DRY GAS SEAL CONTAMINATION
DURING OPERATION AND PRESSURIZED HOLD – BACKGROUND AND POTENTIAL SOLUTIONS

Daniel Goebel (Author, Presenter)
Head of Application Engineering & Service
Compressor Seals & Systems
EagleBurgmann, Wolfratshausen, Germany

Daniel Goebel is leading the Application Engineering & Service Team for Compressor Seals and Systems at EagleBurgmann, located in Wolfratshausen / Germany. He has more than 13 years professional experience in all aspects of compressor gas seals and seal support systems for compressors like application engineering, product management, onsite support and troubleshooting. Daniel Goebel holds a degree in industrial engineering and management of the Munich University of Applied Science and started with EagleBurgmann back in 2002 as application engineer.

Tim Sanford (Presenter)
General Manager
EagleBurgmann Nova Magnetics, Halifax, Canada

Tim Sanford is General Manager of EagleBurgmann Nova Magnetics in Canada. Tim has 25 years' experience in the design and application of magnetically coupled rotating equipment in the sealing industry. Tim is a registered professional engineer and holds a degree in Mechanical Engineering from Dalhousie University in Canada.

Glenn Schmidt (Author, not presenting)
Market Development Manager - Oil & Gas
EagleBurgmann, Houston, USA

Glenn Schmidt is a DGS Consultant to the industry today. Before he was the EagleBurgmann Regional Product Specialist supporting the Americas region with technical and sales support for designing, servicing, repairing, troubleshooting and upgrades of compressors gas seals and systems. His 16-years of experience with gas seals includes instructing a Texas A&M Dry Gas Seal Systems Course and providing input as a member of the API 692 committee developing the standards for compressors gas seals and systems.

ABSTRACT

This paper will discuss the challenges with contamination of gas seals. The reliability of gas seals is largely dependent on having a continuous supply of clean and dry seal gas. In dynamic mode, gas supply systems take product gas from a higher pressure level in the compressor, filter it and use it to create the ideal environment for the gas seal. This typically ensures that the gas seal is provided with effective protection against contaminated process gas.

Compressor gas seals are very robust sealing devices, but need to be operated in a dry and clean environment. The leading root cause of gas seal failures is contamination. One of the most common sources of contamination is during compressor start up, slow-roll, standstill, or shutdown modes or because the conditioning skid is not sufficient. In these modes there is a lack of seal gas flow, which suggests no means to produce seal gas flow is available, such as a high pressure gas source or booster for the seal gas supply. This is where it pays to have a reliable, clean gas supply. Without seal gas flow, sufficient seal gas cannot be provided to the gas seal and results in the gas seal being contaminated.

This paper will describe contamination to the gas seal by process gas, during commissioning, by particle and by liquids, which are caused by inadequate seal gas supply. Then it will focus on different methods of providing seal gas flow during transient conditions. And finally, it will discuss solutions to ensure a reliable, clean gas flow to the seal at all

relevant conditions together with additional possibilities to add robustness to gas seals

INTRODUCTION

As the global energy demands are increasing, oil and gas are still the most important energy sources. Besides oil, and based on increasing oil prices, natural gas has been developed further to fulfill global needs.

Centrifugal process gas compressors are needed in the supply chain for oil production and refinement; for example, CO_2 reinjection, refining processes, petrochemical and chemical operations. For natural gas production and transportation, compressors are required in pipelines and for processes to liquefy natural gas.

Applications where compressors are used, there is typically no backup compressor even though they are critical for the operation of a plant. This is due to the cost of duplicating this type of equipment. Process gas compressors; therefore, have to fulfill very high requirements with regards to availability, reliability and safety.

Process gas centrifugal compressors are typically equipped with gas seals to prevent gas from escaping between the stationary compressor body and rotating shaft. Compressors are normally shut down when high seal leakage occurs, which indicates a seal failure. Shutting down on high seal leakage helps meet safety and environmental requirements and avoid further damage to the equipment. As a consequence, gas seals were designed to fulfill safety and reliability requirements for the industry.

The effectiveness of gas seals to meet these requirements is determined by the quality of gas supplied to the seal. From experience contamination of the seal has been identified as the major root cause for high seal leakage or seal failures and will be discussed further in this paper.

CONTAMINATION OF GAS SEALS BY THE PROCESS GAS

The key elements within a Gas Seal are the sealing faces and secondary sealing elements (Figure 1). A shaft sleeve, which is fixed with the compressor shaft, holds the rotating seat. The rotating seat is sealed against the shaft sleeve with a secondary sealing element, which is a special O-ring or PTFE filled sealing device. The rotating seat has the gas grooves integrated to generate an aerodynamic lift off and provide gas film stiffness during operation. The non-rotating elements combine a seal housing, fixed to the compressor casing, and the non-rotating seal face. The stationary elements are designed to compensate for axial movements of the compressor rotor in relation to the compressor case. The compressor shaft is exposed to axial movement caused by different loads, case expansion from heat and pressure or vibrations. Compensation for axial movements is achieved by allowing the non-rotating face to move along the balance sleeve (sleeve below the non-rotating face, item 2). The nonrotating face is sealed against the balance sleeve with a dynamic sealing element (O-ring or PTFE filled sealing device), which slides on the balance sleeve.

When pressure is applied to the seal or the compressor is rotating the applied forces will hold the seal faces together and maintain the appropriate gap of 3 to 5 microns. When these conditions are not present springs are require to hold the seal faces together.

