Application of Dry Gas Seals in the pumping of liquid hydrocarbons

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Reaching the target in an innovative way

Sulzer ethane pump in an NGL fractionation facility in Houston, Texas. The pump and seal have been running without interruption since conversion to the innovative EagleBurgmann DF-DGS6 sealing solution in 2011.

Keeping NGL (Natural Gas Liquid) pipeline components operating in optimal condition is an ongoing challenge for the oil and gas industry. Rising temperatures in the liquid pumps and the resulting issues for their seals represent one such challenge.

One case experienced at an NGL fractionation facility in the US shows how seal failures when pumping hydrocarbons close to the specific vapor pressure can be analyzed, resulting in durable and sustainable design solutions.

This facility in Houston, Texas separates mixed NGL streams into pure NGL products such as ethane, propane, butane, isobutene and gasoline. Critical components in this system include the ethane injection pumps operating at pressures from 28 bar (410 PSI) to 76 bar (1,100 PSI). The ethane temperature at the suction port must not exceed 16 °C (60 °F) to ensure that the specific vapor pressure never drops below the required values at the shaft seals.

Unfortunately, significant temperature rises are a frequent issue due to atmospheric conditions - then the ethane vaporizes, resulting in seal failure and loss of product.

The solution for an increasingly failure-prone liquid ethane pump was to use an EagleBurgmann DF-DGS6. This is a DiamondFace-bonded mechanical seal that was actually designed for purely gaseous media.

This innovative sealing concept has since proved to be a reliable and durable solution for media with low vapor pressures. There are now many seals of this type in the field around the world. They replace liquid-lubricated seals which cannot handle critical operating conditions and phase transitions.

Why liquid-lubricated pump seals fail

The possibility of transient conditions in the pumped medium is frequently ignored when operating rotating equipment. But it is important to correctly assess the conditions for the sealing system in the start phase and in slow-roll or standby operation and to make sure that sufficient lubricating liquid is supplied to the shaft seal's faces at all times.

Evaluation of the different phases illustrates the factors that affect a mechanical seal's reliability.

Start-up: The pump is primed. Under suction pressure conditions, the liquid ethane penetrates between the seal faces and vaporizes as a result of the pressure drop at the inner diameter of the seal face and stationary seat. Once the pump has started, building up the normal operating pressure (which exceeds the vapor pressure of the medium) in the seal compartment sometimes takes too long. Even a low heat generated between the seal faces can increase the vapor pressure sufficiently to allow the liquid medium in the sealing gap to evaporate. This results in damage to the seal faces and the damage patterns are startlingly clear.

Slow-roll: The problem here is the same as for start-up, only compounded. The discharge pressure cannot be generated until the rotation reaches a threshold speed. The pressure in the seal compartment rises too slowly to guarantee the necessary ethane vapor margin. More and more heat is generated between the seal faces, increasing the probability of insufficient lubrication and thus seal damage.

DiamondFace-bonded seal faces with bi-directional gas grooves of a DF-(P)DGS6 seal for pumps

Standby: The conditions are similar. The seals are also often left sitting idle for months without flushing. It has been shown that deposits collecting on the seal faces and around the seal during standby in turn have negative effects on the seal compartment.

Inefficient operation: Running the pump outside the optimal range and with the wrong operating point parameters results in increased demand for drive power and a reduced delivery rate. Both of these negatively impact the vapor margin in the seal area, which can result in dry running.

Other events that need to be considered when dimensioning the seal supply are temperature fluctuations in the medium, frequent start/stop cycles and, not least, operator error.

In our case, all these factors conspired to give the Texan operator's ethane pump a MTBF (Mean Time Between Failures) of a little over three weeks.
It was clear that something had to be done to counteract the seal failure, resulting product losses and greatly impaired plant availability.
The causes were analyzed in collaboration with the customer, then a team of EagleBurgmann application and design engineers concentrated on finding a reliable and durable sealing solution.

Taking up the challenge

Applications with low vapor margins, such as ethane in our case, have one thing in common: the liquid tends to transition to the gaseous state. A „liquid-lubricated gas seal" would therefore appear to be a perfect solution. Various seal concepts were investigated.

