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TECHNICAL INFORMATION
BULLETIN
Number Twenty-Nine

Selecting Mechanical Seals

What Is a Mechanical Seal?

"What is a mechanical seal?" A definition is better given after the functions of a seal are described.

A container holding a liquid or a gas has a rotatable shaft extending through its housing. This housing is shown in Fig. 1. Fluid is to be kept from escaping where the shaft extends through the housing, especially as the shaft rotates. A ring, part 1, with an O-ring, part 4, is sealed against the housing of the container. It is called the mating ring. Another ring, part 2, with an O-ring, part 3, is mounted onto the shaft. It is called the primary sealing ring. The contacting faces of these rings are lapped flat, within light bands. Initial contact between the faces is maintained by a spring, part 6, which pushes them together. The spring reacts against a retainer, part 7, which is locked to the shaft, perhaps with set screws. As the shaft rotates the primary sealing ring rotates with it. To assure that the primary sealing ring does not slip, the retainer may have drive lugs (not shown) that engage corresponding slots of the primary sealing ring and provide positive drive. With the mating ring stationary, there is relative motion between it and the primary sealing ring.

The primary or "dynamic" sealing is done at the faces of the primary sealing ring and its mating ring. In a properly designed seal they slide relative to each other on a fluid film. The secondary or "static" sealing is done by O-rings or any other suitable gasketing arrangement. They are called secondary seals. The remaining components are referred to as hardware.

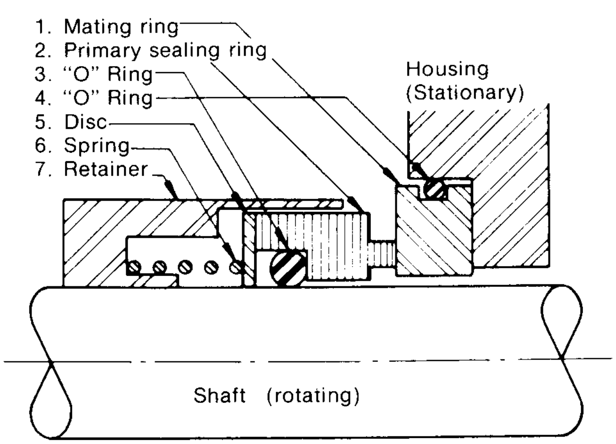


Fig. 1 Mechanical end face seal

The functional categories of a mechanical seal are:

1. Primary sealing ring and mating ring.
2. Secondary seals consisting of O-rings or other suitable gaskets.
3. Hardware consisting mainly of spring and retainer.

A mechanical seal can now be defined as a device which prevents fluid leakage where a rotating shaft extends through a pressurized vessel.

Application information

Before design and material selections can be made at least the following conditions under which the seal will perform must be known:

1. Fluid to be sealed.
2. Pressure of the fluid.
3. Temperature of the fluid.
4. Shaft size.
5. Speed of the shaft.

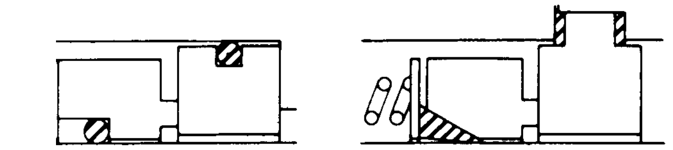
Shaft-run out, end play and vibration data are also important.

Materials of Construction

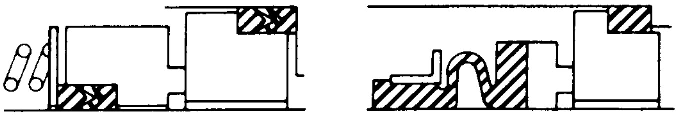
Hardware

Hardware usually presents only such problems as are encountered with normal machine elements. Information regarding mechanical properties and chemical compatibilities can be found in handbooks. Materials commonly used are steel, stainless steel, brass, Monel and Hastelloy materials..

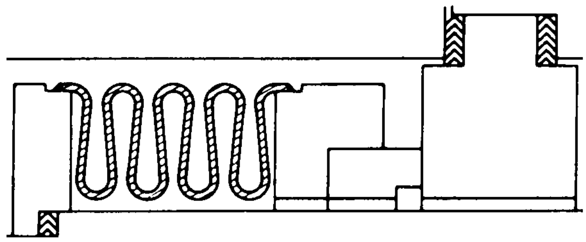
Spring materials should be checked carefully for applications involving corrosion and temperatures. Corrosion acting on a thin cross-sectioned wire weakens it more rapidly than if it were heavier. Therefore springs in a corrosive media must be of the best material. For higher temperatures Inconel X is an excellent material which retains its controlled spring force at operating temperatures to 1800°F.



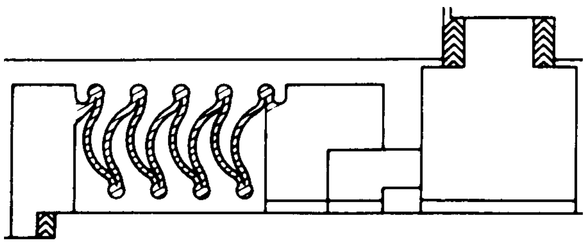
A: O-ring seal **B**: Wedge seal



C: V-ring seal **D**: Elastomeric bellows seal



E: Formed metal bellows seal



F: Welded metal bellows seal

Fig. 2 Secondary seals

Secondary Sealing Elements

Although considered static, meaning that there is no relative movement, the secondary seal at the primary sealing ring slides minutely as wear between the faces of the primary seals takes place. This movement is essential to keep them together. Fluid pressure acting on the back surface of the primary sealing ring and spring force accomplish this. The secondary seal at the seat, however, is truly static.

Configurations for these elements are different depending upon their requirements. Often a-rings, wedges, or other conventional packing arrangements, as shown in Fig. 2, are used.

Many of the materials are of a resilient nature.

Buna, neoprene, Viton® rubber and other elastomers are common. This is advantageous; these materials help to dampen vibrations that could have a disturbing influence at the faces.

