Achieving Reliable Level Detection in Seal Pot Applications

A white paper by Endress+Hauser, Inc.

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Level Switches in Seal Pots

In industrial operations, seal pots protect costly and critical plant equipment. Reliable level switches are extremely important in seal pot applications. To understand the need for seal pots, this White Paper will cover seal basics, the development of modern seal designs, and the systems that maintain and control seal environments.

Seal Basics

Nearly every industrial process uses many different types of seals to eliminate leaks. A modern production facility often maintains literally thousands of seal points. Most of us are familiar with a 'static' seal, the common seal used where no movement occurs at the surfaces to be sealed. A simple gasket or an o-ring often creates a static seal.

Applications in which the surfaces to be sealed move relative to one another require a second seal type, known as a 'dynamic' seal. For example, dynamic seals must be used when a rotating motor shaft transmits power through the wall of a tank to mix the contents of the tank (fig. A). Dynamic seals are also required through the casing of a pump to transport a fluid (fig. B).

Figure A

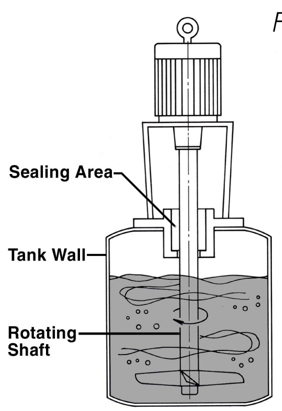
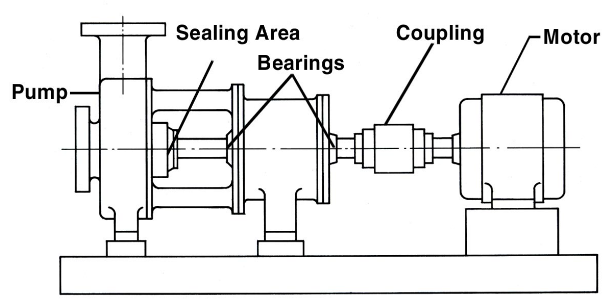
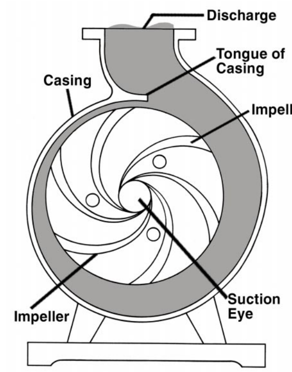


Figure B



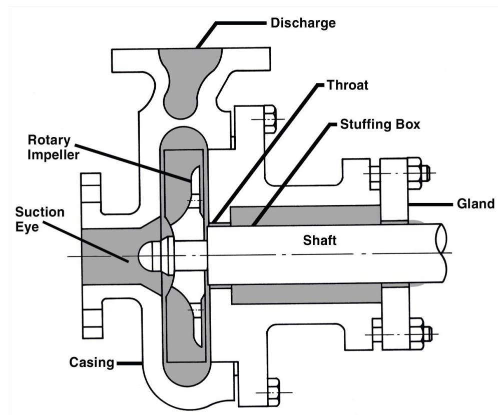
Dynamic seals are frequently located on the shaft of a centrifugal pump. The pump converts the electric motor's rotating energy into velocity, or pressure energy of the liquid or gas being moved.

The rotating impeller vanes transmit the motion to the incoming product, forcing it out under pressure at the pump discharge (fig. C). The discharge pressure forces some product down behind the impeller to the rotating drive shaft. In that location



the product attempts to escape through the small gap between the rotating shaft and the mating surface of the pump casing (fig. D). This gap must exist in order for the shaft to rotate freely.

While methods to reduce the pressure at the gap exist, it is impossible to completely eliminate the internal pressure generated by the pump. Therefore, a sealing solution is required to prevent fluid from leaking out of the pump.



