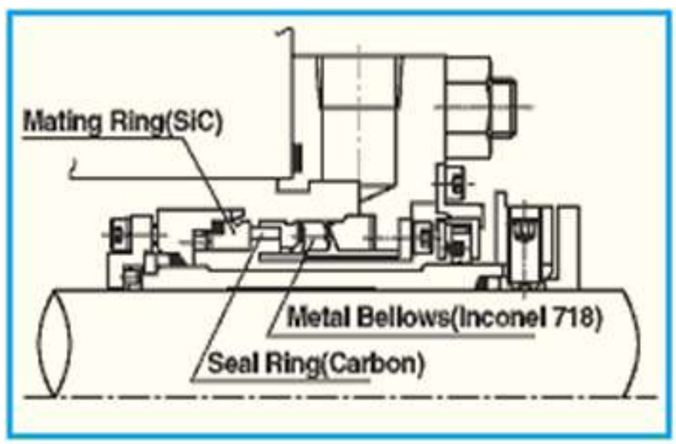


d) Non-Pusher Seals:

Non-pusher or bellows seals do not have to **move** along the shaft or **sleeve** to maintain the seal face contact. The main advantage is the common ability to handle **high and low** temperature applications, and then, **do not require** a secondary seal.

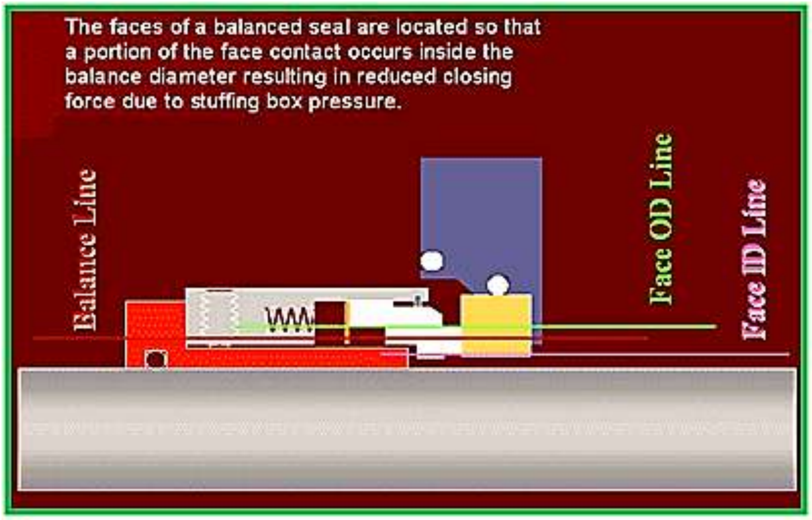
The disadvantage of these types is that its thin **bellows cross sections**, must be better upgraded for use in **corrosive** environments. Examples are Dura CBR and Crane 215, and Sealol 680.

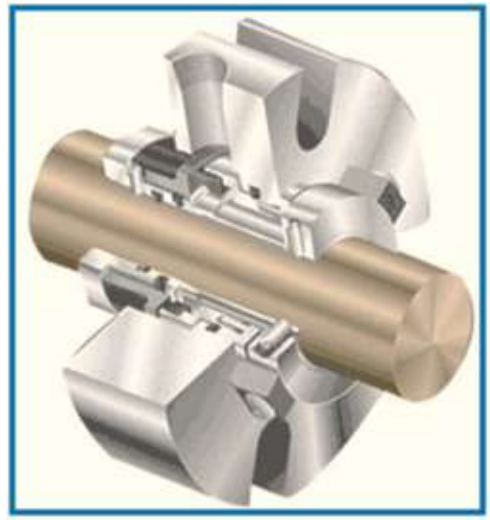




e) Balanced Seals:

Balanced seals have higher-pressure limits, lower seal face loading, and generate less heat. Balancing a mechanical seal involves a **simple design change**, which reduces the **hydraulic forces** acting to close the seal faces. This makes them well suited to handle pumping liquids with poor lubricity and high vapor pressures, such as light hydrocarbons. Examples are Dura CBR and PBR and Crane 98T and 215.

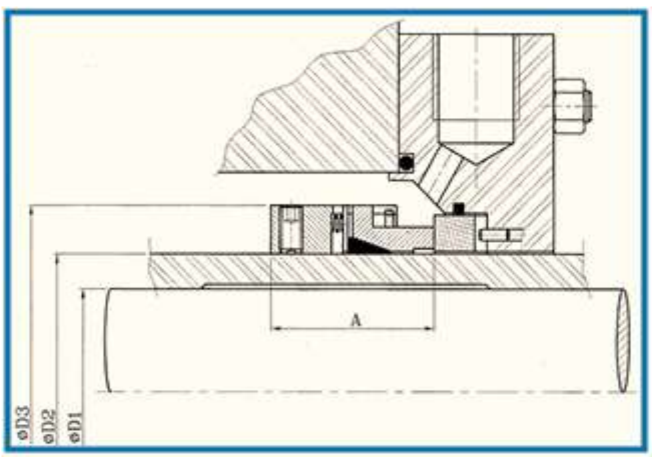


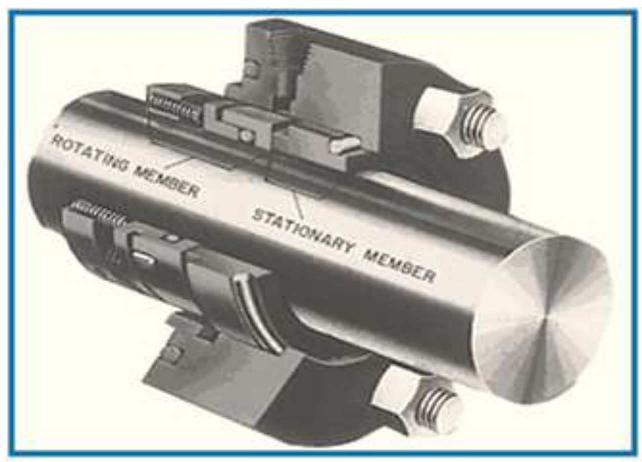


f) Unbalanced Seals:

Unbalanced seals are inexpensive, **leak less** and are much more **stable**, when subjected to vibration, misalignment, and cavitation. The disadvantage is their relative low pressure limit.

Maintenance control must be severe. When the **closing forces** exerted on the seal faces exceed the pressure limit, the **lubricating film** between the faces is **squeezed out,** the highly loaded **dry** running seal may **fail**. Examples for these types are the Dura RO and Crane 9T.



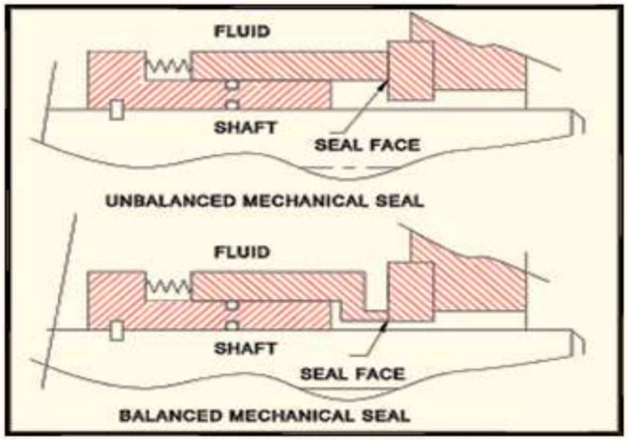


g) Pressure Balanced & Unbalanced Seals:

It is possible to **reduce the seal contact pressure** using a **pressure balanced** or a **pressure unbalanced** seal design, hydrodynamically lubricated, with a controlled proportion of forces generated by the pumped fluid pressure. The fluid film will need to carry substantial lubrication load. However, if the pressure load becomes too high for the film surface, could bring consequent bearing failure.

The **lubricating film** is generally of the order of **3 micrometers thick**, or less. This thickness is critical to the required sealing function. Mechanical seals often have one face of a suitable solid lubricant such that the seal can still operate for a period without the fluid film.

In order for mechanical seals perform extended time periods with low surfaces friction, is necessary good maintenance monitoring for hydrodynamic lubrication. This principle is illustrated in the sketch below.



2. Arrangement and Design:

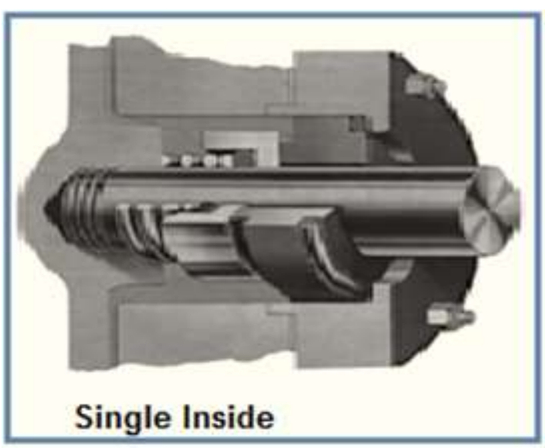
a) Single Inside:

This is the most **common type** of mechanical seal. These seals are easily modified to accommodate **seal flush plans** and can be **balanced** to withstand high seal environment pressures.

This arrangement is recommended for relatively clear **non-corrosive and corrosive pumping liquids,** with satisfactory lubricating properties, where **cost of operation** does not exceed that of a double seal. Examples are Dura RO and CBR and Crane 9T and 215. Reference Conventional Seal.

b) Single Outside:

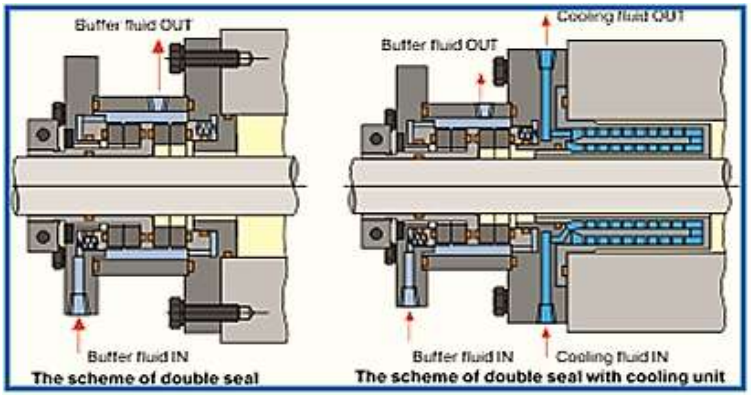
This arrangement offers an **economical** alternative to the expensive metal required for an inside seal to **resist corrosion**. The **disadvantage** is that it is exposed **outside** of the pump, which makes it vulnerable to **damage** from impact and hydraulic pressure. Since these forces work to open the seal faces, they have low pressure limits (balanced or unbalanced).

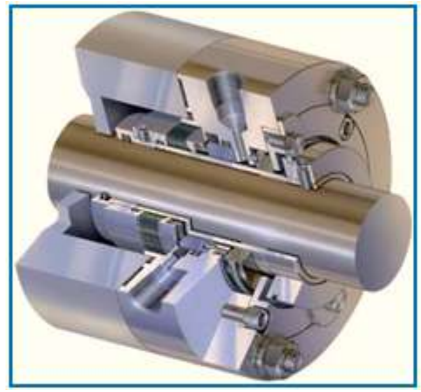


c) Double (Dual Pressurized) Seals:

Double seals can have five times the life of a **single** seal in severe environments. There is a **significant advantage** of **using a double seal** over a **single seal**. The decision between choosing a double or single seal comes down to the initial **cost**, to purchase, operation, environmental issues and user plant emission standards for leakage.

Recommended for fluids that are not compatible with a single mechanical seal (i.e. liquids that are toxic, hazardous, have suspended abrasives, or corrosives which require costly materials).



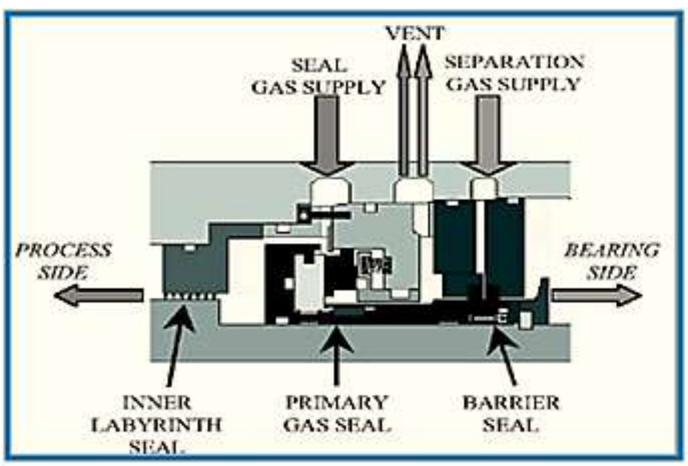


The metal inner seal parts are never exposed to the liquid product being pumped. Viscous, abrasive, or thermosetting fluids are easily sealed, without a need for expensive metallurgy. Recent testing has shown that double seal life is virtually unaffected by process upset conditions during pump operation. Examples are Dura RO and Crane double 811T.

d) Double Gas Barrier (pressurized Dual Gas) Seals:

Double gas barrier seals use **nitrogen or air,** as a harmless and inexpensive barrier fluid, which helps prevent product emissions to the atmosphere and fully complies with emission regulations. These seals should not be used with **toxic or hazardous** pumping liquids that are regulated or in situations where increased reliability is required on an application.

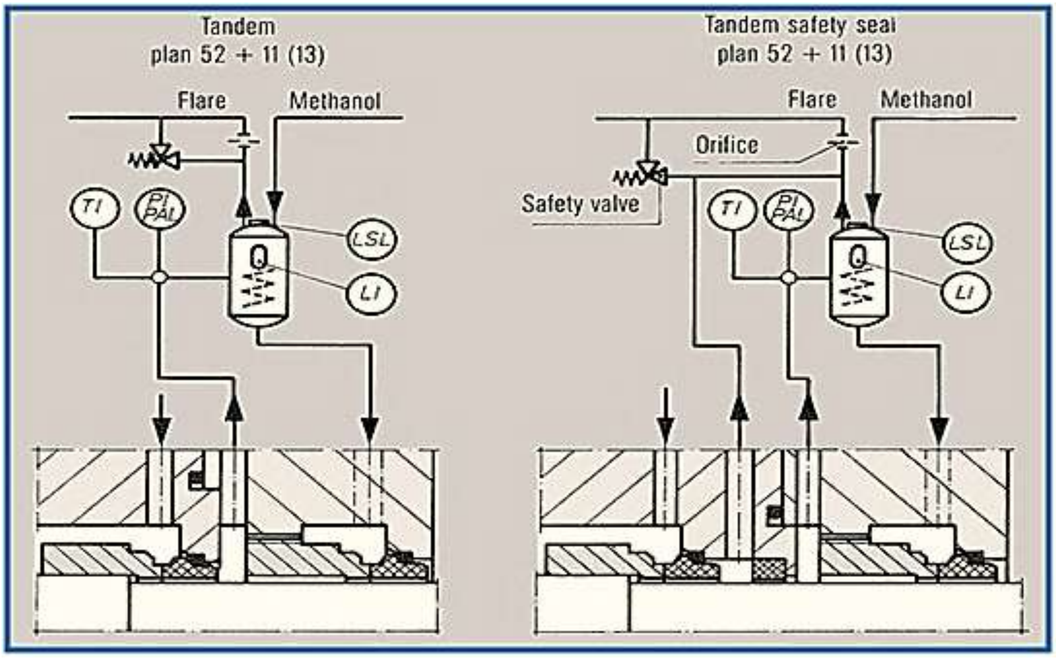
Since these sealing systems work with **inert gas,** like **nitrogen**, to act as a surface **lubricant and coolant** in place of a **liquid** barrier system or external flush required by **conventional** or **cartridge** double seals. This concept was developed because many **barrier fluids** commonly used with double seals can **no longer** be used **due to new emission regulations**. These types are similar to **cartridge** double seals. Examples are Dura GB2OO, GF2OO and Crane 2800.



e) Tandem (Dual Unpressurized):

Tandem seals are used for **processing** products, such as vinyl chloride, carbon monoxide, light hydrocarbons, and other volatile, toxic or hazardous liquids, due to **health, safety, and environmental** considerations. Tandem seals eliminate icing and freezing of light hydrocarbons and other liquids, which could fall below the atmospheric freezing point of water in air (32°F or 0°C). Typical **buffer** liquids in these applications are **ethylene glycol, methanol, and propanol**.

In the event of the **primary seal failing** and the alarm being given, the **second mechanical seal** takes over the entire **sealing function** for a limited period, that is, when the **primary seal fails**, the outboard seal **take over** function until maintenance of the equipment can be scheduled. Tandem seals also increases arrangement reliability. Examples are Dura TMB-73 and PTO.



3. Design Features:

The mechanical seal generally includes three static seals:

The sleeve seal - this is usually an o-ring; The seals between the moving seal member and the shaft or sleeve; This is often an o-ring but can be a Wedge or V-seal; This seal may not be used for bellows type mechanical seals; The housing seal is generally an o-ring of a gasket.

Obs.: All of these seal must be **compatible with the fluid** being contained and the associated environment. These seals limit the design for **high temperature** applications. In this case the **bellows** type alternative may be the best option.

Sealing faces of the mechanical seals are generally pressed together using some form of **spring loading**. Some different **spring loading systems** for sealing faces are available, as shown below:

Single spring; Multiple springs distributed around seal body; Disc Springs; Bellows; Magnetic.

Commonly, for **conventional** mechanical seals the **single spring arrangement** is used. Other spring arrangements are also used when the **space** is restricted. It is vitally important that the **sealing surfaces** are perfectly **flat** and are **parallel**.

The seal faces are usually dissimilar materials with the softer face being the narrower surface. For **abrasive applications,** similar hard materials are used, e.g., **tungsten carbide**.

In every design, the seal surfaces must have **sufficient strength** to withstand the **hydrostatic fluid forces** and must be able to **remove the heat** generated by **sliding** action. **Carbon** is often used **against** bronze, cast iron, stainless steels, etc.

4. Failure Mechanisms:

Mechanical seals have two primary **failure** mechanisms; degradation of the face material and loss of spring or bellows tension. Other failure causes are:

- Degradation of the seal faces, caused by debris that wedges into a seal and causes damage;
- Fatigue, fouling, and/or corrosive environments, which degrade spring and bellows materials.

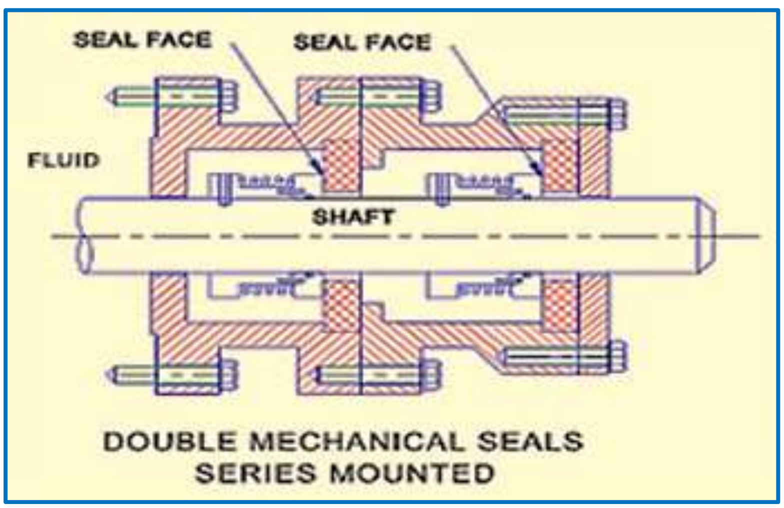
Seal **faces** are **held** together by a **force** that is usually provided by **springs or bellows**. However, compression may be **lost** because of **force loss** of spring, allows the faces to separate more easily.

To minimize the risk of **damage** in seal faces the mechanical seals are often serviced by special **flushing lines** that have **filters** to catch **debris**. To minimize **fatigue loads** on mechanical seals, the seal must be precisely **aligned**, so that spring movement is **minimal** during each shaft revolution.

V. ASSEMBLY OPTIONS:

There are several mechanical seal options:

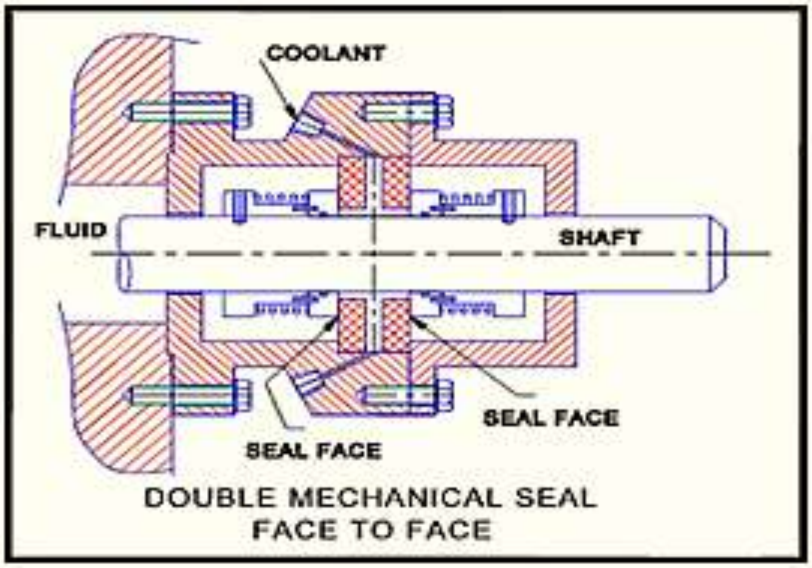
a) **External Seal**: This design is installed on the **outside the stuffing box**, with the sealed pressure **inside**. This provides good access allowing the seal components to be **cleaned**;
b) **Internal Seal**: Generally mechanical seals are mounted **inside the stuffing box**, with the sealed pressure **outside** the seal;
c) **Double Seals**: Mechanical seals **mounted in pairs** are commonly used for sealing **hazardous**, toxic or **abrasive fluids** and often provided with **clean flushing** fluid between the seals.



