CHAPTER SIX

SEALING

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The proper selection of a seal is critical to the success of every pump application. For maximum pump reliability, choices must be made between the type of seal and the seal environment. In addition, a sealless pump is an alternative, which would eliminate the need for a dynamic type seal entirely.

6.1 Sealing Basics

There are two basic kinds of seals:

- Static seals.
- Dynamic seals.

Static seals are employed where no movement occurs at the Juncture to be sealed. Gaskets and O-rings are typical static seals.

Dynamic seals are used where surfaces move relative to one another. Dynamic seals are used, for example, where a rotating shaft transmits power through the wall of a tank (Figure 6.1), through the casing of a pump (Figure 6.2), or through the housing of other rotating equipment such as a filter or screen.

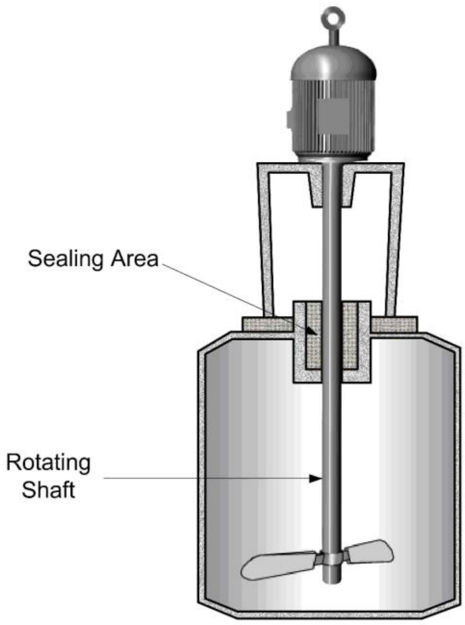

Figure 6.1 – Cross section of tank and mixer

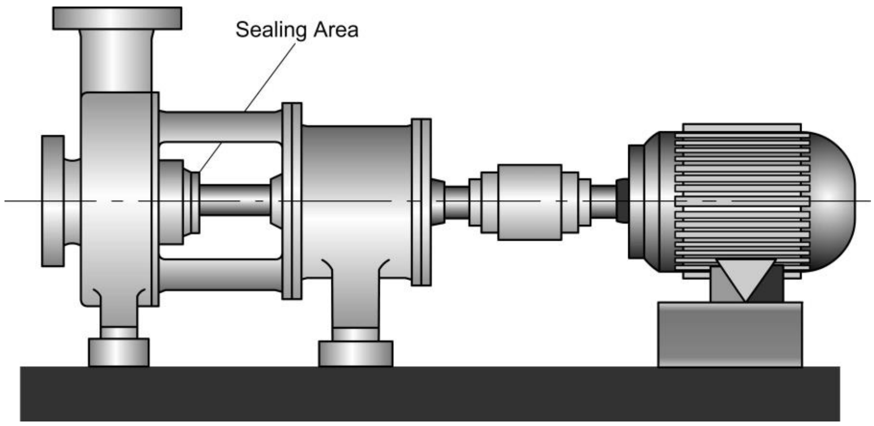

Figure 6.2 – Sealing area in a typical centrifugal pump

A common application of sealing devices is to seal the rotating shaft of a centrifugal pump. To best understand how such a seal functions a quick review of pump fundamentals is in order.

In a centrifugal pump, the liquid enters the suction of the pump at the center (eye) of the rotating impeller (Figures 6.3 and 6.4).

