New mechanical seal raises the bar for compressor reinjection applications

EagleBurgmann
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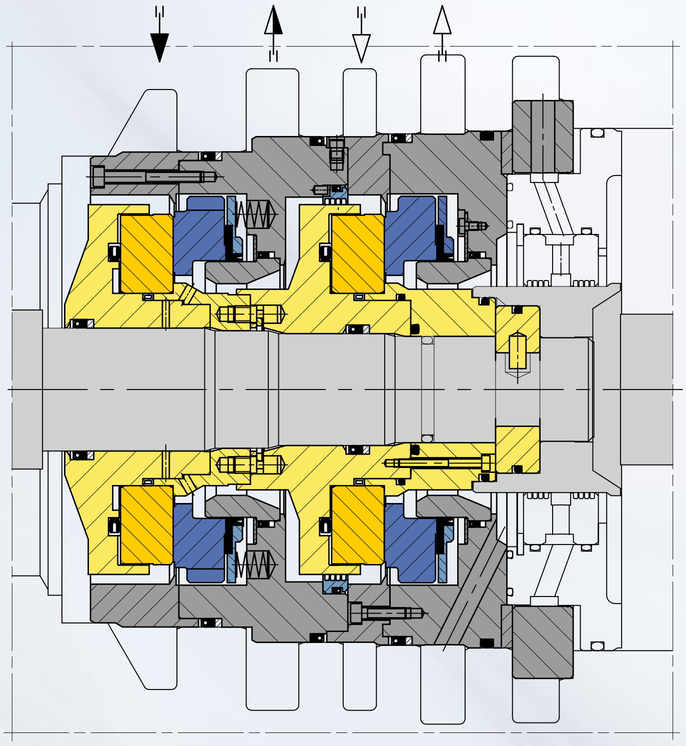
High pressure compressor seal PDGS for Tupi 4 FPSO

EagleBurgmann PDGS compressor seal (cross-section)



Cross-section of a Tupi 4 compressor seal

Off the coast of Brazil, global seal manufacturer EagleBurgmann is raising the bar again, literally and figuratively, by setting a new standard for dry gas seals (DGS) used in ultra high pressure gas-reinjection systems. As they drill deeper under the ocean floor, oil producers are asking for even more pressure to sustain the strong, steady crude flows needed to justify their huge development costs and royalties. Every bar of additional pressure counts. The mechanical seals EagleBurgmann is installing on GE compressors at the Tupi 4 floating production site in the Lula field in the Atlantic Ocean southeast of Rio de Janeiro have the highest static design pressure rating of any DGS certified for deep water gas re-injection compressors. The 428 barg (6,206 PSIG) rating is not just a test-bench achievement; it's the actual operating point for the Tupi 4 re-injection compressors, required for system startup and when the compressor is tripped for whatever reason, as the suction and discharge pressures equalize (settle out pressure). That 428 barg (6,206 PSIG) is several bar more than seals employed by petroleum producers in comparable ultra-high-pressure reinjection systems worldwide.

Gas, be it natural gas or supercritical carbon dioxide (CO_2), is displacing water as the most economical re-injection medium. It's an abundant byproduct of offshore oil production at the Tupi 4 site that is valueless – indeed, an environmental cost as it cannot be vented to the atmosphere. Re-injecting CO_2, in effect, sequesters it below ground.

The Lula field was discovered in 2006 and contains pre-salt oil and gas, so called because hydrocarbon-bearing zones are situated under layers of rock and salt. The ocean depth averages about 2,000 meters and the hydrocarbon zones are 4,000-5,000 meters below that, holding estimated recoverable reserves of 5-8 billion barrels of oil equivalent. Lula is being brought into full production using FPSO (Floating Production Storage and Offloading vessel) platforms. The Tupi 4 partners, led by Brazil's state-controlled oil company, need the highest pressure possible from compressor and mechanical seal within the parameters of safe and reliable operations to create an effective miscible zone to flow the crude to the production well.