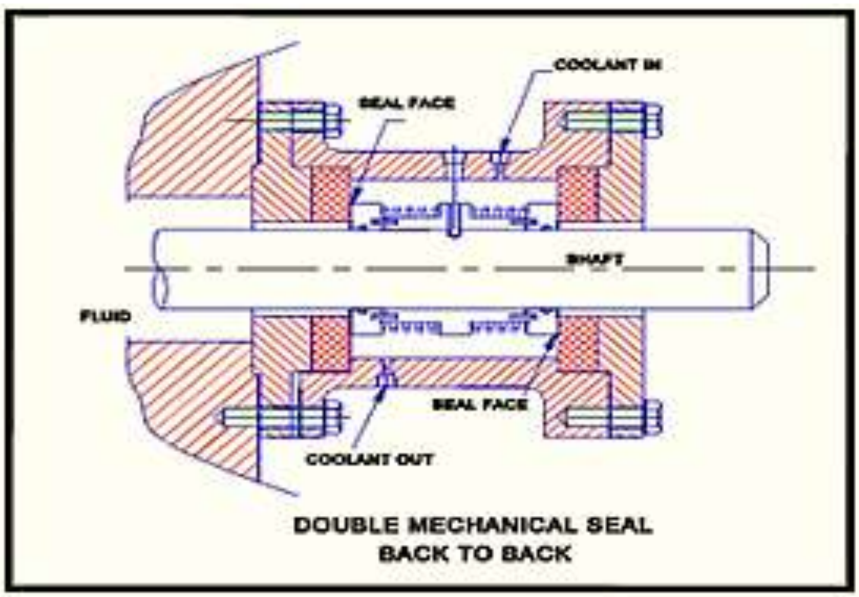
Double seals also provide an **additional** degree of **safety** where the pressure differentials are likely to reverse and/or there is a high risk of the **seal failing**. The double seals **assembly options** are listed below:

1. **In Series**: Types are commonly used **primarily** to overcome the risk of failure of a single seal.

2. **Face to Face**: Used when a **cooling fluid** interface is required. **One** seal is used for the **process** fluid the **other** seal is used for the **coolant**.



3. **Back to Back**: Used when an **abrasive fluid** is being contained and **both** seals are **flushed** with a clean **buffer fluid**. The flushing fluid is introduced at a **higher pressure** the process fluid.



VI. ADDITIONAL EQUIPMENT AND DESIGN:

The use of mechanical seals generally involves the use of **additional equipment**, primarily for the **flushing**, **lubricating and cooling** systems. This includes pumps, coolers, strainers, filters etc.

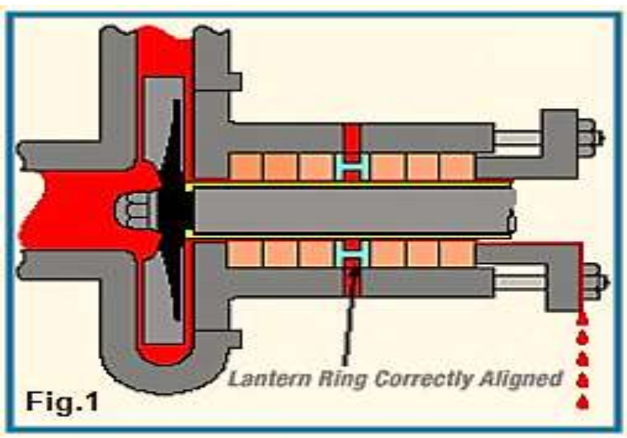
1. Sealing Points for Mechanical Seals:

The faces in a typical mechanical seal are **lubricated** with a **boundary layer of gas or liquid** between the faces. In designing seals for the desired leakage, seal life, and energy consumption, the designer must **consider** how the faces are to be **lubricated** and select from a number of modes of seal face lubrication.

To **select** the **best** seal design, it's necessary to know, as much as possible, about the **operating conditions** and the **product** to be sealed. Complete **information** about the product and environment will allow selection of the best seal for the application.

2. Stuffing Boxes:

The **stuffing box** is the **cylindrical space** in a rotary equipment, such as, a **centrifugal pump** surrounding the shaft. Conventional packings are mostly **fiber** with **lubricants** that can be **squeezed**, cooked or washed out, resulting in out-of position **lantern rings**, over-compressed packing and sleeve wear.



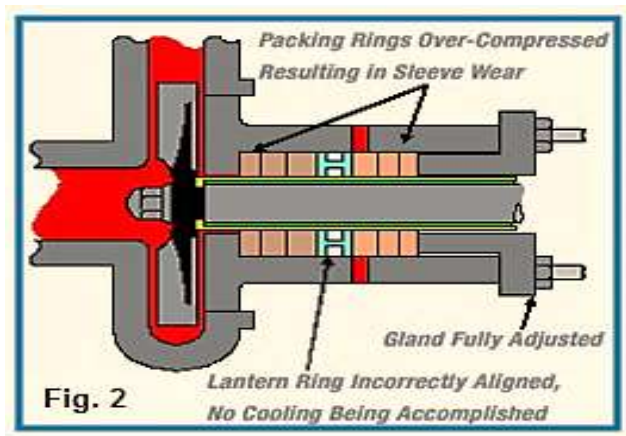
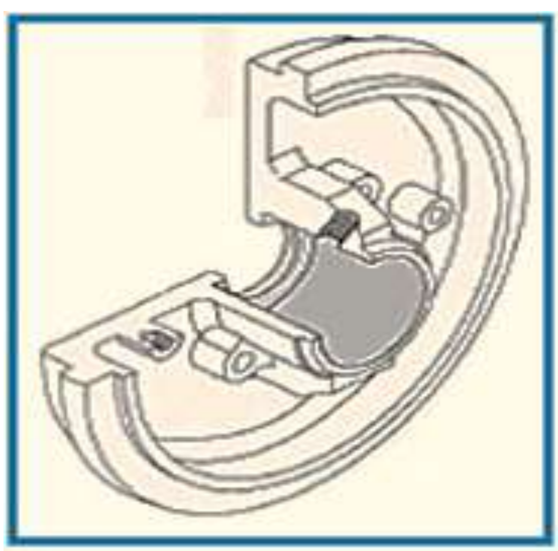


Fig. 1: How a Stuffing Box **looks** when completely **packed** using traditional packings;
Fig. 2: How a Stuffing Box **looks** after **gland** adjustments using traditional packings.

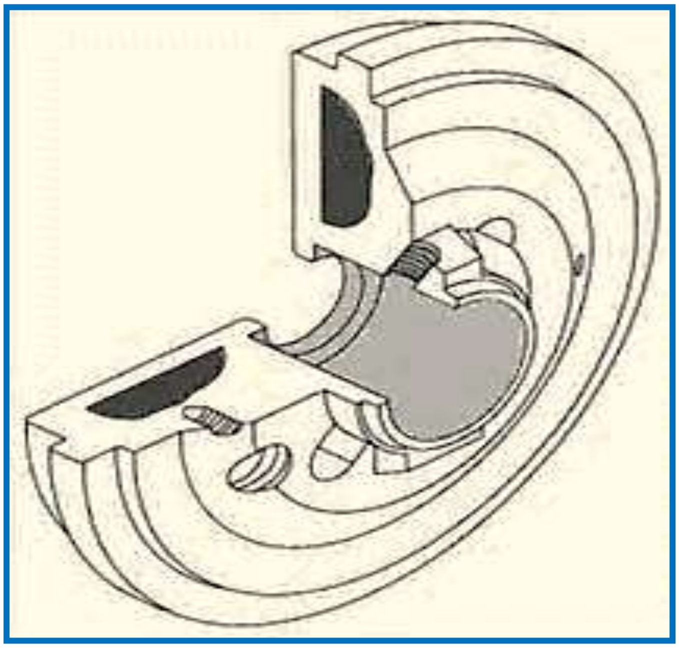
2.1. Standard Bore Stuffing Box Cover:

Designed **thirty years ago** specifically for **packing**. Also **accommodates** mechanical seals (clamped seat outside seals and conventional double seals).



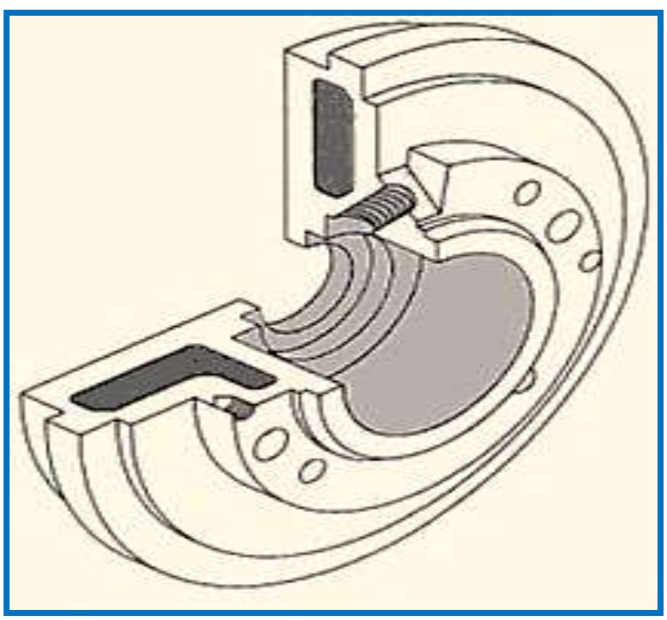
2.2. Jacketed Stuffing Box Cover:

Designed to **maintain** proper **temperature** control (heating or cooling) of the seal environment. (Jacketed covers do not help lower seal face temperatures to any significant degree). Good for **high temperature** services that require use of a **conventional double** seal or **single** seal with a **flush** and **API plan 21**.



2.3. Jacketed Large Bore Seal Chamber:

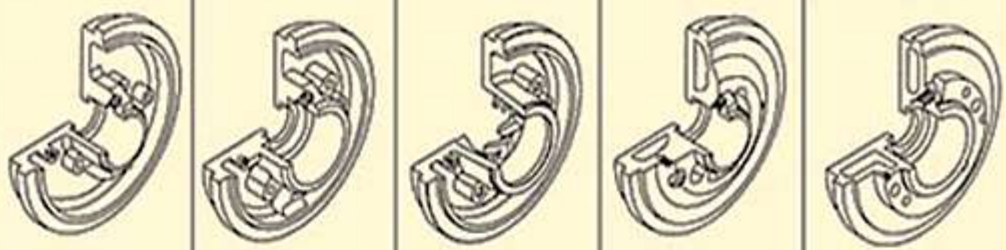
Designed to **maintain** proper **temperature** control (heating or cooling) of the **seal environment** with improved **lubrication** of seal faces. It is ideal for services, such as **molten sulfur** and **polymerizing** liquids. Excellent for **high temperature** services that require use of **conventional** or **cartridge single** mechanical seals with **flush** and **throat bushing** in bottom of seal chamber. Also, this is great for **cartridge double** or **tandem seals**.



2.4. Stuffing Box Cover and Seal Chamber Guide:

Seal Chambers

A — Ideally Suited
B — Acceptable
C — Not Recommended



Service Acceptable Ideally Suited	TYPE 1 Standard Bore Stuffing Box Cover — Designed for packing. Also accommodates mechanical seals.	TYPE 2 Conventional Large Bore — Enlarged chamber for increased seal life through improved lubrication and cooling. Seal environment should be controlled through use of CPI flush plans.	TYPE 3 Tapered Bore — Lower seal face temperatures, self-venting and draining. Solids and vapors circulated away from seal faces. Often no flush required. Superior patented design maximizes seal life with or without solids and vapor in liquid.	TYPE 4 Jacketed Stuffing Box — Maintains proper temperature control (heating or cooling) of seal environment.	TYPE 5 Jacketed Large Bore — Maintains proper temperature control (heating or cooling) of seal environment with improved lubrication of seal faces. Ideal for controlling temperatures on services such as molten sulfur and polymerizing liquids.
Ambient Water With Flush	A	A	A	-	-
Entrained Air or Vapor	C	B	A	C	B
Solids 0-10%, No Flush	C	C	A	C	C
Solids up to and greater than 10% With Flush	B	A	A	B	A
Paper Stock 0-5%, With No Flush	C	C	A	-	-
Paper Stock 0-5%, With Flush	B	A	A	-	-
Slurries 0-5%, No Flush	C	C	A	C	C
High Boiling Point Liquids, no flush	C	C	A	C	C
Temperature Control	C	C	C	B	A
Self-Venting and Draining	C	C	A	C	C
Seal Face Heat Removal	C	A	A	C	A
Molten or Polymerizing Liquid, No Flush	C	C	B	C	C
Molten or Polymerizing Liquid With Flush	C	B	B	C	A

Note: The **selection guide** on this page and the Seal Chamber Guide are designed to assist selection of the proper seal housing for a **pump application**.

2.5. Stuffing Box and Seal Chamber Application Guide:

Stuffing Box Cover/Seal Chamber	Application
Standard Bore Stuffing Box Cover	Use for soft packing. Outside mechanical seals. Double seals. Also, accommodates other mechanical seals.
Jacketed Stuffing Box Cover	Same as above but also need to control temperatures of liquid in seal area.
Conventional Large Bore	Use for all mechanical seal applications where the seal environment requires use of CPI or API seal flush pans. Cannot be used with outside type mechanical seals.
Jacketed Large Bore	Same as Large Bore but also need to control temperature of liquid in seal area.
Tapered Large Bore with Axial Ribs	Clean services that require use of single mechanical seals. Can also be used with cartridge double seals. Also, effective on services with light solids up to 1% by weight. Paper stock to 1% by weight.
Tapered Large Bore with Patented Vane Particle Ejector (Alloy Construction)	Services with light to moderate solids up to 10% by weight. Paper stock to 5% by weight. Ideal for single mechanical seals. No flush required. Also, accommodates double seals. Cannot be used with outside mechanical seals.

3. Large Bore Seal Chambers:

Large Bore Seal Chambers were designed specifically for mechanical seals**,** to provide **increased life** of seals through **improved lubrication and cooling** of faces. Seal **environment** should be controlled through use of **API flush plans**.

Often available with **internal bypass** to provide circulation of liquid to faces **without** using external flush. Ideal for **conventional or cartridge single** mechanical seals, with a **flush and throat bushing** in bottom of chamber. Also excellent for conventional or **cartridge double or tandem seals**.

The introduction of the **large bore** seal chambers has provided three **major benefits** to mechanical seal operation, all of which contribute to increased reliability:

1. The **increased volume** of pumping in the **chamber** permits the liquid to dissipate the **heat** generated by the seal faces more readily, than the **lesser volume** in a stuffing box. Then, the mechanical seal will run **cooler**.

2. As the **outer wall** of the chamber is moved to a greater distance from the seal, the **seal rub** has been eliminated. (Seal rub is a condition where excessive **radial** shaft movement brings the seal into **contact** with the bore of the stuffing box, causing premature failure).

3. As the seal itself **acts** as a **centrifuge** in the chamber, any **solid** particles in the chamber will be **thrown** further away from the seal faces; therefore, the seal will run in a **cleaner** environment.

3.1. Large Cylindrical Bore Seal Chambers:

The Large Cylindrical Bore Chamber **shown in Fig. 1** is the same design as the **stuffing box**, except that the **bore** diameter is **larger**, but only in the area occupied by the seal to control the **temperature** and **pressure** of the pumpage inside the seal chamber.

The **enlarged** bore seal chambers with **increased** radial clearance between the mechanical seal and seal chamber wall provide better **circulation** of liquid to and from seal faces. Improved **lubrication** and heat removal (cooling) of seal faces **extend** seal life and lower maintenance costs.

3.2. Large Tapered Bore Seal Chambers:

The Large Taper Bore Chamber **shown in Fig. 2** provides **increased** circulation of liquid at seal faces **without** use of external **flush**. Offers advantages of lower maintenance costs, **elimination** of **tubing** or piping, lower utility costs (associated with seal flushing) and extended seal reliability.

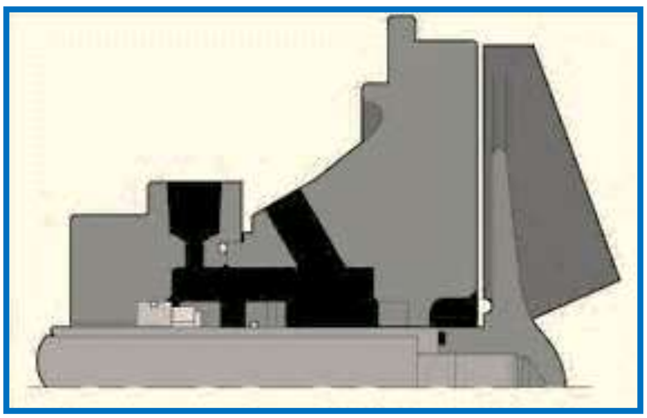


Fig. 1: Large Cylindrical Bore Seal Chamber

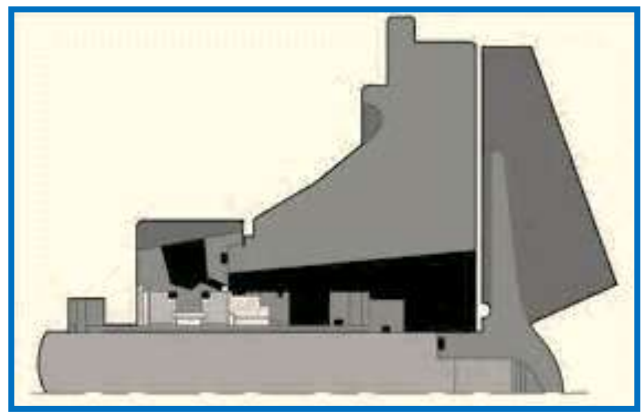
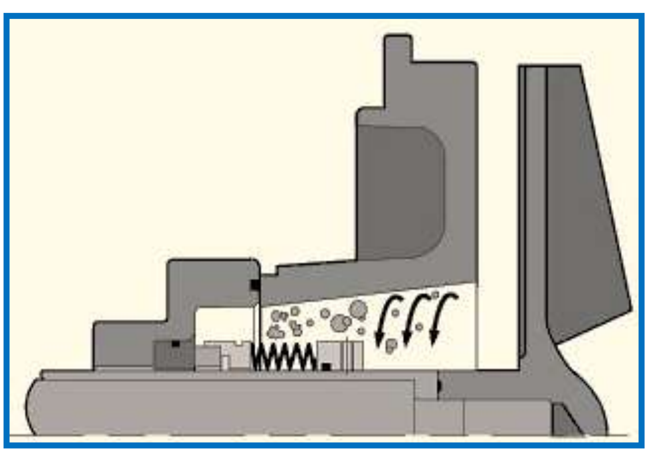


Fig.2: Large Tapered Bore Seal Chamber

3.3. Tapered Bore Seal Chamber with Axial Ribs:

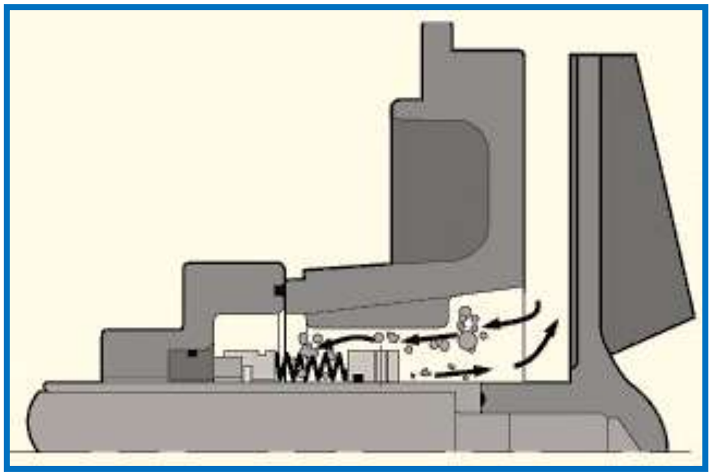
This type of seal chamber can provide **better** seal life, when **air or vapors** are **present** in the liquid. The axial ribs **prevent** entrapment of **vapors** through improved flow in the chamber. Dry running **failures** are eliminated, and solids **less than 1%** are **not** a problem. The new **flow pattern**, however, still places the seal in the path of solids/liquid flow. The consequence on services with significant solids (greater than 1%) is **packing** of the seal **spring or bellows**, solids impingement on seal faces and ultimate **seal failure**.



Tapered Bore Seal Chamber with Axial Ribs

3.4. Tapered Bore with Seal Chamber:

To eliminate seal failures on services containing **vapors** as well as **solids**, the **flow pattern** must direct solids **away** from the mechanical seal, and **purge** air and vapors. The **tapered** bore completely reconfigures the flow in the **seal chamber** with the result that seal failures due to solids are eliminated. Air and vapors are efficiently **removed** eliminating dry run **failures**. Extended seal and pump **life** with lower maintenance costs are the results.