Certain chemical applications require the compatibility of TFE. Fig. 2(B) shows a TFE wedge used as a secondary seal. TFE has exceptional chemical stability. One of its outstanding properties is its low coefficient of friction, 0.04 against itself. It is interesting to note that this is slightly better than ice on

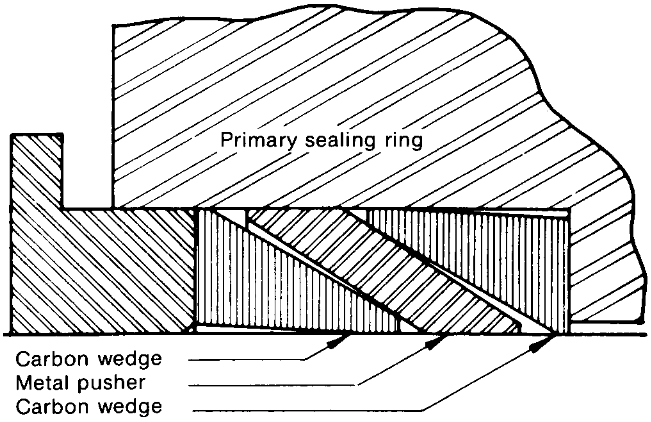


Fig. 3 Compound carbon wedge secondary seal

ice. TFE has also been used successfully at very low temperatures in cryogenic applications. Case histories for liquid oxygen service at -310°F are on file. Unfortunately, TFE is one of the least radiation resistant plastics.

At temperatures above 500°°F the elastomers and TFE lose their versatility. With the use of special material V ring assemblies as secondary seals, the limit can be increased to 650°F. Above this, other materials for secondary seals are employed.

Metallic gaskets provide the answer for secondary sealing at the mating ring. For the secondary seal at the primary sealing ring, which is not truly static but must have some movement, straightforward gasketing cannot be applied. In most of these extreme high temperature cases metal bellows are used as the secondary seal. The bellows can compensate for the face wear by extending slightly. Bellows are of the formed or welded disk types, as shown in Figs. 2(E) and (F), and the material generally is stainless steel. Metal bellows seals are also frequent choices for cryogenic applications although the TFE wedge has enjoyed success.

An interesting development along the lines of a secondary seal for high temperatures has been the so called carbon wedge seal. Basically, the TFE wedge, as shown in Fig. 2(B), is replaced by a carbon wedge. Using carbon can extend the temperature limit to 1200^0 F and even higher in a non-oxidizing atmosphere. A more sophisticated version of this secondary seal type is shown in Fig. 3.

Primary Sealing Elements

The primary sealing elements, the primary sealing ring and its mating ring, are really the heart of a mechanical seal. The faces slide relative to each other, often at high velocities and with considerable contact pressure. Under these conditions the phenomenon known as wear takes place. Although a common term, often accepted quite casually, the mechanism and theory of wear are very complex. Barkan states, "Wear is a surface deterioration of contacting surfaces that destroys their operating relationship or causes rupture if carried far enough. The amount of wear depends on the nature of the contacting materials, the sliding,

Viton is a registered trademark of DuPont Corporation rolling, or impact motion between them, the load imposed, their lubrication, if any, and the chemical action of their lubrication and environment. Because these conditions introduce many types of wear, no standard wear-resistance tests have been recognized. The tests performed in practice are designed to duplicate particular service conditions as nearly as possible." We can appreciate that proper material selection for the sliding parts is most important.

At start-up there is a momentary dry-running period, then boundary lubrication and the eventual goal, full hydrodynamic lubrication. In this respect seal theory resembles that of sliding bearings; it can be postulated generally that a good bearing material may be a promising seal material.

The problem is that bearings usually are lubricated with oil; the "lubricant" for seals includes water, oil, gasoline, salt solutions, sea water, caustics and acids. Table 1 shows typical material combinations that are used as primary face materials.

A detailed study of Table 1 shows that every category contains carbon-graphite, or "mechanical carbon". A recommendation chart for material compatibilities with various liquids shows that for well over 500 liquids about 10 percent require referral to the engineering department for consideration; of the large remainder 96 percent can use mechanical carbon. Of course it is not always the same carbon, for they are made in different grades each having its own virtues. Some are straight carbon-graphite compositions; others are impregnated with oils, synthetic resins, inorganic salts, polymers, and many are metallized with copper, lead, babbit, antimony or silver.

Ninety-six percent is a very impressive figure. The question arises why carbon is such a desirable material. A simple answer is that years of testing and experience have proved it.

Chemical inertness, lubricity, heat dissipation and thermal shock resistance of the carbon compositions provide some insight to why they are desirable wear materials used so extensively in the seal industry.

It is customary to run dissimilar material combinations (reflected in Table 1). From the viewpoint of dynamic similarity it makes no difference which piece rotates or which stands still, so the carbon component could be either the primary sealing ring or its mating ring. Both pieces will wear. The general assumption is that the harder piece wears less but, experience has shown that this is not always true. Under certain conditions, perhaps abrasive in nature, the softer piece is more wear resistant. Hardness alone is no criterion for wear resistance. Attempts have been made to formalize mathematically physical properties versus wear resistance, but no one complete solution has been found.

For water applications at high pressures and temperatures, such as boiler feed pumps, tungsten carbide running against carbon is a good choice.

Ceramic versus carbon is an ideal combination used for many chemical environments. Care must be taken not to use ceramic under temperature fluctuations that occur suddenly, because of its low thermal shock resistance. For some applications a base metal coated with ceramic is used. This strengthens the ceramic which is relatively weak in tension and also enhances its thermal shock resistance. The base metal itself should be chemically resistant to the fluids to which it is subjected so that diffusion through the thin coating will not attack it. Tungsten-carbide run against itself and ceramic versus ceramic are also used, but have limited usage and are restricted to low pressures and slow speeds. Carbon running against carbon is gaining acceptance in a wide range of applications.