The seals developed for the Tupi 4 FPSO and installed on GE Oil & Gas BCL306/D vertical split compressors represent the leading edge of re-injection sealing. They are designed for a maximum shaft speed of 13,844 min^{-1}. The higher 428 barg (6,206 PSIG) raises the level at which the compressor can remain pressurized in the event the compressor is tripped. Avoiding depressurization saves process gas and considerable time by dispensing with the lengthy shutdown and re-pressurization protocols.

For Tupi as it did in the Caspian fields, EagleBurgmann is deploying a tandem DGS with an intermediate labyrinth. Tandem DGS layouts –

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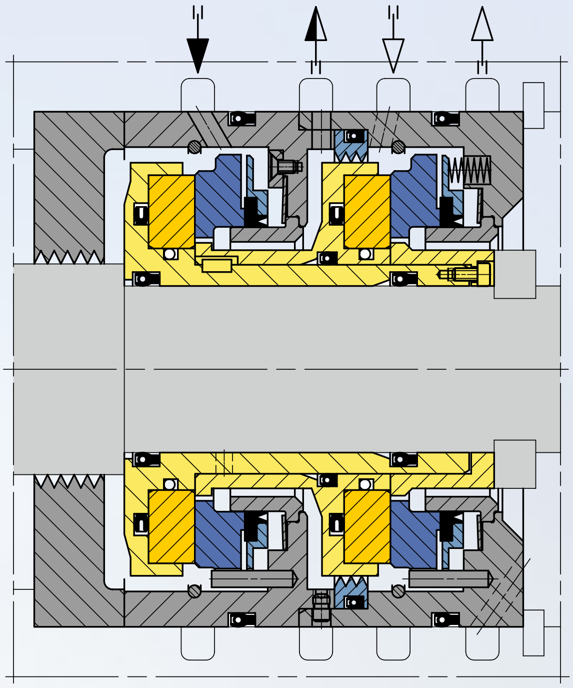
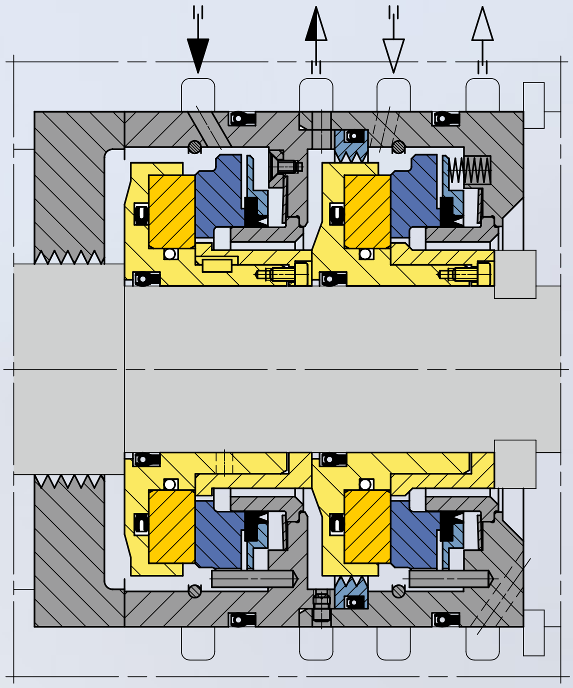


Low pressure seal design with one shaft sleeve

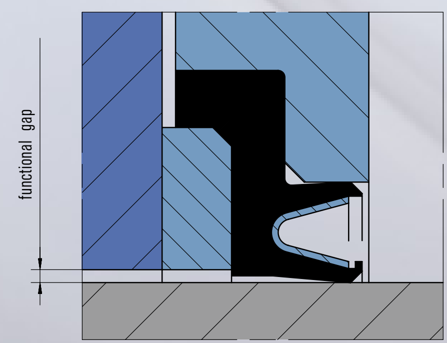


High pressure seal design with two sleeves

comprised of a primary and secondary seal – are used widely in petroleum production and pipeline operations and considered the best choice for ultra high pressure re-injection. The Tupi 4 seal reflects several technical considerations in the EagleBurgmann tandem seal design for ultra high pressure operations to achieve the optimal compromise between leakage reduction and torque at startup. These three are of particular note:

Functional gap at sealing elements

The functional gap of a tandem DGS is the gap between the balancing sleeve and support ring of the dynamic secondary seal. To prevent the sealing element material from extruding, the functional gap is designed as small as possible. Free movement must be ensured under all operating conditions. The functional gap's design must be no more than a few hundredths of a millimeter. This is a tough challenge to manufacture because the variation of the gap height comes under the influence of temperature and pressure and has to be minimized. To achieve this, extensive FE-calculations were carried out by EagleBurgmann prior to design finalization.



Functional gap of a PDGS

Stability under high forces

At ultra high pressure levels, there are tremendous forces caused by the pneumatic load acting on the seal not only in the radial direction, but also in the axial direction. To ensure maximum stability of the seal at such high loads, the cross-sections of the metal sleeves in the seal cartridge have to be larger than those operating at lower pressure.
In the case of the latter, a single sleeve is used, which is assembled above the shaft sleeve. If only one sleeve is used for an ultra-high-pressure DGS, the relatively small cross-sections would be too weak to handle the high axial load. Instead, the sleeves were split to ensure maximum stability of the DGS under ultra high pressure.

Material selection for ultra high pressures

Due to the extreme mechanical loads at ultra high pressure, like the great torque at start-up when the seal faces are still in contact, special emphasis has been given to the selection of materials, including the mechanical properties of the seal faces. EagleBurgmann's extensive experience with hard-to-hard material combinations of seal faces played a significant role in achieving the optimal compromise between gas leakage reduction and torque at start-up. A special fluid-phase sintered silicon carbide material was chosen to ensure maximum strength of the seal faces and at the same time maintain optimum thermal conductivity. Also, at full load, the power produced mainly in the seal gap is in the range of 25 kW due to the sharing action of the high density gas. The seal design and choice of materials is such that this tremendous amount of power is easily dissipated into the surrounding gas and metal parts.

There have been notable advances in re-injection technology since 2000 as new fields have been brought into production in Oman, in the Caspian Sea, and now in Brazil's off-shore. This has spurred EagleBurgmann to develop ultra-high-pressure derivatives of its tried and true DGS used widely in petroleum operations. It's been able to progressively raise the DGS design pressure with refinements to existing DGS design and materials without compromising operational reliability and integrity. For example, the sour gas content of the Caspian oil fields (sour gas is natural gas with high levels of hydrogen sulfide, an aggressive corrosive) presented a more challenging environment for compressor and seal integrity and had to be compensated for in the design as well as materials. The Tengiz and Kashagan fields have 23 % and 17 % H_2S content respectively. In 2005, EagleBurgmann undertook research at the invitation of GE Oil & Gas to develop a new ultra-high-pressure DGS for gas re-injection. The result was a seal with a static design pressure of 425 bar (6,163 PSI) and maximum shaft speed of 12,373 min^{-1} for the Caspian projects, milestones surpassed by the Tupi 4 seal.

Any high-performance seal design must balance multiple objectives to achieve the best possible overall outcome. In the case of the Tupi 4 seal, extensive testing by both EagleBurgmann at its premises and at GE has demonstrated that the seal delivers high reliability in common startup/shutdown scenarios as well as continuous operations at full load, assuring compressor integrity with minimal controlled leakage despite the great pressure exerted. Development isn't stopping there. Research by EagleBurgmann continues to focus on enhancements for re-injection operations at even higher pressure – up to 550 bar (7,975 PSI) – while ensuring optimum safety and reliability.