SYMMETRICAL SEAL DESIGN: A SEALING CONCEPT FOR TODAY

by

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ABSTRACT

The symmetrical seal offers a significant advancement in seal design to pump manufacturers and users. It is the first alternative design to complex seal arrangements which are required to fit a stuffing box designed for packing.

Today, with more demands being made on tighter leakage control and simplified installation, the transition is being made from a conventional stuffing box to a self-contained package seal. The concept of a package seal is not new and dates back to the early days of the pipeline industry when they were supplied to seal split case pumps. What is new is the bolt-on feature of the symmetrical seal, freeing the seal design from the space required for packing. This freedom allows the seal manufacturer to include such sealing features like upstream pumping, when required.

INTRODUCTION

The past ten years saw a rapid development in seal technology. A better understanding of lubricating film development, instabilities in seal performance and horsepower losses led to the design of a variety of seal face configurations. Each of these configurations was successfully used to improve seal life. However, each solution was made to fit a stuffing box designed for packing. This resulted in some complex seal arrangements which represented a compromise in seal design. The stuffing box of a centrifugal pump saw little change over the years.

Most specifications and standards were written such that the mechanical seal was to be interchangeable with packing. The idea was that if a mechanical seal failed, it would be replaced by packing. In practice, this was not the case and when a seal was replaced, it was replaced with another seal. Designing a seal to fit a stuffing box designed around packing was not without its problems. Certainly, it was complicated by federal and state emission standards which led to the application of complex, multiple seal arrangements (Figure 1), on many liquids referred to as VOCs (Volatile Organic Compounds). Space limits of many stuffing boxes left a lot to be desired in terms of good design practice for mechanical seals. This resulted in reduced axial and radial space for the seal so that the sizes of some of the seal parts become an inconvenience for installation and maintenance.

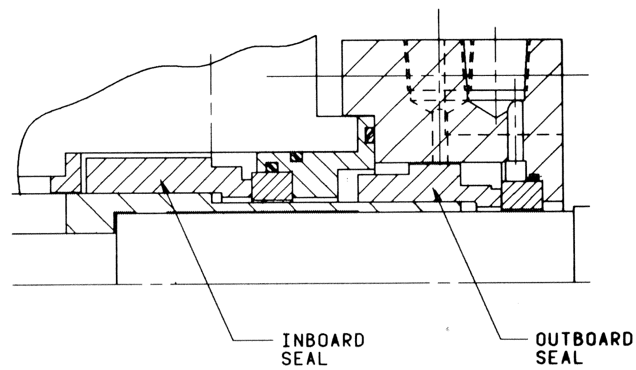

Figure 1. Typical Tandem Seal Arrangement.

Another look was required at the seal installation without the design constraint of fitting to the space of a packed stuffing box.

SPECIFICATIONS OF A SEAL CONFIGURATION

Over the years the mechanical seal has evolved as a machine element, having many options. Manufacturers and users needed to concern themselves as to whether a seal was:

- Balanced or unbalanced
- Rotating or stationary head
- Pusher or non-pusher secondary seal
- Single or multiple spring design
- Single seal arrangement mounted inside or outside the stuffing box
- Double or tandem seals
- Package (cartridge) or non-package seals

Each of these options were used to optimize a seal design for a specific operating environment. The specification selected by a user without regard to stuffing box space might create a design problem for the seal manufacturer, resulting in the development of non-standard components. This created an added problem of parts supply for the initial and replacement seal installations. In a manufacturing environment, users, pump makers and seal manufacturers should not be forced to accept compromises in seal designs that lead to inefficiencies. This could be avoided by providing an alternative to the conventional stuffing box.

CONCEPT OF THE SYMMETRICAL SEAL

To become more efficient as a user or manufacturer, there had to be a change in the way one viewed a seal installation. Sealing concepts had to take into account the seal and stuffing box as one package. The concept of a package seal was not new and dated back to the early days of the pipeline industry when single seals were first applied to split case pumps. What was new was the merging of the stuffing box and mechanical seal to form an uniquely different self-contained package seal referred to as a symmetrical seal (Figure 2).