Selecting the seal configuration

Various fundamental seal designs are available to the seal user. These designs can be modified slightly to meet the dimensional requirements of the equipment and the environmental requirements imposed by the liquid to be sealed.

Balanced Seals

One of the most frequently encountered conditions requiring a slight modification in seal design is pressure. If an inside mechanical seal is called upon to seal high pressures, provision must be made to insure that all of the pressure on the seal is not trying to push the primary sealing ring to the atmospheric side of the stuffing box.

Figure 5 is a cross-section of a conventional inside unbalanced seal. Almost all of the stuffing box pressure is exerting a closing force on the primary sealing ring. Only a very small portion of the primary sealing ring face is exposed over the top of the mating ring, allowing a proportionately small amount of pressure to work against the primary sealing ring in the opposite direction (in addition to the opening force exerted by the liquid film between the faces). If the closing force becomes great enough, the liquid film between the faces is literally squeezed out. Deprived of lubrication and highly loaded, the faces soon destroy themselves. The solution to this problem is to "balance" the seal.

Seal balancing is not a difficult subject to understand. If we are to reduce the closing pressure on the primary sealing ring, a greater area of its face must be exposed to hydraulic pressure that will act in the direction opposite to the closing force.

Figure 6 illustrates a conventional inside seal that has been balanced. Notice that a step in the shaft has allowed the sealing face of the mating ring to be moved radially inward without decreasing the width of the face itself. The primary sealing ring remains mounted on the original shaft diameter, which means that the closing force remains unchanged. Because we have successfully exposed more of the primary sealing ring

Table 1 – Material combinations used for primary sealing faces

For water

Carbon-graphite (also carbon-graphite containing various metals - copper, lead babbit, etc.)	VS	Bronze
		Ni-resist
		Nickel cast-iron (for constant operation only)
		Ceramic
		Stellite (hard facing on 316-stainless or other 300-series stainless or any stabilized stainless)
		Tungsten-carbide
		Malcomized 316-stainless
		Carbon-filled TFE
		Glass-filled TFE
		Chrome-plate on various parent materials (must be thick enough)
		Ceramic-facing on stainless
Tungsten-carbide	VS	Tungsten-carbide
Carbon containing various metals	VS	Stainless steel (Series 400, hardened to Rockwell C-50 or higher)

For caustics

Carbon-graphite	VS	Carbon-filled TFE
		Stellite-faced stainless steel
Carbon-graphite (non-metallic)	VS	Hard-faced 316-stainless steel
Carbon-graphite (metallic, for dilute solutions)	VS	Stellite-faced stainless steel

For salt solution

Carbon-graphite	VS	Stainless Steel
		Ceramic
		Monel
Ceramic	VS	Ceramic-faced stainless
		Ceramic
Carbon-babbitt	VS	Phosphor-bronze

For sea water

Carbon-babbitt	VS	Aluminum-bronze
Stellite on stainless	VS	Aluminum-bronze
Tungsten Carbide	VS	Tungsten-carbide
Bronze	VS	Laminated-plastic

For acids

Carbon-graphite	VS	Hard-faced 316-stainless
		Carpenter 20-stainless
		Stellite
		Chromium boride
		Ceramic
		Hasteloy A, B or C
		Carbon-filled TFE (for non-oxidizing acids)
Ceramic	VS	Stellite (attacked by many mineral acids)
		Glass-filled TFE (oxidizing acids)
		Teflon

For Gasoline

Carbon-graphite	VS	Cast iron
		Carbon-filled TFE
		Glass-filled TFE
		Ni-resist
		Nitralloy
		Ceramic
		Stellite facing on stainless steel
		Stainless steel, 400 series

For oil

Carbon-graphite	VS	Bronze (for few applications)
		Ni-resist
		Cast iron
		Ceramic
		Stellite (hard-facing on 316-stainless steel, especially for high pressures and high velocity)
		Tungsten carbide
		Malcomized 316-stainless
		Carbon-filled TFE
		Glass-filled TFE
		Sintered iron or bronze
		Nitralloy, hardened
		Tool steel, hardened
		SAE-1040 steel
		Stainless steel (400 series, hardened to Rockwell C-50. This is general recommendation as 316-stainless is not hardenable)
Cast iron	VS	Bronze
Graphite molybdenum	VS	Bronze

