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WET SEAL TO DRY GAS SEAL CONVERSION
Considering the benefits of retrofitting your compressor

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ABSTRACT

Dry gas seals are specified in most of the new centrifugal compressors; yet many installed units are still equipped with conventional oil sealing systems.

The benefits of dry gas seals conversions from traditional oil seals to dry gas seals are usually advantageous to compressor operators. However, end users should ask themselves several questions before deciding to retrofit their compressors with dry gas seals. The decision to retrofit a compressor with these upgraded seals may be dictated by economic factors, HSE constraints or technical considerations. Users should consider all of these factors when deciding whether or not to upgrade a compressor with dry gas seals. In addition, the following precautions should be taken during project execution to ensure successful conversion: perform a detailed physical integration analysis of the dry gas seal in the existing compressor; conduct a detailed rotor dynamic analysis; select the proper gas seal system design for the compressor; and plan for operator training.

This paper will discuss the factors end users should consider before upgrading to dry gas seals together with an economic evaluation, and the steps that should be taken to ensure a successful conversion once the decision is made to retrofit a compressor with dry gas seals.

INTRODUCTION TO DRY GAS SEALS

To expect a totally leak-free sealing system between two parts in relative movement is unrealistic (e.g., between a static and a rotating part; between a housing and a shaft; in pumps, thermal motors, etc.). There are, however, efficient devices that may limit leaks, friction and wearing at the interface of the moving parts.

Gas seals are among the most efficient means to minimize process gas leakage to the atmosphere and to reduce wear and friction.

The gas seal is also a reliable means to route effluent leaks to safe areas. Overall, the whole gas compression process benefits from the dry gas seal system.

Figure 1 shows the location of the seals in a typical centrifugal compressor. Their location is quite strategic, as they are the interface between the inside of the compressor (process gas at high pressure and high temperature) and the atmosphere (air and oil mist from the bearing cavity).

Due to the balance line, the gas seal only has to deal with the intake pressure of the compressor during operation and the higher settle out pressure during pressurized stand-still.

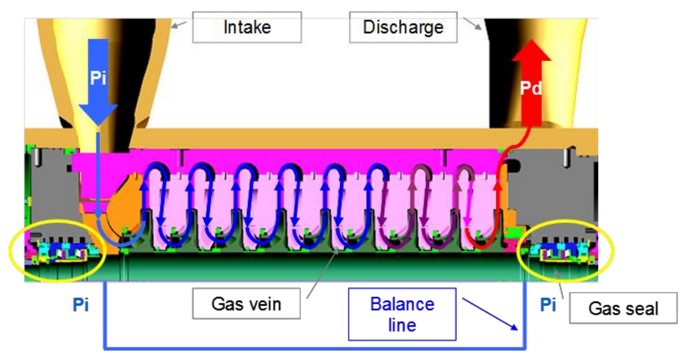

Figure 1. Centrifugal compressor cut-away.

As will be explained later, the gas seal requires a high-quality gas to operate. Therefore, instead of using the gas present in the balance line, the seals are fed with a clean and dry gas, typically taken at the discharge of the compressor.

This gas is dried, filtered, heated if necessary, and its pressure lowered to slightly above the intake pressure before being injected at the primary port of the seal.

The gas-seal principle is simple (Figure 2). The leakage (process gas) must be routed to a safe area; therefore, the leakage is forced to pass between a static and a rotating part. The rotating part is a grooved ring driven by the compressor shaft. The static part is a ring facing the rotating ring (but with only light axial movement).

When rotating, the grooves generate an aerodynamic effect that creates a gap (from 4 to 10 microns) between the rotating and stationary rings. The flow generated by the pressure differential leaks between the two faces, and then this gas leakage is routed to the venting system of the machine (flared or vented).

Because of the gas film between the faces, this constant gap between them prevents the parts from rubbing against each other and makes the gas seal a contact-free device.

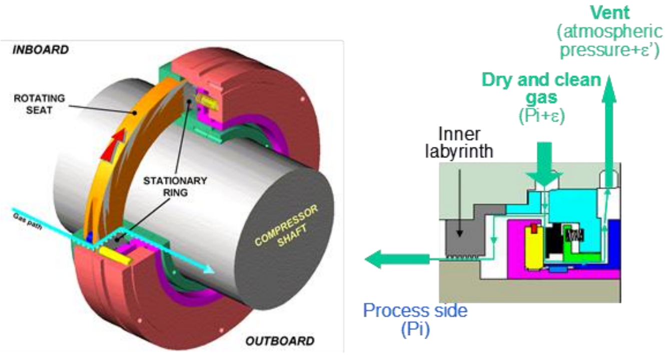

Figure 2. Cut-away and cross-section of a simplified gas seal.