The EagleBurgmann product portfolio already includes gas-lubricated seals for pumps.
The faces of this type of seal offer non-contacting operation on a stable gas film. The options are for a double seal pressurized with an inert gas or a double seal in which the seal on the product side is pressurized by the medium, while the atmospheric side is operated with an unpressurized buffer gas.

Such a gas-lubricated double seal would be perfect for this application, but it does not take account of the imponderables represented by the unpredictable transient conditions and other critical states.

A few seal manufacturers, including EagleBurgmann, have been successfully using gas-lubricated pump seal technology for a long time. In critical applications, however, failure is a recurring problem since the seals require clean gas at the faces at all times. If the factors described above are also taken into account, this becomes a high-risk solution.

Another possible approach for Houston was a liquid-lubricated seal with the seal compartment pressurized directly from the pump's discharge port, as the pressure available at this point is higher. Unfortunately, the seals failed continuously. Particularly on hot summer days when the outdoor temperature rose. What caused this?

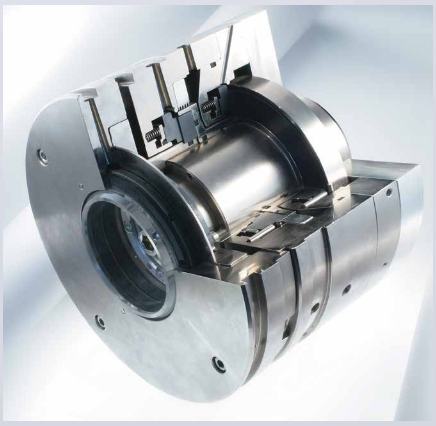
As described above, the liquid ethane tends to be a gas. To keep the medium in the liquid state, it had to be held at a specific temperature and pressure (approx. 21 ... 28 bar (300 ... 400 PSI) at 16 °C (60 °F)). When the pump is working optimally, the temperature and pressure are at the ideal point: the liquid ethane flows through the pump and reaches the shaft seal in the liquid state. But when the outdoor temperatures rise in hot weather, the temperature inside the pump rises accordingly. The ethane in the seal compartment vaporizes and so reaches the seal faces as a gas.

Those capricious transient conditions!

Liquid-lubricated mechanical seals are designed for operation in liquid media. The liquid medium penetrates into the sealing gap and lubricates the seal faces. If gas fractions in the medium cause this lubricating film to lift off, the seal faces will run dry and thus be damaged. In practice, however, many liquid-lubricated seals run in ethane applications without problems. What they all need are uniform, stable operating conditions. Under highly fluctuating conditions, these seals cannot function perfectly.

Dry gas seals are able to seal ethane on their own, provided that the ethane reaches the seal as a gas. For ethane to transition to the gaseous state, either the pressure must fall or the specific vapor pressure must clearly exceed the sealing pressure. This can be achieved quickly by heating the liquid. But using an external heating source increases the complexity and maintenance requirement of the plant, which is not what the operator wants at all.

Design modifications such as narrow gaps and a labyrinth on the product side of the seal generate turbulent flows. The resulting fluid friction encourages a build-up of heat - and heat is also generated at the seal faces. The smaller the sealing gap, the less the leakage but the more heat is generated. This may be sufficient for stable sustained operation, but the risks still remain during start-up, in slow-roll or in standby if there is no friction heat.



A typical design of a Dry Gas Seal

An unconventional approach: Dry gas seals

The team of experts from EagleBurgmann hit upon a surprising and unconventional idea. Why not leverage the properties of a type of seal that is actually designed for sealing compressors, i.e. for gases?

Dry gas seals (DGS) have proved extremely reliable as shaft seals in compressor applications. They have broad sealing surfaces that incorporate structured (uni/bi-directional) gas grooves. These grooves allow lift-off of the seal faces and non-contacting operation. As with liquid-lubricated seals, where dry running can damage the seal faces, with dry gas seals it is the contact of the seal faces that leads to premature wear and ultimately to failure of the seal.

This is because seals in compressors also have critical operating states. Coast-down (slow, controlled compressor run-out), turning (running at low speeds) and ratcheting (turning the shaft a further 90° at set intervals) all cause the seal faces, which are separated from one another under normal conditions, to come into contact. It is this contacting operation that can result in damage to the faces.

To overcome just these situations, EagleBurgmann has developed and successfully applied dry gas seals with an innovative diamond bonding on the seal faces.