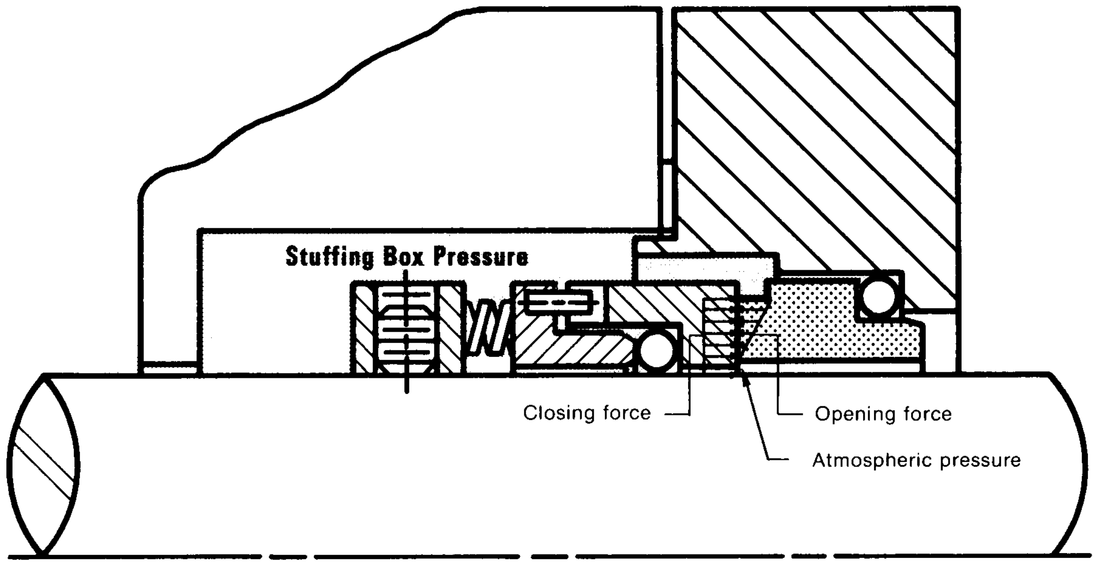


Fig. 5 Inside unbalanced seal

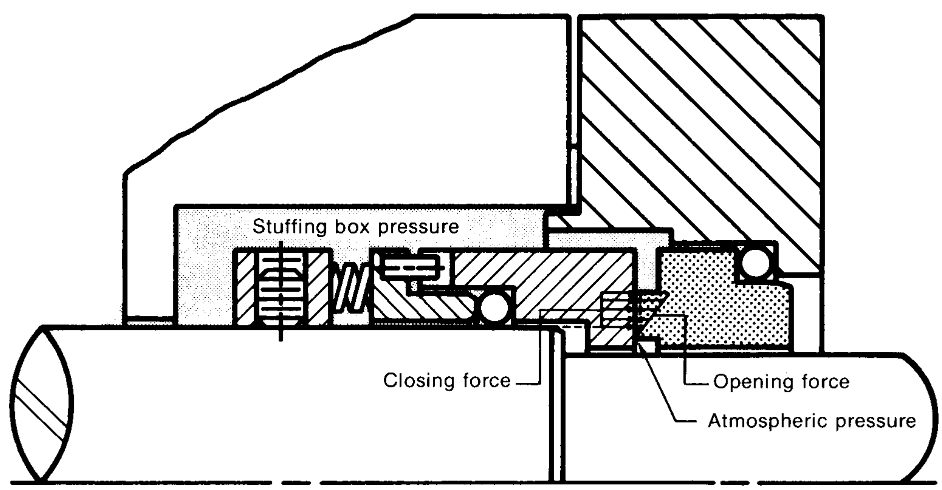


Fig. 6 Inside balanced seal

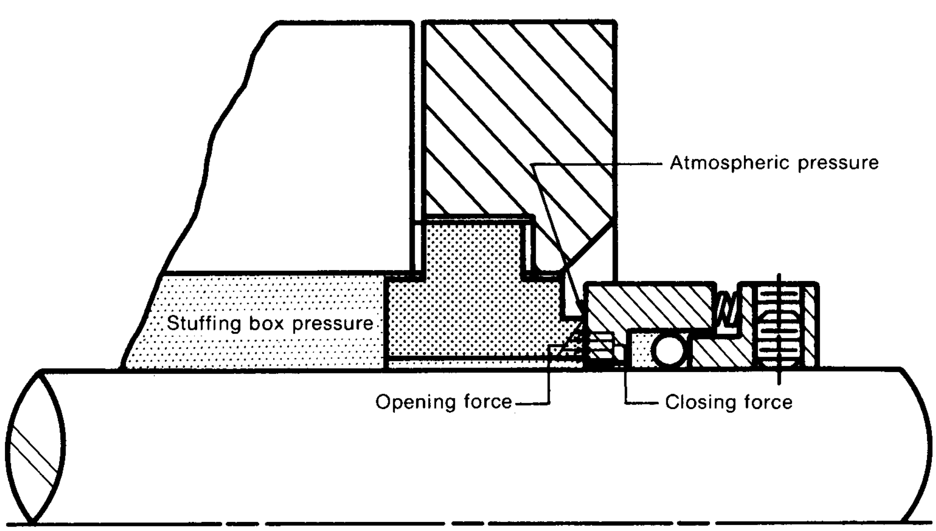


Fig. 7 Outside balanced seal

face to hydraulic pressure working to open the seal, the design is considered balanced. When comparing the surface areas of the seal ring available for the hydraulic pressure to work against, it becomes immediately apparent that the opening force is slightly less than the closing force. This is intentional to insure that the faces are kept in contact at all times.

The method of achieving balance on an outside seal is the same as with an inside seal except the action is just the reverse. Instead of counterbalancing a portion of the closing force imposed by stuffing box pressure, a portion of the stuffing box pressure is added to the closing force, counteracting the opening force exerted by the liquid film between the faces.

Figure 7 is a cross-section of an outside balanced seal. The shaft packing is forced against the retainer, leaving an area under the seal ring exposed to stuffing box pressure. The closing force exerted by the stuffing box pressure, acting against the shoulder of the seal ring, is slightly greater than the opening force exerted by the liquid film between the faces, thereby keeping the faces in contact at all times.

Grinding of the bottom of the counter-bore against which the mating ring is held is important to insure flatness. At high pressures, any high point on this surface would most certainly be transmitted to the sealing ring face resulting in leakage. Figure 8 illustrates a high pressure seal design.

High speed seals

In order to conserve space and achieve a more efficient weight to Bhp. ratio, more attention is being given to high speed pumps with shaft speeds in excess of 6500 FPM (feet per minute). Because dynamic forces begin to exceed the limitations of conventional rotary seal units at these speeds, the roles of the mating ring and the primary seal ring are reversed. The springs become stationary, loading a stationary rather than rotating seal ring. The mating ring is flexibly mounted inside a retainer which is set screwed to the shaft. Rotational drive is transmitted to the mating ring via lugs in the retainer rather than pins. Similar lugs hold the seal ring stationary. Figure 9 illustrates the configuration of a typical High Speed seal.