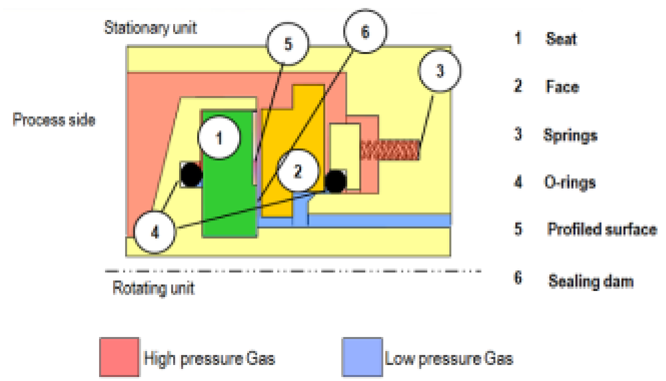

Figure 1: Core parts of Dry Gas Seals

To avoid any wear on the sealing faces, Gas Seals are designed to lift off when operated. This means the rotating seat and stationary face have no contact in operation. This separation is called lift off. The lift off is mainly influence by two effects (Figure 2):

- Differential pressure over the faces
- Circumferential speed

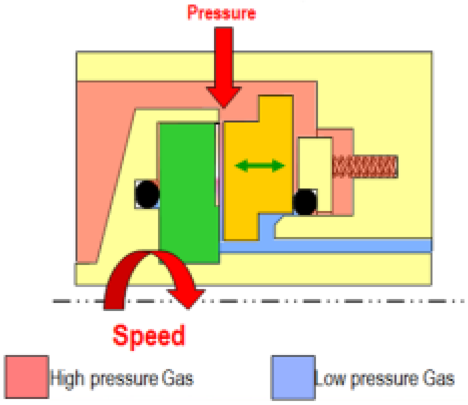

Figure 2: Lift off effect

The seal can lift off at a certain differential pressure, a certain speed or a combination of speed and differential pressure.

The lift off speed and differential pressure depends on the specific operating conditions, like gas type, and detailed seal design.
An example is shown in following diagram:

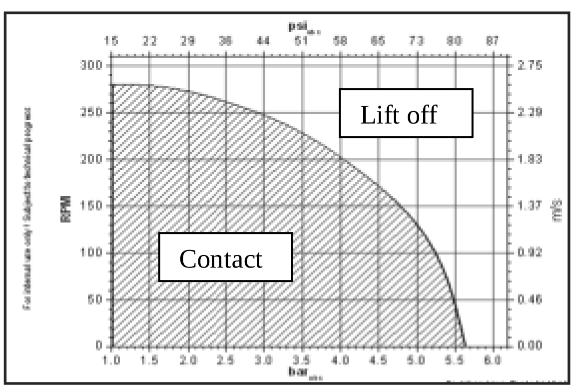

Figure 3: Lift off curve

The most common gas seal arrangements used in the industry for compressors are tandem arrangements (Figure 4) or tandem with intermediate labyrinth arrangements (Figure 5) and will be used for this article as a basis.

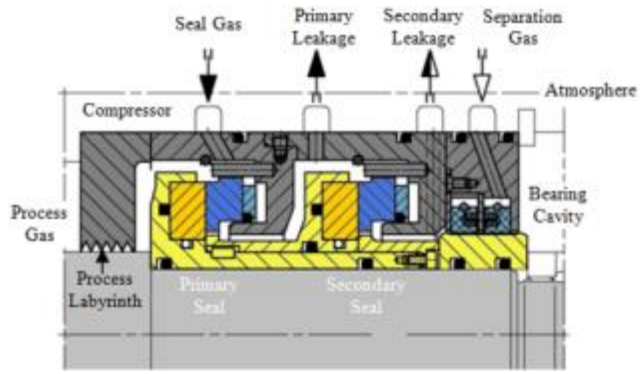

Figure 4: Tandem Seal

Tandem seals consist of two sets of sealing faces. The set closest to the process gas is known as the primary seal. The second set on the atmospheric side of the seal is known as the secondary seal. The secondary seal is a backup seal in case the primary seal fails.

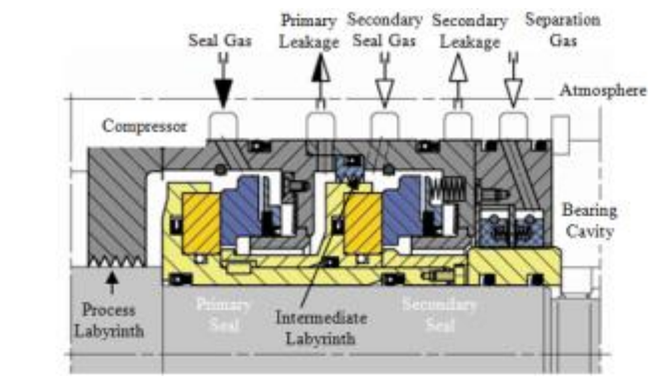

Figure 5: Tandem Seal with Intermediate Labyrinth

Contamination can enter the seal from the bearing side or process gas side of the seal. This paper describes contamination of the primary seal, as this is the cause of the majority of seal failures or high seal leakage alarms during or after a compressor has been in a long period of pressurized standstill.

In general, gas seals are very robust and reliable seals. To ensure the reliability of gas seals, a supply of clean and dry gas (seal gas) is required at all times.

The process gas is a gas, so how does it affect the operation of a gas seal? The gas leaking across the faces is low and should not have a detrimental effect on the seal. The quality of gas is the problem, as well not all components of a gas will stay in a gaseous phase when the gas temperature or pressure changes.