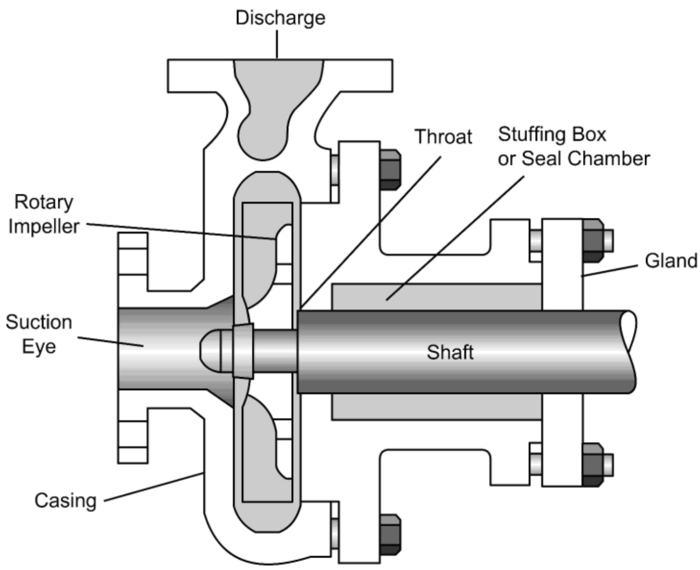

Figure 6.3 – Centrifugal Pump, Liquid End

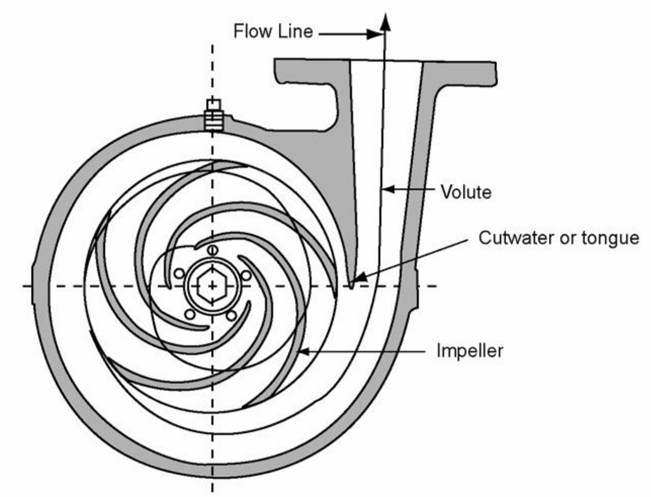

Figure 6.4 – Fluid Flow in Centrifugal Pump

As the impeller vanes rotate, they transmit motion to the incoming product, which then leaves the impeller, collects in the pump casing, and leaves the pump under pressure through the pump discharge.

Discharge pressure will force some product down behind the impeller to the drive shaft, where it attempts to escape along the rotating drive shaft. Pump manufacturers use various design techniques to reduce the pressure of the product trying to escape. Such techniques include: 1) the addition of balance holes through the impeller to permit most of the pressure to escape into the suction side of the impeller, or 2) the addition of back pump-out vanes on the back side of the impeller.

However, as there is no way to eliminate this pressure completely, sealing devices are necessary to limit the escape of the product to the atmosphere. Such sealing devices are typically either compression packing or end-face mechanical seals.

6.2 Stuffing Box Packing

A typical packed stuffing box arrangement is shown in Figure 6.5. It consists of: A) Five rings of packing, B) A lantern ring used for the injection of a lubricating and/or flushing liquid, and C) A gland to hold the packing and maintain the desired compression for a proper seal.

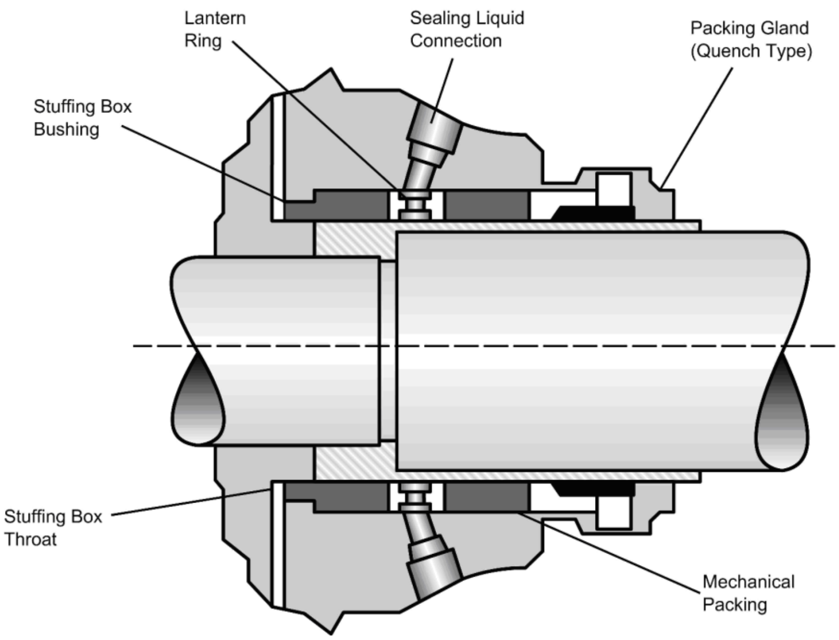

Figure 6.5 – Typical Stuffing Arrangement (description of parts)