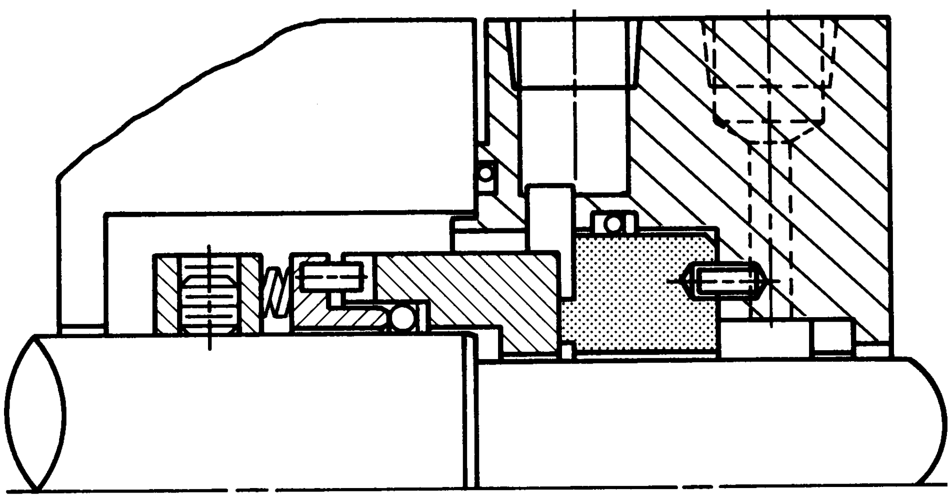


Fig. 8 High pressure seal

For the proper selection of mechanical seals, and especially to determine where balanced seals are required, many factors must be considered. Consultation with the pump or the seal manufacturer is recommended.

High pressure seals

Seals for extremely high pressures demand more design sophistication than standard balance seals. Not only is the ratio between the opening and closing force more critical, but the entire seal must be beefed up to withstand elevated pressures and to insure that the faces do not become distorted.

Specifically, the entire rotary unit cross section is thicker. Special springs are provided to insure proper face loading. Drive pins are heavier to accommodate more torque. The mating ring has a larger cross section to withstand the pressure. The thickness of the primary sealing ring is greatly increased to prevent distortion.

Mechanical seal arrangements

Inside seals

Single inside mechanical seals, typically shown in Figure 5, are the most common types of mechanical seals used. The materials of construction are selected to withstand the corrosive nature of the liquid in the stuffing box. They are easily modified to include environmental controls and can be balanced to withstand extremely high stuffing box pressures.

Inside seals require suitable stuffing box housings for installation and cannot be adjusted without dismantling the equipment.

Outside seals

If an extremely corrosive liquid is encountered that has satisfactory face lubricating properties, an outside seal offers an economical alternative to the expensive metallurgies necessary for an inside seal to resist corrosion. Figure 10 illustrates a common outside

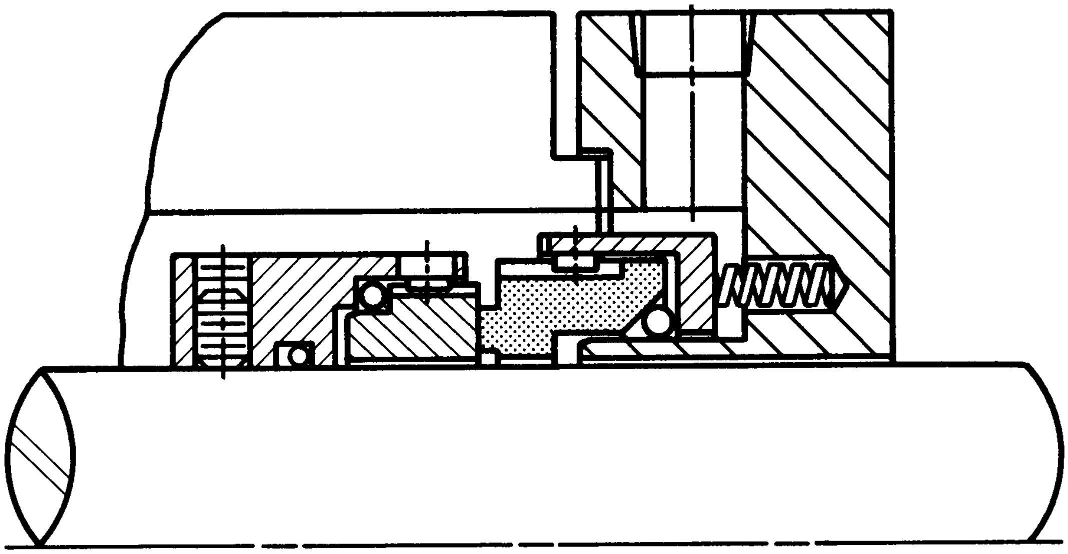


Fig. 9 Typical high speed seal

seal arrangement where only the mating ring, primary sealing ring, and secondary seals are exposed to the product. All of these components can be nonmetallic. The non-sealing parts are exposed only to the atmosphere.

An outside seal can also be used when a piece of equipment is found to have a stuffing box that will not accommodate an inside seal.

Although outside seals are easier to adjust and trouble-shoot because they are exposed, their disadvantages must be recognized. Because an outside seal is exposed, it is vulnerable to damage from impact. Of much greater importance, however, is the pressure limitation of an outside unbalanced seal. In contrast to an inside seal, the hydraulic pressure works to open rather than close the seal faces. Therefore, the seal design depends entirely upon the springs to maintain face contact. Even though a degree of balance can be designed into an outside seal as shown in Figure 7, all outside seals are limited for use with moderate stuffing box pressures.

Double seals

When selecting a seal, a liquid is sometimes encountered that is not compatible with a single mechanical seal. Often such liquids carry abrasive materials in suspension that would rapidly wear the faces; or, the liquid may be so corrosive that extremely expensive materials would be required for the seal components. The solution requires the use of seals which fall under a different design classification. One of these is the Double Mechanical Seal.