Gas Seal Arrangements

A tandem gas seal is typically used for non-hazardous gases. In this arrangement, the sealing gas is injected at a pressure slightly above the intake pressure, so that a vast majority of it (more than 80 percent) passes under the inner labyrinth teeth. The remainder (less than 20 percent) passes through the gap created by the lift-off effect and leaks to the flare (18 percent). The last sealing gas residues (2 percent) leak through the secondary stage to the vent.

The other important device in the compressor seal is the tertiary (or separation) seal, which may be a labyrinth or segmented carbon rings. Its function is to prevent the bearing oil mist from migrating to the seal, and the sealing gas from migrating to the bearing oil. This separation is made by a gas leak which prevents the oil from entering the gas seal area on the inboard side, and also prevents the sealing gas coming from the secondary stage of the seal from polluting the bearing oil.

So, depending on the nature of the separation gas, the gas seal vent may vent a mixture of sealing gas (hydrocarbon) and nitrogen which is acceptable, or a mixture of sealing gas and air.

A tandem gas seal with an intermediate labyrinth is used when the process gas is hazardous, e.g., lethal gas, flammable gas, or when it condensates at the primary seal outlet (Figure 3). In this scenario, a buffer gas, such as nitrogen, sweet gas, or fuel gas is required.

The principle is the same as in the tandem gas seal with the addition of an intermediate labyrinth fed with an intermediate (sometimes called a buffer) gas, generally nitrogen. This prevents hazardous seal gas from leaking into the atmosphere.

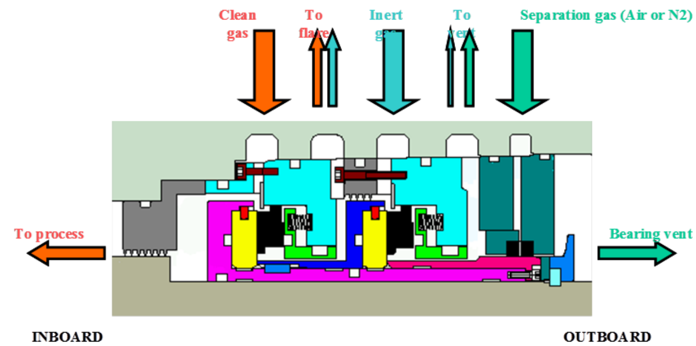

Figure 3. Tandem gas seal with intermediate labyrinth.

A double (-opposed or back-to-back) gas seal is used when the process gas is dirty, or when the sealing pressure is close to atmospheric pressure (Figure 4). A sealing gas (typically auxiliary gas) is needed, such as nitrogen, sweet gas, or fuel gas.

The configuration consists of two sealing faces (rotating ring and static seats) in a back-to-back arrangement. A primary advantage of this seal type is the lower number of ports required: one for the sealing gas; one for the vent; one for the separation gas; and one for the buffer gas (optional). This leads to a simpler and lower cost gas seal panel than tandem with intermediate labyrinth arrangement.

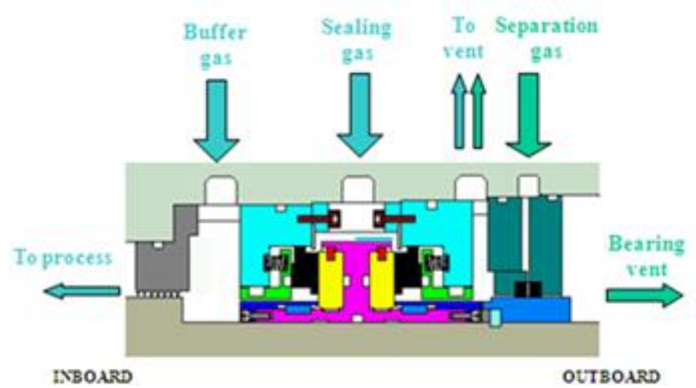

Figure 4. Double-opposed gas seal.

Generally in low-pressure applications, the available process gas pressure is not suitable to feed the gas seal, so an alternate source must be considered (e.g., nitrogen, fuel gas).

The nature of the sealing gas must also be compatible with the nature of the process; the alternate source could trigger unwanted chemical reactions or damage the downstream catalyst.

Why Convert Wet Seals to Dry Gas Seals?