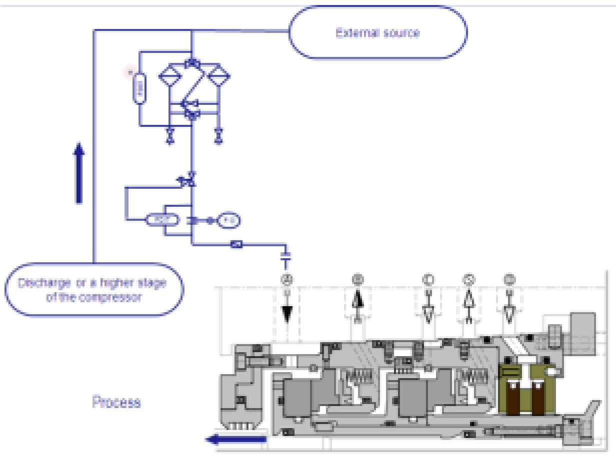

Figure 6: Gas Seal with Clean Gas Supply Installed

Contamination of the gas seal results when untreated process gas is allowed in and around the primary seal. To ensure that potential contamination inside the process itself does not enter the seal - like particles or fluids - a clean gas supply is provided (Figure 6).

Typically, process gas is taken from the discharge nozzle of the compressor. This gas is routed through a filter and regulated to a suitable pressure or flow to ensure clean seal gas supply to the primary seal. The majority of seal gas flows across the process labyrinth back into the process. A minimum velocity of 5 m/s (16.4 ft/s) - at twice the nominal labyrinth clearance – should be maintained underneath the labyrinth towards the process to ensure no contamination enters the primary seal. An alternative to using process gas is an external source gas source.

The seal gas flows in two directions; a small amount flows between the seal faces as controlled leakage and is then routed together with the secondary seal gas to the primary vent. The majority of the seal gas flows underneath the process side labyrinth back into the process (Figure 7).

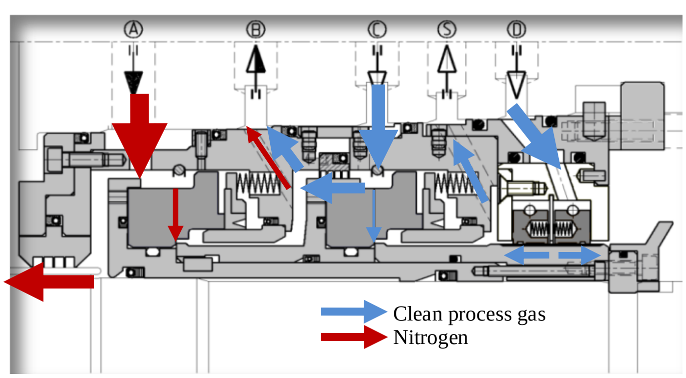

Figure 7: Gas flows within a typical Dry Gas Seal

Different scenarios that contaminate the gas seal are possible, which are discussed in the following.

CONTAMINATION BY PARTICLES

Particles present in the process gas can contaminate the primary seal when seal gas flow across the process side labyrinth is insufficient, or if inadequate filtration or conditioning is provided for seal gas to produce the required quality of gas.

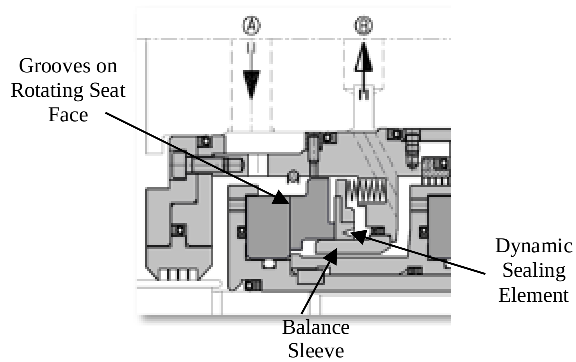

Figure 8: Location of Contamination in Grooves and Dynamic Secondary Sealing

As a consequence particles can enter the gas grooves on the rotating face and the sealing gap (Figure 8). If the size of the particles is small enough, they will blow through the seal. When larger particles are present they get trapped inside the grooves or gap causing negative affects to the sealing behavior or seal reliability. Besides the sealing gap, particles can also block the dynamic sealing element (Figure 10).

The dynamic sealing element is an O-ring or elastomer free sealing device between the non-rotating seal face and the balance sleeve. The non-rotating seal face must slide together with the dynamic sealing element on the balance sleeve axially compensating for axial position or movements of the compressor shaft in relation to the seal housing. The non-rotating face must also move freely to adjust for any movements resulting from the normal seal behavior. If the dynamic sealing element is prevented from moving freely to adjust for axial movements, the seal gap will be affected leading to high seal leakage if the faces are kept open or primary seal failure in case the faces stay in contact. (Figure 9-12).

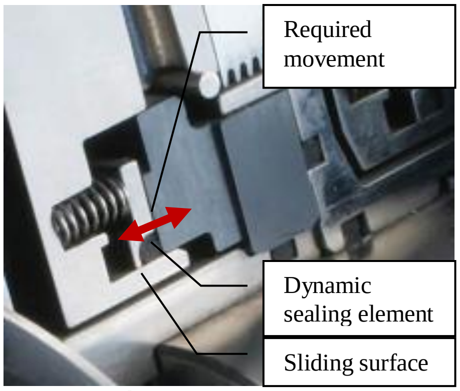

Figure 9: Axial movement DGS


Figure 10: contaminated dynamic sealing element


Figure 11: contaminated seal area behind stationary face


Figure 12: damaged seal faces → damage seal

In order to avoid the above-mentioned scenarios, a supply of clean gas must be provided to the primary seal whenever the compressor is pressurized or in operation. A reliable clean gas flow ensures no contamination from the process gas will enter the primary seal.

In the next steps, proper filtration must be selected. Typically, filter elements are selected to remove particles as small as 3 µm and sometimes even 1 µm. This ensures larger particles than the seal gap can tolerate are removed producing a clean quality gas for the primary seal. Seal gas filters have high alarms on differential pressure to identify when filter elements require replacement. Dual filter housings are used so replacing filter elements can be completed during compressor operation without interrupting seal gas flow. Filters supplied with seal gas systems have limitations on the volume and size of liquids and particles they can manage. Higher levels of contaminants in the seal gas will require additional filtration. This filtration pre-filters the gas and typically contains some type of liquid knock out.

