Dual Sealing Systems; a.k.a. Double and Tandem

New terminology or old, dual sealing systems offer proven solutions for today's emissions requirements.

By Patrick M. Flach

If the term "dual sealing systems" doesn't mean much to you, don't panic. The wording is new to almost everyone. If you are familiar with double and tandem seals, however, you will soon feel comfortable with the new terminology. Although the terms "double seals" and "tandem seals" describe arrangements of mechanical seals, they have come to refer to pressurized or non-pressurized seals as well.

OLD NOMENCLATURE AND DEFINITIONS

The following familiar names and definitions come from the Fluid Sealing Association (FSA) Mechanical Seal Handbook:

Double Seal. Two mechanical seals mounted back-to-back, face-to-face or in tandem, designed to permit a liquid or gas buffer fluid between them. [See Figures 1a, 1b, & 1c.]

Tandem Seal. A multiple seal arrangement consisting of two seals mounted one after the other, with the faces of the seal heads oriented in the same direction. [See Figure 1c]

Buffer Fluid. A fluid that is introduced between two seal elements, quite often at a pressure that is higher than the pressure of the fluid on either side of the seal assembly (also called a barrier fluid).

NEW NOMENCLATURE AND DEFINITIONS

The following new terms are found in the Society of Tribologists and Lubrication Engineers (STLE) Special Publication SP-1 A Glossary of Seal Terms and the American Petroleum Institute API Standard 682.
Dual Mechanical Seal. A seal arrangement using more than one seal in the same seal chamber in any orientation that can utilize either a pressurized barrier fluid or a non-pressurized buffer fluid. (Previously referred to as a double or tandem seal.)

Barrier Fluid. A fluid that is introduced between dual mechanical seals to isolate the pump process liquid from the environment. The pressure of the barrier fluid is always higher than the process pressure being sealed.

Buffer Fluid. A fluid used as a lubricant or buffer between dual mechanical seals. The fluid is always at a pressure lower than the pump process pressure being sealed.

Bellows Seal [metal]. A type of mechanical seal that uses a flexible metal bellows to provide secondary sealing and spring-type loading.

Pusher Type Seal. A mechanical seal in which the secondary seal is mechanically pushed along the shaft or sleeve to compensate for face wear.

From these new definitions a new terminology has evolved: Dual Seals Pressurized or Dual Seals Unpressurized. A Dual Seal Pressurized uses a barrier fluid and was previously referred to as a double seal. A Dual Seal Unpressurized uses a buffer fluid and was previously referred to as a tandem seal.

EARLY DUAL SEALS

During the late 1940s and early 1950s soft packing was the preferred method for controlling leakage from centrifugal and rotary pumps. As mechanical seals made their way into industry, questions were raised about their safety. Union Pump Company (formerly Union Steam Pump), a manufacturer of centrifugal pumps for the refining industry, answered these questions by developing and obtaining a patent for its Uni-Lok System (Figure 2). This system consisted of two spring loaded rings, soft packing and a buffer tank in series with a primary single mechanical seal. Theoretically, if the mechanical seal with the new technology failed, the two rings of packing would act as a backup and control the leakage.

Uni-Lok can be considered one of the first dual seal concepts commercially available. We have come a long way since its inception, but many modern sealing systems still use a buffer/barrier tank. The difference is that contemporary systems employ more than one seal in the stuffing box or seal chamber.

FEDERAL EMISSION REGULATIONS

Mounting concern about emissions of hazardous compounds into the atmosphere has led to stricter regulations on leakage from pumps and other equipment. The 1990 amendments to the Clean Air Act (CAA) are examples of such regulations. Under Title III of the CAA the U. S. Environmental Protection Agency (EPA) has signed the National Emission Standard for Hazardous Air Pollutants (NESHAP). This rule controls the amount of emissions of certain volatile hazardous air pollutants (VHAP) from manufacturing processes producing synthetic organic chemicals. The rule is referred to as the Hazardous Organic NESHAP or HON. Subpart H of HON covers provisions for equipment leaks that affect pumps and other equipment in VHAP services.

Leakage standards take the form of work practices and are not equipment mandates. The standards do define a leak and require that less than 10% of the pumps in a process be classified as leaking. Pumps in VHAP services must be visually checked each week for drippage, which is defined as a leak. Seal leakage also may be detected during monthly tests, if results exceed the HON rules. Pumps in light liquid services equipped with dual mechanical seals are exempt from monthly monitoring if the barrier fluid is not a VHAP and the barrier pressure exceeds the process pressure. Dual non-pressurized seals are also exempt from monthly monitoring provided that the buffer fluid system is monitored and the buffer fluid reservoir is vented to a closed-vent system. Rules pertaining to refineries are forthcoming.