1. The number one reason for retrofitting conventional wet seals to dry gas seals is reliability

Dry gas seals are non-contacting mechanical seals which eliminates the issue of seal wear. Theoretical lifetime is limited only by the secondary sealing elements (usually O-rings or polymer-based seals) whose lifespan can be up to 15 years. It is not uncommon to see dry gas seals operating for more than 10 years before being refurbished which is much longer than is expected for oil seals.

Not only is the gas seal more reliable, but so is the whole sealing system, because it is made of static components. Oil seal systems, on the other hand, have more components, including rotating machines (pumps, motors/turbines) and are more often prone to unscheduled maintenance and down time. Wet seals can cause up to 1.5 % production down time or 5 days per year whereas the dry gas seal availability is estimated at 99.9% (Saxena, 2003). The dry gas seal failure rate is around 0.175 failures per year or one failure every six years (Bloch, 2005).

2. Local (or company-wide) HSE Regulations

Elimination of oil contamination by process gas has a positive environmental impact, since sour oil needs to be treated, stored and disposed. Sour seal oil treatment and disposal has a significant cost.

In terms of safety, retrofitting a wet seal system removes the possibility of a lube oil tank explosion. This can occur when gas breakout from the seal return oil can increase the flammable gas concentration above the lower explosive limit when the oil reservoir breather is clogged or overwhelmed from excessive gas leak at the seals (Saxena, 2003).

Conversion to dry gas seals on a butadiene compressor (classified as carcinogenic to humans by inhalation) resulted in zero emissions and no more hazardous risks when treating contaminated oil.

3. Reduced Operating Costs

Energy costs drop significantly, since seal oil pumps and degassing tank heating systems are not required when using dry gas seals. An oil pump averaging at 50 kW at $0.07 per kWh and 8,000 hours per year will save $28,000 per year on electricity.

Power losses due to shear forces in gas seals are much lower than losses experienced in oil seals, which results in energy savings as well. Compared with a negligible 2-3 kW frictional loss in dry gas seals, up to 1% of compressor shaft power is lost in wet gas seals (Saxena, 2003). Compressor shaft power ranges typically from 2 to 25 MW (larger compressors) or even 65 MW for LNG compressors. At 2 MW the electricity saving is already $11,200 per year and $140,000 per year at 25 MW.

4. Reduced Maintenance Costs

As stated above, the simplicity of gas seal systems means routine maintenance is less frequent and less costly than with oil seal systems. 1.5% production downtime at 8,000 hours per year equals 120 hours per year. For five technicians at $ 36 per hour (US Bureau of Statistics 2012) the maintenance costs for wet seals can amount to $21,600 per year.

5. Reduced Emissions

Wet seal gas leakages are reduced more than 10-fold with gas seals, credited to the very thin running gaps between the seal faces. This results in cost savings for the end user, and reduced penalties on taxable gas flaring. Dry gas seals typically leak up to 3 scfm/seal (4.83 Nm3/h) whereas wet seal leakage range is 20-100 scfm/seal (32.2-161 Nm3/h) (Natural Gas STAR Partners 2006). As an example, for natural gas the gas cost savings can average between $81,600 and $465,600 per year at $5 per Mcf.

6. Process Quality

Contamination of process gas by seal oil is eliminated, enabling higher quality process gas. Costs related to oil removal from process gas are also eliminated. A good example is closed loop/refrigeration processes where process gas treatment is costly. Seal-oil change-out is required every 4,000 to 8,000 hours (Bloch, 2006). Changing 50 m3 once a year at $1.5 per liter will cost $75,000 per year.

7. Maintainability

Some operators now have more experience with dry gas seals than with oil seals. This may compel end users to retrofit a fleet at a specific plant or site to achieve consistent sealing technology throughout.

Dry gas seals are supplied as cartridges by vendors and the gas seals OEM usually performs their maintenance/ refurbishment.

These seven benefits may or may not all be applicable to all situations, and it should be noted that wet seals to dry gas seals conversions are not straightforward. The following recommendations are offered to help make the retrofit project a success.

How to Ensure a Successful Retrofit from Wet Seals to Dry Gas Seals

Physical Integration

Integration of the dry gas seals in the original compressor head/cavity must be checked. The number and location of supply and vent ports (at least four ports are required on gas seals) should be reviewed. End users should also consider inboard and outboard diameters; seal cartridge length; and the locking system of the gas seal to the compressor shaft.

In some instances, compressor shaft and compressor head rework are required. This should be assessed as soon as possible during the project to avoid project delays and cost overruns.