The function of packing is to control leakage and not to eliminate it completely. The packing must be lubricated, and a flow from 40 to 60 drops per minute out of the stuffing box must be maintained for proper lubrication.

The method of lubricating the packing depends on the nature of the liquid being pumped as well as on the pressure in the stuffing box. When the pump stuffing box pressure is above atmospheric pressure and the liquid is clean and nonabrasive, the pumped liquid itself will lubricate the packing (Figure 6.6).

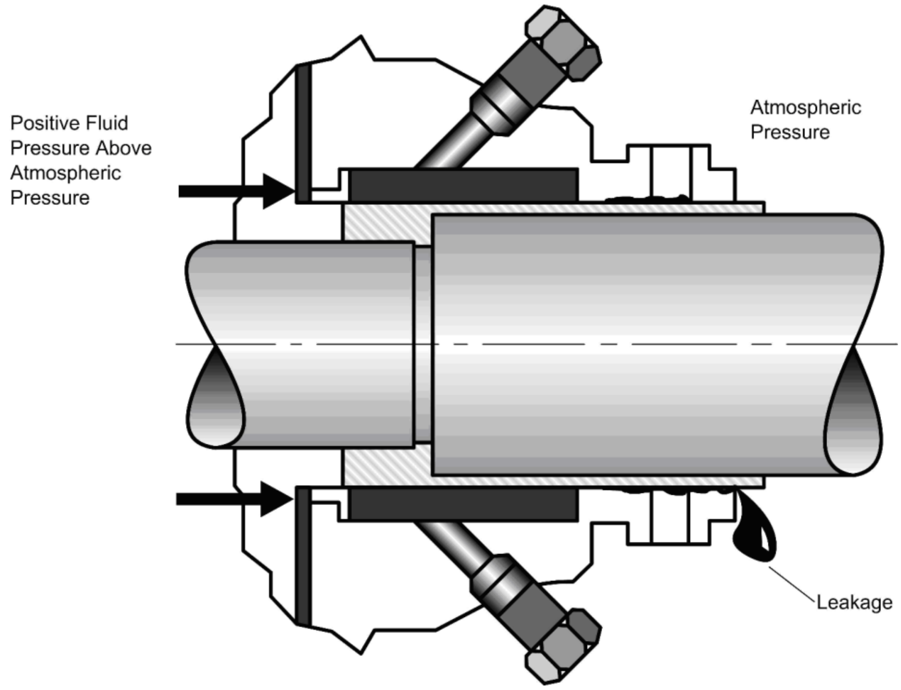

Figure 6.6 – Typical Stuffing Arrangement when Stuffing Box Pressure is Above Atmospheric Pressure

When the stuffing box pressure is below atmospheric pressure, a lantern ring is employed and lubrication is injected into the stuffing box (Figure 6.7). A bypass line from the pump discharge to the lantern ring connection is normally used providing the pumped liquid is dean.

