Mechanical Equipment - Course 330

AXIAL MECHANICAL SEALS

There are two basic methods of obtaining shaft sealing in pump casings: conventional stuffing boxes, making use of soft pliable packing and face type mechanical seals, the latter being the newer method. Two special methods of sealing different from the above two use fixed labyrinths and floating seal rings. These two will not be discussed in this lesson. As the conventional stuffing box method was discussed in Lesson 430.15-1 no further mention of it will be made here.

Face type mechanical seals have certain advantages and disadvantages which are:-

Advantages

1. Reduce friction
2. Elimination of wear on shaft or shaft sleeve
3. Low controlled leakage over a long service life
4. Relative insensitivity to small shaft deflection or end play.
5. Freedom from periodic maintenance.

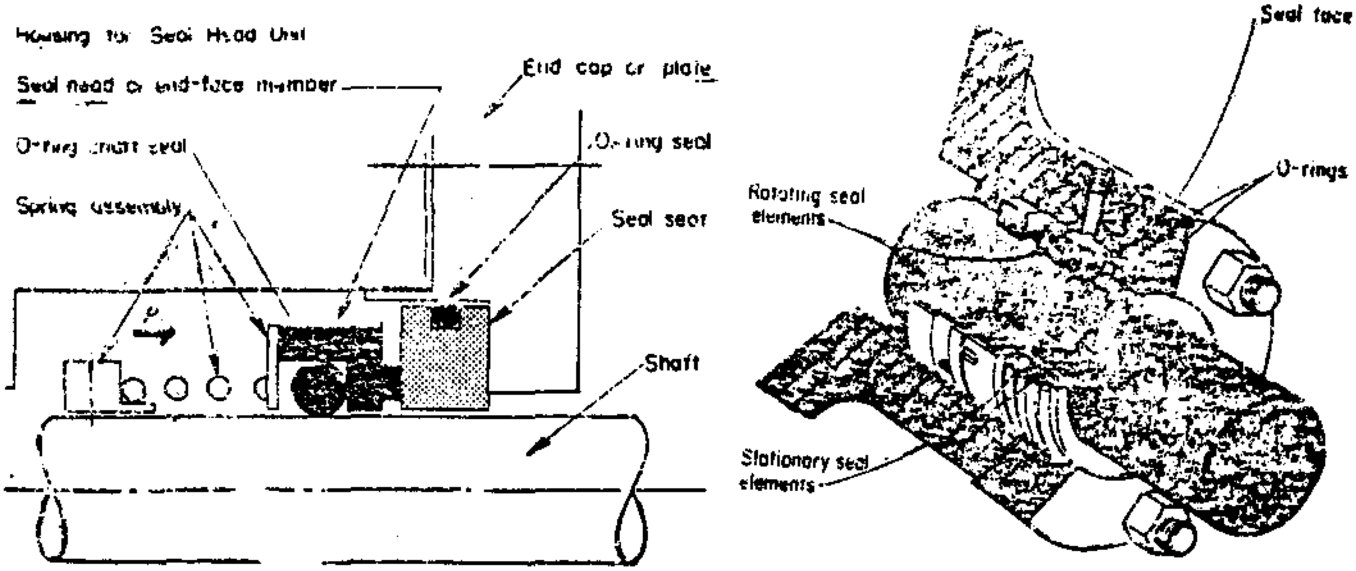
Disadvantages

1. Being a precision component it demands careful handling and installation.

2. Seal failure results in a lengthy shut-down, because to replace it one usually has to remove the driving motor and associated couplings.

Basic Design

A face type mechanical seal consists of two mating seal rings, one stationary one rotating, with extremely smooth parallel faces, a spring loading device and static seals. A typical seal is shown in section and cutaway in Figure 1.



Basic End-Face Mechanical Seal Design

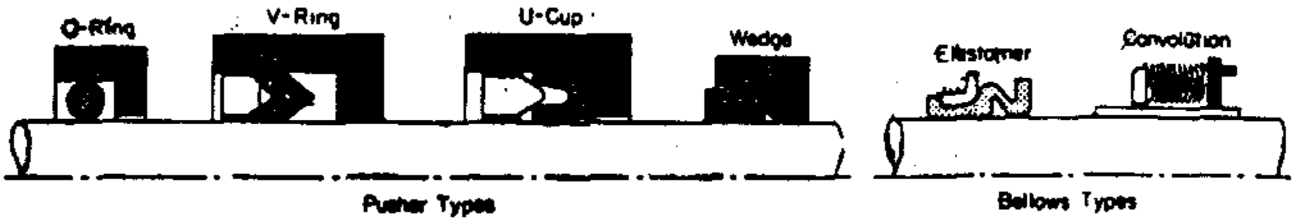
Figure 1

The rotating seal head which is fixed to the shaft is held against the stationary seal seat by means of the spring force and the hydraulic load acting upon it. Sealing takes place between the two surfaces of the seal head and seal seat. Since the rotating seal head is stationary with respect to the turning shaft, sealing at their junction point is accomplished easily through the use of an O-ring. A static seal is also obtained between the seal seat and the pump end cap by means of an O-ring.