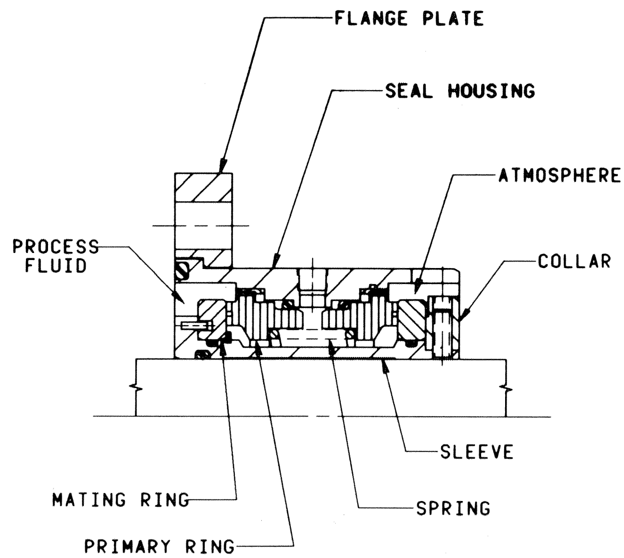

Figure 2. Symmetrical Seal Design.

A symmetrical seal package offers a great deal of flexibility to the end user. Since the stuffing box has become the seal housing, the seal itself is no longer designed to fit the shaft, but rather the bore of the unit. This allows the internal wear parts of the seal, the primary and mating rings and their associated static seals, to fit a range of shaft sizes by replacing the sleeve. This design has a stationary seal head with single coil spring construction.

Both the primary and mating rings in Figure 3 form the sealing plane. The faces are designed to stay closed with just process pressure on the outside diameter of the seal face or when internally pressurizing in the seal chamber. This feature allows the package to be used as a single, double, or tandem seal without any additional seal parts. The balanced primary ring construction helps to reduce power losses.

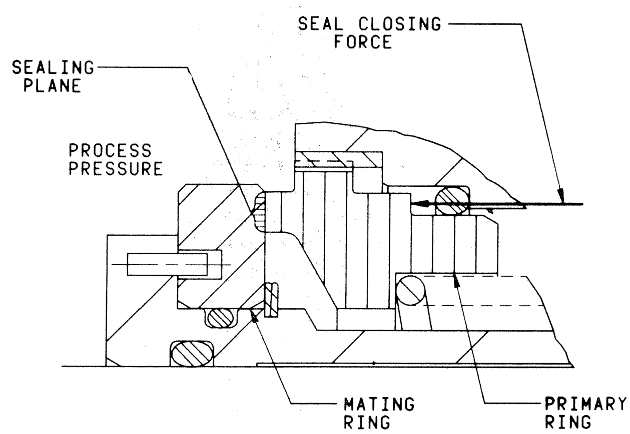

Figure 3. Sealing Plane.

TEST RESULTS

The symmetrical seal was first introduced to the pharmaceutical industry as a dry running seal for agitator service. Depending on the chemicals involved in the mixing process, the seal would be used as a single or tandem seal. The dry running feature eliminated the need for a lubrication system. Laboratory results have proven the concept for this type of application [1]. Typical leakage for a 2 inch diameter seal operated dry at mixer speeds and dropped off to approximately zero after an initial run-in time of 30 hours. The leakage results at low speed are illustrated in Figure 4. The leakage was through the inboard seal with a pressure differential of 175 psig. The fluid sealed was air at 250°F. The seal was also operated with 0.125 inches of misalignment to simulate large shaft runouts. Seal face temperatures were also measured and are illustrated in Figure 5. The face materials used in this study were carbon and tungsten carbide.

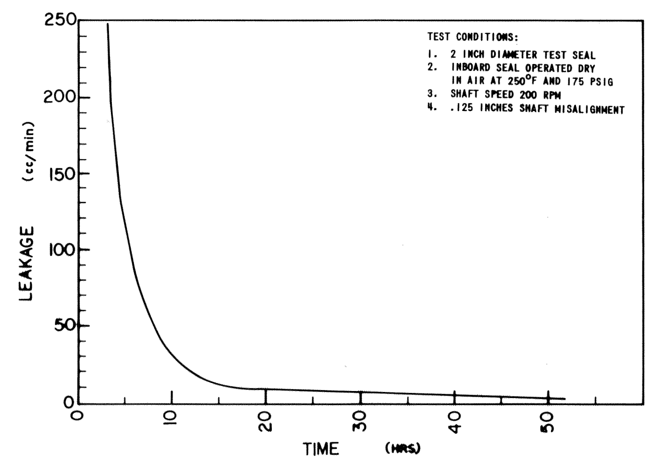

Figure 4. Results of Inboard Seal Leakage at Low Speed.