If a mechanical seal cannot operate in the same liquid environment as the pump, then an artificial

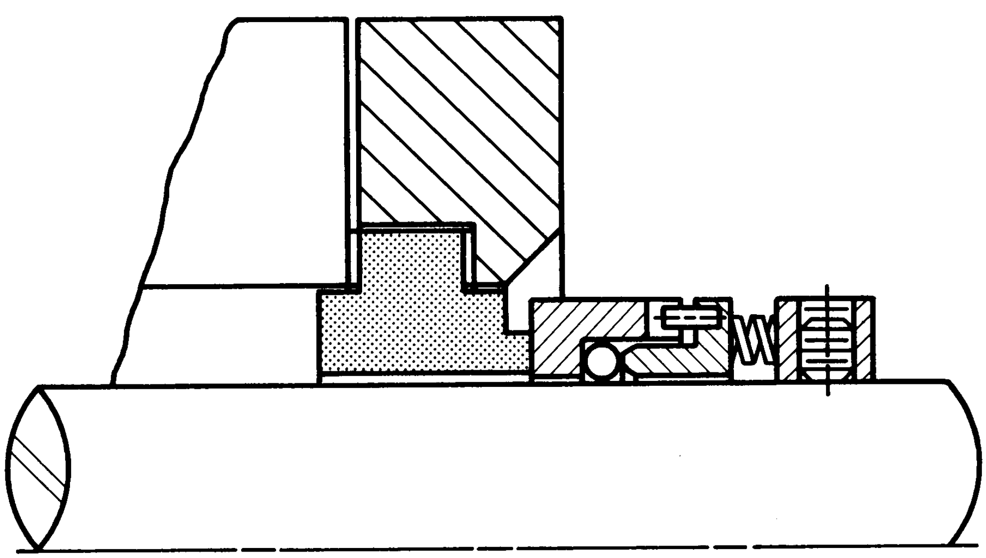


Fig. 10 Single outside seal

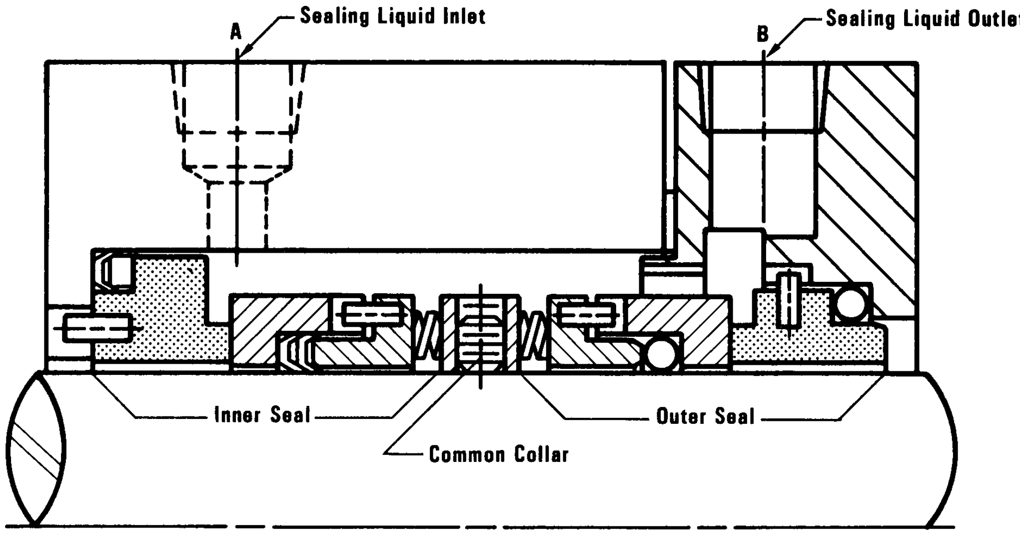


Fig. 11 Double inside seal

environment must be created for the seal. Imagine, for example, that a dirty, corrosive liquid must be pumped that would abrade the seal faces and require the use of expensive materials to provide the necessary resistance to chemical attack. A logical solution is to seal some liquid other than the product, a liquid that is clean and non-corrosive.

Figure 11 depicts a typical double seal. A liquid, such as water, is injected into the stuffing box at point A and exits at point B. With this arrangement the water, at a higher pressure than the product trying to enter the box, surrounds the double seal and provides lubrication to both sets of seal faces. The inboard seal prevents the water from entering the pump while the outer seal prevents the water from escaping to the atmosphere.

The differential pressure across the inner seal is the difference in pressure between the sealing liquid pressure and the product pressure acting on the stuffing box; the differential pressure across the outer seal is the difference in pressure between the sealing liquid and the atmosphere. Either or both of the seals may be balanced if the differential pressures exceed the limitations of unbalanced seals.

Double tandem seals

Another variation in seal arrangement can be found in the double tandem seal illustrated in Figure 12. The purpose of this seal is not to create an artificial environment as is the case with the double seal discussed above, but to provide a back-up seal in the event the inner seal fails. The inner seal functions in a manner identical to a conventional single inside seal. The cavity between the inner and outer seal is flooded from a closed reservoir. The liquid in the reservoir provides lubrication to the outer seal. Because the space between the seals is only flooded and not under pressure, the product, not the liquid in the reservoir, lubricates the faces of the inner seal. If the inner seal fails, the resulting pressure rise in the area between the