Shaft sealing elements include O-rings, V-rings, U--cups, wedges and bellows (see Figure 2). The first four of these elements are referred to as "pusher-type" seals. As the seal face wears these pusher type elements are pushed forward along the shaft maintaining a seal. Typical pusher seal materials include elastomers, plastics, asbestos, and metal.

Bellows shaped sealing members differ from the pusher type in that it forms a static seal between itself and the shaft. All axial movement is taken up by the bellows flexure. Molded elastomers and corrugated metals are used for bellows.

The bellows type seal element unlike the pusher type member, is not subject to dust contamination. Any material collected in front of the pusher type member may produce a barrier. Also only the metal bellows type are applicable to extreme temperature conditions.



Shaft-sealing Configurations for Pusher and Bellow-type Seals

Figure 2

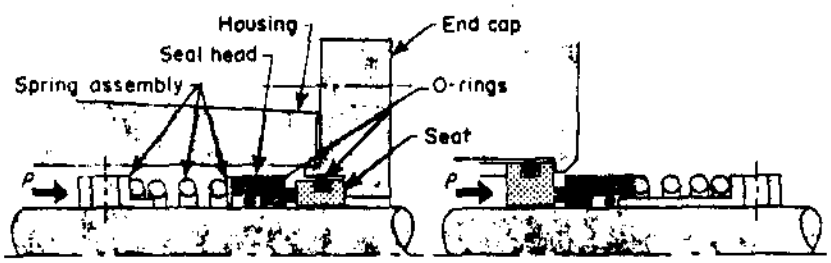
Spring assemblies are added to energize the end-face member axially, keeping the seal faces together during periods of shutdown or lack of hydraulic pressure in the unit.

Various types of springs are used in spring assemblies - single springs, multiple springs and wave springs. Multiple spring design is the most commonly used type. It has a shorter axial requirement than a single coil spring and resist unwinding to a higher degree than single coil spring when subjected to centrifugal force. Face loading can be more readily varied simply by adding or subtracting springs. Wave springs have the advantage of minimum space requirements but greater change in loading for a given deflection is required.

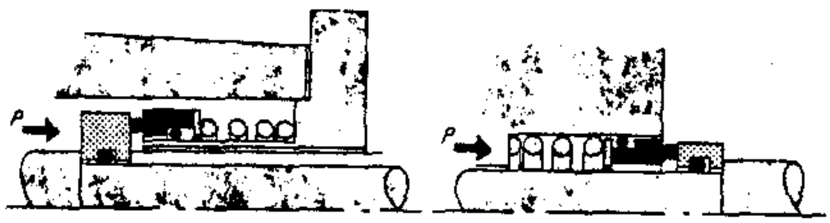
Positive drive is applied to seals to secure mechanical engagement to the shaft and to eliminate stress on the static seals. There are many types of positive drive, some of which are dent drives, key drives, set screw drives, pin, dowel and roll pin drive, snap ring drives, etc. The type of drive used depends upon loading requirements.

Stationary and Rotating Seals

The seal design used can have a rotating or a stationary seal head with respect to the shaft. The end face seal illustrated in Figure 1 has a rotating seal head and a stationary seal seat. Figure 3 illustrates both rotating and stationary seal heads, internally and externally mounted.



Rotating Seal Heads



Stationary Seal Heads

Figure 3

An internally mounted rotating seal design is the more commonly used type of seal arrangement in pumps, particularly where balancing is necessary. Balanced seals are discussed further on in this lesson.

Stationary heads are best applied when comparatively high speeds are encountered. The stationary seal head with its relatively simple rotating seat member requires less critical dynamic balancing than the rotating seal head with all of its components.

Externally mounted seals in some cases, simplify installation and removal, and also adjustment. For large equipment or cramped quarters cartridge seals have been developed which permit installation and removal of individual parts without having to remove bearings, couplings, housings and other components.