CONTAMINATION BY LIQUIDS

When a compressor is hot during normal operation, the operating temperature ensures the gas stays a gas for most applications. So as the seal gas flows from the discharge tap, through the seal gas system, into the primary seal cavity and through the seal - dropping in pressure and temperature from discharge pressure down to atmospheric pressure - it remains a gas. Examples of applications where the gas always stays a gas are pure Ethylene or Propylene compressors, as these gases condensate at very low temperatures. For other applications, such as wet gas pipeline, as the gas flows through the seal gas system and seal, liquids are formed in the gas. These liquids are detrimental to the gas seal.

As indicated in figure 13, as the pressure and temperature of any substance changes its state will change. For gas seals any time the seal gas is not a complete gas it is detrimental to the seal. In a gas seal system the gas pressure is dropped as it flows through the system.

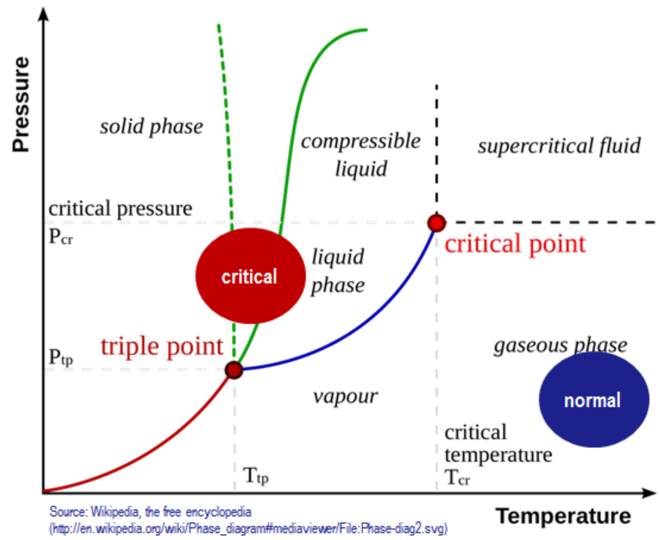

Figure 13: P-T diagram (source: From Wikipedia, the free encyclopedia)

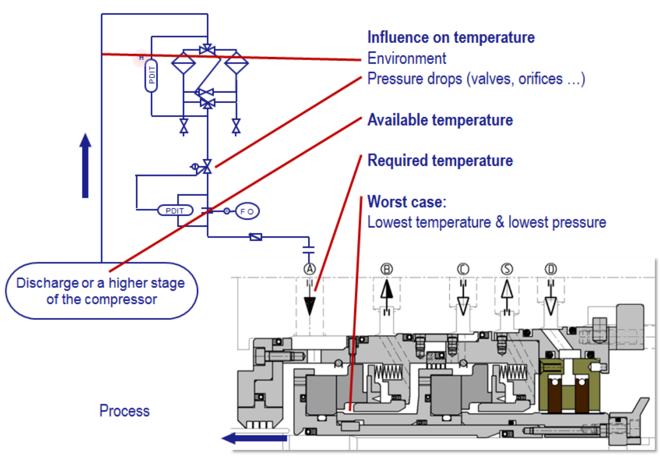

Figure 14: Seal Gas temperature

When a gas drops in pressure it will change in temperature. This is known as the Joules Thompson effect. Control valves and orifices to manage pressure and flow in a seal gas system will change the temperature of the gas. The seal gas also drops in pressure as it flows between the seal faces changing the temperature of the gas. For most gases this is a lower temperature, which will move the gas conditions to the left in P-T diagram and possibly crossing the critical temperature line (dew line) turning it into a vapor (dual phase). Besides the Joules Thompson effect, there is also the environment that has an influence on the seal gas temperature. Ambient temperatures can cool exposed supplying lines, which will drop the temperature of the gas and move the gas conditions to the left.

As gases can be made up of different components, these will change the critical temperature (dew point) of a gas. For gas pipelines where methane is the major component there are also heavier hydro carbons (Figure 16) within the gas which change the critical temperature (dew point) dramatically. Even small differences in the gas composition can make the difference whether a gas stays a gas or liquids or vapors begin to form.

If liquids enter the gap between the rotating seat and stationary face high shearing forces are created generating heat. The heat generated leads to gap instability causing contact between the rotating seat and stationary face damaging the seal faces and resulting in a seal failure. If a failure does not occur during operation with the liquid contamination, the seal will fail at the next subsequent start from increased shear forces.

Identifying when liquids will form is based on the gas composition -components in the gas. Many seal failures occur because liquids form in the gas during normal or transient conditions. This is typically the result of no consideration for the gas dew point - no dew point analysis (Figure 15) is completed- or an inaccurate gas composition is used to complete a dew point analysis. Both of these can result in liquid forming in the seal gas and a system design that does not meet the needs of a dry gas seal.

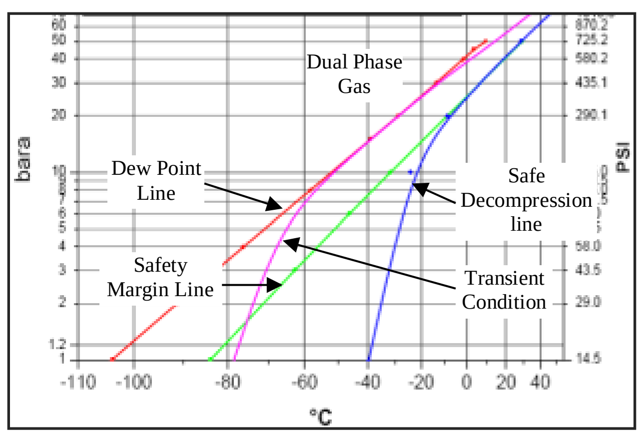

Figure 15: Example of Dew Point Analysis for Seal Gas

To identify and provide the correct system to prevent liquids in seal gas several steps must be taken. The first step is an accurate analysis of the gas composition to identify all the components in the gas for each gas being used for seal gas supply. This includes any changes in the gas composition over time, due to upset process conditions and alternate gases used for seal gas. Most analyses of gas compositions do not include information on components higher than C5 or C6 (Figure 16).