Evolution of Dynamic Seals

To combat the leakage problem, pump manufacturers have used a variety of seal designs to combat this leakage problem over the years. Initial attempts sometimes simply restricted clearance between the shaft and the pump casing (or tank wall) by using a resilient, compression packing material around the shaft. The packing material was installed in an extension of the pump casing, called a stuffing box (fig. E). Bolts tightened on the external gland force pressure to the packing material. When forced against the shaft, the material creates a tight seal that allows enough slippage for the shaft to rotate. Packings now encompass a wide assortment of compressible materials, available in many shapes to satisfy a growing range of demanding requirements. While this method is effective for certain applications, eventually friction, wear, and heat will result in some leakage. This prohibits use in critical applications where product loss cannot be tolerated.

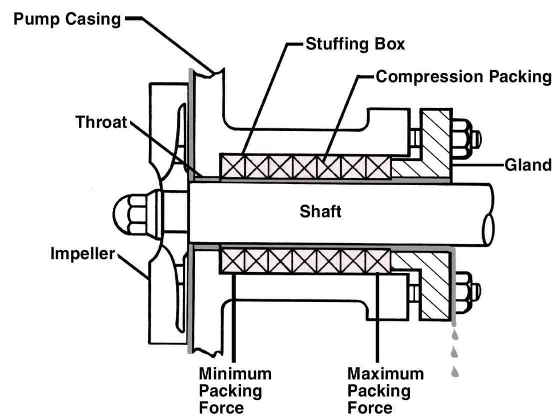


Figure E

One major group of dynamic seal designs employs the theoretical absence of any rubbing contact between the mating surfaces. A second, more common group involves rubbing contact between the shaft and the seal surface. This group includes the compression packing design mentioned above, as well as end-face mechanical seals (commonly referred to as mechanical seals).

The heart of a mechanical seal features a set of seal faces, one that rotates with the shaft, and a second stationary seal face. Varying industrial requirements have resulted in numerous seal arrangements and materials, as well as an elaborate set of additional hardware, normally involved in the complete assembly. We can only attempt to illustrate the basic concept here. Essentially, each arrangement achieves a tight seal by utilizing two very flat, lapped faces, positioned perpendicular to the shaft, which rub together (fig. F).