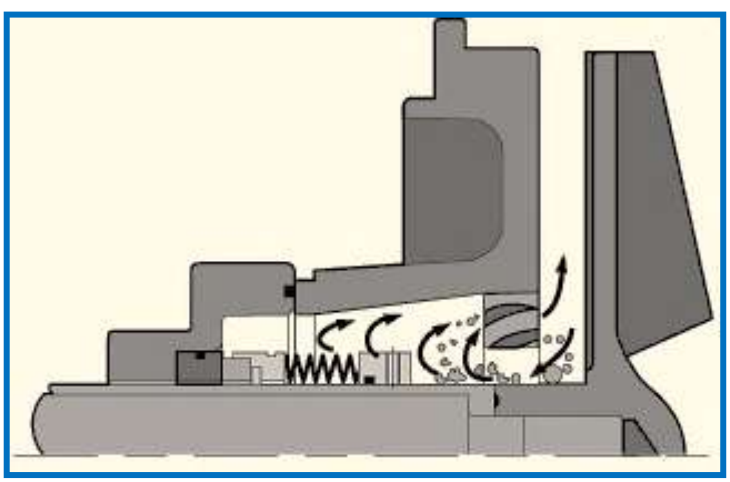

Tapered Bore with Seal Chamber

3.5. Large Tapered Bore:

The **flow path** created by the **vane** directs solids **away** from the mechanical seal, using this Large Tapered Bore design, and the amount of **solids** entering the bore is **minimized**. Air and vapors are also efficiently **removed**. On services with or without solids, air or vapors, the Tapered Bore is an **excellent** solution for extending seal and pump **life** and lower maintenance costs.

Some **solids** continue to **flow** toward shaft. Other solids are **forced back** out by centrifugal force (generated by back pump-out vanes). **Clean** liquid continues to move toward mechanical seal faces. Thus, solids, air, vapors are flown **away** from the seal.

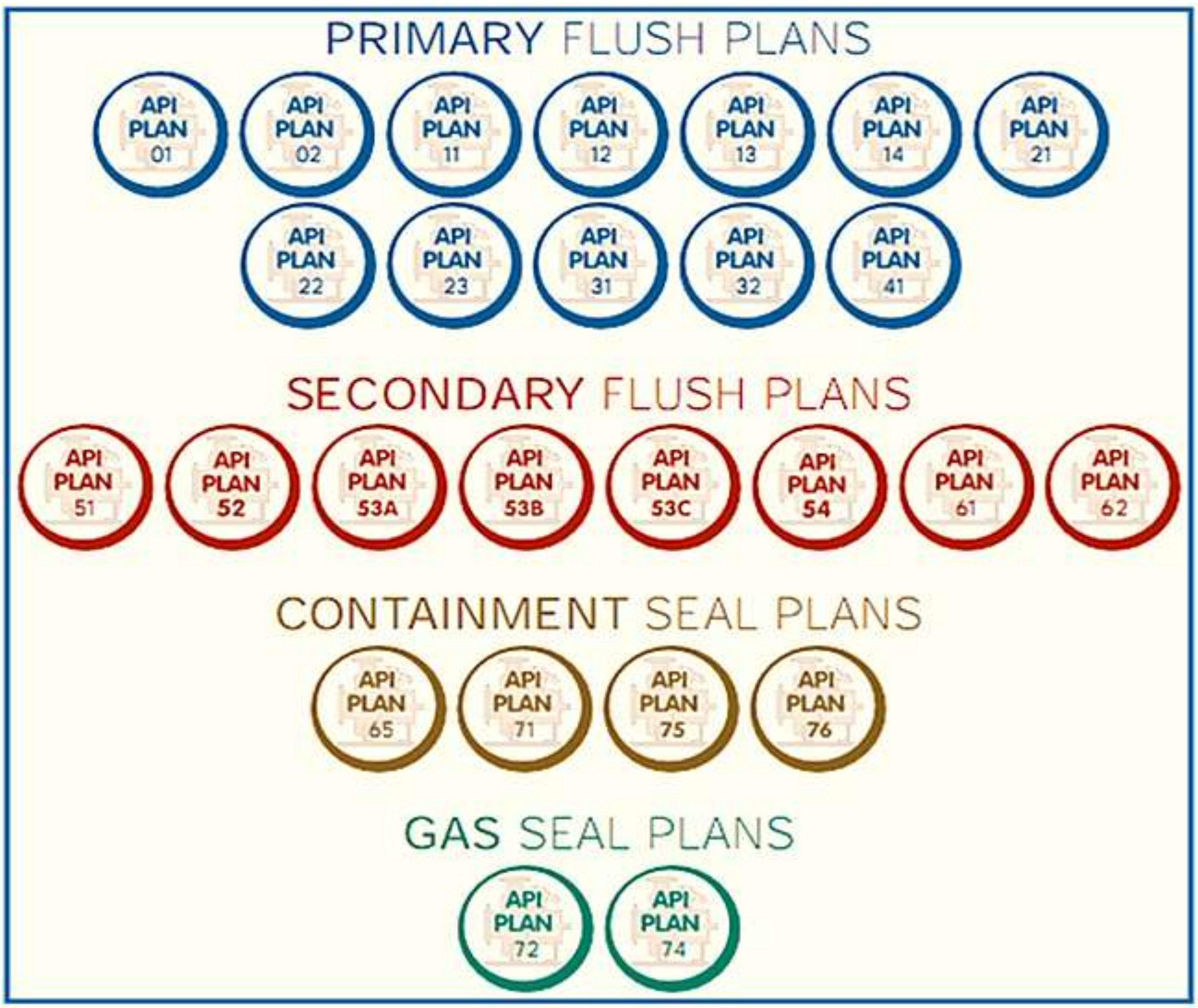
The **low pressure** zone created by the **vane ejector** makes all solids, air and vapor liquid mixtures **exit** the seal chamber **bore**. The flow in the tapered seal chamber type assures efficient heat removal (cooling) and lubrication. The **heat is dissipated** and the surfaces are continuously flushed with **clean** liquid.


Large Tapered Bore

VII. MECHANICAL SEALS ARRANGEMENTS:

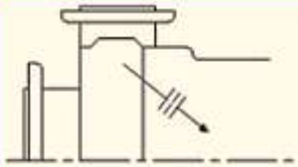
The **American Petroleum Institute** (API) created a **numbering system** for a variety of **seal flush plans**. The API flush plans are now located in **API Standard 682** and the corresponding ISO standard, ISO 21049. The purpose of API 682 is to assist in the selection and operation of **end face mechanical seals** in seals in centrifugal pumps. It is based on the combined **knowledge** and experience of seal manufacturers, engineering companies and end **users**. API 682 is **primarily** intended for use in the petroleum, natural gas and chemical industries, but is often referenced for other **types of equipment** and industries. The American National Standard Institute (ANSI) adopted a slightly different designation system.

The purpose of a mechanical seal flush piping is to lubricate and cool the pump's mechanical seal. One of the **most commonly used type** of mechanical seal **flush piping** is the **API Plan 11 or Plan 13**. Although these piping plans are intended for API pumps, the same piping plans are widely used in other pumps because they are simple and inexpensive. The American Petroleum Institute (API) issues guide lines to help professionals select various types of controls for mechanical sealing applications.



1. Standard API Arrangements:

These piping arrangements are described below, in a series of plans issued by the API.

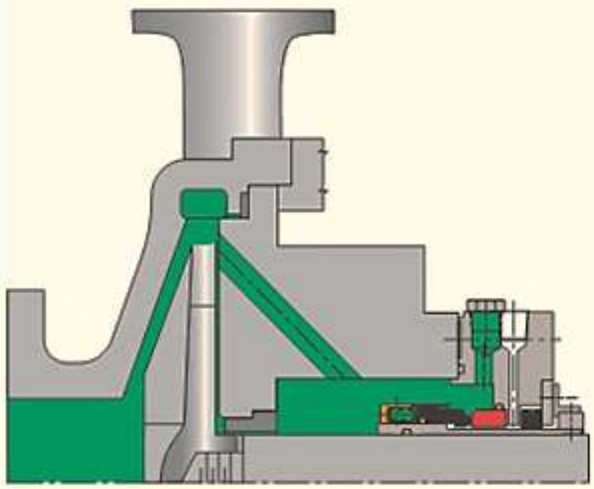


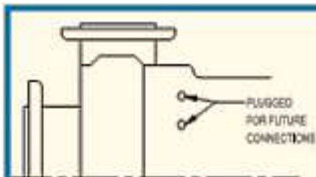
Plan 01
Single Seals

Description: Plan 01 is an internal recirculation from the pump discharge area of the pump into the seal chamber, similar to a Plan 11 but with no exposed piping.

Advantages: No product contamination and no external piping, which is advantageous on highly viscous fluids at lower temperatures to minimize the risk of freezing that can occur with exposed piping.

General: This flush plan should only be used for clean products as dirty products can clog the internal line. Not recommended on vertical pumps.



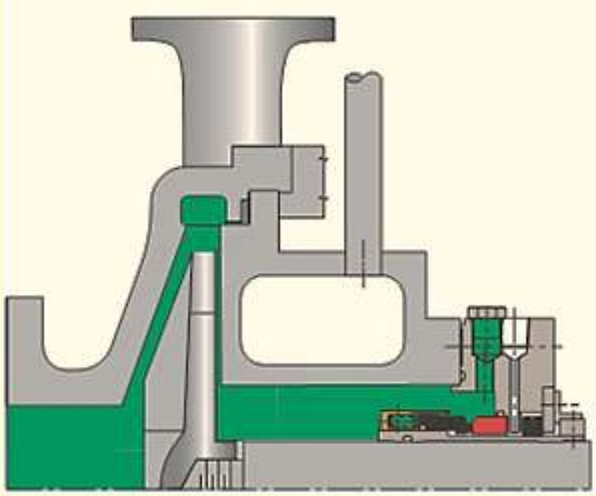


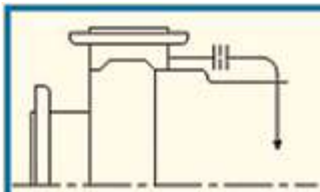
Plan 02
Single Seals

Description: Plan 02 is a non-circulating flush plan where adequate vapor suppression can be assured.

Advantages: Solids are not continually introduced into the seal chamber, no external hardware is required, and natural venting occurs when used with a tapered bore seal chamber.

General: Ideal with large bore/tapered bore ANSI/ASME B73.1 or specialised ISO 3069 seal chambers or with hot process pumps utilizing a cooling jacket. On the latter services, a Plan 62 with steam can also provide some additional cooling.



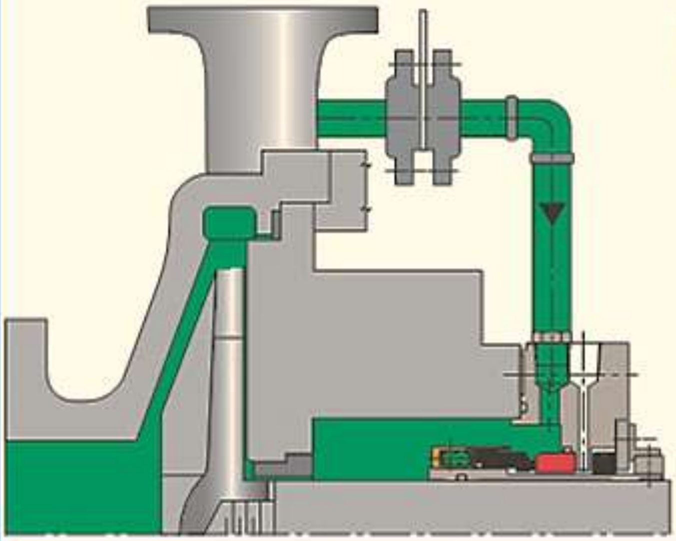


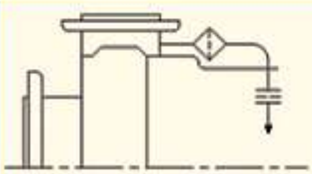
Plan 11
Single Seals

Description: Plan 11 is the most common flush plan in use today. This plan takes fluid from the pump discharge (or from an intermediate stage) through an orifice(s) and directs it to the seal chamber to provide cooling and lubrication to the seal faces.

Advantages: No product contamination and piping is simple.

General: If the seal is setup with a Distributed or Extended flush, the effectiveness of the system will be improved.



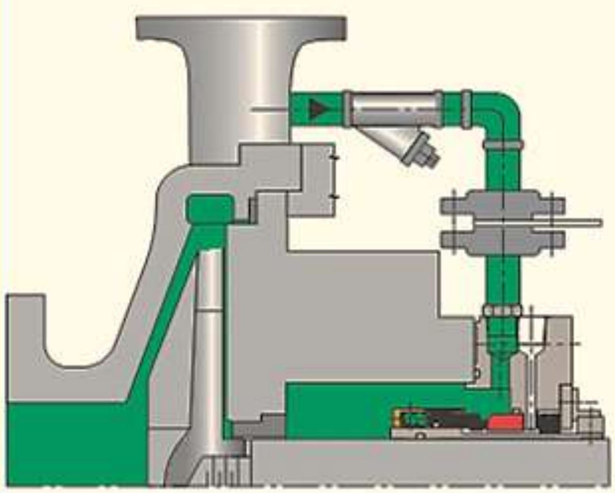


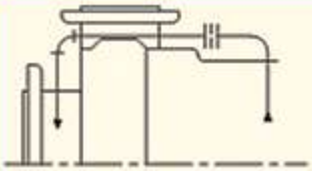
Plan 12
Single Seals

Description: Plan 12 is similar to Plan 11, except that a strainer or filter is added to the flush line.

Advantages: No product contamination and solids are removed from the flush stream keeping the seal clean.

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 alert the user that the filter or strainer is clogged.



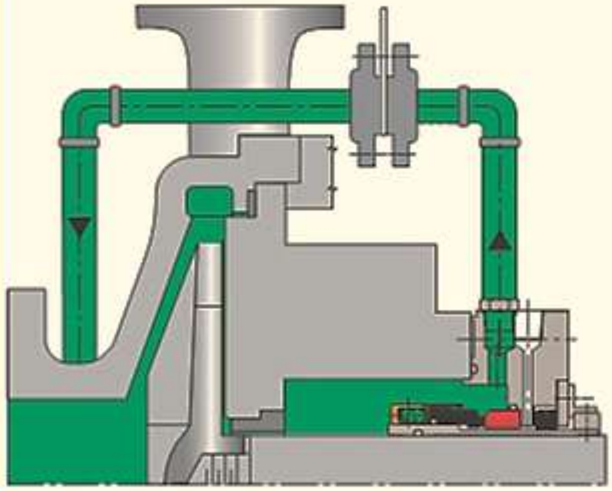


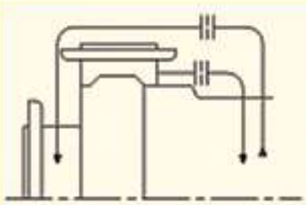
Plan 13
Single Seals

Description: In a Plan 13 the flow exits the seal chamber 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.



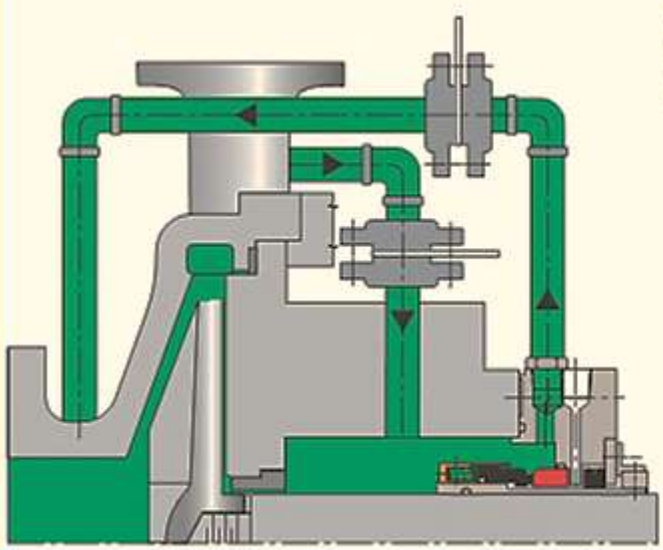


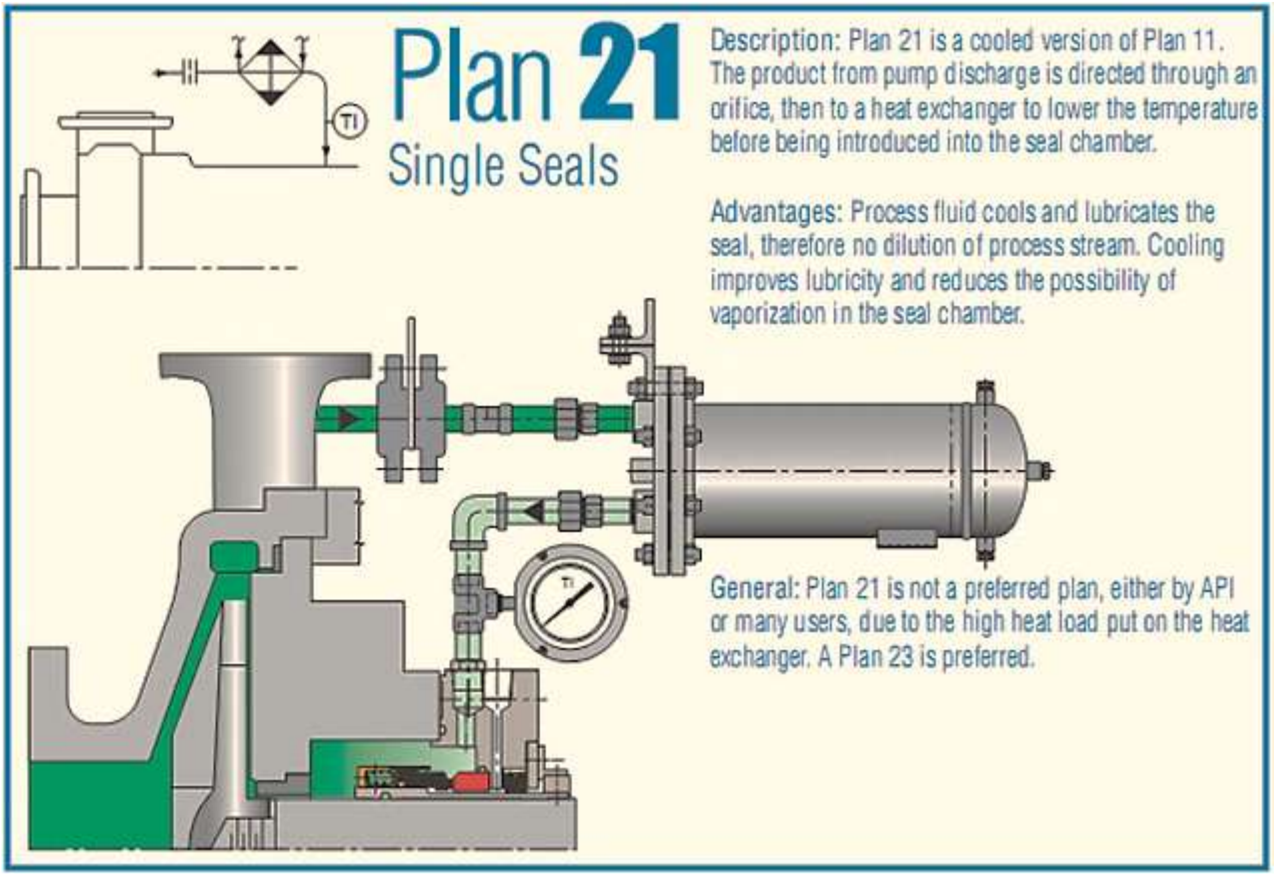
Plan 14
Single Seals

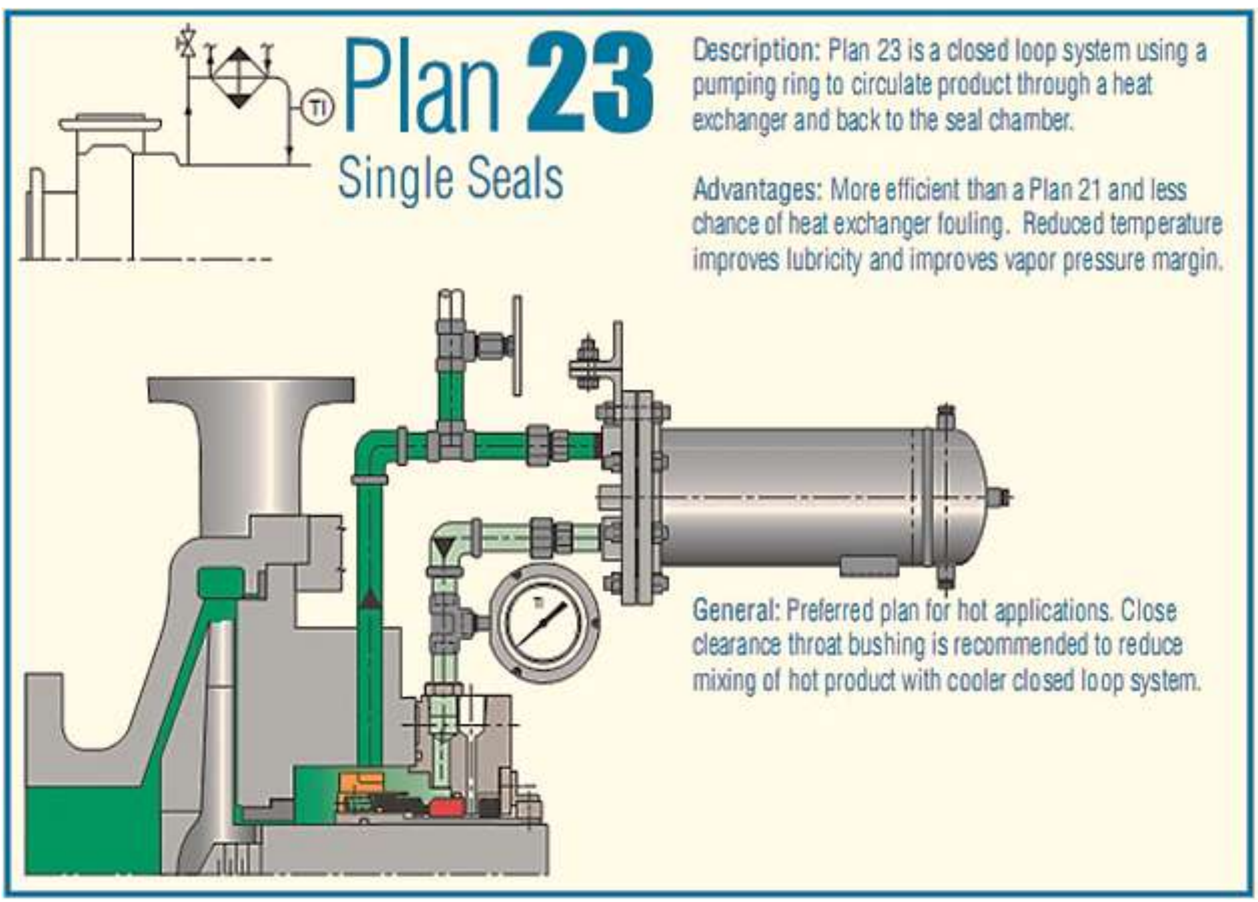
Description: Plan 14 is a combination of Plans 11 and 13. Flush is taken off of pump discharge, sent to the seal chamber, and piped back to pump suction.