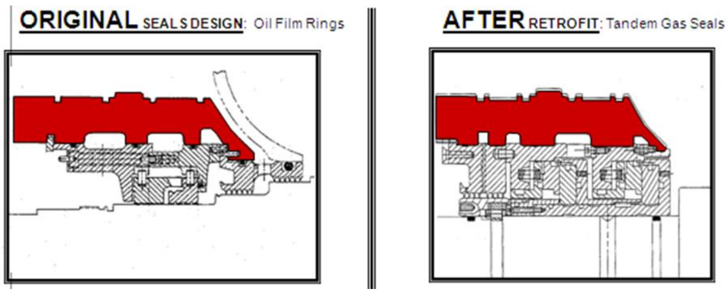

Figure 5. Wet seal versus dry gas seal layout

Seal Systems Study

While dry gas seals operation usually isn't a concern during normal running conditions, transient conditions (start-up including first start, shutdown) and standby (pressurized and unpressurized) must be taken into account during the seal system design. In other words, a supply of dry and filtered seal gas at the right pressure must be ensured at all times.

The use of an alternate source of seal gas may be required during start-up, shutdown and standby. If not available on site, end users may consider supplying a conditioning skid. This can include a pre-filter, booster and heater.

In any case, the best way to select the proper source of seal gas is to run a phase map analysis and make sure that a sufficient margin (20°C per API 614) to the dew point line (and hydrates formation line, if applicable) is maintained at all times in the gas seal panel and inside the gas seal.

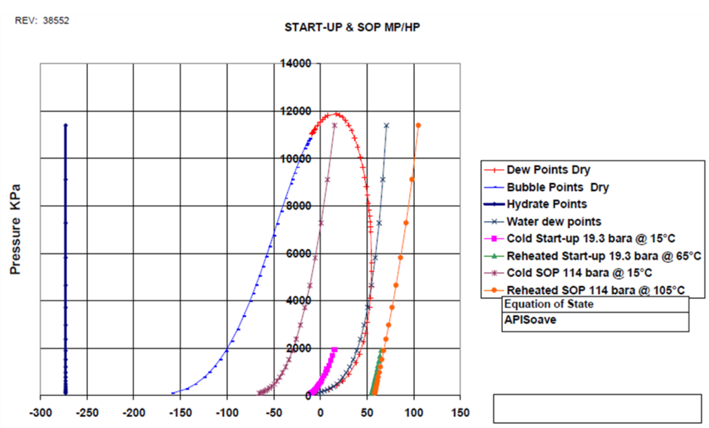

Figure 6. Phase map analysis at start-up and SOP conditions

On top of the suitability of seal gas, availability and suitability of secondary seal gas (when tandem gas seals with intermediate labyrinth are selected) and separation gas (usually nitrogen or air for separation barrier seals or labyrinth) must be checked.

Finally, a physical integration study of the gas seal panel must be performed, including space requirements and interconnecting piping/tubing to and from the compressor.

Rotor dynamic Check

Retrofitting from wet seals to dry gas seals will affect rotor dynamic response since oil seals have better damping characteristics than dry gas seals. Performing a rotor dynamic analysis will confirm if amplification factor and logarithmic decrement are still acceptable with gas seals. In most cases, no further modification is required; however, there are some critical applications (long shaft, high speeds, etc.) where additional upgrades must be incorporated (damper bearings, hole pattern seals, etc.).

Training

Training of the operators should be standard practice. While dry gas seals usually require no or little monitoring, they are considered as "black boxes". There are a few indicators that can help assessing the health of a gas seal.

Proper installation in the compressor as well as basic checks and maintenance on the gas seal system is also of prime importance. Failing to do so may lead to premature dry gas seal failures.

CONCLUSION – WEIGHING THE ADVANTAGES

Dry gas seals have several advantages compared to conventional wet seals: higher reliability; safer operation; reduced emissions; lower operational and maintenance costs; and improved process gas quality. These advantages may help end users justify an investment if an acceptable return on investment can be demonstrated.

However, as described in the second part of the article, careful studies must be made and all operating conditions must be evaluated. Provided all precautions are taken, dry gas seals may well be the most reliable mechanical seals currently available.

NOMENCLATURE

kW = kilowatt
KWh = kilowatt hour
$ = US Dollar
MW = megawatt
LNG =liquefied natural gas
scfm = standard cubic feet per minute
Nm3/h = normal cubic meters per hour
Mcf = thousand cubic feet of natural gas
SOP = Settle Out Pressure
bara = bar absolute

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