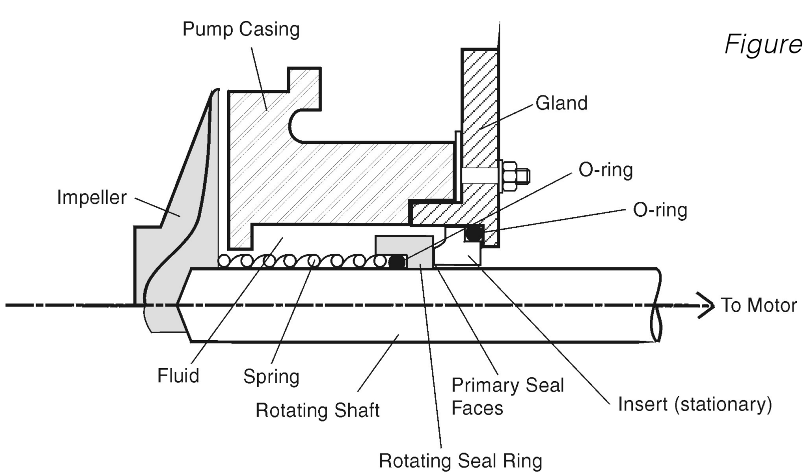


Figure F

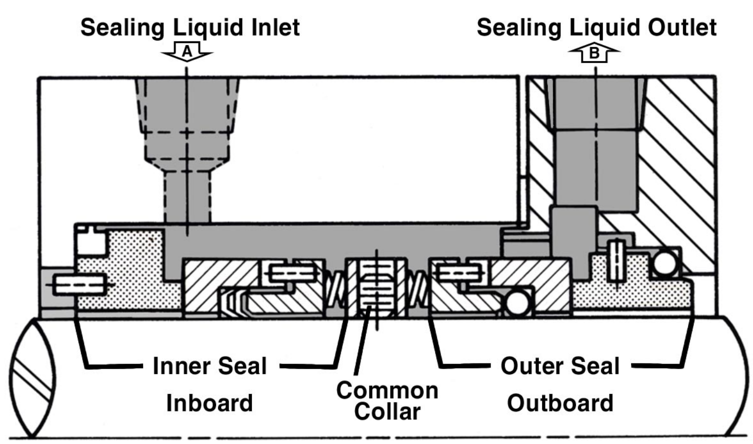
In most designs the two faces are made of dissimilar materials to prevent any adhesion. One face is usually a non-galling material, such as carbon-graphite; and the other, a relatively hard substance. A boundary layer of gas or liquid lubricates the rubbing faces. Operating conditions dictate the method in which this is accomplished. Selection of the proper seal design ensures long life with minimal maintenance or risk of failure. However, advanced training and technical knowledge are required to adequately maintain these seals.

Mechanical seals overcome the disadvantages of compression packing. Initial costs may be higher, and maintenance for mechanical seals may require more advanced operator training. However, leakage amounts can be controlled to meet the strict environmental and safety standards of regulatory agencies. If maintained properly, the long-term maintenance costs can actually be lower than the cost of using compression packings.

Double Seals

Applications involving certain toxic, hazardous, or corrosive fluids cannot tolerate leaks into the environment - eliminating use of a single mechanical seal. In such cases a double seal, using a compatible liquid injected into a seal chamber, offers a solution (fig. G).

Figure G



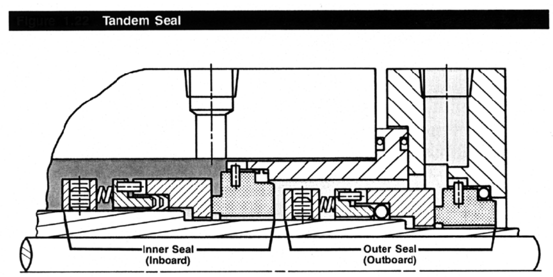
With this liquid, referred to as the 'barrier fluid,' a valve downstream of the chamber outlet maintains a higher pressure than that of the product being pumped (usually 15 to 30 psi greater than the process). The pressurized barrier fluid prevents contact of the hazardous product and the inner portion of the seal, while also lubricating both seal surfaces. The inner seal prevents the barrier fluid from entering the product, while the outer seal prevents the barrier fluid from leaking into the environment. By never contacting the product, the seal's inner parts are only exposed to the safe barrier fluid, eliminating the need for expensive seal materials.

Process fluids pumped as a liquid but existing as a gas at atmospheric conditions (such as a light hydrocarbon), may be sealed using a double seal with an unpressurized buffer fluid. An immiscible buffer fluid such as diesel fuel is used. Any product leaking through the inner seal bubbles up through the buffer fluid into the reservoir, where it can be vented to a flare.

Tandem Seals

More stringent OSHA and EPA regulations have led to development of a newer seal arrangement, the tandem seal. It is now in higher demand for use with volatile, toxic, carcinogenic, or hazardous fluids.

Figure H



The tandem seal's design allows the inner seal to withstand full product pressure (fig. H). The outer seal operates in the barrier fluid at atmospheric or very low pressure (lower than the process). If friction creates excessive heat, the barrier fluid can be pumped across the outer seal, back to a fluid supply tank in a closed loop. Cooling coils or heat exchangers are sometimes added to the tank to cool the fluid. Here again, the outer seal acts as a redundant seal. Therefore, if any hazardous product leaks across the inner or primary seal, it enters the seal chamber and mixes with the barrier fluid. The reservoir contains the leakage, instead of allowing it to escape into the environment. If the outer seal leaks first, only harmless buffer fluid escapes. Maintenance can be scheduled prior to the occurrence of any problems with the inner seal.

Reservoir pressure variation from thermal expansion is normal. However, rising liquid level in the reservoir indicates product leakage beyond the inner seal. Rapidly dropping liquid level without visible leakage of the outer seal or piping indicates seal leakage into the process.