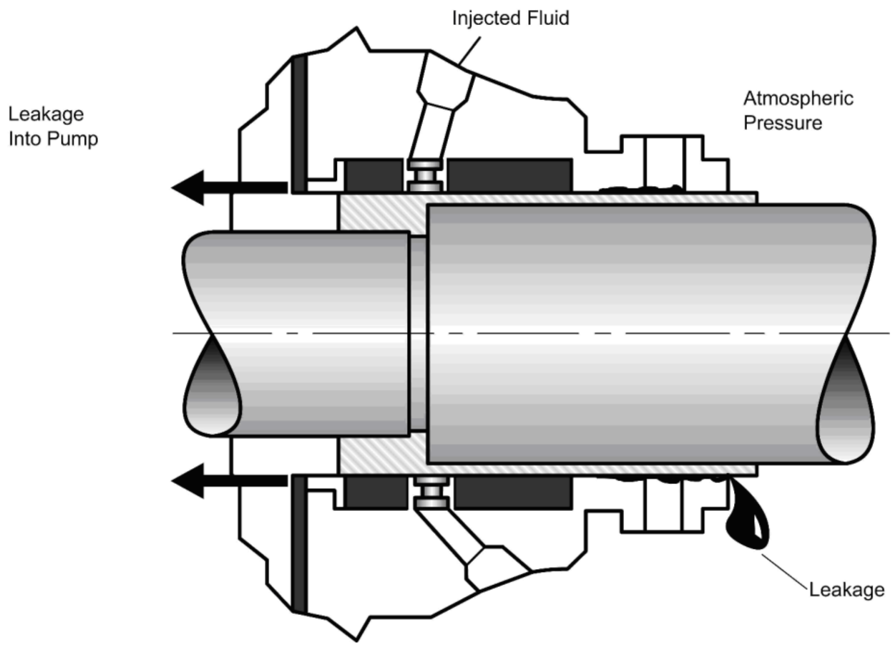

Figure 6.7 – Typical Stuffing Box Arrangement when Stuffing Box Pressure is Below Atmospheric Pressure

When pumping slurries or abrasive liquids, it is necessary to inject a clean lubricating liquid from an external source into the lantern ring (Figure 6.8). A flow of from 0.2 to 0.5 gpm is desirable and a valve and flowmeter should be used for accurate control. The seal water pressure should be from 10 to 15 psi above the stuffing box pressure, and anything above this will only add to packing wear. The lantern ring Is normally located In the center of the stuffing box. However, for extremely thick slurries like paper stock, it is recommended that the lantern ring be located at the stuffing box throat to prevent stock from contaminating the packing.

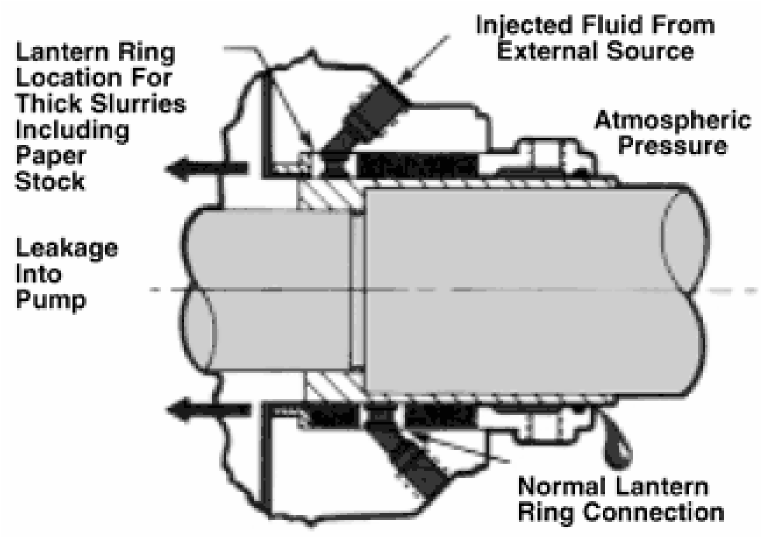

Figure 6.8 – Typical Stuffing Box Arrangement when Pumping Slurries

The gland shown in Figures 6.5 through 6.8 is a quench type gland. Water, oil, or other fluids can be injected into the gland to remove heat from the shaft, thus limiting heat transfer to the bearing frame. This permits the operating temperature of the pump to be higher than the limits of the bearing and lubricant design. The same quench gland can be used to prevent the escape of a toxic or volatile liquid into the air around the pump. This is called a smothering gland, with an external liquid simply flushing away the undesirable leakage to a sewer or waste receiver.

Today, however, stringent emission standards limit use of packing to non-hazardous water based liquids. This, plus a desire to reduce maintenance costs, has increased preference for mechanical seals.