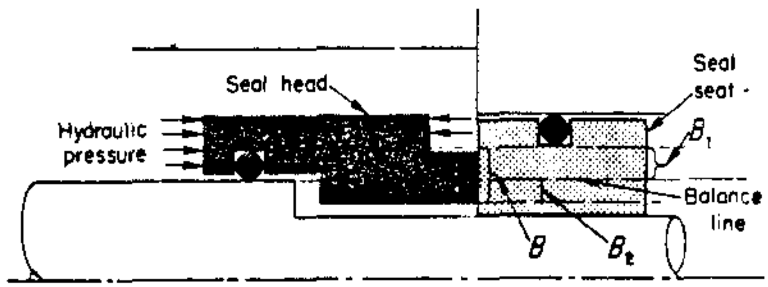
Axial Mechanical End Face Seal Operation

Flow through the seal face is limited by the resistance offered by the two faces. In most cases, leakage is so small that liquid passing through the interface path evaporates into the surrounding air, and the seal appears to be leakless. Some leakage is necessary as it acts as a lubricant to reduce the friction between the two faces. It also removes heat generated at the seal faces. The seal materials are usually poor conductors of heat.

The flow resistance developed by the seal faces depends upon the unit pressure between them. This unit pressure is produced by the hydraulic and spring force pressing the faces together. To help reduce friction between the stationary and rotating face the seal faces must be flat, parallel and very smooth. Also the face materials selected must have low coefficients of friction.

Counterbalancing a small part of the closing force is the pressure gradient acting across the seal interface. This pressure gradient is a result of the liquid pressure acting on one side of the interface and atmospheric pressure on the other.

If very high pressures must be sealed, a different design of seal is necessary which will reduce the crushing or closing force between the seal faces. This seal, called a balanced seal, is shown in Figure 4.



Partial balance achieved when head sealing face is lowered by means of a step cut in the sleeve. Hydraulic pressure acts against a portion of the total face area B. The factor of "per cent of balance" is created by distributing the area of B_1 and B_2 above and below the balance line respectively.

Balanced Mechanical Seal for High Pressure Service

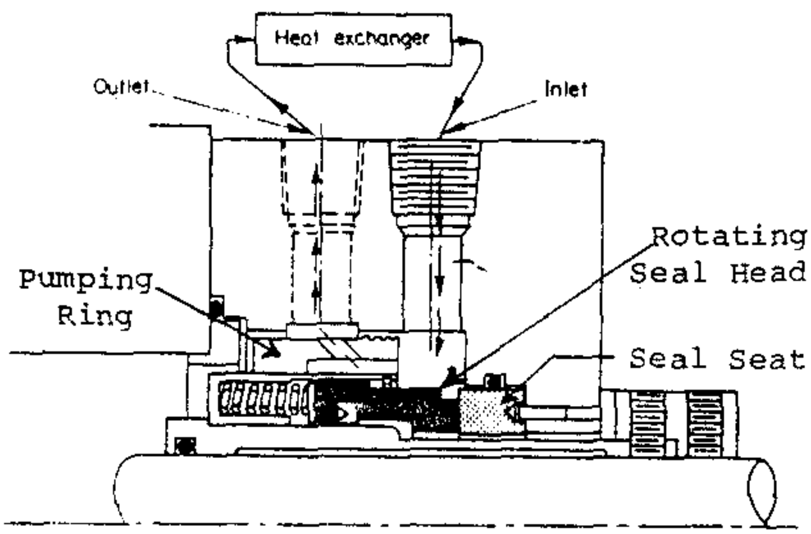
Figure 4

By machining a step on the rotating seal face and a shoulder on the shaft or the shaft sleeve part of the hydraulic force acting on the opposite end of the seal face is balanced. The shoulder on the shaft and the step on the rotating seal face considerably increase the cost of the seal.

Cooling and Lubricant

It is necessary to reduce the liquid temperature at the seal face to some value well below the liquid's atmospheric boiling point otherwise flashing or vaporization of the liquid will take place in the interface. The effect will be a loss of the liquid lubricant permitting the seal faces to run dry. Localized heating of the faces cause minute particles of material to break away forming leak paths. In addition as the liquid vaporizes or flashes, a large volume increase suddenly occurs. The effect is that of small explosions that causes the seal faces to separate, relieve pressure build up and then close rapidly because of the unbalanced spring and hydraulic forces. The rapid closing heavily loads the brittle faces and often breaks away more material.

A water jacket surrounding the whole seal assembly is one way to achieve cooling. Another method cools the liquid from the seal in a separate cooler and then injects the cooled liquid at the seal faces. In this method a small pumping ring on the drive collar of the seal provides the energy needed to overcome friction in the cooler. This method is illustrated in Figure 5.