Fluid Control

The task of installing the system that controls the environment for the various barrier fluids is just as important as selecting an application's compatible seal design and materials. The seal environment critically impacts the seal's operation and longevity. Control of the barrier fluid is essential to maintaining the ideal environment.

The seal environment involves:

- Viscosity (or lubricity) of the fluid at the seal faces;
- Mechanical conditions like cavitation, vibration, and run-out;
- Abrasive conditions;
- Temperature conditions;
- Gaseous conditions.

Several API/ANSI piping 'plans' exist as standards for designing the fluid supply systems for these seals. Each has a specific intended use, depending on the application involved, and each must be installed and maintained per these plans to allow for safe operation. Plan 52 is for lower-pressure Tandem Seals, and Plan 53 is for high-pressure Double Seals. Improper control and maintenance of the seal environment could result in total seal failure, along with leakage of undesirable products into the atmosphere.

Seal Pots

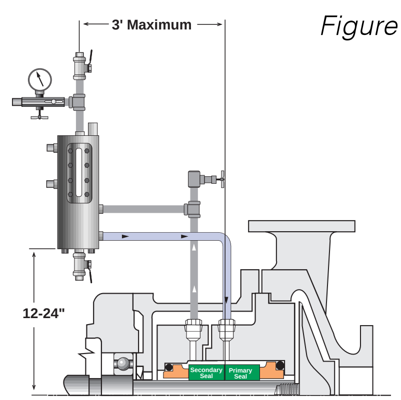
Figure I

As part of these fluid control systems, many API/ANSI plans require an external tank assembly. Commonly referred to as 'seal pots,' these supply tanks serve as a reservoir of clean, pressurized barrier fluid to double or tandem seal assemblies (fig. I). These tanks, or seal pots, generally utilize either a high-level or low-level liquid switch. In some instances both types are used.

In a dead-ended system, the fluid is supplied to the seal chamber, providing the positive internal pressure on the seal that is required to maintain lubrication. In other systems, the fluid may actually be circulated in a closed loop between the seal pot (tank) and the seal chamber (fig. J).

In both cases, the seal pot is pressurized and instrumentation monitors the fluid level. Fluid loss would result in catastrophic failure of the seal and dangerous conditions. Therefore, operators must know if the fluid level drops too low, indicating a fluid loss problem. This is accomplished using a

Figure J



low-level switch (fig. K). Additionally, a high level switch may be required in some applications. The high-level switch indicates hazardous product leakage across the primary seal and into the seal chamber, which adds fluid volume and raises the seal pot level.

Outputs from these switches connect to alarms and/or the plant control system, initiating immediate corrective action. All pots use a pressure gauge, with some systems requiring a pressure switch to activate an alarm or shutdown the pump for added safety.

Seal design is complex, and proper selection is critical for safe plant operation. While this paper can only scratch the surface regarding the basics of seal technology, it is important to stress the significance of selecting the right seal for the application, and the proper control of the fluid system. Large offerings of seal designs are available from pump manufacturers to suit numerous applications. Typical installations are given in Table 1.

An array of suitable barrier fluids exists to ensure reliable operation under a wide range of applications and operating conditions. Today's fluid choices include synthetic lubricants such as hydraulic oils, gear oils, compressor oils, turbine oils, and semisynthetic greases. Any errors in selection or maintenance of the seals and fluid systems may lead to devastating results. Therefore, monitoring of fluid