6.3 Mechanical Seals

A mechanical seal is a sealing device which forms a running seal between rotating and stationary parts. They were developed to overcome the disadvantages of compression packing. Leakage can be reduced to a level meeting environmental standards of government regulating agencies and maintenance costs can be lower. Advantages of mechanical seals over conventional packing are as follows:

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

6.3.1 The Basic Mechanical Seal

All mechanical seals are constructed of three basic sets of parts as shown in Figure 6.9:

- A set of primary seal faces: one rotary and one stationary (shown in Figure 6.9 as seal ring and insert).
- A set of secondary seals known as shaft packings and insert mountings such as O-rings, wedges and V-rings.
- Mechanical seal hardware including gland rings, collars, compression rings, pins, springs and bellows.

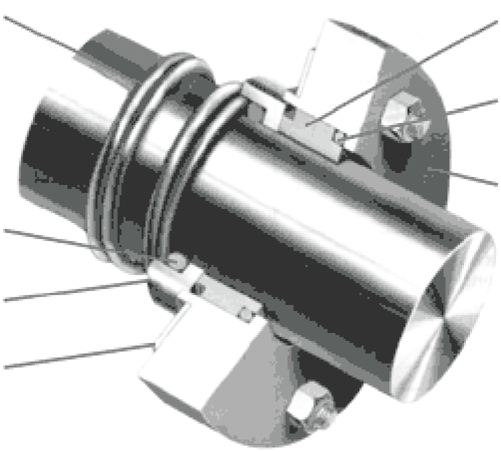

Figure 6.9 – A Simple Mechanical Seal

6.3.2 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 these two flat mating surfaces minimizes leakage. As in all seals, one face is held stationary in a housing and the other face is fixed to, and 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. 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 the smaller mating surface and is commonly called the wear nose.

There are four main sealing points within an end face mechanical seal (Figure 6.10). The primary seal is at the seal face, Point A. The leakage path at Point B is blocked by an O-ring, a V-ring or a wedge. Leakage paths at Points C and D are blocked by gaskets or O-rings.

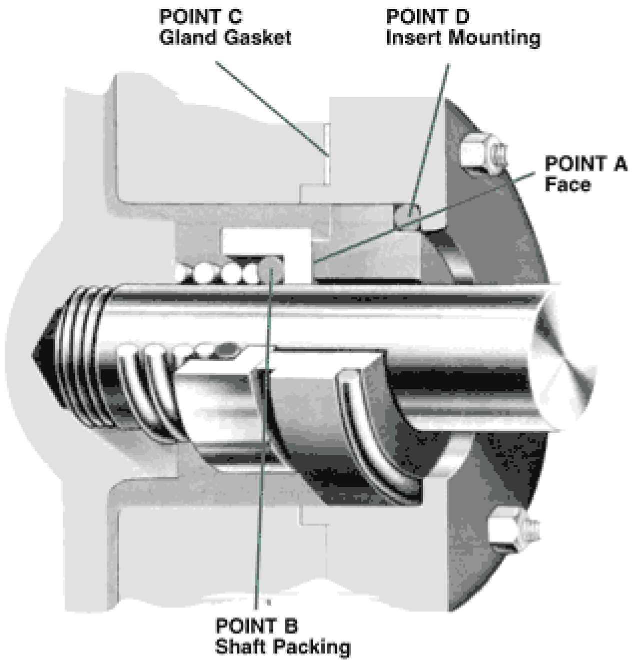

Figure 6.10 – Sealing Points for Mechanical Seal

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.

6.3.3 Mechanical Seal Types

Mechanical seals can be classified into several types and arrangements:

PUSHER:

Incorporate secondary seals that move axially along a shaft or sleeve to maintain contact at the seal faces. This feature compensates for seal face wear and wobble due to misalignment. The pusher seals' advantage is that it's inexpensive and commercially available in a wide range of sizes and configurations. Its disadvantage is that ft's prone to secondary seal hang-up and fretting of the shaft or sleeve.

Figure 6.11 – Pusher type seal

UNBALANCED:

They are inexpensive, leak less, and are more stable when subjected to vibration, misalignment, and cavitation. The disadvantage is their relative low pressure limit. If the closing force exerted on the seal faces exceeds the pressure limit, the lubricating film between the faces is squeezed out and the highly loaded dry running seal fails.