The key is the DiamondFace bonding

EagleBurgmann DiamondFace is a microcrystalline diamond bonding for mechanical seals. It is extremely hard and wear-resistant, offers excellent heat conductivity, maximum chemical resistance and low friction. The bonding adhesion also exceeds all known practical requirements.
This demonstrably increases the service life of mechanical seals several times over; the maintenance intervals are extended accordingly and the life cycle costs greatly reduced.

DF-(P)DGS6 - the solution for highly volatile media

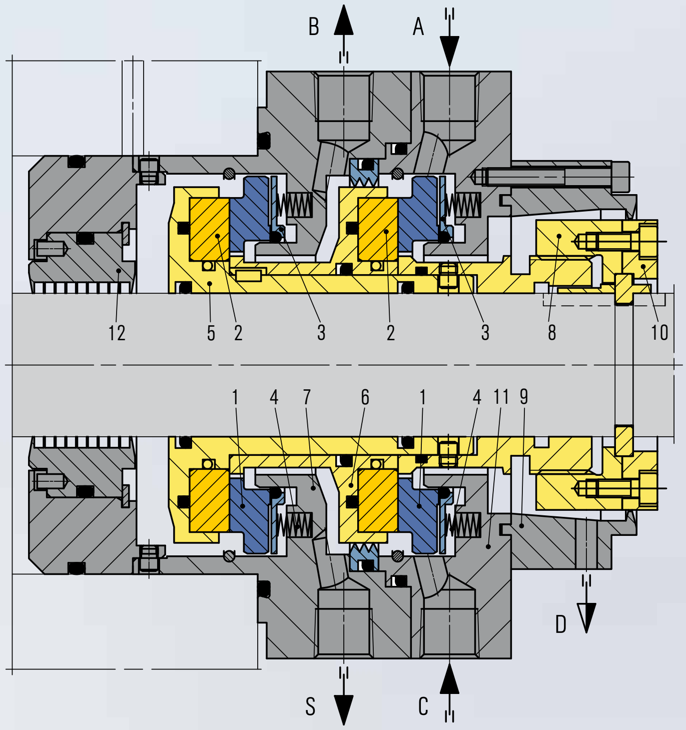
The ethane pump in Houston was retrofitted with the DF-DGS6 and brought into service in July 2011. The solution sealed the medium reliably and safely in both the liquid and the gaseous state.
In transient conditions that can result in dry running and contact of the seal faces, the DiamondFace bonding on the faces protects the seal against damage.

The mode of operation was also simplified: The seals require no flushing (API Plan 02). The previously-used filters can be omitted - so do not have to be maintained.

After a few months, the operator reported that ethane gas leaking to the flare system had dropped by 83 %, a value that improved even further to more than 90 %.

After eight months, the pump was stopped and opened for remedial work on the impeller.
The operator wanted the seal to undergo dynamic testing at the same time so the results could be compared with the original data. The seal was removed and tested at EagleBurgmann Houston. The seal faces showed no signs of scoring whatsoever. They looked as good as new.
The sealing components were cleaned and reassembled. The DF-DGS6 was then extensively tested on a dynamic test rig. The seal was in perfect condition and delivered excellent results (with a leakage rate below the value determined in the acceptance test), so the operator immediately reinstalled it in the pump with no further work.
The seals have been running without problems ever since. Operating periods in excess of 5 years are now feasible with the DF-(P)DGS6 solution.

Over 150 EagleBurgmann DF-(P)DGS6 seals („P“ stands for the high pressure version) are now being used successfully in many different NGL applications worldwide - more recently even in CO_2 applications.



EagleBurgmann tandem seal DF-DGS6 with intermediate labyrinth

Face and seat of the process side seal have DiamondFace bonding.

1	Seal face, stationary
2	Seat, rotating
3	Thrust ring
4	Spring
5	Shaft sleeve and seat retainer
6	Intermediate sleeve
7	Housing (size matched to installation space)
8	Adjustable nut for axial misalignment
9	Split ring
10	Clamping ring
11	Cover
12	Process side labyrinth
GBI	Gas buffer inlet
GBO	Gas buffer outlet
D	Drain

Yellow parts rotating, blue stationary, gray: housing and pump shaft.

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