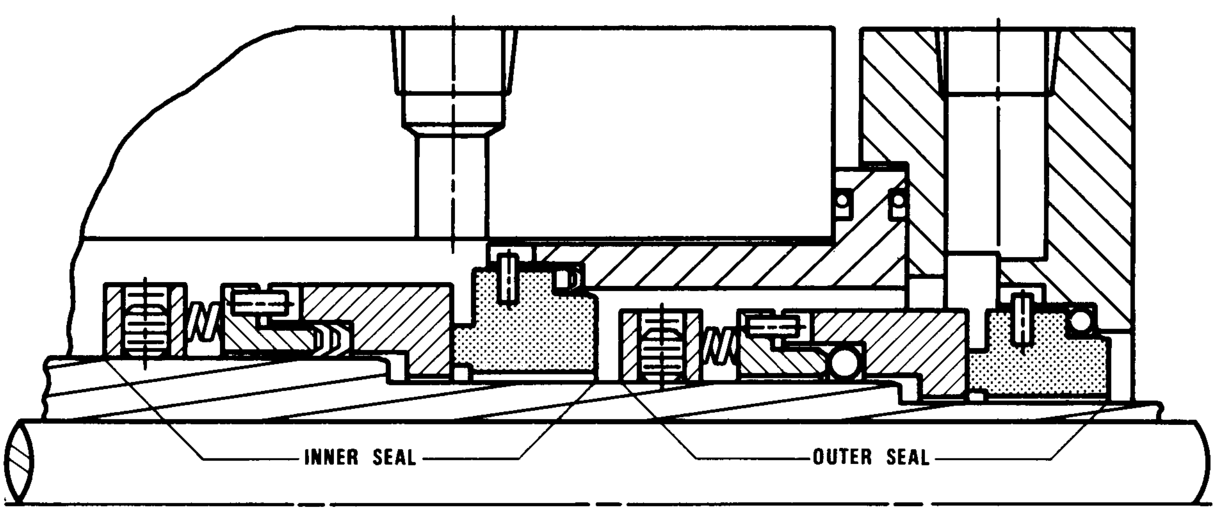


Fig. 12 Double tandem seal

seals is sensed at the reservoir, where it can either be registered on a gauge or activate an alarm. In any event, a failure of the inner seal can be detected while the outer seal assumes the responsibility of sealing the shaft until repairs can be made.

Since the tandem seal does not require the liquid between the seals to be at a higher pressure than the product pressure, the inner seal can be balanced for high stuffing box pressures without requiring a higher sealing liquid pressure. If a conventional double seal were used in place of a tandem seal, product pressures would have to be limited in order to prevent the hydraulic pressure from opening the inner seal faces. A tandem seal, however, is capable of being balanced to accept high stuffing box pressures.

pressure, the role of the inner seal remains identical to that of any single seal while the outboard seal simply serves as a back-up in the event the inner seal fails. A situation such as this would identify the inside-outside assembly as a tandem seal.

Factors causing malfunctioning

Malfunctioning either renders the seal useless from the beginning, or if observed after a period of time, gives warning that certain energies are initiating destruction. The latter is the more common. It takes time for a material that is overworked to become fatigued and certain chemical actions are associated with duration. Destruction, however, can be quite sudden and complete, as for instance a ring rotating at high speed being pulled apart by centrifugal force.

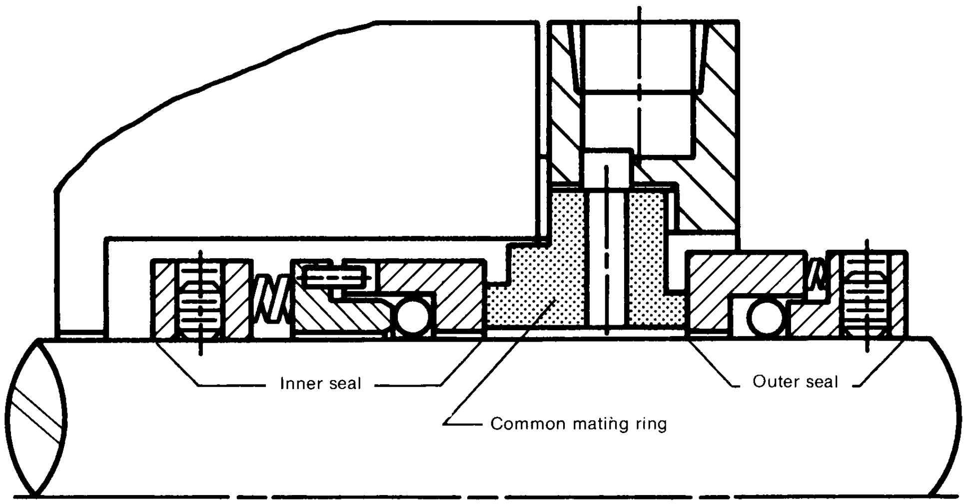


Fig. 13 Double inside-outside seal

Double inside - outside seals

Requirements for tandem or double seals are sometimes encountered where the stuffing box is too shallow to accommodate conventional designs. Therefore, it becomes necessary to turn to an alternate seal arrangement. In this case the alternative is the inside-outside double seal.

The inside-outside double seal is assembled as the name implies: one seal inside the stuffing box and one outside the stuffing box, with both seals rotating against opposite ends of the same stationary mating ring. Figure 13 illustrates an inside-outside double seal assembly, using an unbalanced inner seal and a balanced outer seal.

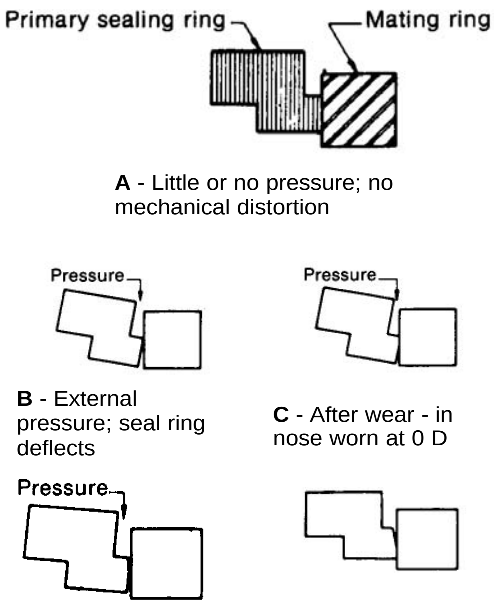
Whether the inside-outside arrangement is to be considered a tandem or double seal depends on its function. If the liquid used between the seals is at a higher pressure than the product in the stuffing box, then the purpose of this design is to lubricate the inner seal with a liquid other than the product. This is the role of a true double seal-creating an artificial environment in which the mechanical seal can operate. However, if the liquid is circulated between the seals at a lower pressure than the equipment stuffing box

Energies that contribute to destruction can be grouped into mechanical, thermal, chemical and radiation. Usually several work in combination with each other.

Mechanical

Mechanical forces resulting from the pressure of the medium being sealed become larger as pressures go up. Destruction to the ultimate breaking point seldom occurs since the parts are designed sufficiently strong in this respect. But the sealing faces, lapped flat to several light bands, are very sensitive to minute distortions. Distortion is a frequent reason for seal misbehavior.