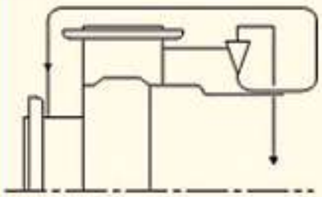
Advantages: Cooling can be optimized with the flush directed at the seal faces. Plan allows for automatic venting of the seal chamber.

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



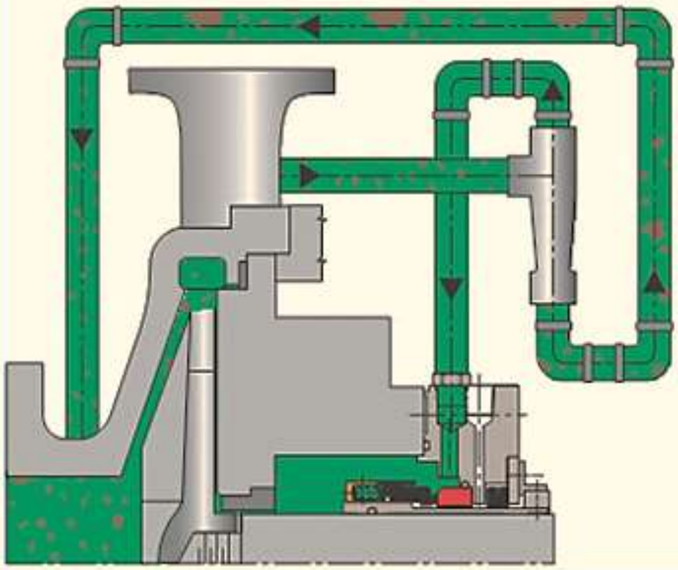

Plan 21
Single Seals
Description: Plan 21 is a cooled version of Plan 11. The product from pump discharge is directed through an orifice, then to a heat exchanger to lower the temperature before being introduced into the seal chamber.
Advantages: Process fluid cools and lubricates the seal, therefore no dilution of process stream. Cooling improves lubricity and reduces the possibility of vaporization in the seal chamber.
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. A Plan 23 is preferred.
TI


Plan 23
Single Seals
Description: Plan 23 is a closed loop system using a pumping ring to circulate product through a heat exchanger and back to the seal chamber.
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.
TI



Plan 31

Single Seals



Description: Plan 31 is variation of Plan 11, where an abrasive separator is added to the flush line. In this plan, the product is introduced to the abrasive separator from the discharge of the pump.

Advantages: Unlike a strainer or filter, the abrasive separator does not require cleaning. Solids are removed from the flush stream keeping the seal clean.

General: This plan should be used for services containing solids that have a specific gravity at least twice that of the process fluid. Typically the separator requires a minimum pressure differential of 15 psi (1 bar) to operate properly. High pressure differentials may require the addition of an orifice upstream of the cyclone.

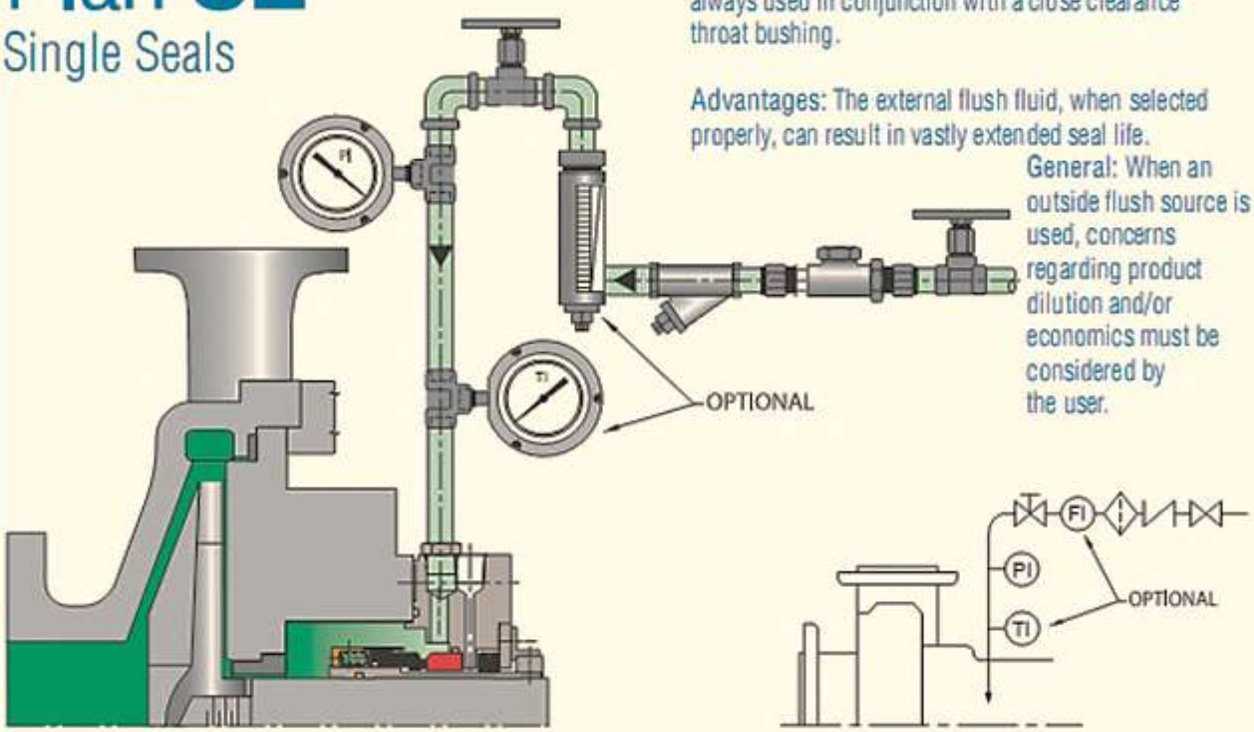
Plan 32

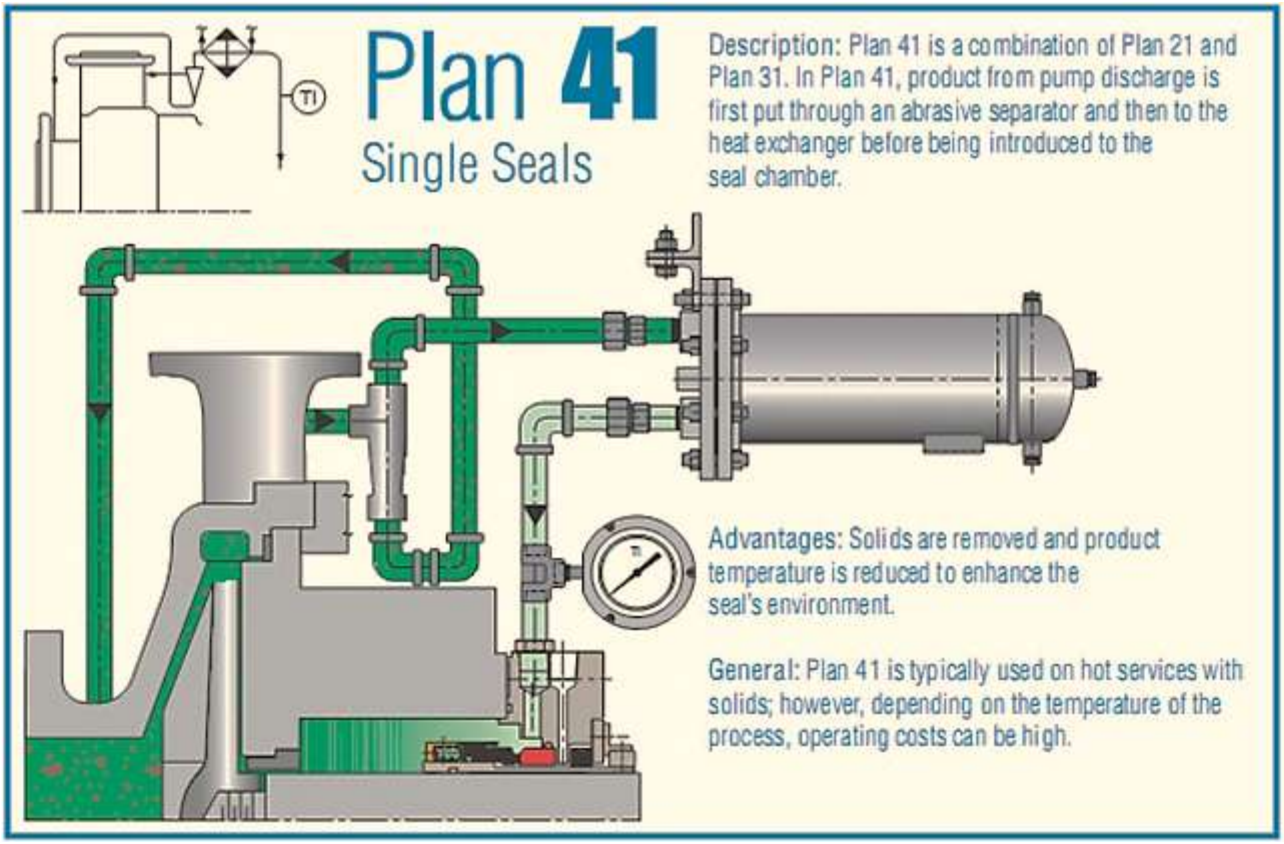
Single Seals

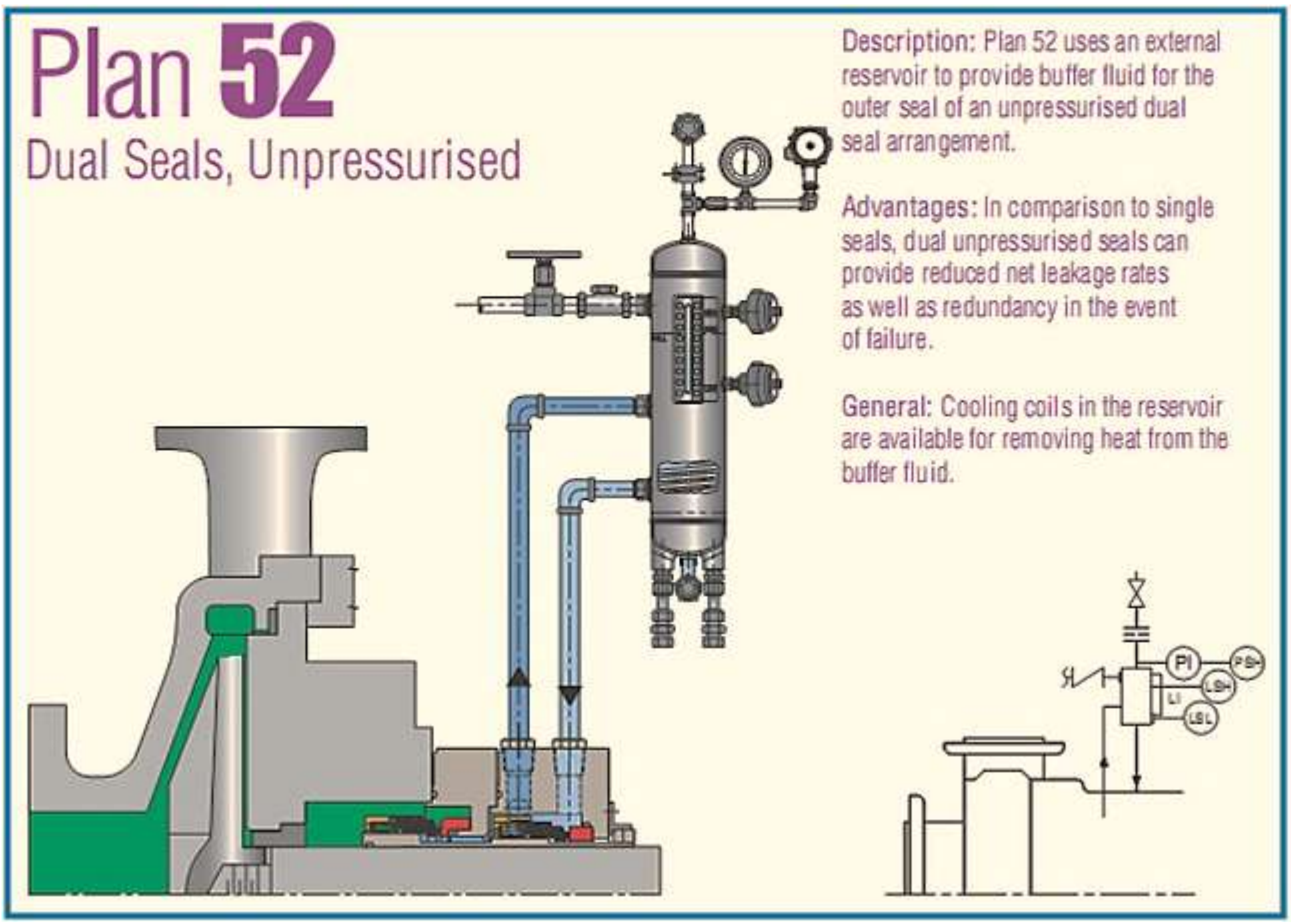
Description: Plan 32 uses a flush stream brought in from an external source to the seal. This plan is almost always used in conjunction with a close clearance throat bushing.

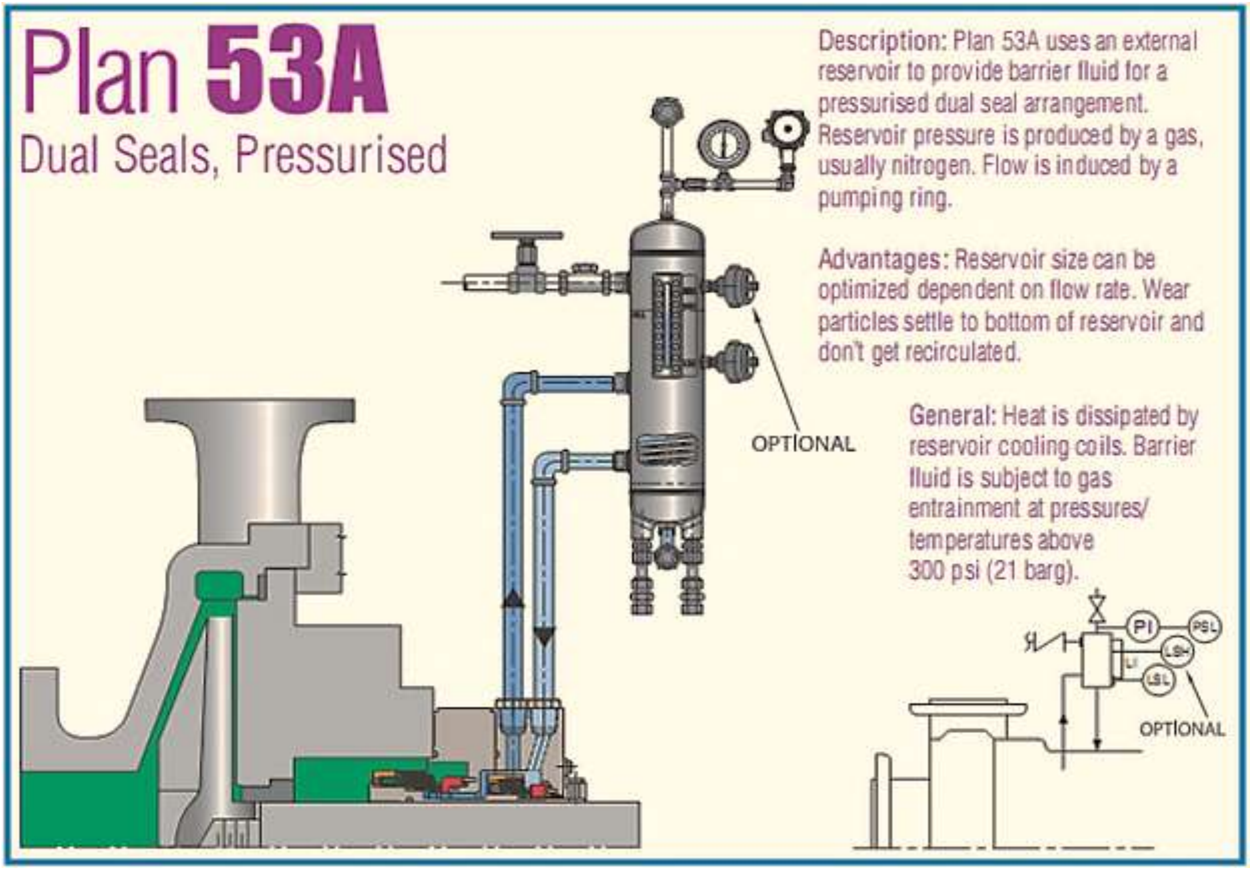
Advantages: The external flush fluid, when selected properly, can result in vastly extended seal life.

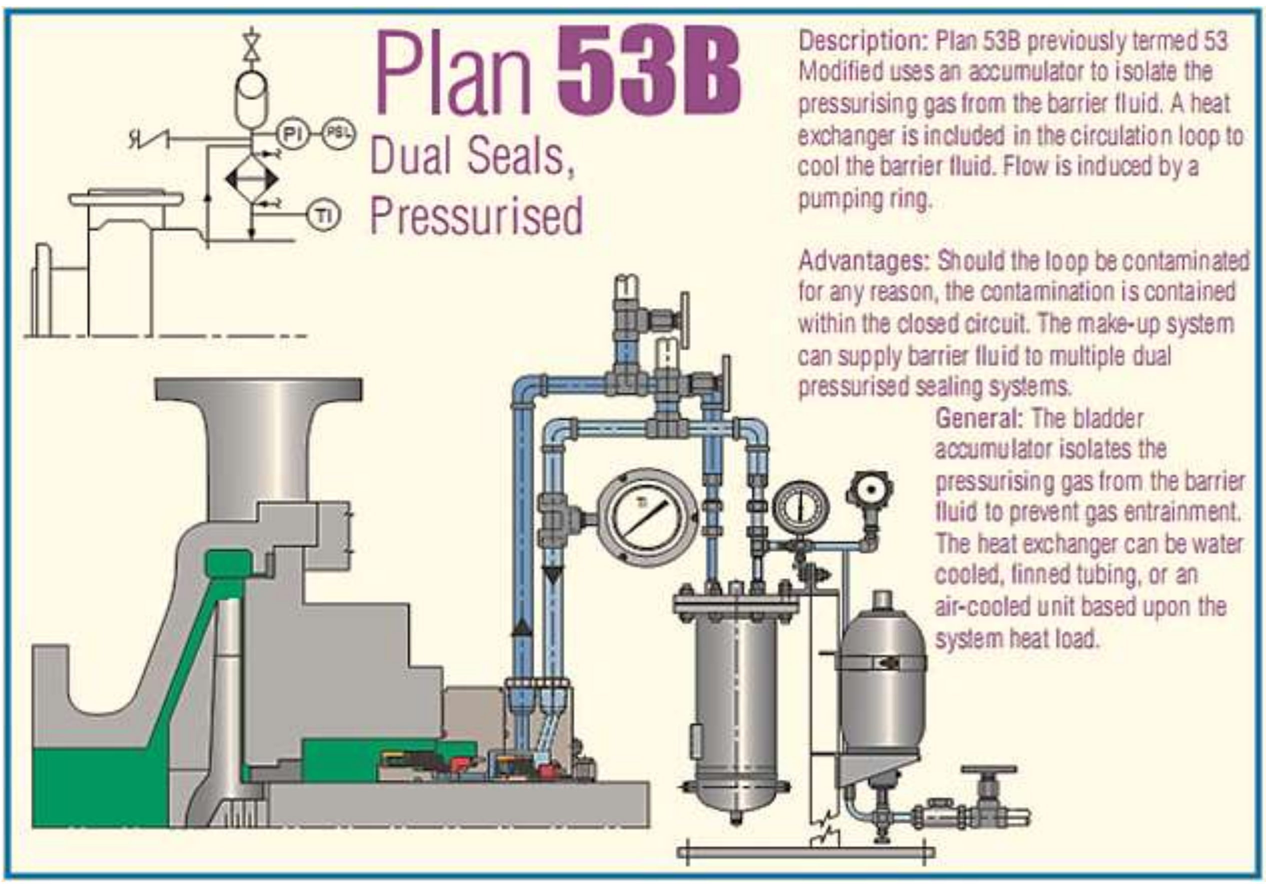
General: When an outside flush source is used, concerns regarding product dilution and/or economics must be considered by the user.

