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What Determines Seal Leakage?

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What determines seal leakage?

The purpose of a mechanical seal is to prevent leakage, but all seals leak to some controlled degree. However, it is important to note that this minimal leakage can be so restricted that specific designs are capable of adequately meeting all emission requirements. Seal failure is defined as excessive leakage. The seal can be described as a controlled leakage device represented by two nonporous, plane, parallel walls separated by a distance h , the seal face separation. Assuming constant physical properties and laminar, incompressible flow, the leakage rate is proportional to the pressure and to the cube of the face separation.

As should be expected, large seals tend to leak more than small seals. In theory, leakage would be greater for a narrow face seal than for a wide face seal, but in practice, narrow face seals often leak less because the sealing gap for narrow faces is usually less than for wide faces.

Seal Face Separation

The seal face separation, h , cannot be easily calculated, but is the same order of magnitude as the combined surface roughness of the primary ring and mating ring. The sustainable minimum face separation is limited by the friction, wear and lubricating properties of the material pair and fluid. In practice, this gap is affected by many parameters including face flatness, load, viscosity and speed; it can easily vary from 5 to 50 micrometers or more. Specifications often require flatness within two helium light bands (23 micrometers). During operation, distortions may easily produce deviations from flatness of ten light bands or more. For these reasons, leakage rates can vary considerably from seal-to-seal, test-to-test or even day-to-day.

Face Treatments

Various face treatments can be applied to the sealing faces such as slots, grooves, waviness or special lapping processes. These treatments are designed to enhance lubrication and increase hydrodynamic lift, which in turn reduces seal face friction. This increases the film thickness between the seal faces. They are primarily used in two situations:

- a) Liquids with poor lubricating qualities
- b) Heavy face loads relative to the load bearing quality of the seal face materials

In using face treatments in light hydrocarbons and other services where vaporization occurs between the seal faces, a high balance ratio is required to maintain face contact and minimize leakage.

Principal Leakage Factors

Often seal face leakage rates will depend on pump/motor operating conditions. If operating vibration levels are high, the shaft suffers from excessive radial or axial movement or is misaligned excessively, leakage rates tend to be higher.

Typically, seals leak more during dynamic operation than in a static condition under fluid pressure. During shaft rotation, a fluid film develops between the seal faces to separate them with a larger gap, which causes higher leakage. In a static condition, the faces physically contact each other and have nil leakage. An exception can be standby seals that have previously been run dynamically. The dynamic operation may establish a non-flat face pattern, as shown in Figure 1, which may leak more than when the seal is running.

Under steady state operating conditions, a typical face seal will contact and gradually wear in. The leakage rate at start-up tends to be higher than when the seal is worn in, particularly with hard face material combinations. The wearing process changes the face profiles to compensate for the seal face pressure and thermal distortions and affects the seal face surface finish. If wear is severe, the surface finish can become rough and the leakage will increase. Abrasives in the sealed fluid can destroy the seal face surface finish in a short time. Some applications have material film transfer between the faces. If the material build-up on the face is not uniform, it can cause higher leakage.

Load

If the loading conditions change, the worn faces will start another wear transition. Sometimes, the faces have been badly worn and excessive fluid pressure opens them under the new loading condition. This can lead to uncontrollable leakage. To survive changing operating conditions, the seal can be designed to avoid contacting wear but with a controllable consistent leakage. A hydrostatic coned face seal is a design example. This type of seal will leak one order of magnitude higher than conventional contacting face seals. More advanced non-contacting non-leaking seal designs have also proven feasible, but have limited application range.

Leakage Sources

In most cases, the seal leakage comes from the sealing interface. However, in some situations, leakage may come from the secondary sealing area, such as O-rings. This could be due to O-ring degradation caused by chemical attack, overheating and loss of resilience from compression set. In rare occasions, the sealing rings are porous and fluid leaks through the bodies.

The above leakage problems can be identified with static pressurization.

Measuring Leakage

Leakage limits may be given as a volumetric rate, such as milliliters per hour (ml/hr), or as a mass leakage rate, such as grams per hour (g/hr). For volatile organic compounds (VOCs), limits are sometimes expressed as a concentration, i.e., 200 parts per million (ppm), of the VOC. This is usually referred to as an allowable emission rate; the measurement is taken according to EPA Method 21. An emission rate of 1,000-ppm is equal to a mass leakage rate of 5.6-g/hr. Another rough rule of thumb is that a milliliter of liquid contains about 20 drops; therefore, a volumetric leakage rate of 3-ml/hr would be about

60 drops per hour or a drop per minute.

Some states, notably California, have a “no visible leakage” requirement; in practice, this means that visible leakage of three drops per minute is considered a major leak and the pump must be shut down for repair.

Other Factors Affecting Leakage

Factors that tend to increase leakage, other than those that cause seal face damage are:

- High fluid viscosity (typically above 30-cP or 32-cST)
- Low seal balance (60 to 65 percent range)
- Low face pressure due to unloading forces
- Very narrow faces (< 0.100-in)—Edge chipping, surface damage and wear have a more dramatic effect on leakage