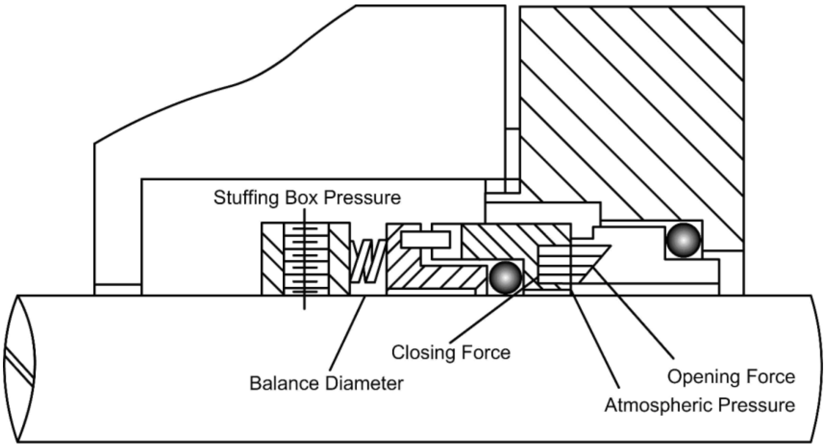

Figure 6.12 – Unbalanced type seal

CONVENTIONAL:

This type requires setting and alignment of the seal (single, double, tandem) on the shaft or sleeve of the pump. Although setting a mechanical seal is relatively simple, today's emphasis on reducing maintenance costs has increased preference for cartridge seals.

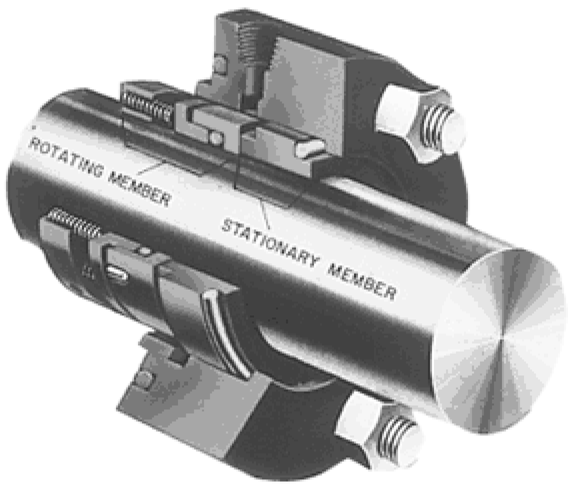

Figure 6.13 – Conventional type seal

NON-PUSHER:

The non-pusher or bellows seal does not have to move along the shaft or sleeve to maintain seal face contact, The main advantages are its ability to handle high and low temperature applications, and does not require a secondary seal (not prone to secondary seal hang-up). A disadvantage of this style seal is that its thin bellows cross sections must be upgraded for use in corrosive environments.

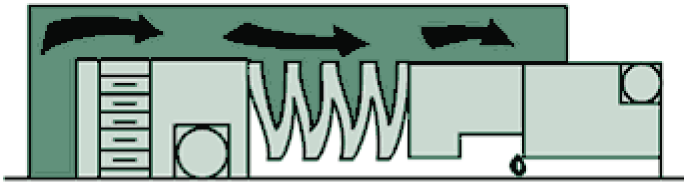

Figure 6.14 – Non-Pusher type seal

BALANCED:

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

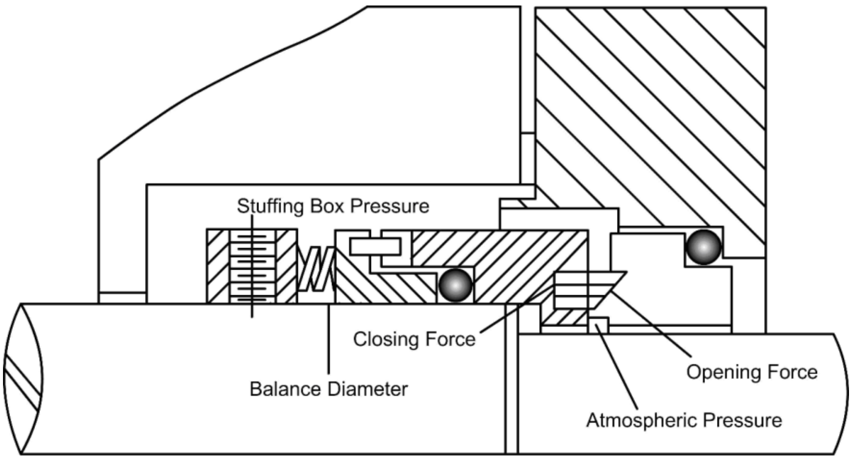

Figure 6.15 – Balanced type seal

CARTRIDGE:

This type has the mechanical seal pre-mounted on a sleeve including the gland and fit directly over the shaft sleeve (available single, double, tandem). The major benefit, of course is no requirement for the usual seal setting measurements for their installation. Cartridge seals lower maintenance costs and reduce seal setting errors

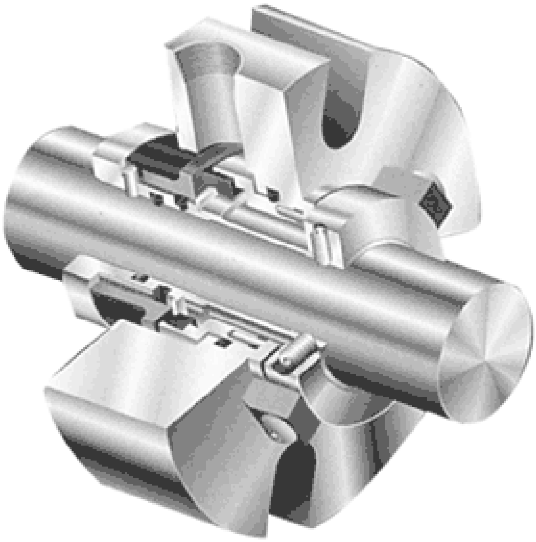

Figure 6.16 – Cartridge type seal

6.3.4 Mechanical Seal Arrangements

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. Recommended for relatively clear non-corrosive and corrosive liquids with satisfactory' lubricating properties where cost of operation does not exceed that of a double seal.

SINGLE OUTSIDE:

If an extremely corrosive liquid has good lubricating properties, an outside seal 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 works to open the seal faces so they have low pressure limits (balanced or unbalanced).

DOUBLE (DUAL PRESSURIZED):

This arrangement is recommended for liquids that are not compatible with a single mechanical seal (i.e. liquids that are toxic, hazardous [regulated by the EPA], have suspended abrasives, or corrosives which require costly materials). The advantages of the double seal are that it can have five times the life of a single seal in severe environments. Also, the metal inner seal parts are never exposed to the liquid product being pumped, so viscous, abrasive, or thermosetting liquids are easily sealed without a need for expensive metallurgy. In addition, recent testing has shown that double seal life is virtually unaffected by process upset conditions during pump operation.

The final decision between choosing a double or single seal comes down to the initial cost to purchase the seal, cost of operation of the seal, and environmental and user plant emission standards for leakage from seals.

Figure 6.17 – Double pressurized seal arrangement

DOUBLE GAS BARRIER (PRESSURIZED DUAL GAS):

Very similar to cartridge double seals ... sealing involves an inert gas, like nitrogen, to act as a surface lubricant and coolant in place of a liquid barrier system or external flush required with 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. The gas barrier seal uses nitrogen or air as a harmless and inexpensive barrier fluid that helps prevent product emissions to the atmosphere and fully complies with emission regulations. The double gas barrier seal should be considered for use on toxic or hazardous liquids that are regulated or in situations where increased reliability is the required on an application.

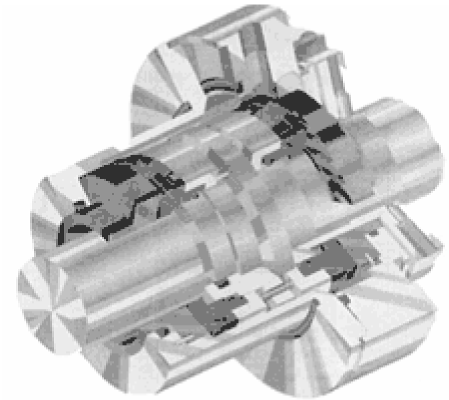

Figure 6.18 – Double gas barrier seal arrangement

TANDEM (DUAL UNPRESSURIZED):

Due to health, safety, and environmental considerations, tandem seals have been used for products such as vinyl chloride, carbon monoxide, light hydrocarbons, and a wide range of other volatile, toxic, carcinogenic, or hazardous liquids.