Component	% mol
Methane	89,415
Ethane	7,0
Propane	1,095
N-butane	0,121
I-butane	0,094
N-pentane	0,018
I-pentane	0,025
Hexane+	0,006
Nitrogen	0,80
CO2	1,424

Figure 16: Typical natural gas pipeline gas composition

Process people are not concerned with the trace components higher than C5 or C6. Some procedures also dry the gas sample before the analysis is completed. This eliminates components that turn to liquid and affect the operation of the gas seal. Another concern is when the composition of the process gas changes over time. Even minor changes in the gas composition can significantly change the dew point of a gas, as indicated in Figure 17 and 18. So it is elemental for a reliable result when establishing the phase envelope that an accurate and complete gas composition is provided. Possible changes in gas composition over time must be considered as well.

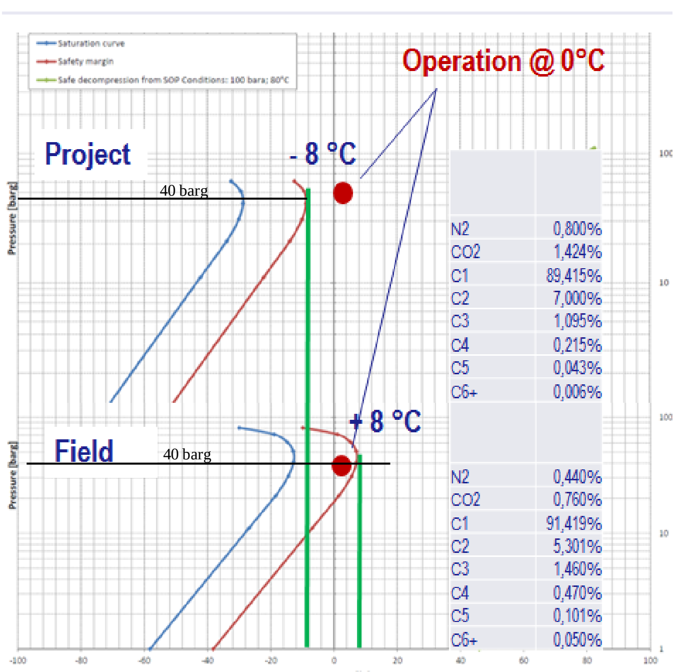

Figure 17 & 18: Example - Dew point curve during the project phase and with field gas composition project phase

With this information the second step is to produce the seal gas dew point line. Identifying at what temperature and pressure components in the gas will turn to liquids. Pressures and temperatures to the left of the dew line results in a dual phase gas; liquid in the gas. This is the area the seal gas must not operate in. The third step is to plot the decompression curve with the minimum margin from the dew line. (Industry standards have identified the safety margin as 20 degrees Kelvin.)

The last step is collecting, analyzing and plotting all operating conditions; in particular conditions where the gas is at high pressure, like settle out pressure and when the temperatures of the gas changes. Taking these measures will show what temperature the gas must be for a given pressure to prevent liquids from forming. This is critical for designing the correct seal gas supply system and preventing liquids forming in a seal gas.

CONTAMINATION DURING PRESSURIZED STAND STILL CONDITIONS

Due to environmental concerns, it is more difficult to vent compressors to atmosphere. Typically if compressors are stopped after a certain period of time they will be depressurized sending the gas to flare or atmosphere, resulting in emissions penalties or fines. Situations can also necessitate keeping a compressor pressurized ensuring a quick response to demand. Having a gas seal fail on a compressor restarted when supporting demands does not result in reliable production, profits or reducing environmental concerns. As identified above particles in seal gas or primary seal cavity, or liquids that form in a seal gas are root causes for the majority of seal failures. To prevent these failures from occurring, ensuring a clean and quality seal gas for the primary seal is essential. This maintains a reliable seal that will not fail during standstill conditions and prevent failures when restarting a compressor or shortly after a restart.

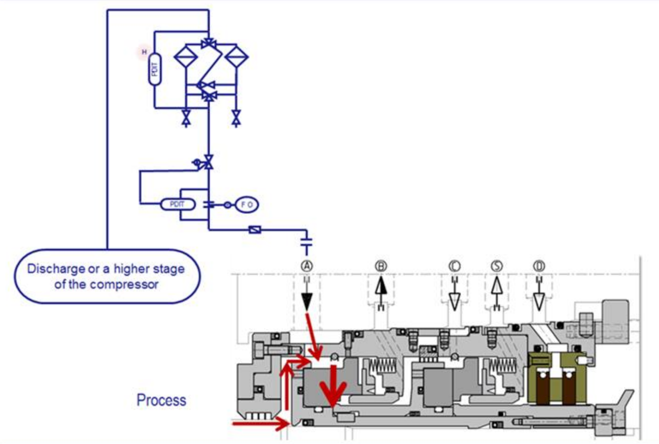

Figure 19: Process gas flow during pressurized stand still

During a pressurized stand still condition, seal gas flow; therefore clean and quality seal gas to the primary seal, is only present when an alternate supply or means of producing seal gas flow is provided. Seal gas flow during normal operation is generated by the discharge pressure, as indicated previously, which is higher than the pressure at the seal. If no means to produce a higher pressure/flow is provided during a pressurized hold, unconditioned process gas from the compressor flows into the primary seal cavity via the process labyrinth, when the seal gas flow is lost. When the compressor is not rotating, or slowly rotating, but still pressurized, leakage through the gas seal still occurs. This means the gas leaking through the seal is unconditioned process gas from the compressor, allowing unconditioned gas to enter the primary seal cavity and contaminating the primary seal (Figure 19).