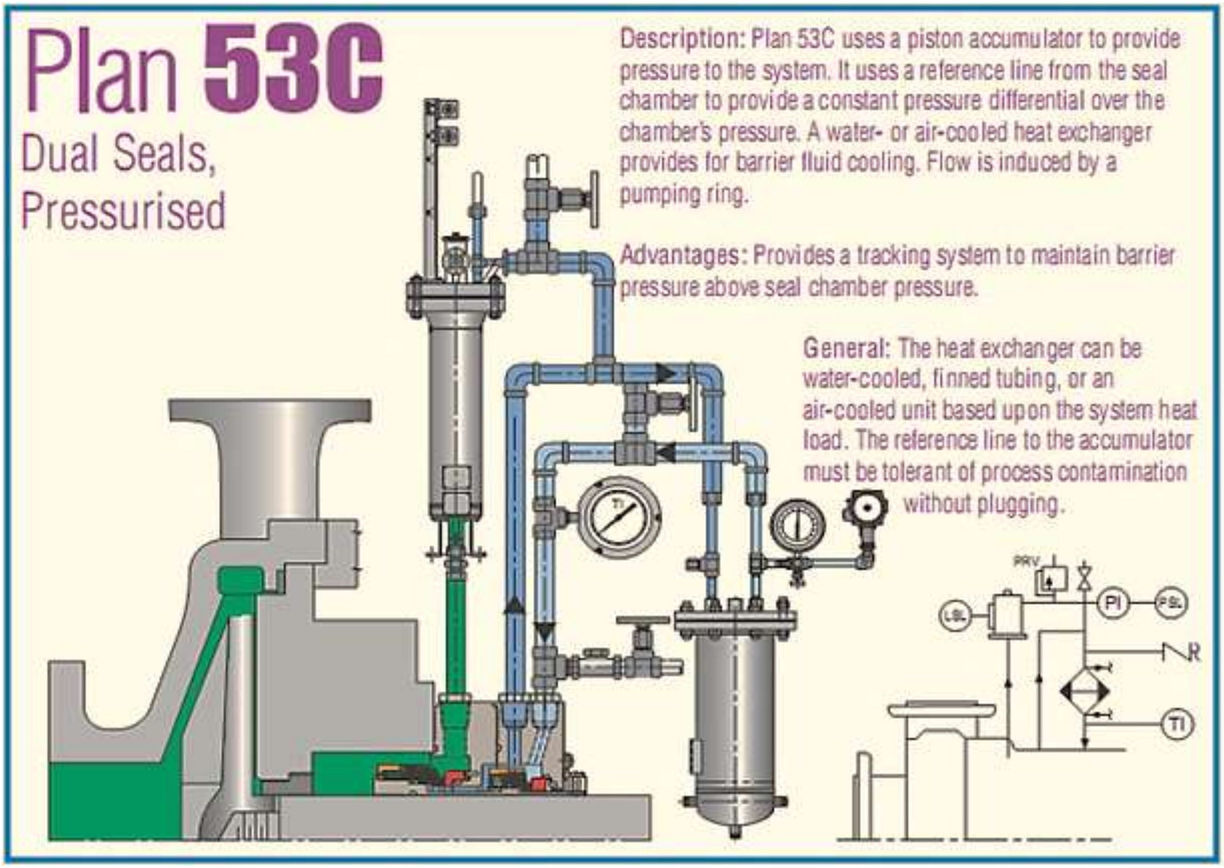


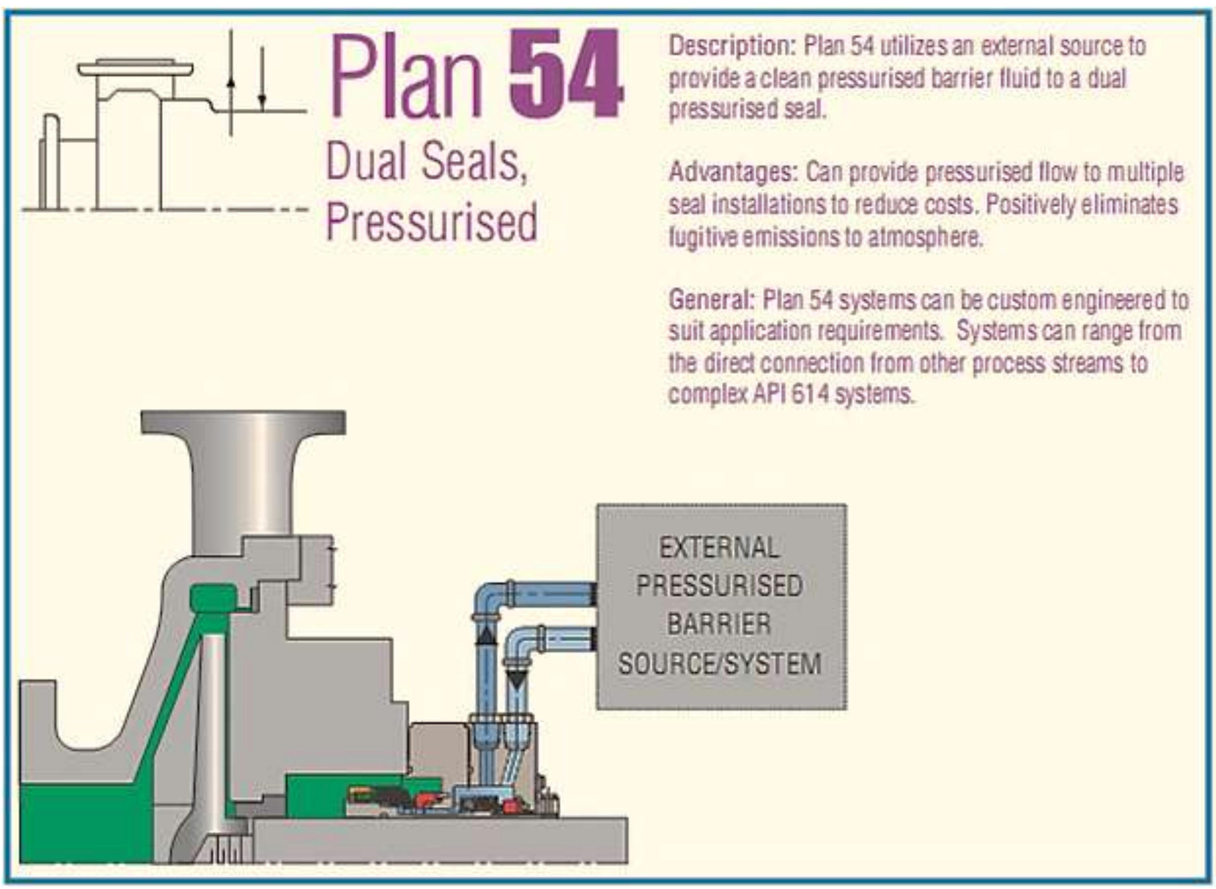

Plan 41
Single Seals
Description: Plan 41 is a combination of Plan 21 and Plan 31. In Plan 41, product from pump discharge is first put through an abrasive separator and then to the heat exchanger before being introduced to the seal chamber.
Advantages: Solids are removed and product temperature is reduced to enhance the seal's environment.
General: Plan 41 is typically used on hot services with solids; however, depending on the temperature of the process, operating costs can be high.
TI

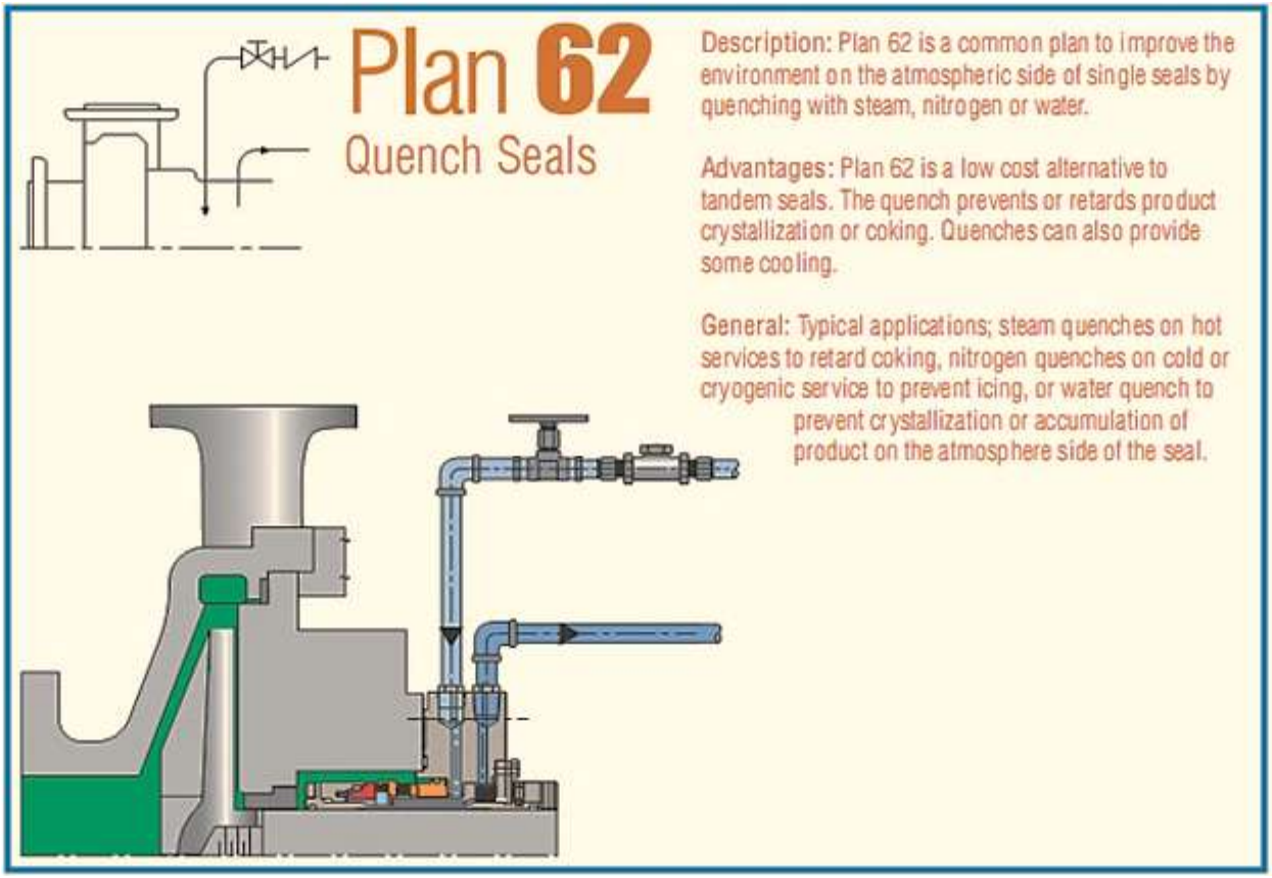

Plan 52
Dual Seals, Unpressurised
Description: Plan 52 uses an external reservoir to provide buffer fluid for the outer seal of an unpressurised dual seal arrangement.
Advantages: In comparison to single seals, dual unpressurised seals can provide reduced net leakage rates as well as redundancy in the event of failure.
General: Cooling coils in the reservoir are available for removing heat from the buffer fluid.
PI
PSH
LSH
LI
LSL

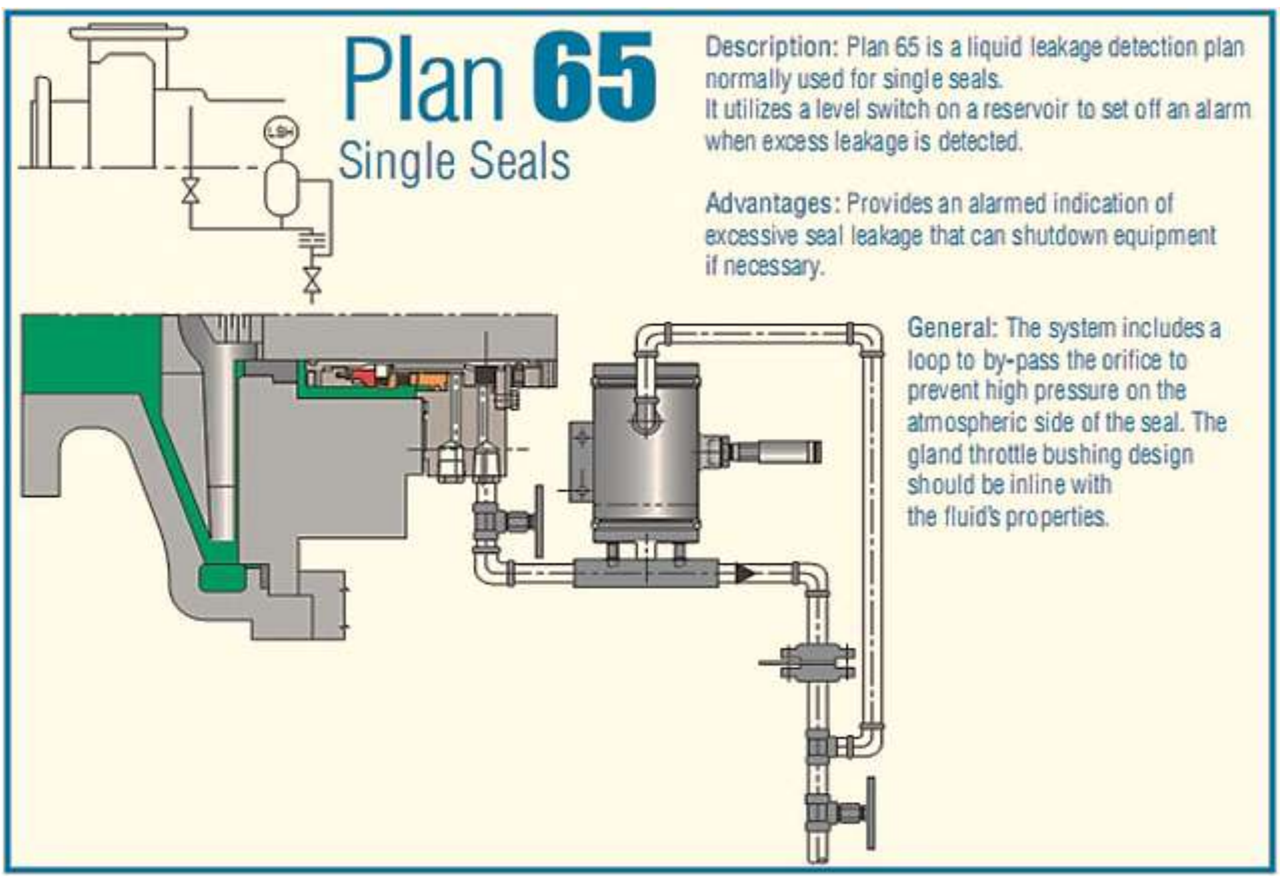

Plan 53A
Dual Seals, Pressurised
Description: Plan 53A uses an external reservoir to provide barrier fluid for a pressurised dual seal arrangement. Reservoir pressure is produced by a gas, usually nitrogen. Flow is induced by a pumping ring.
Advantages: Reservoir size can be optimized dependent on flow 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 (21 barg).
OPTIONAL
PI
PSL
LSH
LSL
OPTIONAL

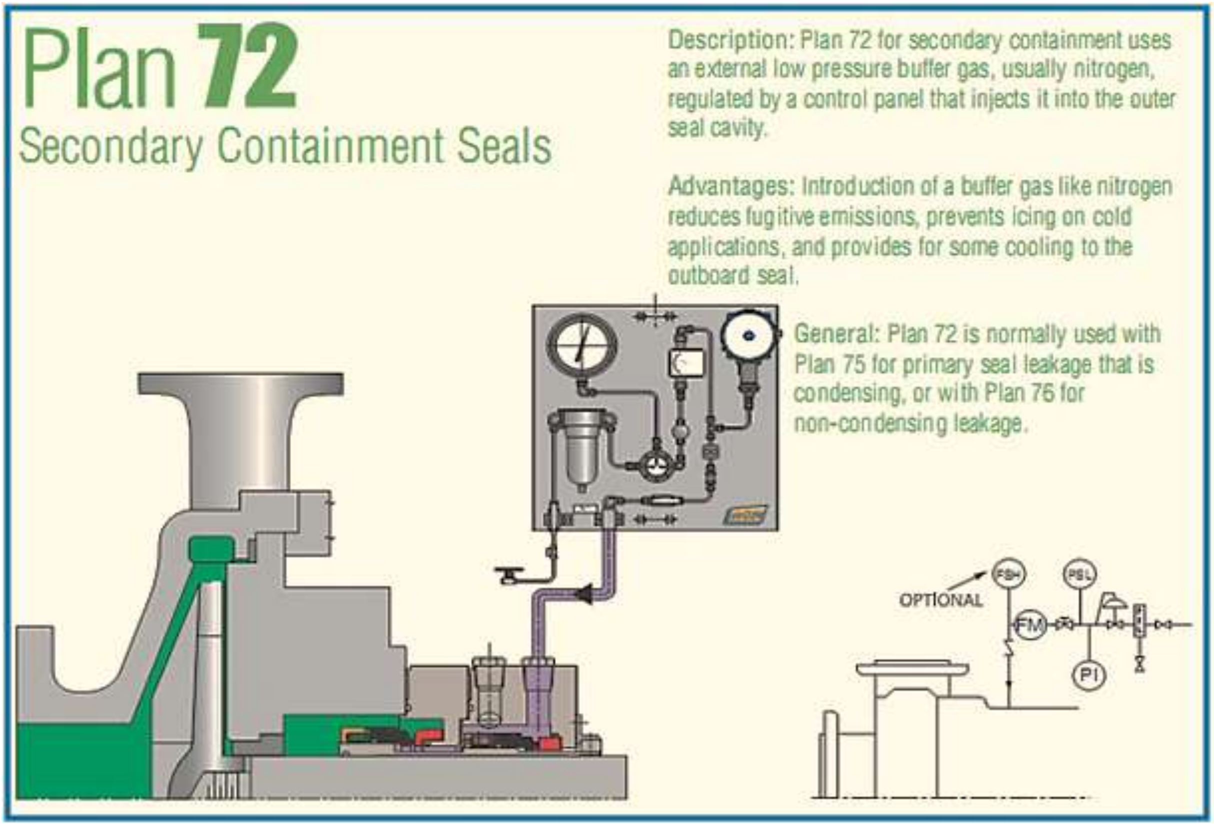

Plan 53B
Dual Seals, Pressurised
Description: Plan 53B previously termed 53 Modified uses an accumulator to isolate the pressurising gas from the barrier fluid. A heat exchanger is included in the circulation loop to cool the barrier fluid. Flow is induced by a pumping ring.
Advantages: Should the loop be contaminated for any reason, the contamination is contained within the closed circuit. The make-up system can supply barrier fluid to multiple dual pressurised sealing systems.
General: The bladder accumulator isolates the pressurising gas from the barrier fluid to prevent gas entrainment. The heat exchanger can be water cooled, finned tubing, or an air-cooled unit based upon the system heat load.
PI
PSL
TI


Plan 53C
Dual Seals, Pressurised
Description: 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 chamber's pressure. A water- or air-cooled heat exchanger provides for barrier fluid cooling. Flow is induced by a pumping ring.
Advantages: Provides a tracking system to maintain barrier pressure above seal chamber pressure.
General: The heat exchanger can be water-cooled, finned tubing, or an air-cooled unit based upon the system heat load. The reference line to the accumulator must be tolerant of process contamination without plugging.
PRV
LSL
PI
PSL
R
TI

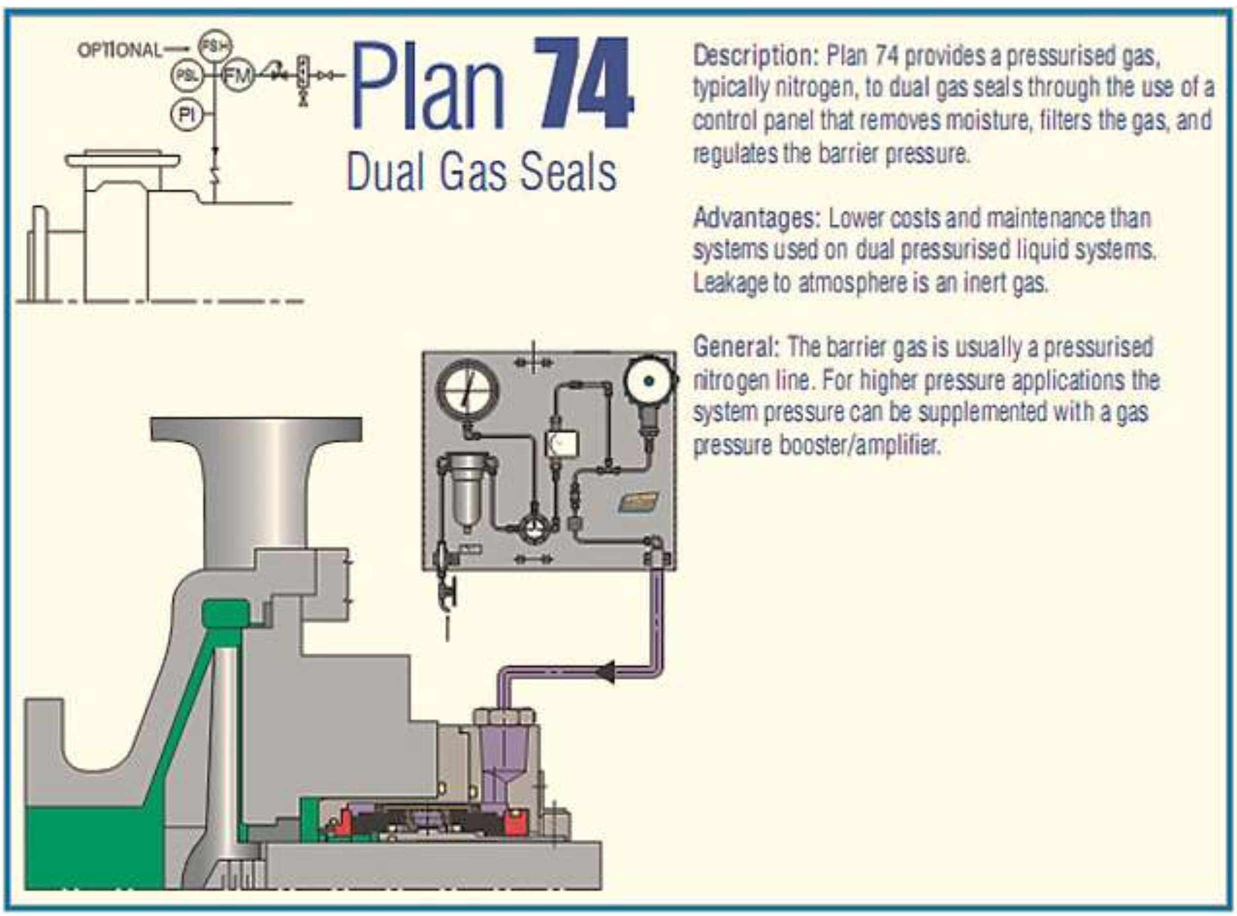

Plan 54
Dual Seals, Pressurised
Description: Plan 54 utilizes an external source to provide a clean pressurised barrier fluid to a dual pressurised seal.
Advantages: Can provide pressurised flow to multiple seal installations to reduce costs. Positively eliminates fugitive emissions to atmosphere.
General: Plan 54 systems can be custom engineered to suit application requirements. Systems can range from the direct connection from other process streams to complex API 614 systems.
EXTERNAL PRESSURISED BARRIER SOURCE/SYSTEM


Plan 62
Quench Seals
Description: Plan 62 is a common plan to improve the environment on the atmospheric side of single seals by quenching with steam, nitrogen or water.
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; 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 atmosphere side of the seal.

