Dry gas seal systems - *part 2*

BEST PRACTICES FOR DESIGN AND SELECTION, WHICH CAN HELP PREVENT FAILURES

R. J. AIMONE, W. E. FORSTHOFFER AND R. M. SALZMANN

The first article in this series (p. 20, Jan./Feb. 2007) discussed best practices for Dry Gas Seal (DGS) selection and design.

This article will cover:

- Seal gas conditioning
- Seal gas control
- Primary vent systems

The source of seal gas may be the compressor discharge, an intermediate pressure point, or an external process or inert gas, or the compressor discharge. For the majority of applications, the seal Gas Conditioning Unit (GCU) will consist only of filtration (5 microns absolute) and moisture-removal equipment. The best practice is to use dual coalescing filters and automatic drainers with high level alarms. However, two special situations may require additional gas conditioning.

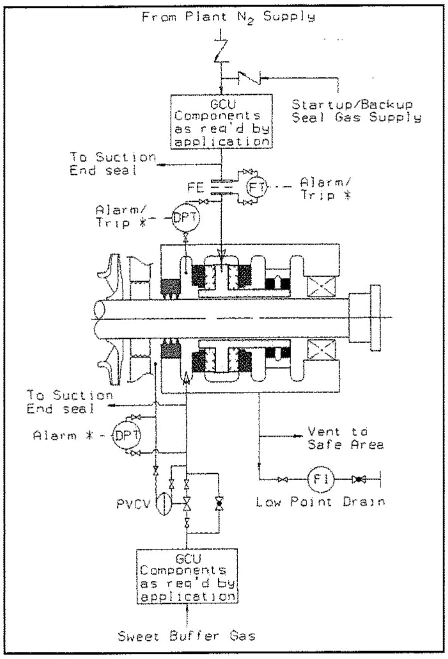


***Figure 1:** Above is a best practice double DGS system. Differential pressure control of the buffer gas is used. A seal gas control valve is not required because the system N_2 header pressure is regulated*

Seal gas conditioning

Cryogenic nitrogen (N_2 that has been liquified) can damage the carbon stationary faces during slow-speed operation — turning gear ratcheting or slow roll — when the faces are in contact. Cryogenic N_2 is typically very dry, with a dew point as low as -90°C (-130°F). But the self-lubricating quality of carbon is based on the ability of its crystalline structure to adsorb and hold certain gases, including water vapor, which significantly reduce rubbing friction *[1]*.

In the absence of water vapor, carbon has poor lubricating properties, and can wear rapidly. Therefore, dew point conditioning is required whenever carbon stationary elements are used in either face or circumferential seals, when rubbing contact is anticipated for extended periods. For large steam or gas turbine-driven compressors that require slow roll for extended periods below the DGS lift-off speed, the best practice is to condition the N_2 upstream of the coalescing filter system, raising its dew point to -30°C (-22°F), or higher.

Methods to increase N_2 dew point include mixing saturated nitrogen — from a bubbler chamber — with cryogenic nitrogen in an appropriate ratio, or mixing moist air with cryogenic nitrogen, keeping the oxygen content below 5%. A dew-point monitor and low-dew-point alarm are required for safe operation.

Saturated seal gas, either in the system or entering downstream of the GCU, exposes the DGS to liquid condensation and carry-over into the seal chamber and between the DGS faces. The risk of seal damage is high when liquid enters the area between the faces. The best practice is to assure that the gas is superheated to approximately 15°C (27°F) above the gas condensing temperature at the lowest operating pressure in the primary vent. The addition of a heater to the GCU may be sufficient for this purpose. However, if the required temperature rise could cause polymerization, a cooler, separation vessel and re-heater may be required *[2]*. If the seal gas contains C6+ components, they must be identified and individually considered in determining saturation conditions.