Per the previous section on contamination by liquid, the ambient temperature must be considered. The reason for this is the compressor and seals will be at an ambient temperature during stand-still conditions. If unconditioned process gas is exposed to these conditions as the gas drops in temperature and pressure when passing through the seal face liquid forms and contaminates the dry gas seal (Figure 20).

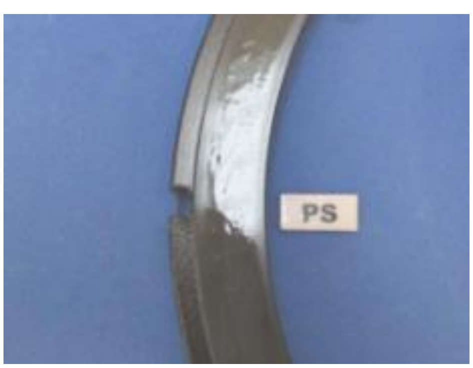

Figure 20: Contaminated seal face

When liquids form between the seal faces while the compressor is not rotating, they may stick together. The flat surfaces of the stationary face and rotating seat are within 2 light bands of flatness. With flat surfaces like this, the liquid will create a bond between the stationary face and rotating seat. On one hand, this is good because it will reduce the seal leakage or even totally eliminate it. The downside is that the strength of the bond is so great when rotational force is applied to the seat; the drive pins and the stationary seat are typically damaged. This causes high seal leakage during the start or restart of a compressor, identifying a seal failure and the requirement to replace the seal (Figure 21).

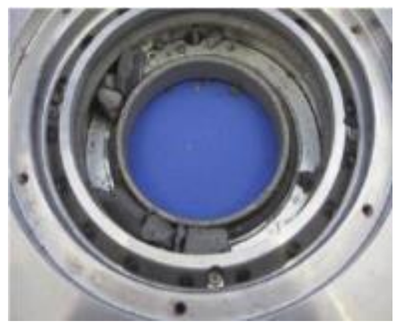
Figure 21: Destroyed seal faces after startup with contaminated sliding faces

If the line representing pressure and temperature drop of the seal gas passes through or close to the dual phase envelope. There are a couple of possible solutions for this.

An outside source can be used, but the same analysis must be completed on an accurate composition of this gas. A concern with using an outside source is gas volume is added to the compressor/process. This increases the pressure in the compressor/process. As the pressure builds in the system, the gas must be vented to maintain the clean flow of gas to the gas seal. Due to stricter environmental regulations, this is becoming more difficult to do.

The ideal solution is to circulate the gas within the system. Dirty or wet gas is drawn out of the compressor through a conditioning system to bring it to the quality and temperature required for the gas seal and pushed into the seal cavity. This ensures the gas seal is provided a gas that does not allow liquid to form between the seal faces.

Conditioning a seal gas can require only filtering the gas using coalescing filters. Or conditioning can be as complex as cooling the gas to form the liquid, a liquid knockout to remove liquid, a heater to provide minimum dew point margin, heat trace for maintaining temperature, a booster to move the gas and final filtration to ensure nothing is passing through to the seal. Proper analysis of the dew point and operating conditions will define the required conditioning to ensure the right quality of gas is available for the gas seal.

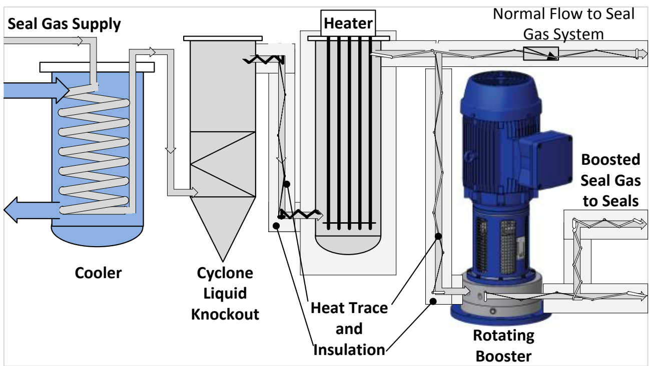

Figure 22: Diagram of a complex gas conditioning system

The movement of the gas is one of the most important requirements for providing reliability for a dry gas seal; circulating seal gas from the compressor through the seal cavity. During normal operation there is sufficient differential pressure between compressor discharge and sealing pressure. When sufficient differential pressure is not present, typically during a stand still condition, a booster is required. There are currently air-driven piston pumps being used for this application, but these have been proven unreliable, especially when required to operate for long periods of time or when not sized correctly; typical limit is 50 cycles / minute for reasonable life.

The air driven boosters (Figure 23) are positive displacement piston type boosters and the one used as an example will provide 1:1.78 pressure ratios. They incorporate many moving parts in the booster to operate the unit. There are poppet valves, shuttle valves, check valves, piston rod and pistons that all have seals and wearing parts. These require maintenance and affect the reliability of the unit.

The principle operation of the booster uses air as the drive media. It is supplied through a shuttle valve to apply pressure on one end of the piston or the other. The position of the shuttle valve spool is controlled by pressure and determines which end of the piston pressure is applied.

The position of the spool is controlled by a pilot system, spring and poppet valves. The poppet valves control pressurization and depressurization of the pilot system. The spool movement is also assisted with a spring to move the spool when pilot system is unpressurized. When the piston pushes against the poppet valve on right hand end of the cylinder the pilot system is pressurized and the shuttle valve spool is moved to the left allowing air pressure to enter the drive cylinder and move the piston to the left.