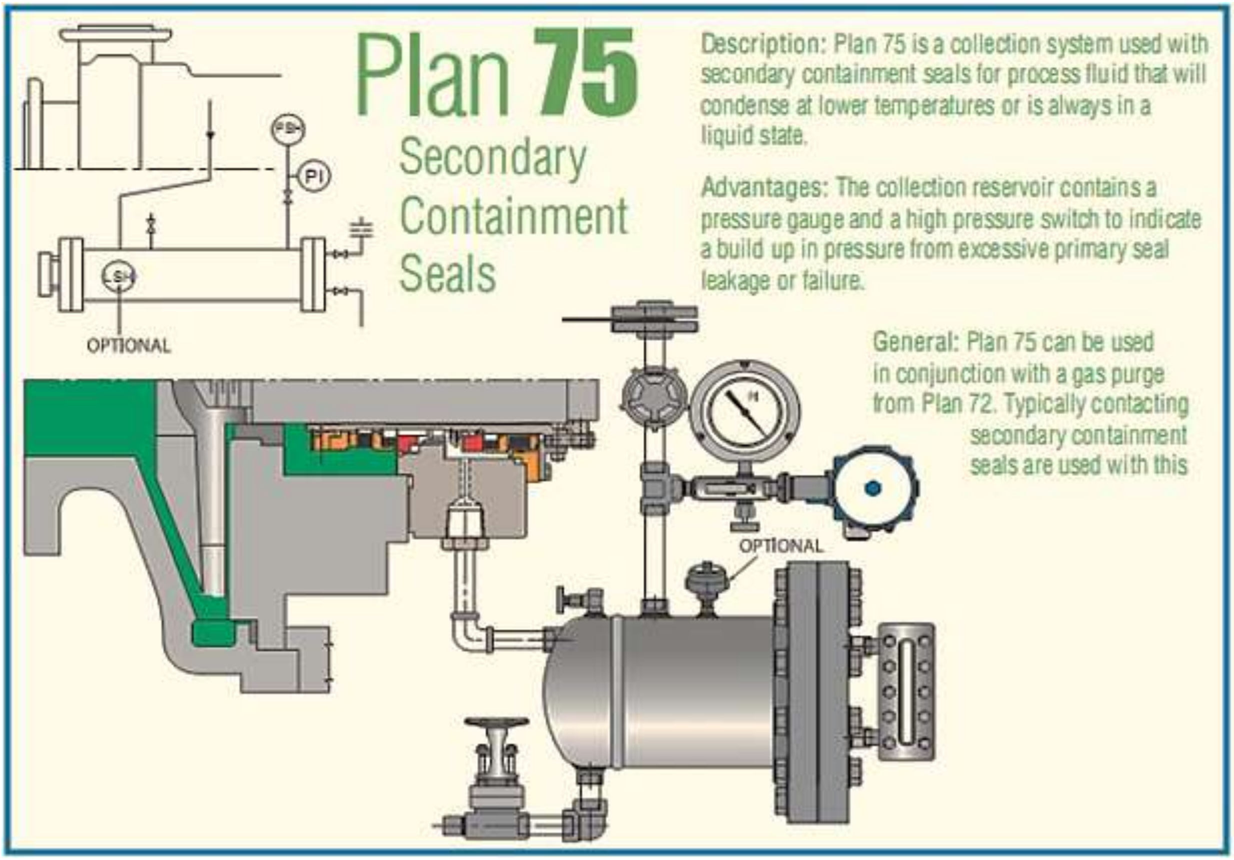

Plan 65
Single Seals
LSH
Description: Plan 65 is a liquid leakage detection plan normally used for single seals.
It utilizes a level switch on a reservoir to set off an alarm when excess leakage is detected.
Advantages: Provides an alarmed indication of excessive seal leakage that can shutdown equipment if necessary.
General: The system includes a loop to by-pass the orifice to prevent high pressure on the atmospheric side of the seal. The gland throttle bushing design should be inline with the fluid's properties.



Plan 72
Secondary Containment Seals
Description: 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.
OPTIONAL
FSH
PSL
FM
PI



OPTIONAL
FSH
PSL
FM
PI
Plan 74
Dual Gas Seals
Description: Plan 74 provides a pressurised gas, typically nitrogen, to dual gas seals through the use of a control panel that removes moisture, filters the gas, and regulates the barrier pressure.
Advantages: Lower costs and maintenance than systems used on dual pressurised liquid systems. Leakage to atmosphere is an inert gas.
General: The barrier gas is usually a pressurised nitrogen line. For higher pressure applications the system pressure can be supplemented with a gas pressure booster/amplifier.


Plan 75
Secondary Containment Seals
Description: 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 contacting secondary containment seals are used with this
PSH
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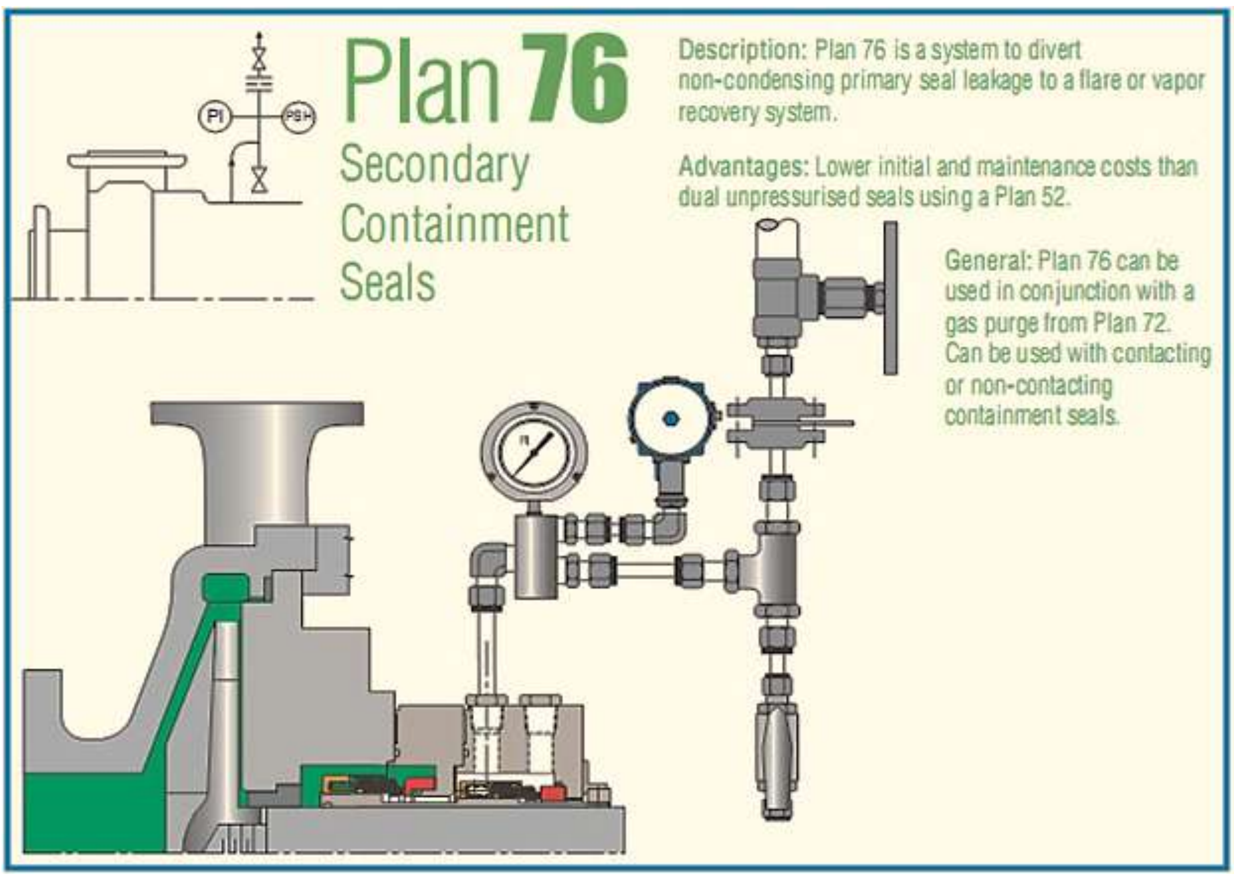

Plan 76
Secondary Containment Seals
Description: Plan 76 is a system to divert non-condensing primary seal leakage to a flare or vapor recovery system.
Advantages: Lower initial and maintenance costs than dual unpressurised seals using a Plan 52.
General: Plan 76 can be used in conjunction with a gas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

2. Common Double Seals Arrangements:

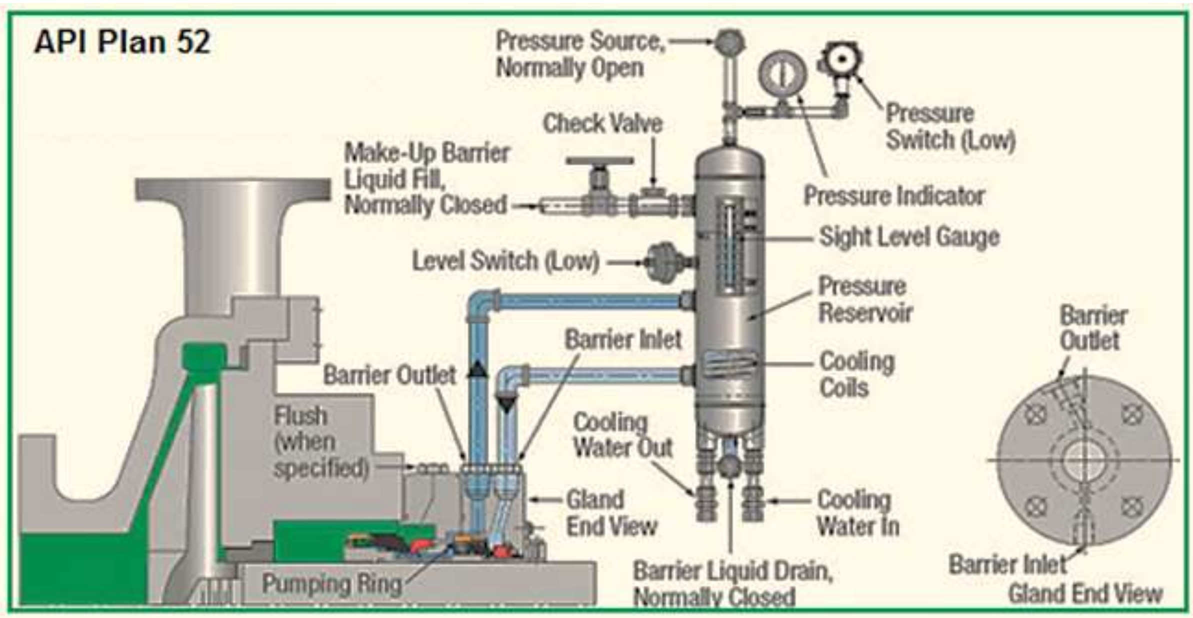
The most **common double seals arrangements** are API Plan 52, 53A, 53B and 53C in API 682, since that **API Plan 53 B and 53 C** have been **added** and **old plan 53** is **renamed** as **API Plan 53 A**. Seal **life** are defined in terms of the **time** period in which the mechanical seal functions properly, under its specified **service**. The descriptions below serve as **guidelines**:

2.1. API Plan 52:

The reservoirs or **fluid tanks** are also standard designed and contain **2 to 5 gallons** of a specified **buffer fluid** to be circulated between two seal arrangements:

- **The product lubricates the inner seal:** The **differential pressure** between the seal chamber and the buffer fluid should be at least **25 psi** to insure the inner seal receives adequate lubrication.

- **The product lubricates the outer seal:** In order to provide a **driving force**, the buffer fluid is maintained with a minimum of **5 to 10 psig,** on the buffer fluid.



The following **guidelines** should be followed when **installing** a **PLAN 52** system with a circulating ring:

1) The **distance** from the bottom of the reservoir to the **centerline** of the shaft should be approximately **12 to 18 inches**. Keep the seal pot as close to the pump as possible. Preferably under 4 feet.

2) Volume of the seal pot is generally **one gallon per inch** of shaft size with a minimum of **2 gallons**. The **fluid level** in the reservoir should be maintained at least one inch above the return line connection.

3) The supply **line** from the **reservoir** to the seal should be at least **0.5" to 0.75" tubing**. From the seal **returning** to the pot, **0.5" tubing** is adequate. The tubing should always have an upward **slope** to the horizontal **runs** in the **return line** to prevent air traps in low spots (1-5 degree slope).

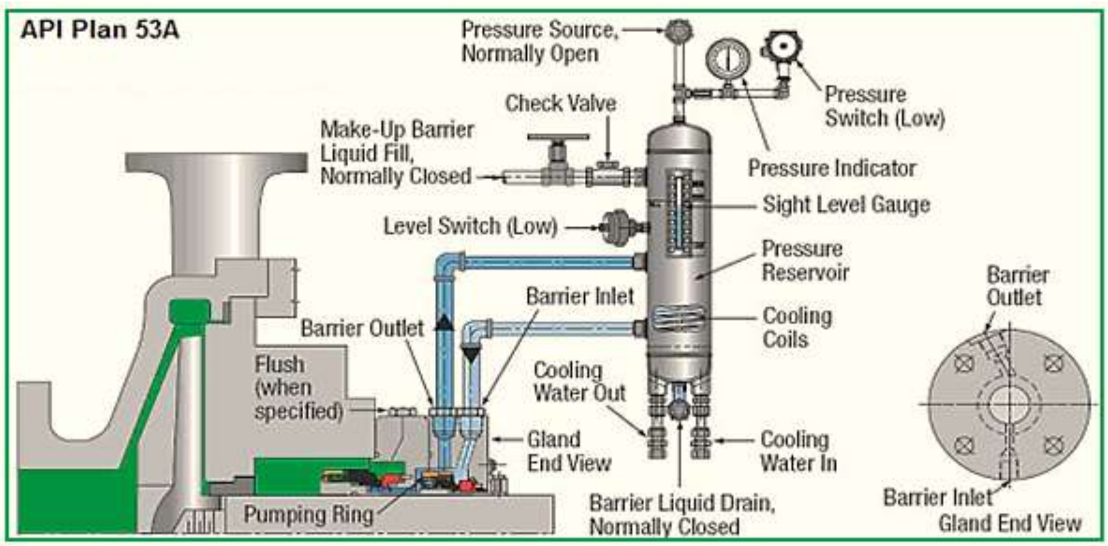
4) For **vapour pressure** more than 5.0 kg/cm² (70 psi), API Plan 52 is **not recommended**. Since the **stuffing box pressure** is **higher** than the **buffer** fluid pressure, the outer seal can be **instrumented** to **detect** an inner seal **failure**.

2.2. API Plan 53A:

Is the **simplest plan** of the three; it has **no moving** parts and is **easy** to operate. The **barrier fluid** is pressurized by an **external source** (nitrogen cylinder or a regulated supply of nitrogen). The API 682 **discourages** this plan **above 150 psi** barrier fluid pressure.

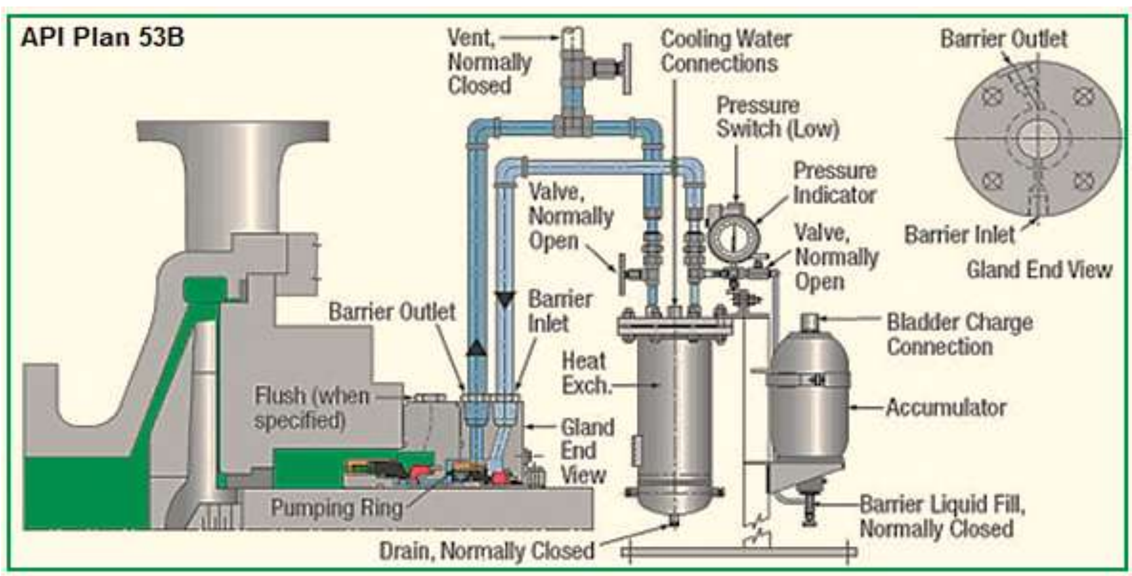
The **reservoir** provides makeup fluid for **normal** seal leakage. Excessive seal leakage is **detected** by a change in **fluid level** in the reservoir. At **higher pressures**, this can lead to significant gas absorption into the **barrier fluid**, resulting in **poor seal** performance.

The **primary disadvantage** of this plan is that there is an **interface** between the **pressurization gas** and the **barrier fluid**. The barrier fluid pressure is maintained **higher** than the maximum stuffing box press.



2.3. API Plan 53B:

This system is a **dual pressurized system** that **eliminates** direct gas contact with the barrier liquid using a **bladder accumulator**, which acts as a barrier between the gas and the barrier fluid. The **pressurizing gas** does not come into direct contact with the barrier fluid.



The **bladder** is pressurized with **gas** prior to **filling** the system with barrier liquid. As the system is filled, the bladder is **compressed**, thus provides a **positive pressure** on the barrier liquid.

Only **small** a volume of **liquid** is in circulation, therefore chances of thermal **degradation** of barrier liquid is more difficult. The circulation of barrier **fluid quantity** is reduced (in comparison with API Plan 53A) due to additional **cooler**.

The disadvantage is that the barrier **fluid pressure** is maintained **higher** than the maximum stuffing box press. Then it keeps maximum **pressure** on the seal faces all the time.

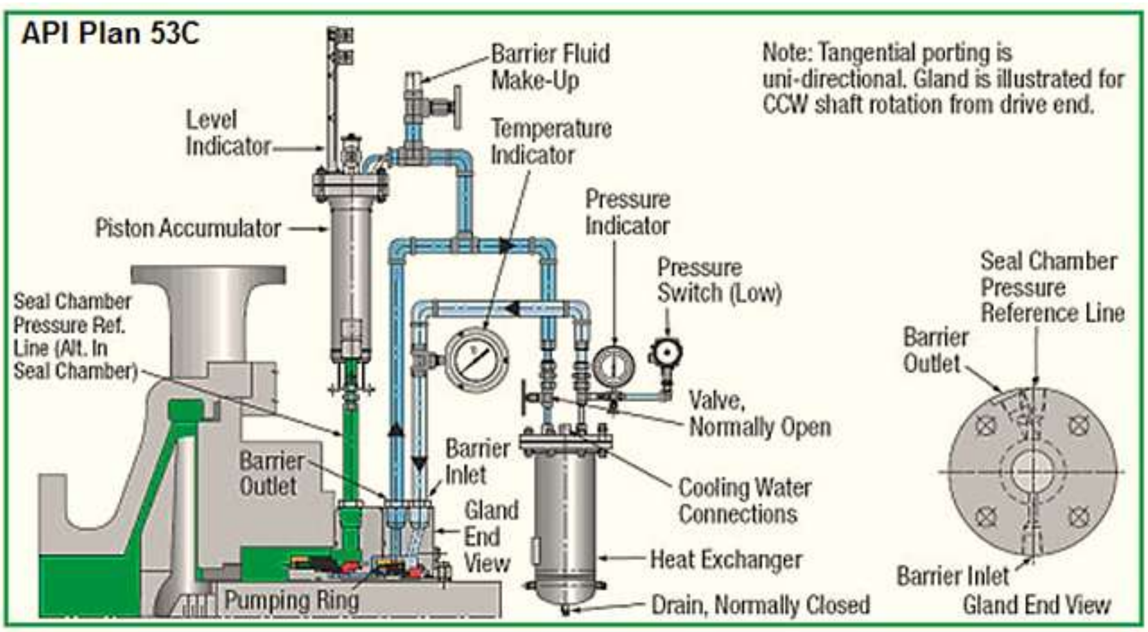
2.4. API Plan 53C:

This arrangement is also a **dual pressurized system** that **eliminates** the use of **gas** for pressurization through the use of a **piston accumulator**. Barrier liquid is **stored** on the **topside** of the piston and the seal chamber is **connected** to the bottom of the piston accumulator.