Fig. 14 shows a primary sealing ring and its mating ring. With little or no fluid pressure the faces are parallel. As pressure increases the lip folds to the exaggerated position shown in A and wears to the condition at C. As pressure is relieved the lip folds back as shown in D and E. If pressure is steady the faces will wear in and conform to the condition in E. However, if it fluctuates greatly, angularity at the faces changes with every pressure change and the wedge-shaped gap at the faces permits fluid to start pushing them apart. Leakage increases. The situation, carried far enough could open the faces causing excessive leakage



A - Little or no pressure; no mechanical distortion

B - External pressure; seal ring deflects

C - After wear - in nose worn at 0 D

D - Pressure relieved; seal ring deflects back

E - Pressure back to condition at "A". Gap enables leakage

Fig. 14 Mechanical distortion due to pressure

The stiffness of a material depends on its modulus of elasticity. The higher the modulus the less the material deflects or distorts under the same conditions.

An interesting example drawn from experimental practice may serve as a case in point. A carbon seal ring and a tungsten-carbide mating ring were selected to seal 400 psi water fluctuating to 200 psi periodically. This is not a high pressure, since case histories successfully record 5000 psi applications. At 400 psi the seal ran well. After lowering the pressure to 200 psi leakage increased heavily and the test was terminated. Too much angular deflection, caused by the 50 percent pressure fluctuation, was the culprit.

The carbon seal ring was now exchanged for one of a special bronze composition and the test repeated. The seal performed well-no design change being made, just a different material used. The bronze performed better because of its higher E-modulus. It therefore deflected less and enabled the seal to perform. If bronze is not a compatible material with the liquid being sealed then a heavier cross section carbon piece will resist deflection to the same extent that the bronze does.

Should space not permit this then another approach to the problem is to make the seal ring of tungsten-carbide and the mating ring of carbon. The much simpler shape of the mating ring, essentially a narrow ring, deflects radially as pressure acts on it, and no angularity for wedge action is created. The seal ring having a more complex shape yields easily to non-uniform distortion. This is resisted tremendously by the high E modulus of tungsten-carbide which is 100×10^6, or almost 10 times greater than bronze and over 30 times that of carbon. However, an intricately shaped tungsten carbide piece is expensive.

The base material itself is not cheap and the finish machining usually consists of diamond grinding which is costly. An economical solution is shown in Fig. 15. Here the tungsten-carbide face is a ring of simple cross section held in a stainless steel mating ring. Design and material selection are well balanced against each other resulting in a good solution to the problem.

Too high a face loading between the primary sealing ring and its mating ring can be troublesome, especially with higher pressures. The liquid film between the faces could be squeezed out, power consumption go up, the bearing load limit of the material would be exceeded and excessive heat generated. To avoid these conditions seals are hydraulically balanced, as discussed above.

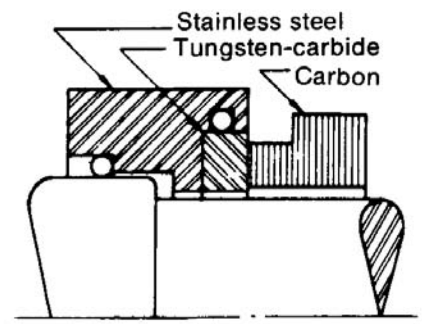


Fig. 15 Seal for high fluctuating pressures

Thermal

Heat, if not properly dissipated, can cause seal malfunctioning. Temperature at the faces is often higher than might be suspected. Between the faces the temperature may be several hundred degrees higher than that of the immediate environment. Thermal conductivity of the materials should be good. Viscosities of liquids decrease as temperatures go up. With poor lubrication the rubbing of the seal ring on the mating ring may cause heat checking of some materials. Heat checking is a surface condition involving many fine cracks, often visible only under a microscope, resulting from sudden thermal gradients at the running faces. Among the many materials used as face combinations, tungsten-carbide is very resistant to heat checking.

Sometimes the liquid itself may cause thermal malfunction. At high temperatures coking of some oils may occur. Deposits build up and eventually could open the faces.

Owing to different coefficients of thermal expansion, parts that depend on shrink fits may become loose or undesirable stresses may occur.

Strength and E-modulus of metals decrease with temperature, whereas with carbons they increase.

To improve these conditions cooling is often introduced in the immediate vicinity of the faces.

Chemical

Actual operating conditions are most important.

Velocity or agitation of the liquid relative to the material components accelerates corrosion. Temperature increases corrosion rates geometrically. A rule of thumb says that a 35° F. rise of a corrosive liquid doubles the corrosion rate.

In general acid solutions are more corrosive than alkaline. However, high alkaline solutions can corrode faster than acids and even carbon, with its high degree of versatility, must be selected cautiously. Material selection must take pH values into consideration.

Oxidizing agents must be reckoned with for they are powerful corrosion promoters and oxygen from the air, often in dissolved form, is frequently present.

Inhibitors such as sodium dichromate used to protect new piping can cause many seal problems. Concentrations above 250 ppm will shorten seal life.

Electrochemical action, known as galvanic corrosion can be minimized by selecting material combinations not too far apart on the galvanic series chart. Generally the farther apart the material densities the more acute the condition. Specific cases should be checked. The fluid itself is important. Distilled water is a poor conductor; strong salt solutions such as brine and sea water are good conductors and accelerate galvanic corrosion.

Radiation

Radiation changes are caused by rays emitted from radioactive substances. Alpha and beta rays cause little damage. Of primary concern in selecting materials are the more penetrating gamma rays and neutrons.

The changes can be temporary or permanent. Of interest are the permanent changes which persist after the material has been removed from the radiation field. Radiation dosages must be checked against values given in handbooks and charts to determine the effect of irradiation on material properties.

In general it can be said that the structural materials such as carbon steels and stainless steels, alloys of aluminum, nickel and copper have the best radiation resistance. Inorganic materials such as graphite, carbides, glass and ceramics show many changes in material properties. Elastomers vary widely in radiation resistance. Plastics, with the exception of TFE, generally have equal or better radiation resistance than the elastomers. Besides the effects on the material itself the effects of radiation on the fluid being sealed should be checked. Changes in its properties may influence material selection.

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