DUAL SEALS

The following dual seal systems are presented in STLE’s Special Publication SP-30 Guidelines for Meeting Emission Regulations for Rotating Machinery with Mechanical Seals.

Non-Pressurized Seals
  Contacting
  Dry-Running
Pressurized Seals
  Contacting
  Non-contacting

Low-leakage, contacting mechanical seals are described as having faces that have found an equilibrium position such that they are barely touching. A very thin film of the product or sealing fluid lubricates the seal faces. This is referred to as “mixed lubrication.” With the faces barely
touching and mixed lubrication, friction is low, and little heat is generated. The result is acceptable wear over a long seal life.

A non-contacting seal arrangement is a special design in which the faces are configured to be lubricated by a full-fluid film of the product or sealing fluid.

The seal faces do not touch each other during operation.

A dry-running seal is described as a dual non-pressurized seal, arranged in series, with a low emission inner seal and a dry-running full-contact outer seal.

Non-Pressurized, Contacting. Dual (tandem) sealing systems have been used for years to control emissions to the atmosphere and as safety back-ups. The inner seal of such an arrangement is cooled by piping similar to that described in API Plan 11, 13 or 32. A buffer fluid provides cooling and lubrication to the outer seal and buffer emissions. This is usually accomplished by means of an API Plan 52 or some similar piping arrangement. Circulation of the buffer fluid is accomplished by means of a pumping ring or other internal circulating device.

Advantages
- near zero emissions to atmosphere
- contains emissions during system upsets
- not subject to monthly monitoring

Disadvantages
- requires fluid buffer system
- higher initial cost
- higher maintenance cost
- buffer fluid maintenance
- hazardous process fluids can migrate to buffer fluids
- hazardous waste

The main reason for using a non-pressurized fluid buffer system with dual seals is to lubricate the outer seal. These systems consist of a seal pot or tank, connecting piping and associated valves and pressure gauges. They are usually made from stainless steel and have a high price tag.

Although the cost of the buffer fluid can be an issue, the cost of maintaining these systems is a bigger concern. The more upsets in an operating system, the more migration of product to the buffer fluid, and the more it needs to be changed. After the buffer fluid has been changed, it becomes a hazardous waste and must be dealt with as such.

Pressurized, Contacting. These dual (double) seals have also been used for years to control emissions to the atmosphere and as safety mechanisms. They are used in applications where the product being sealed is dirty, abrasive or polymerizing. The barrier fluid is used to cool and lubricate both sets of seal faces and therefore is at a pressure higher than the product being sealed (usually 20-25 psid). The barrier fluid enters the seal chamber, or stuffing box, near one set of seal faces and is removed near the other set of faces. To ensure circula-
An internal circulating device should be supplied. Seal setting is so important to the performance of this type of seal that cartridge arrangements are strongly recommended. API Plan 53 and 54 are the most common pressurized piping arrangements used for these seals.

**Advantages**
- near zero emissions to atmosphere
- contains emissions during system upsets
- not subject to monthly monitoring

As stated, this is a pressurized barrier system. Therefore, the barrier fluid tends to migrate into the product. The 20–25 psi pressure differential keeps most of the emissions in the pump, however, and does not allow them to migrate into the barrier fluid. Emissions to atmosphere are usually much lower than in a non-pressurized buffer system arrangement.

Pressurized barrier seal systems operate better during plant upset conditions than non-pressurized buffer systems do because the inner seal faces are lubricated by the barrier fluid as opposed to the product. Dual pressurized seals also do not require monthly monitoring.

**Disadvantages**
- requires a fluid barrier system
- high initial cost
- high maintenance cost
- barrier fluid maintenance
- hazardous process fluids can migrate to barrier fluid
- hazardous waste
- barrier fluid can enter fluid
- complex barrier fluid pressuring system

Dual pressurized seal arrangements require barrier systems. They are like the non-pressurized systems except that they are more complex. Complex systems like these have a higher initial cost and are more expensive to maintain.

During some system upsets, like losing barrier fluid pressure, hazardous process fluids can enter the barrier system and contaminate the barrier fluid which then becomes a hazardous waste that must be addressed.