Tandem seals eliminate icing and freezing of light hydrocarbons and other liquids which could fall below the atmospheric freezing point of water in air. A tandem also increases online reliability. If the primary seal fails, the outboard seal can take over and function until maintenance of the equipment can be scheduled.

Figure 6.19 – Tandem seal arrangement

6.3.5 Mechanical Seal Selection

The proper selection of a mechanical seal can be made only if the full operating conditions are known:

1. Liquid
2. Pressure
3. Temperature
4. Characteristics of Liquid
5. Reliability and Emission Concerns

Liquid: Identification of the exact liquid to be handled is the first step in seal selection (fresh water, sea water, hydrocarbon condensate, acids, oily water… etc). The metal parts must be corrosion resistant, usually steel, bronze, stainless steel, or Hastelloy. The mating faces must also resist corrosion and wear. Carbon, ceramic, silicon carbide or tungsten carbide may be considered. Stationary sealing members of Buna, EPR, Viton and Teflon are common.

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.

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.

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.

6.3.6 Seal Housing

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.

6.3.6.1 Standard Bore Stuffing Box Cover

Standard bore stuffing box cover was designed thirty years ago specifically for packing. Also accommodates mechanical seals (clamped seat outside seals and conventional double seals.)

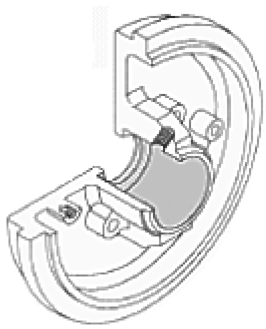

Figure 6.20 – Standard bore stuffing box cover

6.3.6.2 Conventional Large Bore Seal Chamber

Designed specifically for mechanical seals. Large bore provides increased life of seals through improved lubrication and cooling of faces. Seal environment should be controlled through use of CPI or 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 in conjunction with a flush and throat bushing in bottom of chamber. Also excellent for conventional or cartridge double or tandem seals.

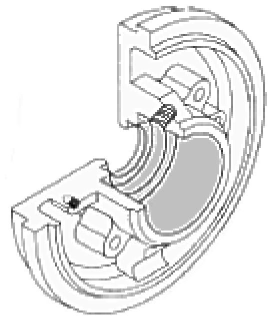

Figure 6.21 – Conventional Large Bore Seal Chamber

6.3.6.3 Large Bore Seal Chambers

Introduced in the mid-80's, 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.

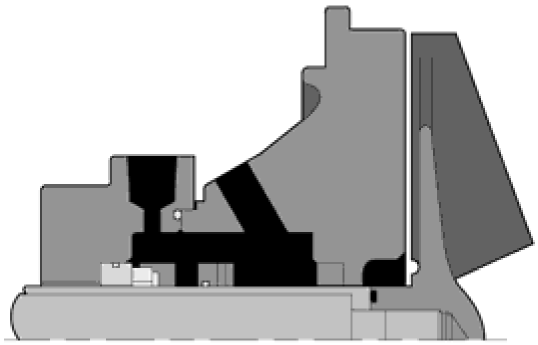

Figure 6.22 – BigBore™ Seal Chamber

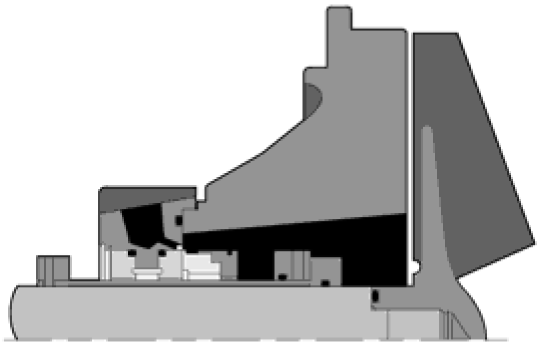

Figure 6.23 – TaperBore™ Seal Chamber