Regardless of the application, an alternate source of seal gas is required during start up or shut down, when the process compressor is not delivering sufficient pressure, or to back up the independent seal gas source. This alternate seal gas must meet all of the requirements enumerated above for the primary seal gas. N_2 may be used if the system can tolerate it. If N_2 is not acceptable, an amplifier unit (pressure booster) may be necessary when process gas is not available at sufficient pressure. Reciprocating piston or diaphragm compressors are currently the most common choice, however small dry rotary screws have been used successfully and are potentially more reliable. In mega-plant applications, or where justified by potential revenue loss, dual amplifier units are recommended.

Seal gas control

The DGS control system design depends on the type of seal being used, and must consider all the anticipated operating conditions. This section will focus on double and tandem DGS applications (Figures 1, 2 are not complete P&IDs). Regardless of the design of the seal gas control system, the option to trip the machine — based on monitored seal parameters and other parameters — depends on the HazOp review, and economic evaluation of the consequences of the shutdown for each plant.

Double seals can help simplify the seal gas control system, minimize the quantity of seal gas, and optimize system reliability. As noted in the previous article, double seals are normally applied where an inert seal gas (usually N_2), which is compatible with the process, is available at a pressure exceeding the maximum process pressure at the seal interface (to prevent a seal pressure reversal). If N_2 from a regulated system is used, the seal gas control valve can be eliminated (Figure 1).

If the process gas is sour, a sweet buffer gas must be injected between the process labyrinth and DGS to prevent sour gas contact and potential DGS fouling. Differential pressure control is typically used. Flow control is also an acceptable option, provided the flow is sufficient to maintain a velocity of 15 m/sec (50 ft/sec) through the process labyrinth at twice the maximum design clearance.

Tandem seals are the most common DGS application, and are required when an inert gas is either not available at sufficient pressure or not compatible with the process. The traditional control arrangement is to maintain a differential of 35 kPa - 70 kPa (5 psid -10 psid) over the balance or equalization chamber pressure, using one Pressure Differential Control Valve (PDCV). This arrangement is adequate when the sealing pressure is greater than the maximum pressure that can occur in the primary seal vent cavity.

However, this control scheme can expose the primary seal to possible pressure reversals

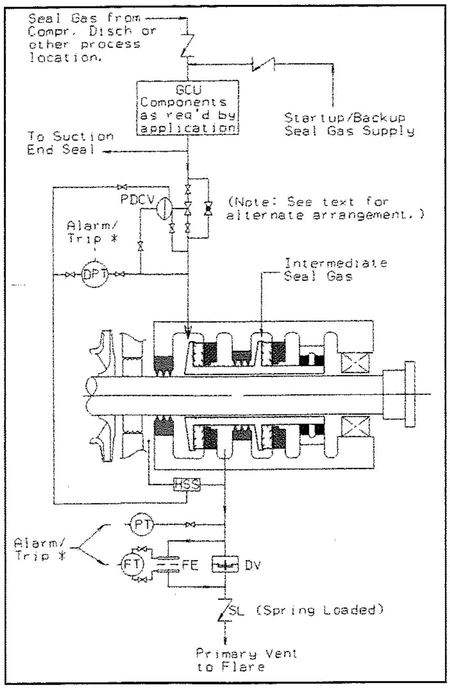


Figure 2: Tandem seal systems can be designed to avoid failures due to sub-atmospheric suction pressures

in low-pressure services, where the maximum cavity pressure of the primary vent can exceed the sealing pressure. While the flare header pressure is normally low (7 kPag - 21 kPag or 1 psig -3 psig), the maximum design flare pressure that can exist during a major upset, or during an Emergency Shut Down (ESD) can range from 140 kPag - 340 kPag (20 psig - 50 psig).

Therefore, the maximum pressure in the primary seal vent cavity can be equal to the maximum flare pressure plus losses through check valves, orifices, and piping in the vent line. For services with low, or sub-atmospheric suction pressures, even "normal" conditions in the primary vent can cause a reverse differential on the primary seal, unless the system design precludes this possibility.