When the piston hits the poppet valve on the left hand side, the pressure is vented from the pilot system and the spring assists in moving the spool to the right. This will vent the pressure in the cylinder on the right and pressurize the cylinder on the left. As the piston moves back and forth check valves on the process end open and close to draw pressure in from the suction on one side of the piston and push process gas out on the other side of the piston. This produces the seal gas flow.

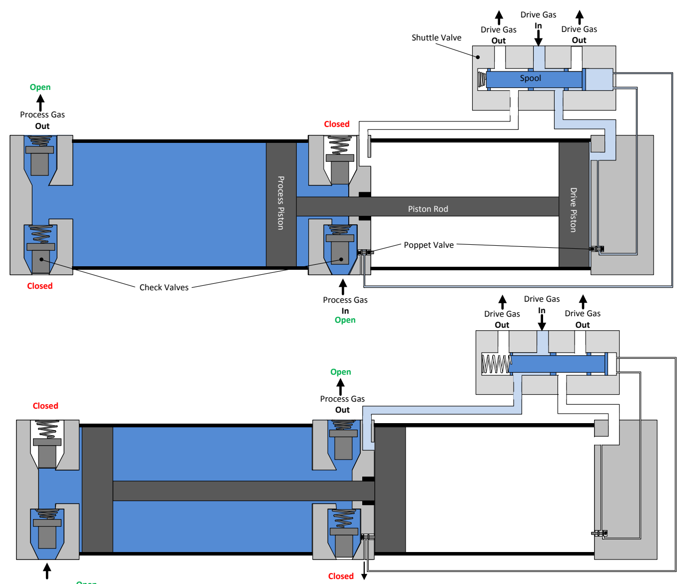

Figure 23: Operation principle piston type booster

These systems are complex not only for the booster itself, but the system required to ensure it is operating, controls for the drive gas, over pressure protection and monitoring wear of seals. With the many wear parts and additional equipment to operate the unit it becomes a very costly system and has many reliability concerns. Dirt and debris in the shuttle valve, poor quality or excessive cycling of poppet valves, ice buildup in the shuttle valve spool, poor quality air and many other issues have prevented these types of boosters from operating reliably. Due to these reliability issues air driven boosters have not performed well and are not the best option for long periods of continuous operation.

To ensure reliable operation of gas seals and compressor - during standstill conditions - a reliable device to circulate the seal gas must be used. As rotating equipment is generally much more reliable than reciprocating, the best booster design will be a centrifugal type (Figure 24).

Many booster designs require shaft seals, resulting in additional leakage of gas. If a magnetic coupled or canned booster is used, this eliminates any additional gas leaking; no gas to manage or leaking to atmosphere. One of the most important parts in a centrifugal design is the impeller. The impeller design must handle a wide range of operating pressures and varying gas. If the correct impeller is not used changing gas conditions can result in a booster failure.

Selecting a rotating, clean gas booster provides the ability to use standard reliable electrical motor. The use of a variable speed drive provides the capability to manage the varying gas density and wider range of operating pressures with lower power consumption. This allows for minimal capital to install and operate the booster. The integration of an air-driven device, which is the standard for piston type solutions, uses large volumes of air to drive the units. This requires installation of other equipment just to support an air driven booster.

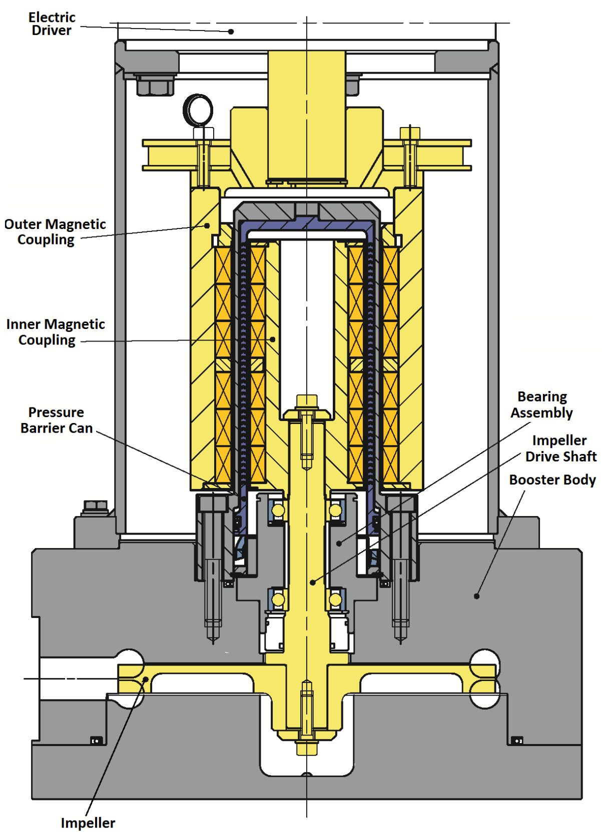

Figure 24: Operation principle rotating type booster

The equipment used for circulating seal gas is used not only for standby conditions, but anytime there is insufficient pressure across the compressor to deliver adequate seal gas flow. With the correct circulation unit provided, the compressor can be placed in a pressurized hold for a nearly unlimited period of time. Continued supply of clean dry gas to the gas seals will ensure the ideal conditions for the gas seal and guarantee a trouble free start or restart of your compressor.

Figure 25: Centrifugal Type Booster

Piston type boosters are primarily designed to generate pressure increase allowing installation in line with pressure reduction elements, like pressure control valves, flow control valves or orifices. Though these units generate more than sufficient pressure boost they are limited in the flow produced. Due to this they do not always achieve the flow required to achieve minimum velocity across the process labyrinth. To achieve the required velocity across the process labyrinth, two or even more of these units are needed; more air volume is required to drive them. Using this type of booster requires accepting lower velocities or higher air consumption with multiple units.