Figure K

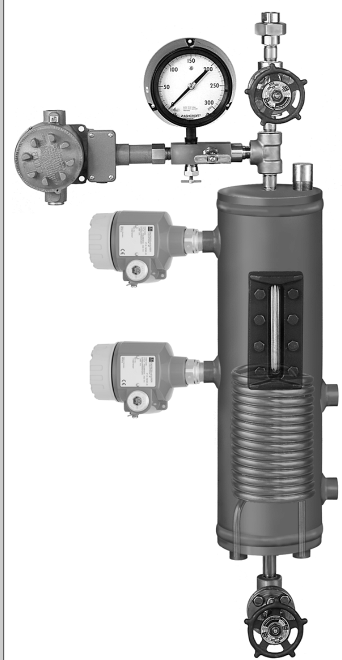


Table 1

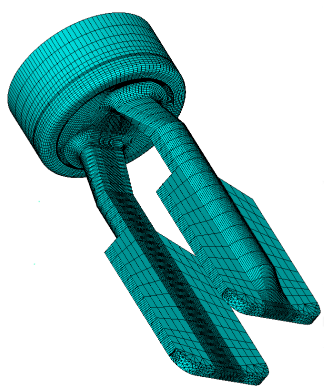
Boiler Feed Water	Sulphuric Acid	Heat Transfer Fluids
Cryogenics	Plating Solutions	Petroleum Refinery Service
Ammonium Nitrate	Sodium Hydroxide	Black Liquor
Latex	Effluent Treatment Plants	Nitric Acid
Pulp & Paper	Abrasive Slurries	Crude and Residual Oils
Mercury	Vinyl Chloride	Phosphoric Acids & Phosphates
Pthalic & Maleic Anhydride	Nuclear Power Plants	Fuel Alcohol Plants
Oilfield Waterflood Services	Fossil Fuel Power Plants	Nuclear Power Plants
Condensate Pumps	Main Boiler Feed Pumps	Molten Polymers
Fugitive Emissions	Fugitive Emissions - Chemical & Pharmaceutical Experience	Fugivite Emissions - Refinery & Petroleum Experience

levels is essential. And, because the various mechanical seal configurations and fluid combinations can produce conditions that vary widely, proper selection of the level monitoring instruments, most notably the level switch, is imperative for safe operation.

Under a wide range of conditions (such as viscosity, pressure, temperature, density, dielectric, conductivity, air bubbles, and foam), the level detection device's reliability hinges on its ability to maintain safe operation, even when difficult conditions exist. Although traditionally used in this application, ultrasonic gap systems, floats, capacitance, and conductive instruments are not designed for reliable use as a universal switch under all of these possible conditions. Faulty operation or failure can occur if the correct switch technology is not chosen.

The American Petroleum Institute publishes an industry standard for "Shaft Sealing Systems for Centrifugal & Rotary Pumps." It includes data sheets to specify a system suitable for the given application. Incorporated in the data sheet is a section for the required level switches, allowing the user to indicate the desired switch technology.

Figure L



The only switch technology designed to withstand ALL of these conditions is the tuning fork design, employing the frequency shift principle. Throughout decades of field use, the tuning fork design has demonstrated its ability to function under the most severe conditions. A tuning fork unit is unaffected by foam, air bubbles, vibration, temperature swings, high pressure, density changes, viscosity changes, buildup, or shifts in the fluid's dielectric. No other type of switch technology exists with such universal applicability. In the absence of moving parts or calibration requirements, there is nothing to wear out or adjust over the life of the instrument. Therefore, long-term maintenance issues are minimized (sensor forks shown in fig. L).

These devices also offer continuous self-monitoring of both the sensor element and the electronics to signal if any internal faults occur, adding another degree of safety.

For the most reliable seal pot operation, users should only consider a frequency shift tuning fork level switch. The typical $3,000 to $5,000 cost of the seal pot systems - and the added costs resulting from personal injury, cleanup, fines, and plant downtime - mandates using the most reliable liquid level switch to monitor these fluid levels.

Summary

Armed with a better understanding of mechanical seal design, fluid control systems, and seal pot installations, readers can better appreciate the engineering effort that goes into each critical seal application. And, due to the complexity of this science, there is no reason to settle for inferior level switch technology to safeguard these systems.

If switches now in use result in reliability issues or a maintenance problem, then it's time to seriously consider use of a frequency shift tuning fork to overcome these problems.

Footnote: *Endress+Hauser gratefully acknowledges the artwork and illustrations for this White Paper which were contributed by Flowserve, a worldwide provider of industrial flow management services.*