Piston design is such, that a **slightly higher pressure** (about 1.0 to 2.0 kg/cm^2) is **generated** at the top of the **accumulator**. The top portion of accumulator is **connected** into the **seal loop**. Since the piston accumulator **pressurizes** the barrier fluid, based on the **stuffing box** pressure, the barrier pressure automatically **tracks** actual operating conditions including system upset.

The barrier fluid pressure is maintained **slightly higher** than stuffing box pressure and so there is no need of **Nitrogen** pressurization. Only a **minimum** instrumentation is required, for a **low liquid alarm** and the **differential** pressure alarm.

Disadvantages: There is a chance of a piston **slow movement** and in the cases of **small leakage**, the response may be **poor**. Also only **small** volume of liquid is in circulation, therefore, there are also chances of **thermal degradation** of the barrier liquid.



3. Type, Grade and Class:

The **ASTM F1511 – 11** specification also covers **mechanical end-face seals** for centrifugal and positive displacement pumps for **shipboard** use. Mechanical seals shall be classified by type, grade, and class.

Types: **Type A** - inside single mounted seals; **Type B** - outside single mounted seals; **Type C** - double seals; **Type D** - tandem seals; **Type E** - gas seal; and **Type F** - special arrangements and applications for vacuum or gas seal.

Grades: **Grade 1** - basic end face seal; **Grade 2** - cartridge seal; and **Grade 3** - split seal.

Classes: **Class 0** – non-split seal assembly; **Class 1** - partial split seal assembly; solid gland, **Class 2** - partial split seal assembly; split gland; **Class 3** - fully split seal assembly; solid gland; and **Class 4** - fully assembly split gland.

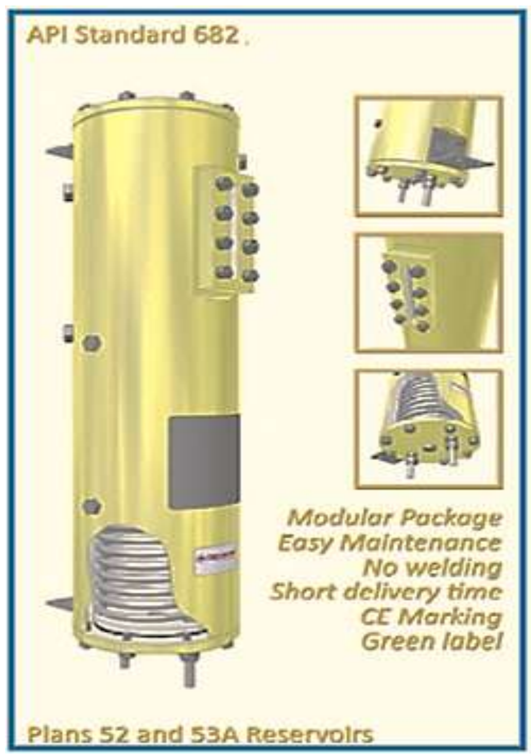
4. Seal Support Reservoirs or Fluid Tanks:

Seal support **tanks or reservoirs** are installed with the involved **rotary equipment**, commonly with **pumping stations**, to supply a **lubrication system** or **buffer barrier fluids**.

These reservoirs provide **volumetric storage** for the barrier or buffer fluid, and also frequently include an integral **cooling coil** to facilitate **removal** of **heat** generated by the mechanical seal.

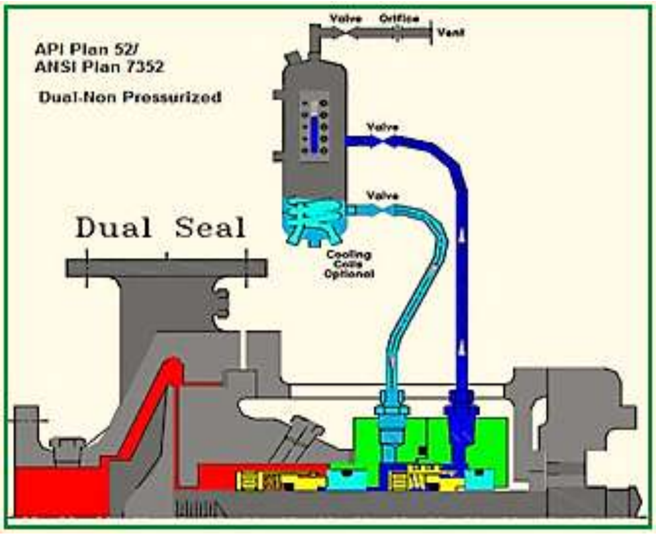
However, seal reservoirs sometimes become a collection point for **contaminates** and **abrasion** products. In this issue, this demonstrates how a lower initial cost **welded reservoir** may be more costly over its lifetime than its initially more expensive **flanged counterpart**.

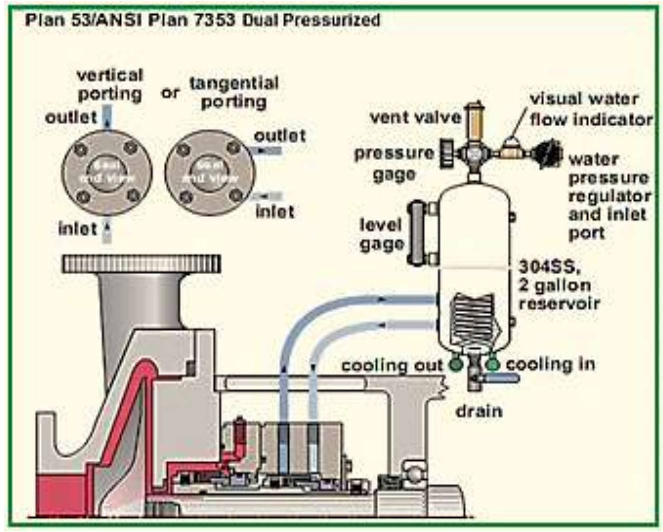
All tanks or reservoirs are **designed** in accordance with **ASME Code Section VIII**, **Division 1**, and **welded** according to **ASME Section IX**, including inlet, outlet, vent and fill along with two mounting lugs as minimum connections.



Note: Many **pumping stations** or **rotary equipment** in industrial applications utilize **dual** (double or tandem) mechanical seals. The **barrier** or buffer system that supports this type of seal frequently **includes** a **tank or a reservoir** defined according to **API Standards**.

The **dual non-pressurized** (API Plan 52/ANSI Plan 7352) and **dual pressurized** systems (API Plan 53/ANSI Plan 7353) are shown below:





5. Seal Support Systems API 610/682 - Changes from 8th through 10th Editions:

Item	8th Edition	9th/10th Edition *
Pump Types	• Rigid coupled in-lines, horizontal foot mounted overhung, and built in mechanical seal pumps added to list requiring customer approval. • In-line pump must be bearing frame type unless specified by the purchaser.	Foot mounted design now allowed, when approved by a customer, if service temp. is < 150 °C (300 °F).
Casing design pressure	Design pressure no less than 600 psig	No change.
Flanges	300 RF minimum implied (based on 600 psig casing design pressure)	No change.
Casing joints	Metal to metal joint with confined controlled compression gasket	No change.
Bolting	Studs and nuts required. Cap screws require purchase approval	No change.
Casing mount	Centerline mounting required for horizontal overhung pumps. • Casing mount (with baseplate) must be sufficiently rigid to limit coupling end shaft displacement to levels permitted by API 610. A bearing housing support (frame foot) cannot be used.	Still requires centerline mounting for horizontal overhung pumps except, when approved by customer, foot mounted horizontal overhung may be used if service temperature is < 150 °C (300 °F).
Auxiliary connections to casing	Minimum Schedule 160	No change.
Casing vent	Need for venting based on capability to prevent loss of prime during starting sequence	No change.
Shaft Concentricity	Concentricity limit specified at 0.001 inch	No change.

6. Quenching Flow Rate (Standard):

Quenching fluid:	Flow rate:
Water:	1~2 l/min
Steam:	0.5 kg/h
N2 Gas:	0.3 kg/h

7. Examples for Sealing and Material Code:

BSTFO = Balanced, **single-acting** mechanical seal, **throttle bush**, dynamic and static secondary seals (o´rings) made of FKM and seal faces/ secondary seats of **tungsten carbide** against **silicon carbide**.

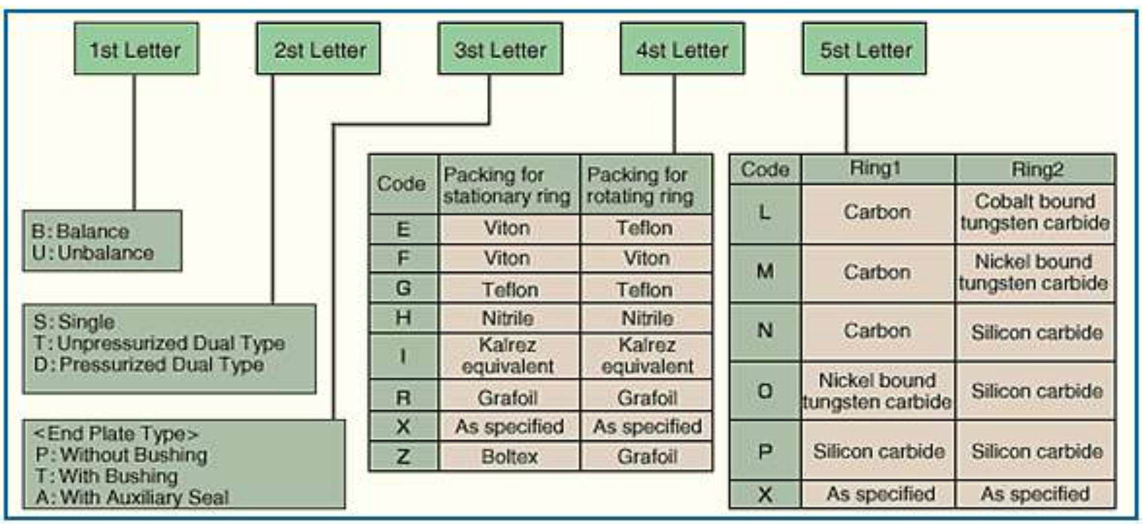
8. Example of Designation to API 682:

Mechanical Seal - C2 A1 A 3161 is a Mechanical Seal according to:

Category: C2 - up to 41 bar; 400°C;
Arrangement: A1 - single seal/cartridge;
Seal type A: Balanced, inboard, pusher type seal;
3161: API plan 31 and 61.

API standards are referred to **world-wide**, mainly in the area of Refineries, Oil & Gas and Petrochemical industries. **API 610** and **API 682** are relevant for mechanical seals and pumps. **API 682** (3rd edition) specifies different Sealing Systems using as parameters - category, arrangement and API plan(s).

API Mechanical Seals Designations:



1st letter: **B** = Balanced;
U = Unbalanced.

2nd letter: **S** = Single-acting;
T = Double-acting (tandem/ unpressurized);
D = Double-acting (pressurized with barrier pressure).

3rd letter: **P** = Plain, without throttle bush;
T = Throttle bush with quench, leakage and / or drainage connection;
A = Additional/ auxiliary seal (has to be stated).

4th letter: Secondary Seal Materials.

5th letter: Face Materials.

9. Mechanical Seals Materials:

9.1. Silicon Carbide:

Silicon Carbide: Is a bluish-black material created by **fusing silica and coke**. It is in the same family as **Ceramic** (due to the Silica), but has much better **lubrication** qualities and is **harder**. The most common silicon carbide used in a mechanical seal is **reaction-bonded** silicon carbide.

In chemical applications, however, **Sintered Silicon Carbide** may be recommended. However, Sintered Silicon carbide sacrifices the **pressure velocity ratios** due to the **lack** of **unreacted** free carbon. Either grade of SIC can usually be **re-lapped** and **polished** to be reused.

9.2. Tungsten Carbide:

Tungsten Carbide: A very versatile seal face like the silicon carbide. it is a chemical compound containing equal parts of **tungsten and carbon atoms**. In its most basic form, tungsten carbide is a **fine gray powder**, but it can be **pressed** and formed into shapes through a process called **sintering** for use in industrial machinery, cutting tools, abrasives, other tools and instruments, and jewelry. Tungsten carbides generally come in two primary types:

- Nickel Bound (Ammonia applications should be avoided);
- Cobalt Bound (May be used in Ammonia).

Ideal for **high pressure applications** due to a high modulus of elasticity, which helps **prevent** face distortion. Tungsten carbide also can be **re-lapped** and polished to be **re-used**. The most common complaint of Tungsten Carbide seal faces is "**Leaching**" that is **caused** by chemicals like **Ammonia**. It causes minor **leakage** and a large increase in the **wear** of the opposing seal face (especially carbon).

9.3. Carbon:

Carbon: Is the most **often** used seal face. Carbon has excellent **anti-frictional** qualities and is compatible with an extremely **wide range** of temperatures and **corrosive environments**. It is not however **good** in **abrasive** applications. Synthetic carbon is a resin-impregnated **carbon graphite**. The final resin impregnation is only used to make the **carbon gas-tight**, and only penetrates the **surface** of the part.

Note: Pure Carbon P-658RC is the preferred **grade** and is standard in all ASP seals. “Machinable” grades often used by seal **repair shops** are manufactured to be **porous**, so that the resin impregnation penetrates the entire part. Carbon is **not acceptable** in the presence of a strong **oxidizing** agent.

9.4. Ceramic:

Ceramic: Generally is a **99.5% aluminum oxide** that offers excellent **wear characteristics** due to its **hardness**. It is chemically inert and can be **applied** to nearly any product. However, ceramic cannot handle the **thermal shocks** that **Ni-resist** seats can. So, ceramic 99.5% pure aluminum oxide (alumina) is always preferred. Lower **purity grades** (typically 85%) are available, but are more **subject** to chemical **attack** and thermal shock.

9.5. Ni-Resist:

Ni-resist: Is a form of **white iron alloy**, which has **nickel** added to it to **lower** the friction generated by the **rotating** face. It is an **inexpensive** seal face and ideal for **fresh water** applications.

9.6. GFPTFE:

Glass Filled PTFE: Or also known as Teflon (R). Gives the chemical resistance of PTFE, however **glass** must be **added** to give the face **hardness**, and to **prevent** cold flow issues associated with PTFE.

9.7. Metal Components:

AISI 316 Stainless Steel: Can usually be specified for **seal** components. For springs, **Hastelloy C-276** resists stress **corrosion** cracking and is **standard** in all ASP seals.

10. O'rings - Elastomers Application:

Fluorocarbon (Viton or Fluorel): Hardness 75 is preferred. **Avoid** colored (brown or green) grades; the **clay fillers** used to replace **carbon** black are subject to **chemical attack**. - 15°F to +400 °F.

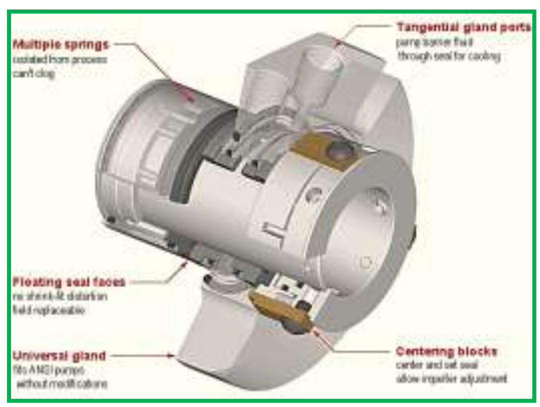
Ethylene Propylene (EP, EPR, EPDM): Peroxide cured grades are **preferred**. -65 °F to +300 °F.

Neoprene: Excellent for sealing **refrigeration** fluids such as Freon ®. -65 °F to +250 °F.

Aflas: Preferred for combinations of **oil and amines or ammonia**: sour crude oil, sour gas, refrigeration. -20 °F to +400 °F.

Obs.: When **selecting** an **o-ring compound**, be sure to **consider** not only the main **fluid pumped**, but also the **minor** constituents of the pumpage, and any **fluid** used periodically to clean out the system.

11. Example of a Mechanical Seal Specification:



1. Features:

- Cartridge, seal design as per API 682 / ISO 21049;
- Dual seals according to API Plan 52 / 53;
- Category 1, type A, Arrangements 1, 2 and 3;
- Balanced, shrink-fitted seal faces;
- Solid seats, single seal with API Plan 11 and 61;

2. Operating Range:

- Shaft diameter: d1 = 20 to 110 mm (0.75 in. to 4.3 in.);
- Pressure: p1 = 22 bar (319 psi);
- Temperature: t = -40 °C to 260 °C (-40 °F to 500 °F);
- Sliding velocity: v = 23 m/s (75 ft/s).
- Concentricity limit at 0.001 inch.

3. Materials:

- Seal face: Silicon carbide sintered;
- Seat: Silicon carbide sintered;
- Secondary seals: NBR or EPDM;
- Springs: Hastelloy;
- Metal parts: CrNiMo Steel.

4. Recommended Applications:

- Chemical, Petrochemical, Oil & Gas industry;
- Highly viscous hydrocarbons;
- Toxic and hazardous media;
- Low solids content and low abrasive media;
- Vertical ANSI chemical standard pumps.

VIII. BARRIER AND BUFFER FLUID SELECTION:

According to API 682, a **fluid** between two seals in a **dual seal** at **higher** pressure than the pump process pressure is a **barrier fluid**. The dual seal pressurized this way is also called a **double seal**. The barrier fluid completely isolates the **pumped process fluid** from the **environment**. Dual seals with **buffer fluid**s are called **tandem seals**. The **buffer fluid** should be at **lower** pressure than pump process pressure.

A barrier or buffer fluid should be:

- Compatible with the process, to the environment and the workers;
- Compatible with the seal materials;
- A good lubricant and heat transfer medium for the seal faces.

Some good choices for barrier and buffer fluids:

- **Water/Ethylene Glycol Mixture:** Almost as good as water for heat transfer; doesn't **freeze** in outdoor applications. Mix **50%/50%** by volume is easiest to mix, and gives good freeze **protection**. Use a corrosion-inhibited industrial grade.

- **Water:** Excellent heat transfer characteristics. **Cannot** be used in **freezing** conditions.

- **Water/Propylene Glycol mixture:** Water/ethylene glycol, but usable in **food** applications.

- **Kerosene or Diesel Fuel:** Low **viscosity** to flow well and transfer **heat** and a good lubricant. Low emissions of **vapor** pressure aren't a problem.

- **Light Mineral and Synthetic Oils:** Generally good. Within synthetics, polyalphaolefin (PAO) based fluids usually better than **ester-based**. Synthetic oils specifically **formulated** for use as mechanical seal **barrier fluids** are available, including grades accepted by FDA and USDA.

1. Barrier and Buffer Fluid Installation:

Dual mechanical seals require that the **barrier or buffer liquid** be introduced between the seals for **cooling** and **lubrication**. The most economical and commonly used method is a **reservoir** piped to the seal. The reservoir can be used in **remote** locations without elaborate piping systems.

The **dual seal** with barrier fluid pressure, **greater** than the process pressure is often called a **double seal**. This mode of pressurization **prevents** leakage of product into the reservoir or to the environment. Reservoir pressure is usually maintained at **15-30 psi (1-2 bar)** greater than process pressure. Bottled **nitrogen and compressed air**, when available in the plant, are also common sources of pressure.

Dual seals with **buffer fluid**s are called **tandem seals**. The **buffer fluid** should be at **lower** pressure than pump process pressure. The reservoir may be **pressurized** to split the pressure between **inboard** and **outboard** seals or to force the **buffer** liquid between the outboard seal faces for lubrication. Product leakage is contained by the reservoir.

A process fluid that is pumped as a **liquid**, but also exists as a **gas** at **atmospheric conditions**, such as a **light hydrocarbon**, may be **sealed** using a **dual seal** system with an **unpressurized** buffer fluid. An **immiscible** buffer fluid, such as **diesel fuel** may be used. Any product that **leaks** through the inboard seal **bubbles up** through the **buffer** liquid in the reservoir, where it can be **vented** to a flare.