To provide an idea of the requirements for a piston booster an example for a pipeline application with the below conditions will be used:

Shaft size 150 mm (5.9 inches)
Operating conditions 70 Bar (1015 psig) 23 C (73.4 F)
Required flow for 5 m/s (16.4 ft/s) at twice the labyrinth clearance 389 Nm3/hr (229 scfm)
Output of Piston Booster at 90 cycles/min 332 Nm3/hr (196 scfm)
Drive air required for one unit 62.6 Nm3/hr (36.8 scfm)

Based on the size and operating condition for the above example the required seal gas flow for each seal is more than one piston booster can provide. To meet the recommended flow for 2 seals, 3 boosters should be used for the application. This would require almost 78 scfm of air to provide the required flow for with the boosters cycling at 70 cycles a minute. Other boosters which produce high pressure ratios will consume even more air.

	225H
Power Consumption (kW)	6.7
Running Torque (Nm)	25.6
Estimated Temp Rise (°C)	20.2
Estimated Outlet Temp (°C)	43.2
Check Bearing Loads	OK

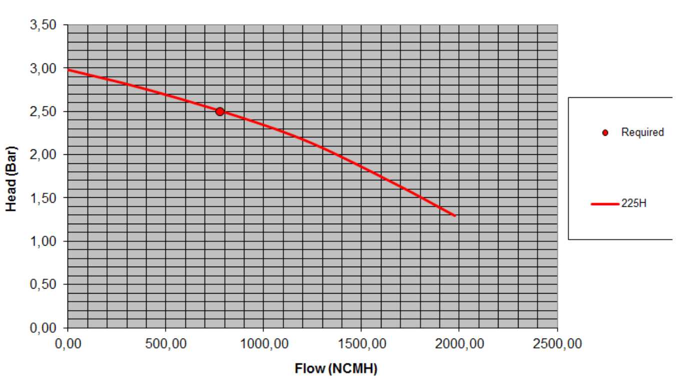

Figure 26: Booster performance chart

To cover the required seal gas volume only 1 centrifugal booster is required (Figure 26).

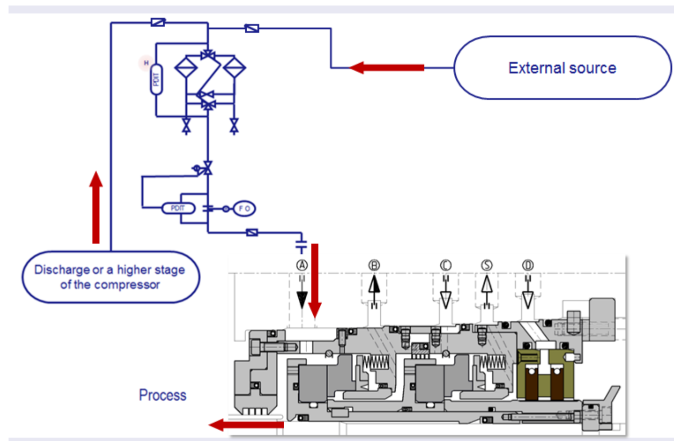

Figure 27: Typical Seal Supply System with Centrifugal Seal Gas Booster installed

Centrifugal booster designs use 5 to 20 horsepower electric motors, so as long as power is available the booster has the available resources to operate. To minimize required horsepower a centrifugal booster is installed parallel to pressure reduction elements (Figure 27). The impeller design generates high flows to ensure the required velocity across the process side labyrinth. This minimizes the head required to generate flow through a system; therefore, minimizing the horsepower requirements. With a variable frequency drive, the speed is adjusted to manage flow and head requirements; efficiently delivering seal gas to the primary seal and maintaining sufficient velocity across the process labyrinth.

Figure 28: Installed booster skid

CONCLUSION

Contamination is the leading cause for a dry gas seal failure. As identified in this article, if process gas or inadequately conditioned seal gas is provided to a dry gas seal it will affect the reliability of the seal. To prevent this from happening, an accurate gas analysis, correct conditioning components and seal gas flow whenever pressure is present in the compressor are required. When a compressor is in pressurized standby, using an alternate gas requires venting of gas pressure and leads to environmental concerns. Incorporated a booster in the system eliminate venting of process gas and prevents contaminated process gas from enter the primary seal. A reliable booster delivers the recommended seal gas flow until the compressor is restarted to prevent failures in standby situations, on compressor restarts or shortly after a compressor is restarted, conditioned seal gas is provided to a dry gas seal it will affect the reliability of the seal. To prevent this from happening, an accurate gas analysis, correct conditioning components and seal gas flow whenever pressure is present in the compressor are required. When a compressor is in pressurized standby, using an alternate gas requires venting of gas pressure and leads to environmental concerns. Incorporated a booster in the system eliminate venting of process gas and prevents contaminated process gas from enter the primary seal. A reliable booster delivers the recommended seal gas flow until the compressor is restarted to prevent failures in standby situations, on compressor restarts or shortly after a compressor is restarted.

NOMENCLATURE

Dew Point: the temperature and pressure where liquids begin to form in a gas.
Dual Phase Envelope: The temperature and pressure where both gas and liquid are present in a specified gas composition.
Joules Thompson effect: Temperature drop as a result of a certain pressure drop.

BIBLIOGRAPHY / SOURCES

Figure 13: Wikipedia, the free encyclopedia (http://en.wikipedia.org/wiki/Phase_diagram#mediaviewer/File:Phase-diag2.svg)
Drawings, sketches, pictures and calculations are taken from EagleBurgmann documentations, calculations and marketing platform (© EagleBurgmann Germany GmbH & Co. KG)

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