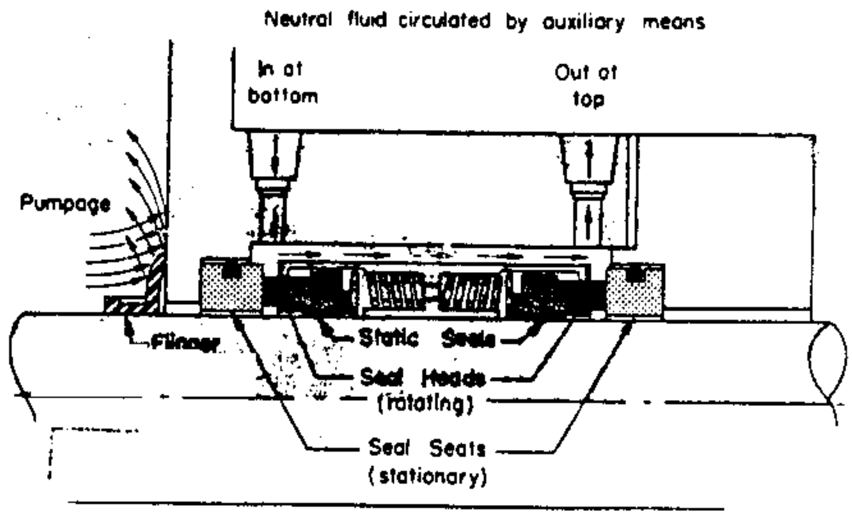


Heat Exchanger and Pumping Ring

Figure 5

Some provision is also necessary to prevent solid particles from damaging the seal faces. Several effective ways of accomplishing this are in use. In one method the seal faces are flushed with clear liquid. Another method simply injects filtered liquid from the pump discharge into the stuffing box.

In cases where contamination of the pumpage is not permitted a double seal design of the type shown in Figure 6 can be used. The neutral fluid is circulated between the two seals at a higher pressure than the pressure against the inboard seal faces thus preventing any outward flow of the pumpage.



Double-Seal Technique for Isolating Seal Fluid From Pumpage

Figure 6

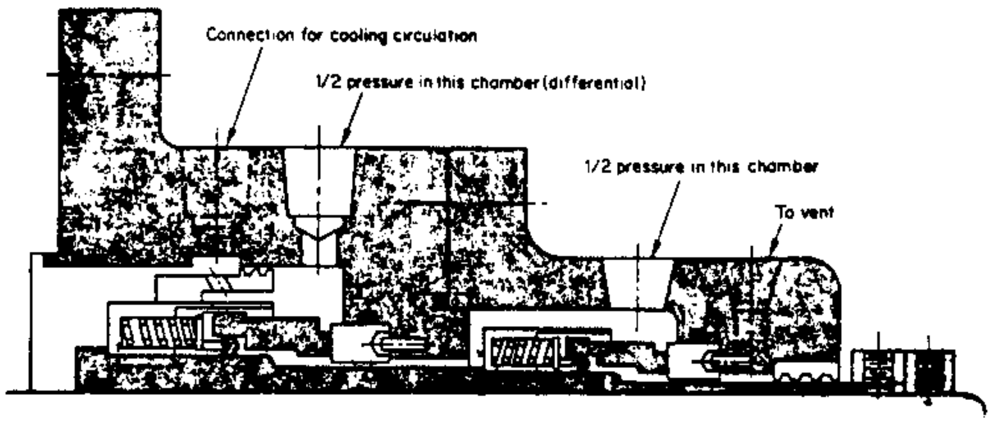
Face Material Combinations

The seal face material combinations depends primarily on the type of working medium. In high-pressure, high temperature water sealing systems found in nuclear power plants, stellites, tungsten carbide, and carbon graphite are commonly used materials. Stellites and carbides are usually used for the rotating seal face whereas the graphite is used for the stationary seal face.

Applications

One of the most critical areas of shaft sealing takes place in the Primary Heat Transport Circulating Pump found in Nuclear Power Plants. These particular pumps, using the

Pickering pump as an example, have a rated capacity of 10,000 Igpm. The heavy water circulated is at approximately 500°F and 1000 psig. These large pumps have a shaft seal of a type designed to collect seal leakage. The seal assembly contains two functionally identical face seals in tandem. A typical tandem seal arrangement is illustrated in Figure 7. (This is not the Pickering pump seal assembly). By breaking down pressures in the respective chambers, each seal faces only the resulting pressure differentials. Tandem seals are used where extra safety is needed, particularly when operating at high pressures.



Tandem Seal Arrangement

Figure 7

ASSIGNMENT

1. List the advantages and disadvantages of the axial mechanical seal.
2. What is the function of the spring in the seal assembly?
3. Why is leakage necessary through an axial mechanical seal?
4. What method is used to partially balance a mechanical seal?
5. Describe a tandem seal arrangement.

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