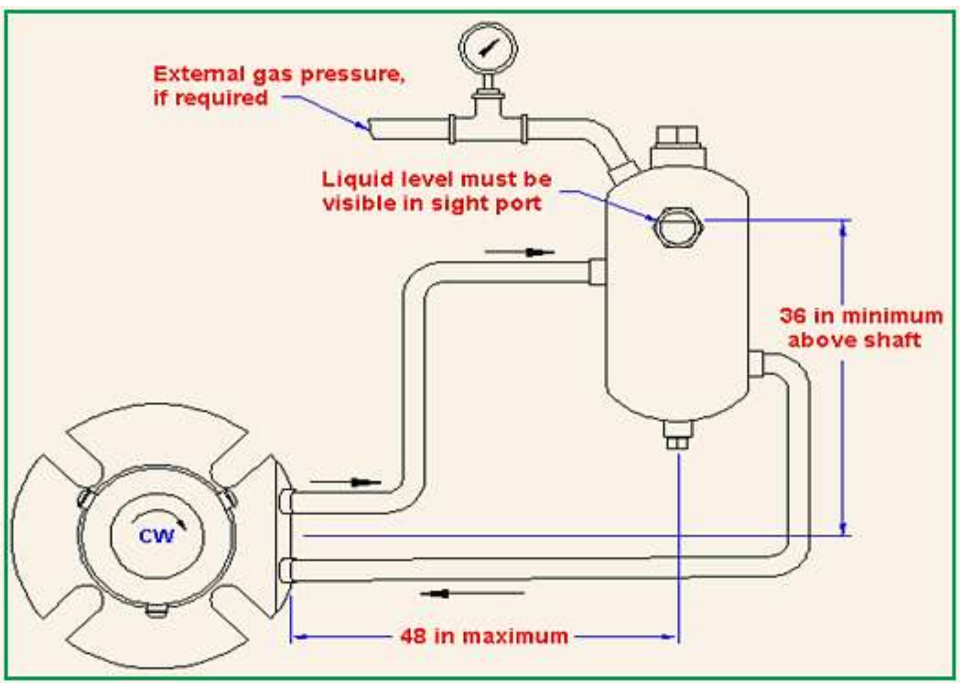
2. Installation:

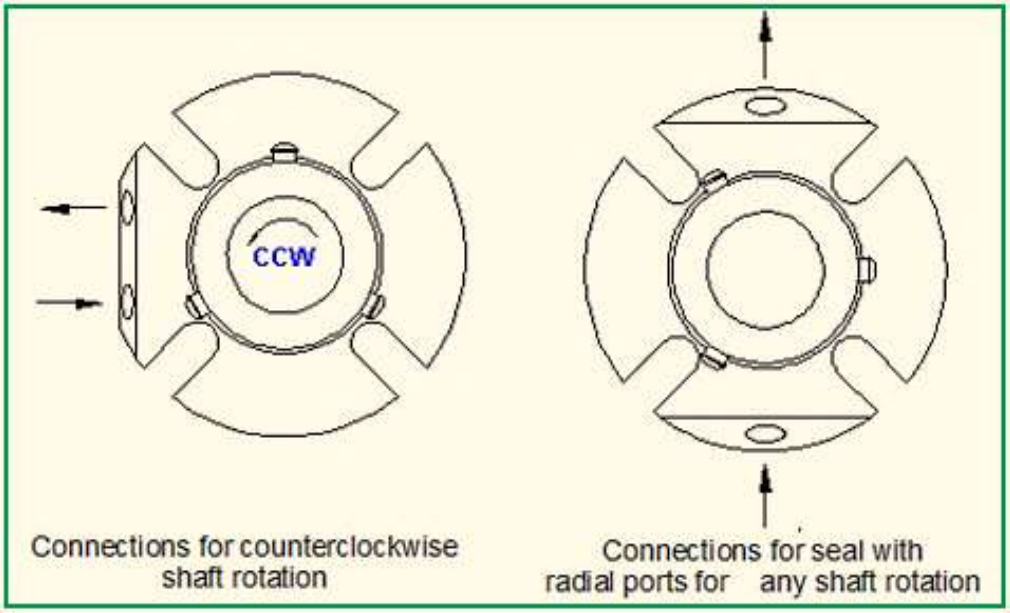
Locate the **reservoir not more** than **4 feet** (1.2 m) from the **seal**, with the bottom of the reservoir **12-18 inches (30-45 cm) above** the centerline of the **pump shaft**. Mount the reservoir to a **rigid support** where a **sightglass** can be easily **visible** for **inspection** and where the fill ports are accessible.

Fill the **reservoir** to the **center** of the **sightglass**. This provides **enough** barrier liquid to **allow** for losses, while leaving headspace in the reservoir to allow for **thermal expansion**. Eliminate any **air trapped** in the seal or piping by loosening the fittings on the seal gland temporarily.

3. Monitoring:

Reservoir pressure **variation** caused by **thermal expansion** is **normal**. Rising liquid level in the reservoir indicates **leakage** of product past the inboard seal of a **tandem seal**. If the level **drops** slowly, the **barrier liquid should be replenished**. Rapidly dropping liquid level without visible leakage of the outboard seal or piping **indicates** inboard seal leakage into the product.





4. Mechanical Seals Selection:

It´s very important to know the full operating conditions to go on with the proper selection of a mechanical seal. The conditions to be checked are:

Type of Liquid: Identification of the exact liquid to be handled is the first step in seal selection. The metal parts and mating faces must be corrosion resistant, usually steel, bronze, stainless steel, or Hastelloy.

Carbon, ceramic, silicon carbide or tungsten carbide may be considered. Stationary sealing members of Buna, EPR, Viton and Teflon are common.

Characteristics of Liquid: Abrasive liquids create excessive wear and short seal life. Double seals or clear liquid flushing from an external source allow the use of mechanical seals on these difficult liquids. On light hydrocarbons balanced seals are often used for longer seal life even though pressures are low.

Pressure: The proper type of seal, balanced or unbalanced, is based on the pressure on the seal and on the seal size.

Temperature: In part, determines the use of the sealing members. Materials must be selected to handle liquid temperature.

Reliability and Emission Concerns: The seal type and arrangement selected must meet the desired reliability and emission standards for the pump application. Double seals and double gas barrier seals are becoming the seals of choice.

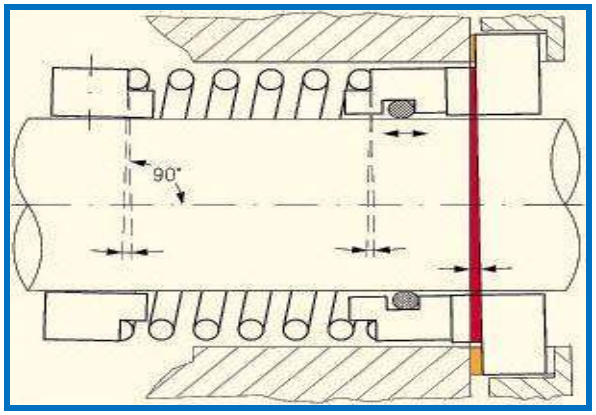
5. O´Ring Elastomers Selection:

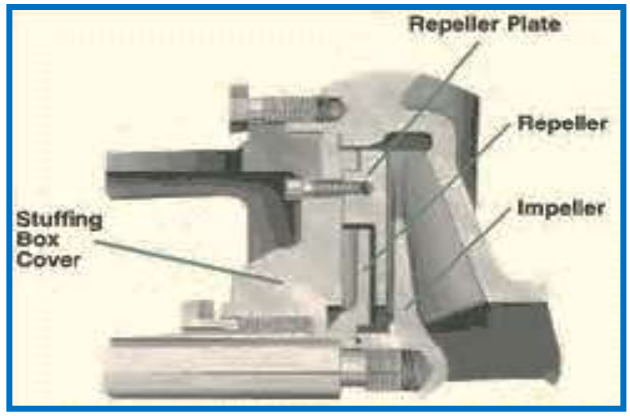
Ò Ring Elastomers: The basic core **polymer** of an elastomeric **compound** is a **rubber**, produced either as **natural** gum **rubber** or manufactured synthetically by the chemical industry. To make **reliable selection** of **O-ring compounds** for use in **mechanical seals**, all constituents of the **sealed fluid** must be known. O-rings can also be **degraded** by **fluids used periodically to clean** the pumping system. Although detailed checking of each constituent is required to ensure proper **elastomer selection**, the few **simple guidelines,** below, can provide a starting point.

Fluoroelastomer (Viton®, Fluorel™): Fluoroelastomers or fluorocarbons O-rings have excellent physical properties and compression set resistance.	
Recommended: Oils Water, including wastewater Acids (many) Benzene, toluene Chlorine, chlorinated solvents Ethylene glycol	**Not recommended:** Caustics, alkalis Ketones (acetone, MEK) Amines, ammonia Ethers Acetic acid Steam
Ethylene Propylene (EP, EPT, and EPDM): EP resists caustics, and is commonly used in pulp and paper processing. EP is the first choice for hot water and steam service. EP is rapidly attacked by petroleum oils and greases, so be sure to use silicone lubricant when installing EP O-rings.	
Recommended: Steam, hot water Caustics Ketones (acetone, MEK) Acetic acid Ethylene glycol Ethanol	**Not recommended:** Oils, most lubricants Acids Benzene, toluene Hydrocarbons (aromatic and aliphatic) Ethers
Aflas™ (tetrafluoroethyene/propylene dipolymer): Aflas resists combinations of amines and oils, and is therefore used in sour oil and gas and in refrigeration applications. Cost is comparable to fluoroelastomers.	
Recommended: Sour oil and gas Oils, lubricants Amines, ammonia Steam, hot water Acids Caustics	**Not recommended:** Toluene Non-polar solvents Ethers Ketones Chlorinated solvents Acetic acid
Kalrez® (perfluoroelastomer): Perfluoroelastomers resist high temperatures and a wide range of chemicals. Compression set resistance is inferior to fluoroelastomers. Cost is high, approaching 100 times that of fluoroelastomers.	
Recommended: Almost all chemicals:	**Not recommended:** Where other elastomers can be used

IX. DYNAMIC SEALS:

Dynamic mechanical seals are designed with **spring** elements mounted in the **dynamic (rotating) part** of the seal system. Dynamic seals, work like a small backwards pumping impeller. Tolerances exist on the various parts of the **seal** and **pump**, as on the **retaining ring** and the machined cover relative to the shaft axis. Also, the secondary seals that handle shaft sealing with a **repeller**, when the unit is **shut down**, are not normally as good as a mechanical seal. As the result the **stationary face of the seal** is never at right angles to the shaft axis. The spring elements of a **dynamic seal rotate with the shaft** so that the springs of the rotating face must adapt to the slightly eccentric stationary face twice per revolution.





Dynamic Seals are very simple by **fitting a repeller plate** between the **stuffing box and impeller**, eliminating the **need** for a mechanical seal. The **repeller** functions like an impeller, **pumping** liquid and solids **out from the stuffing box**. When pump is **shut down**, the packing (as shown above) or a **secondary seal** prevents pumpage from leaking. The seal has to make a continuous back and forth axial movement in order to keep the faces together.

X. LEAKAGE FAILURES:

The **leakage path gap** varies as the faces are subject to varying external loads which tend to move the faces relative to each other. The operating life of a seal is complete when either face has **worn entirely**. If either face has completely worn, the cause of **failure** is evident and no further inspection is required unless this occurred in a very short time. If both faces are **intact**, seal parts shall be inspected. Major seal problems and possible causes are as indicated below.

1. Causes of Seal Leakage:

Seal Problems:	Possible Cause / Corrective Action:
Seal spits and sputters ("face popping") in operation.	Seal fluid vaporizing at seal interfaces. This can be due to inadequate cooling of seal faces or seal unbalance.
Seal drips steadily.	This can happen if seal faces are not flat, distortion of seal faces or damage to seal faces. Distortion of gland plate due to over tightening. Damage to secondary seal during installation. Overaged O-Rings Spring failure Erosion / corrosion of seal parts.
Seal squeals (gives sound) during operation.	Inadequate liquid to lubricate seal faces.
Accumulation of carbon dust outside the gland.	Inadequate liquid to lubricate seal faces.
Short seal life.	Abrasive fluid. Misalignment of the equipment with its driver. High vibration.

Note: The **API 682** (Shaft sealing systems for centrifugal and rotary pumps) requires that the sealing systems "have **high probability** of meeting the objective of at **least three years** of **uninterrupted** service while complying with **emission regulations**".

The leakage can be reduced according to a necessary level, meeting **environmental standards** of regulating agencies and maintenance costs can be lower. The **advantages** of mechanical seals over **conventional packings** are as follows:

- Zero or limited leakage of product (meet emission regulations);
- Reduced friction and power loss;
- Elimination of shaft or sleeve wear;
- Reduced maintenance costs;
- Ability to seal higher pressures and more corrosive environments;
- The wide variety of designs allows use in almost all pump applications.

In order for the mechanical seal to **perform over an extended time** period with **low friction** the faces are generally **hydrodynamically lubricated**. The fluid film will need to carry substantial load. If the load becomes **too high** for the **film surface contact** will take place with consequent bearing **failure**.

This **lubricating film** is generally of the order of **3 micrometers thick**, or less. This **thickness** is critical to the required sealing function. Mechanical seals **often have one face** of a suitable **solid lubricant**, in such a way that the seal can operate for a **long period** without the fluid film.

XI. MECHANICAL SEALS APPLICATIONS:

- Scrubbing sections of power station flue gas desulphurization systems;
- Paper industry;
- Operation Pressure: 16 bars;
- Operation Temperature: -20 to 160 °C;
- Speed to 10m/s.

High Performance Corrosion Resistant Seals:

- API 682 design features, options of Carbon / Tungsten Carbide / Silicon Carbide faces;
- High Quality Silicon Carbide seats;
- Operation Temperature -50 to 200 °C;
- Operation Pressure to 20 Bars;
- Speed to 25 m/s.

Elastomer Bellows Seals:

- Hot water & mild;
- Operation Temperature -40 to 205 °C;
- Operation Pressure too +40 bars;
- Speed to 13 m/s (2,500 fpm).

Agitator Cartridge Seals:

- Suitable for areas where there is a risk of explosion;
- Temperature: -25 °C to 200 °C;
- Pressure: vacuum to 16 bar;
- Speed: up to 570 rpm.

XII. SEAL OPERATION AND ENVIRONMENT:

The **number one cause** of **pump downtime** is failure of the shaft seal. These **failures** are normally the result of an unfavorable seal environment, such as **improper** heat dissipation (cooling), **poor lubrication** of seal faces, or **seals operating** in liquids containing **solids**, **air or vapors**.

To achieve **maximum reliability** of a seal application, **proper choices** of seal housings (standard bore stuffing box, large bore, or large tapered bore seal chamber) and seal environmental controls (CPI and API seal flush plans) must be made. Environmental controls are **necessary** for reliable performance of a mechanical seal on many applications:

- **Corrosion:** Corrosion can be controlled by **selecting seal materials** that are not attacked by the pumpage. When this is difficult, external fluid injection of a **non-corrosive** chemical to lubricate the seal is possible. **Single or double seals** could be used, depending on if the customer can stand delusion of his product.

- **Temperature Control:** As the seal rotates, the faces are in contact, generating heat due abrasion, and if is not removed, the temperature in the stuffing box can cause sealing problems.

- **Heat:** A **simple by-pass** of product over the seal faces will **remove** the heat generated by the seal. For higher temperature services, by-pass of product through a **cooler** may be required to cool the seal sufficiently. External **cooling fluid injection** can also be used.

- **Operating Control:** Mechanical seals do not normally function **well on liquids** that contain solids or can **solidify** on contact with the atmosphere. By-pass flush through a filter, a cyclone separator or a strainer are methods of providing a clean fluid to lubricate seal faces.

- **Strainers**: Are effective for particles larger than the openings on a **40 mesh screen**. Cyclone **separators** are effective on solids **10 micron** or more in diameter, if they have a **specific gravity** of **2.7** and the pump develops a differential pressure of **30-40 psi**. Filters are available to remove solids **2 microns** and larger.

- **Quench Type Glands**: Are used on fluids which tend to **crystallize** on exposure to air. Water or steam is put through this gland for washing away. If external flush with **clean liquid** is available, this is a **better fail** proof system. Lip seal or restricting **bushings** are available to control flow of injected fluid to flows as low as **1/8 GPM**.

- **API 682 Qualification Test Conditions:**

Test fluid	Test conditions	
	Pressure (MPa)	Temperature (℃)
Water	0~0.3	20~80
20wt%-NaOH	0~0.7	20~80
Low temp. mineral oil	0~1.6 (Type B,C) 0~3.4 (Type A)	20~90
Hot oil	0~1.6 (Standard design) 0~3.4 (Special design)	150~260
Propane	1.0~1.7	30

XIII. API AND CPI STANDARDS:

The **API** (American Petroleum Institute) is an universal **standard** being used by oil refineries throughout the world, combined with the **CPI** (Chemical Process Industry) standards. The subjects include:

- Seal design;
- Materials;
- Accessories;
- Instrumentation;
- Inspection, testing and preparation for shipment.

The API specification addresses just about everything about mechanical seals. The **API standard 682** define the most common manufacturing conditions, as described below:

- All standard mechanical seals, shall be of the cartridge design. The standard single arrangement pusher seal shall be an inside-mounted balanced cartridge seal. The standard, un-pressurized dual mechanical seal shall be an inside, balanced, cartridge mounted mechanical seal (with two rotating flexible elements and two mating rings in series).

- Outer seals shall be designed to the same operating pressure as the inner seal, but do not have to be balanced. Cooling for the inboard seal is achieved by a seal flush. Cooling for the outside seal is accomplished by a circulating device moving a buffer fluid through an external seal flush system.

- The standard pressurized dual mechanical seal shall be an inside, balanced, cartridge mounted mechanical seal (with two rotating flexible elements and two mating rings in series). The inner seal shall have an internal (reverse) balance feature designed and constructed to withstand reverse pressure differentials without opening.

- The standard configuration for API single pusher and all dual mechanical seals is for the flexible elements to rotate. For seals having a seal face surface speed greater than 25 meters per second (5000 feet per minute), the standard alternative of stationary flexible elements shall be provided.

- O-ring grooves shall be sized to accommodate perfluoroelastomer O-rings. The minimum radial clearance between the rotating member of the seal and the stationary surfaces of the chamber and gland shall be 3 mm (1/8 inch).

- The shaft shall be concentric and have a total indicated run out of not more than 125 micrometers (0.005 inch). Shaft centering or use of seal gland bolts is not acceptable.

- Seal chamber pressure for single seals, and for the inner un-pressurized dual seal, shall be a minimum of 3.5 bar (50 psi.) or 10 percent above the maximum fluid vapor pressure at seal chamber fluid temperature. This margin shall be achieved by raising the seal chamber pressure and/or lowering the seal chamber temperature.

- On vertical pumps the seal chamber or gland plates shall have a port no less than 3 mm, (1/8") above the seal faces to allow the removal of trapped gas. The port must be orificed and valved.

- A shaft wearing resistant sleeve, corrosion, and erosion resistant material shall be provided to protect the shaft. The sleeve shall be sealed at one end. The shaft sleeve assembly shall extend beyond the outer face of the seal gland plate.

- Sleeves shall have a minimum radial thickness of 2.5 mm (0.100 inches), shall be relieved along their bore leaving a locating fit at or near each end, diametral clearance shall be 25 micrometers to 75 micrometers (0.001 inch to 0.003 inch.

- Drive collar set screws shall be of sufficient hardness to securely hold the wearing sleeve in the shaft. Shaft to sleeve diametrical clearance shall be 25 micrometers to 75 micrometers (0.001 inch to 0.003 inches).

- One of the seal face rings shall be premium grade, blister resistant carbon graphite with suitable binders and impregnates to reduce wear and provide chemical resistance. Several grades are available; therefore, the manufacturer shall state the type of carbon offered for each service.

- The mating ring should be reaction bonded silicon carbide (RBSiC) or self-sintered silicon carbide (SSSiC). Abrasive service may require two hard materials. The seal ring shall be reaction bonded silicon carbide and tungsten carbide (WC) with nickel binder

- Unless otherwise specified, metal bellows for the type B seal shall be Hastelloy C. For the type C seal, Inconel 718. For services below 150°C (300°F) the chamber seal shall be Fluoroelastomer O'Ring. For temperatures over 150°C (300°F) or when specified, graphite-filled type 304 stainless steel spiral wound gaskets should be used.

- For dual mechanical seals, forced flush and barrier/buffer fluid systems shall be provided. If a dual seal buffer/barrier fluid reservoir is specified, a separate barrier/buffer fluid reservoir shall be furnished for each mechanical seal.

- Systems that rely upon a thermo-syphon to maintain circulation during normal operation are not allowed. Seal systems that utilize internal circulating devices, such as a pumping ring, that rely upon the rotation of the mechanical seal to maintain circulation, thermo-syphon is allowed, when the seal is not running.

- The inner seal of a dual seal either balanced or reverse balanced depends upon whether high pressure barrier fluid or lower pressure buffer fluid is circulated, calls for the dual seals to be mounted in series (tandem),

- Almost all gas dual seals supplied to refineries to date have been supplied in the "back to back" configuration which is the worst possible installation method for slurry and abrasive service.

- The specification approves rotating seals only and recommends stationary seals for speeds above 5000 fpm (25 m/sec). The fact is that stationary seals are almost always a better choice for leak free and the more severe fugitive emission sealing.

- A seal chamber 50 psi (3.5) bar above vapor pressure does not make any sense in the majority of balanced seal applications. Quenching fluid is introduced into the seal gland to wash away leakage and control the environment outboard the seal.

- Flushing fluid is a process fluid from an outside source introduced into the stuffing box that dilutes the pumpage. It is seldom desirable, but sometimes necessary.

XIV. LINKS AND REFERENCES:

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2. www.PumpLearning.org,
3. **Erro! A referência de hiperlink não é válida.**
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13. www.pump-zone.com/
14. API 610, API 682 AND ISO 20149
15. ANSI B73.1 – Mechanical Seals
16. ASTM F1511-11 - Specification for Mechanical Seals for Shipboard Pump Applications.