A significant number of DGS failures in recent years have occurred in low-suction-pressure refrigeration, and other services. Figure 2 shows a system that has been used successfully in applications with low suction pressure. A PDCV at each seal controls the seal gas pressure to the inlet cavity at a nominal value of 35 kPa -70 kPa (5 psi - 10 psi) above the higher of the following values; reference gas pressure and primary seal vent cavity pressure measured upstream of the vent orifice. This is accomplished through the use of a high signal selector device at each seal, which assures that the primary seal will always have a positive differential of at least 35 kPa - 70 kPa (5 psid - 10 psid), even if the primary vent pressure increases significantly during an upset or ESD.

Another approach that has been used successfully for large machines, where the seal gas flow represents a relatively small recirculation loss, is to use one PDCV for both seals. In this scheme, the sensing point for the primary seal vent pressure is moved to a location in the primary vent that is common to both seals. The differential pressure controlled by the PDCV is then set high enough (typically 200 kPa - 350 kPa or 30 psid - 50 psid) to assure that it will always be greater than the maximum pressure drop across the orifice, piping, and any other component between the sensing point and the primary seal-vent cavity. This pressure also provides for the maximum allowable primary seal gas leakage flow.

Regardless of whether one or two PDCVs are used, the best practice is to assure that the control valve always operates within the acceptable valve coefficient — known as "CV" — range. For large units where seal gas flows can vary widely, an orifice can be installed in parallel with the PDCV for normal flow conditions. In this arrangement, the PDCV will remain closed unless flow conditions dictate otherwise, and the smaller valve will always operate in the acceptable CV range (10% - 90%). The key element in low-pressure service is to monitor the primary seal differential, as well as the process labyrinth differential, and control the seal gas pressure based on the higher of the two values to assure that a primary seal pressure reversal is not possible under any anticipated circumstances.

In low-pressure service the seal gas pressure should be controlled to ensure that a primary seal pressure reversal is not possible . . .

Primary vent systems

The term "primary vent" has traditionally been applied to tandem seal applications. For double seals, there is only one vent between the DGS and the separation seal (Figure 1). Since this vent will normally not contain hydrocarbons, it is generally not connected to the flare system, and may not always be monitored. Therefore, for double seal applications, the best practice is to monitor and alarm, or trip the system if N_2 inlet flow to the seal assembly increases. Operators of large, high-revenue plants may decide to trip only when outer seal failure is imminent. High N_2 flow plus high outer seal flow may be used to trip these units.

For tandem seals, the primary vent, which normally contains hydrocarbons, is connected to the flare system and is instrumented to monitor the health of the primary seal (Figure 2). This system must provide the operating team with sufficient information to monitor the condition of the primary seal, maintain safe operation of the compressor for the longest possible time, and safely shut down the compressor when a dangerous condition exists.

Below are best practices for the primary vent:

Locate the primary seal chamber vent at the bottom (6 o'clock) position on the seal cartridge, with a low point drain in the vent piping adjacent to the machine. This will permit checking for liquids in the primary vent chamber. The required piping configuration, and when the drain will be opened, should be determined during the HazOp review.

Intermediate labyrinths with N_2 injection are recommended for all tandem seals. To prevent masking the primary seal leakage, flow control of intermediate N_2 is the best practice. (Details concerning the N_2 injection system for the intermediate seal labyrinth will be covered in the next article.)

A flow measuring device is recommended in the primary vent to monitor flow. The device may be an adjustable orifice — but tamper-proof, with a set point lock or cover — or a fixed orifice. Orifice sizing is to be based on the expected leakage from the primary seal plus the intermediate labyrinth flow. Measuring primary vent flow to facilitate troubleshooting is always recommended, regardless of what parameters will be used for alarm and trip (flow or pressure).

Use low-pressure, loss-flow elements that measure loss of low pressure to monitor seal leakage and intermediate labyrinth flow rates. Piping should be generously sized to minimize primary vent cavity pressure in the event of a primary seal failure. Seal cavity vent openings, internal to the compressor, should be checked so that they are not undersized.