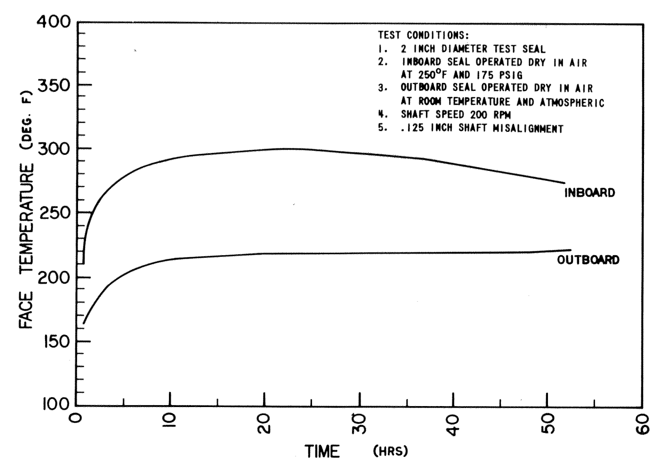

Figure 5. Seal Face Temperatures at Low Speed.

The study of the symmetrical seal was extended to determine operating limits at pump speeds of 3600 rpm. single, double, and tandem seal arrangements were evaluated in water and oil [2].

The single seal illustrated in Figure 6 was successfully run with water as the process liquid at pressures of 300 psig and temperatures of 300°F. The results were extremely encouraging for this design. A conventional seal fitted to a stuffing box design for packing would have to be cooled to 180°F for good running performance. The test was repeated in oil with excellent results. However, the oil temperature was limited to 200°F to prevent material from carbonizing at the seal faces.

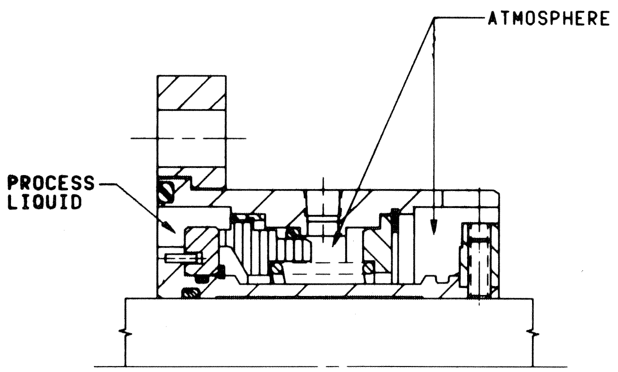

Figure 6. Single Seal Arrangement.

The double seal, illustrated in Figure 7, was tested with the process liquid being water at 300 psig and 300°F. The seal chamber was filled with water and pressurized to 325 psig. A small amount of water was circulated to maintain a temperature of 300°F. The seal was successfully run at these conditions. This test was rerun with oil in the seal chamber and outboard seal leakage occurred at 50 psig. The same primary ring used on the low speed agitator tests and on water tests at pump speeds did not perform as well in oil at higher speeds. The original low speed primary ring had hydropad features at the inside diameter of the seal face. A combination of lift-off and thermal effects caused the seal leakage. The hydropad feature was removed and a flat seal face was retested successfully to a pressure of 325 psig. The results qualified the seal for both water or oil buffer liquids to pressures of 325 psig, at 3600 rpm. Water temperatures were limited to 300°F, oil temperatures to 200°F to prevent carbonization of the oil.

Tandem seals, illustrated in Figure 8, were tested with the process liquid being water at 300 psig and 300°F. The seal chamber was run dry at atmospheric pressures with no adverse effects to the outboard seal. A face temperature of the outboard seal was measured at 376°F, while the process liquid at the

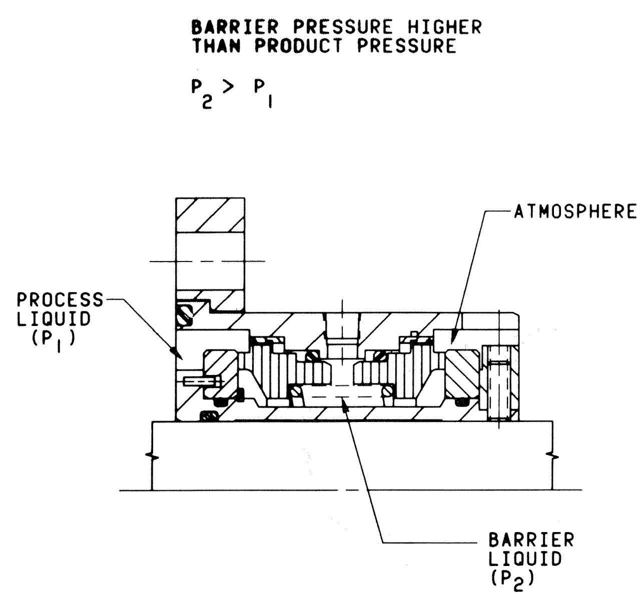

Figure 7. Double Seal Arrangement.

inboard seal was 300°F. The test was rerun for both water and oil in the seal chamber at 50 psig. Each test was successful. A small quantity of liquid was circulated to maintain seal chamber temperatures of 300°F for water and 200°F for oil.