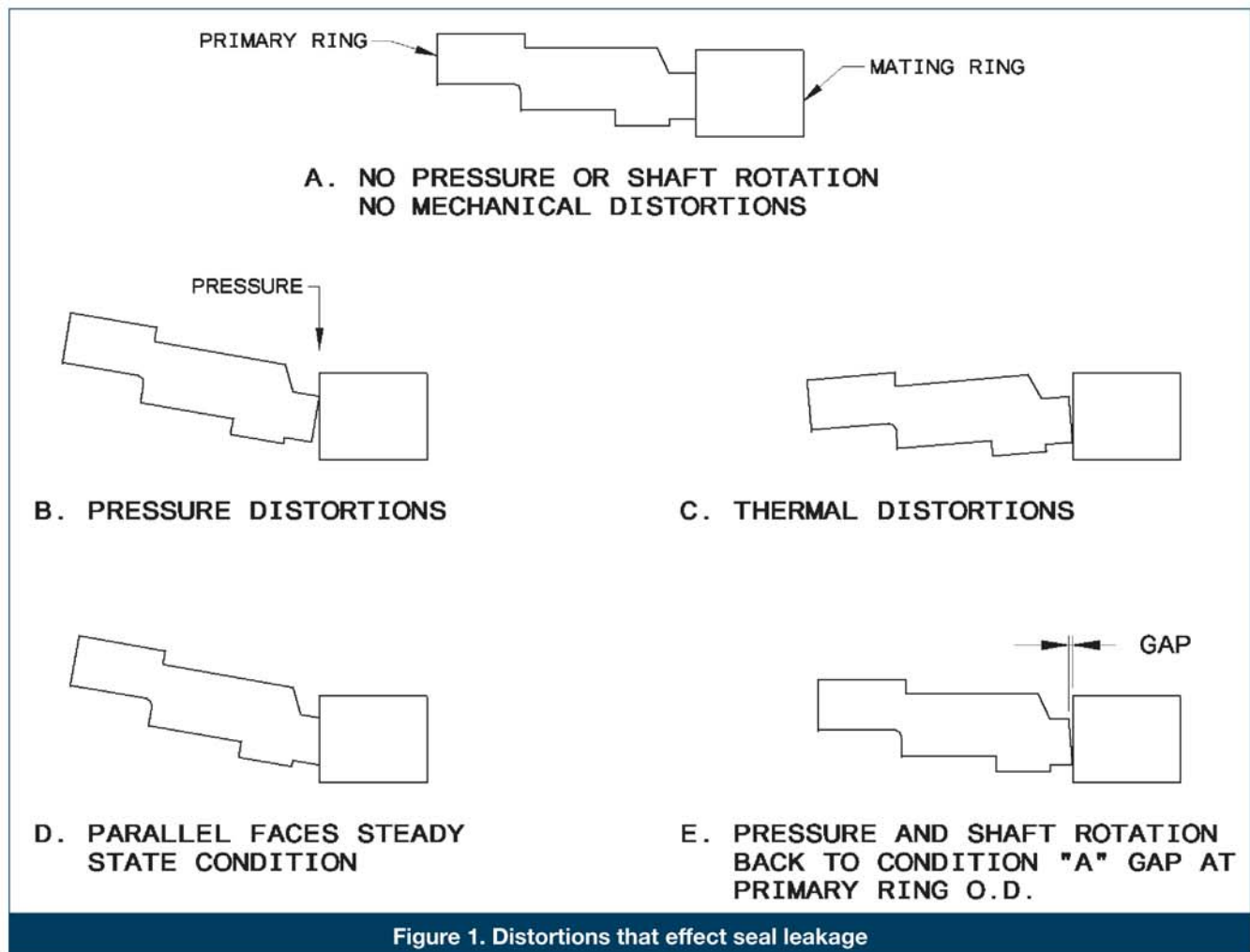


Figure 1. Distortions that effect seal leakage

In theory, leakage would be greater for a narrow face seal than for a wide face seal, but in practice, narrow face seals often leak less because the sealing gap for narrow faces is usually less than for wide faces.

than wider face widths

- Face treatments or special lapping techniques to increase sealing gap
- Composite face materials (due to rougher surface finish)
- Excessive converging sealing gap due to thermal distortions
- Excessive divergent sealing gap due to pressure distortion
- Wiping action of seal face over mating ring
- Distorted seal faces (high and low spots from some mechanical condition)

Summary

Mechanical seals are designed to produce an acceptably low level of leakage to function effectively. Many individual internal and external factors, as well as interactions between them, affect the rate of seal leakage. Some design features or treatments enhance reliability but contribute to some marginal

increase in leakage. The source of most leakage usually is the interface between the two seal faces, but can also come from secondary seals such as O-rings.

A balance must be established between steady state and transient operating conditions to control the negative factors that lead to increased leakage. Contact your mechanical seal supplier to determine the design that best establishes this balance for a specific set of operating conditions.

Next Month: *How do I determine bolt torque for flange connections?*

We invite your questions on sealing issues and will provide best efforts answers based on FSA publications. Please direct your questions to: sealingquestions@fluidsealing.com.

P&S

Fluid Sealing Association

Sealing Sense is produced by the **Fluid Sealing Association** as part of our commitment to industry consensus technical education for pump users, contractors, distributors, OEMs and reps. *This month's Sealing Sense was prepared by FSA Members Gordon Buck and Tom Lai.* As a source of technical information on sealing systems and devices, and in cooperation with the **European Sealing Association**, the FSA also supports development of harmonized standards in all areas of fluid sealing technology. The education is provided in the public interest to enable a balanced assessment of the most effective solutions to pump technology issues on rational total Life Cycle Cost (LCC) principles.

The **Mechanical Seal Division** of the FSA is one of five with a specific product technology focus. As part of their educational mission they develop publications such as the *Mechanical Seal Handbook*, a primer intended to complement the more detailed manufacturer's documents produced by the member companies. This handbook served as the basis for joint development of the more comprehensive *Hydraulic Institute* publication: *Mechanical Seals for Pumps: Application Guidelines*. Joint FSA/ESA publications such as the *Seal Forum*, a series of case studies in pump performance, are another example as is the *Life Cycle Cost Estimator*, a web-based software tool for determination of pump seal total Life Cycle Costs. The *Sealing Systems Matter* initiative also was launched to support the case for choosing mechanical

seals that optimize life cycle cost, safety and environmental compliance.

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