During normal operation some barrier fluid can enter the product because the barrier fluid is at a higher pressure. Also, if the inner seal fails, the barrier fluid will enter the product; thus a compatible barrier fluid is a must and can be hard to find.

**Non-Pressurized, Dry-running.**
A non-pressurized, dry-running, secondary containment seal is a product of modern sealing technology. This type of seal is supplied as a cartridge arrangement that helps maintain proper face loads and allows for easy installation. Containment seals like the one in Figure 3 use a metal bellows that also helps maintain low face loads, the secret to long lasting dry-running seals. If a pusher seal were used as the containment seal, the force necessary to slide the O-

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ring could be greater than the minimum face load required for low face wear and long life.

These seals can be used with a bellows or pusher inside seal that is cooled and lubricated by an API Plan 11, 13, 23 or 32. The piping plan for the dry-running outboard seal is shown in Figure 4 and is discussed under advantages.

Advantages
- no buffer fluid system required
- low initial cost
- low maintenance cost
- no hazardous waste
- contains emissions during systems upsets
- not subject to monthly monitoring
- full safety/containment feature

Unlike non-pressurized or pressurized contacting and pressurized non-contacting dual seal arrangements, which require a fluid buffer/barrier system to lubricate their faces, dry-running seals do not require fluid lubrication. This lowers initial as well as maintenance costs.

Emissions passing by the inner seal faces are vented to a flare or vapor recovery system. In this way the pressures across the dry-running seal are minimized and very little process fluid emissions pass to the atmosphere.

Also, the problem of hazardous waste, which is generated from contaminated barrier/barrier systems used on pressurized and non-pressurized contacting seals, is eliminated.

A dry-running seal contains emissions during system upsets and acts as a safety backup seal. In addition, when connected to a Closed-Vent System (vapor recovery system or flare), a dry-running seal meets the requirements of the National Emission Standard for Equipment Leaks and is not subject to monthly monitoring.

Disadvantages
- requires a vapor recovery system, flare or other closed-venting system

The National Emission Standard for Equipment Leaks requires this type of seal to be connected to a flare or vapor recovery system.

Pressurized, Non-Contacting.
Technology in the form of sophisticated computer programs and new manufacturing techniques were used during the development of gas compressor seals. Today this technology is being applied to pump seals in the form of grooved faces. These offer both hydrostatic and hydrodynamic lift-off capabilities. A hydrostatic seal maintains a film thickness between the faces by means of pressure, even without relative motion. The pressure is provided either by external source or by the pressure differential across the seal. A hydrodynamic seal has special geometric features on one or both of the mating faces. These features are designed to pro-

HEAT TO HEAD

Competitor's reaction-bonded SiC seal face after 300 hours exposure to 50% NaOH.

1992 The Carborundum Company
duce separation between the faces. This "lift" arises solely from the relative motion between the stationary and rotating portions of the seal faces. By pressurizing these dual seals with nitrogen or other inert gases, separation of the seal faces occurs at a very low rpm. Because the faces are open, very small amounts of nitrogen leak into the product being sealed and to the atmosphere. Also, there is no contact at the faces; therefore, very little heat is generated.

Advantages

- zero emissions to atmosphere
- no liquid barrier/buffer system required
- low power consumption
- low heat generation
- low wear–long life
- not subject to monthly monitoring

Release of fugitive emissions to the atmosphere is eliminated by maintaining a gas barrier system pressure of 20-30 psi over the product pressure being sealed. The pressure of the gas barrier fluid also provides hydrostatic lift, which helps separate the faces. During normal operation minimal power is required to drive the seal, so very little heat is generated, resulting in low face wear and long life. Monthly monitoring of emissions is not required for these pressurized dual seals.

Disadvantages

- requires nitrogen or other inert gas supply
- requires a gas supply regulating system

For proper operation of this type of seal, it is essential to maintain and regulate a supply of inert gas at 20-30 psi over the product pressure.

CONCLUSION

The technology of controlling pump leakage has come a long way since the days of soft packing. The first step was the development of single mechanical seals. Then came systems like the Uni-Lok, dual non-pressurized contacting (tandem) seals, and dual pressurized contacting (double) seal. Dual non-pressurized and dual pressurized seals are being used in many applications today and will continue to be used because of their performance history and service life.

Emission regulations have inspired seal designers and manufacturers and users of pumps to work together in advancing technology even further. Today, as a result, pump users can choose either a pressurized, non-contacting or a non-pressurized, contacting seal as the solution to particular sealing applications.

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