The same structural parts for the double seal are used for the tandem seal arrangement. Only the pressure in the seal chamber is reduced to operate the seal as a tandem.

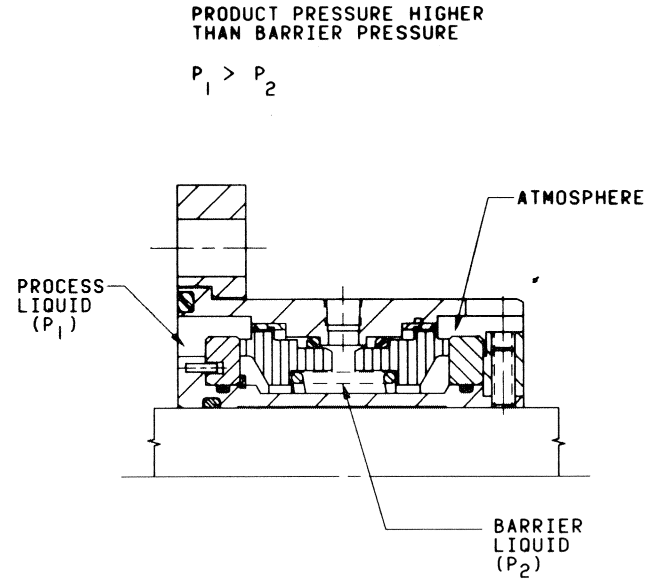

Figure 8. Tandem Seal Arrangement.

UPSTREAM PUMPING

The concept of the symmetrical seal allows us to consider an additional feature—one of upstream pumping. Upstream pumping is defined as moving a small quantity of liquid from the low pressure side of a seal face to its high pressure side. This is accomplished by a change in seal face geometry on the rotating mating ring. For example, early experiments have demonstrated that a 1-¾ inch diameter seal operating in water at 1800 rpm, can pump 0.6 ml/min. at 800 psig [3]. This concept when applied to the symmetrical seal, Figure 9, would allow a plant operator to bring a water line or a neutral liquid directly to the seal chamber. The low pressure liquid can be made to flow in

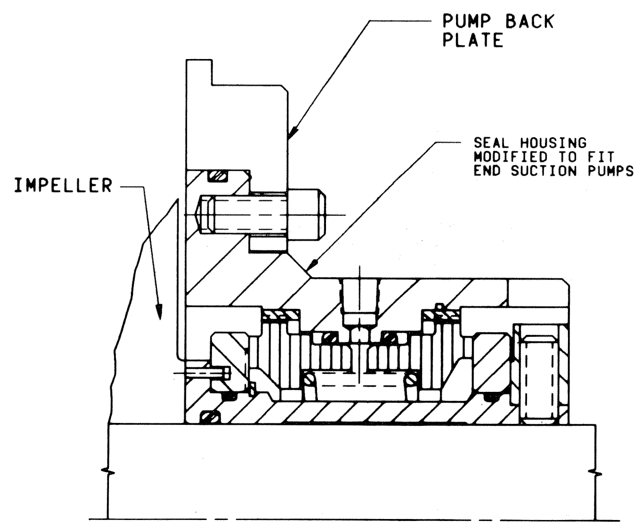

Figure 9. Symmetrical Seal with Upstream Pumping Feature.

minute quantities to higher pressures through the pumping action of the seal faces. This flow of clean liquid could be used to keep the inboard faces clean on abrasive services or to provide lubrication to the inboard seal when pumping liquids with poor lubricating qualities. Still another use is to control emissions of hazardous liquids to plant atmosphere. In effect, upstream pumping creates a non-contacting seal. This type of technology is an extension of the work being done on dry running gas seals.

CONCLUSION

Many benefits of the symmetrical seal are yet to be realized. The limits of this seal have been established at 300 psig, 300°F and 3300 rpm. The concept offers the user maximum flexibility to use single, double, or tandem arrangements with the same hardware. Wear parts are interchangeable between inboard and outboard positions. Also, with a change in sleeve design, wear parts could fit a range of shaft sizes. Increased clearances allow the unit to handle large amounts of shaft runout.

The symmetrical seal, when used as a multiple seal arrangement, can be bench tested before installation. The package seal with upstream pumping can be used, without the need for a pressurized barrier fluid, to solve problems in handling abrasives, liquids with poor lubricating properties, or as an additional emissions control device.

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3. Zutaut, George H., "Performance Evaluation of Reverse Type 28 Spiral Groove Seals," John Crane-Houdaille, Incorporated, Mechanical Test Lab Project 2091, pp. 1-5 (October 10, 1982).