If a complete primary seal failure can cause the pressure in the primary vent cavity to exceed the pressure that can be delivered by the N_2 system, the best practice is to relieve the vent pressure below the N_2 system pressure. A weight-loaded, stem-guided, full-flow disc valve is recommended. A rupture disc can randomly fail and will require a unit shutdown for replacement.

A spring-loaded check valve is recommended in the piping at the flare header connection. This prevents the back flow of flare gas into the primary vent chamber, and maintains a positive pressure differential across the secondary seal. The check valve is normally designed to exert a minimum back pressure of 35 kPag (5 psig) in the primary vent cavity, assuring a minimum 35 kPad (5 psid) positive differential over the secondary seal. However, the required secondary seal pressure differential should be determined by the seal vendor, based on anticipated turning gear operation and seal lift-off speed.

Primary vent systems have traditionally been provided with pressure or flow instrumentation — usually Triple Modular Redundant (TMR) — to trip the compressor unit on a significant increase in pressure or primary vent flow rate. With the increase of process unit size, and corresponding increase of daily revenue loss, many end-users are reconsidering this approach. Decisions regarding machinery trips must ultimately be made by the operating team for each plant as early as possible in the project (pre-Front End Engineering Design phase). The goal is to avoid spurious trips and unscheduled shutdowns, while maintaining the safety of the plant and the integrity of the machinery.

Specifying shutdowns

DGS are precision components, and significant transient variations can occur in monitored parameters. Therefore, the best practices for shutdown are:

• Set trip levels as high as reasonably possible, but below the minimum available N_2 pressure
• Always use TMR (including wiring and logic) for trip functions
• Consider requiring more than one parameter to exceed allowable settings to initiate an automatic trip
• Require provisions for monitoring the condition of the secondary seal, as well as the primary seal, to permit action in the event of its deterioration or failure

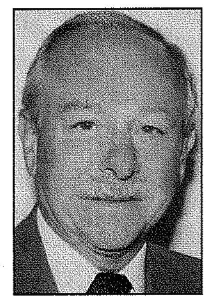
References:

[1] Paxton, R. Robert, "Manufactured Carbon: A Self-Lubricating Material for Mechanical Devices," CRC Press, Inc., 1979.

[2] Forsthoffer, W.E., "How to prolong dry gas seal life", Turbomachinery International, Sept./Oct. 2005

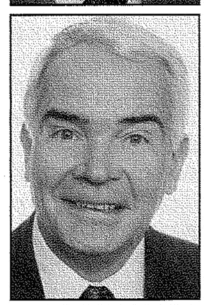
Footnotes:

The next article will focus on the best practices for intermediate and separation gas systems and discuss best practices for condition monitoring of DGS systems.

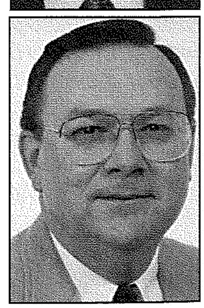


No responsibility is assumed by the authors for any injury and/or damage to persons or property as a matter of product liability, negligence or otherwise, or from any use or operation of any methods, products, instructions or ideas contained in these articles. TI

Authors:



Robert Aimone has 47 years experience in the machinery field; in operations, maintenance, design, specification and troubleshooting. He spent over 30 years on the technical staff of Mobil Oil Corporation and the last six years as president of his own consulting firm, REMO.



William Forsthoffer has over 36 years experience in the turbomachinery industry as a designer (DeLaval), facilities engineer (Mobil), and field troubleshooter and trainer. In 1990, he founded Forsthoffer Associates Inc., (FAI), a turbomachinery consulting firm.

Dick Salzmann has 44 years in the turbomachinery field, including 36 years with Delaval Turbine Inc. and its successors. His experience covers machinery application, design, testing, training and troubleshooting. Salzmann has been consulting for the