Mechanical seal raises the bar in compressor re-injection applications

Off the coast of Brazil, global seal manufacturer EagleBurgmann Germany GmbH & Co Kg is raising the bar again – literally and figuratively – by setting what it claims is a new standard for dry gas seals used in ultra-high-pressure gas re-injection systems.

As oil producers drill deeper into the ocean floor they need greater pressure to sustain the strong, steady flow of crude needed to justify their huge development costs and royalties. Every bar of additional pressure counts.

The mechanical seals that the company is installing on GE compressors at the Tupi 4 floating production site in the Lula field in the Atlantic Ocean, south-east of Rio de Janeiro, have the highest static design pressure rating of any dry gas seal (DGS) certified for deep-water gas re-injection compressors.

The 428-barg (6206-psig) rating is not just a test-bench achievement, it is the actual operating point for the Tupi 4 re-injection compressors that is required for system start-up and when the compressor is tripped for whatever reason, as the suction and discharge pressures equalise (settle out pressure). This pressure is several bars higher than that experienced by seals employed by petroleum producers in comparable ultra-high-pressure re-injection systems worldwide.

Lula field

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 2000 m and the hydrocarbon zones are 4000–5000 m further below – holding estimated recoverable reserves of 5–8 billion barrels of oil equivalent. Lula is being brought into full production using floating production storage and offloading vessel (FPSO) platforms. The Tupi 4 partners, led by Brazil's state-controlled oil company, need the highest pressure possible from the compressors and mechanical seals – within the parameters of safe and reliable operations – to create an effective miscible zone to flow the crude to the production well.

Re-injection medium

Gas, be it natural gas or supercritical carbon dioxide, is displacing water as the most economical re-injection medium.

It is an abundant by-product of offshore oil production at the Tupi 4 site that is valueless – indeed, it is effectively an environmental

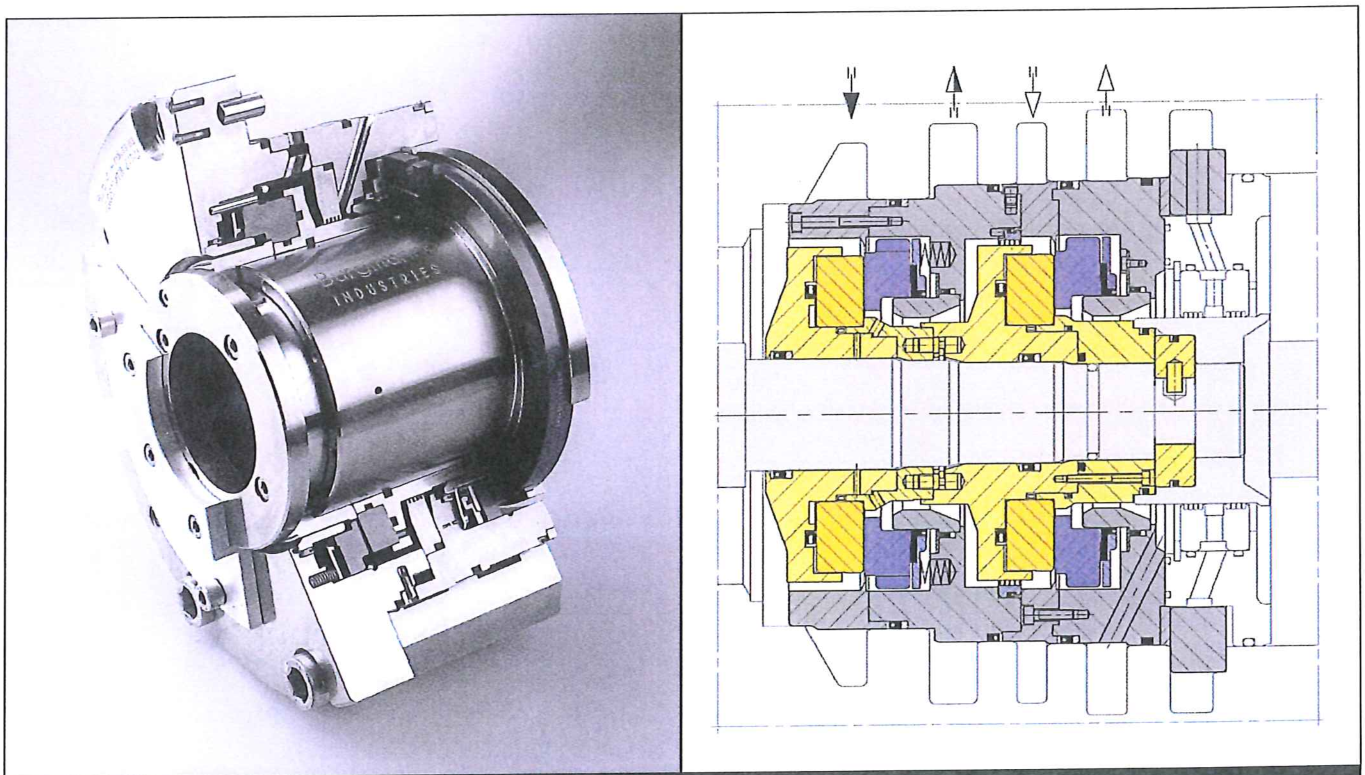

Figure 1. Cross-section of EagleBurgmann's PDGS compressor seal (*left*), and cross-section of a Tupi 4 compressor seal (*right*).

cost because it cannot be vented to the atmosphere. In effect, re-injecting carbon dioxide sequesters it below ground.

Re-injection seals

The seals developed (see **Figure 1**) for the Tupi 4 FPSO, and installed on GE Oil & Gas BCL306/D vertical split compressors, represent the leading edge of re-injection sealing, says EagleBurgman.

They are designed for a maximum shaft speed of 13 844/min. The higher 428-barg (6206-psig) raises the level at which the compressor can remain pressurised in the event of it being tripped. Avoiding depressurisation saves process gas and considerable time by dispensing with the lengthy shutdown and re-pressurisation protocols.

For Tupi – as it did in the Caspian fields – EagleBurgmann is deploying a tandem DGS with an intermediate labyrinth. Tandem DGS layouts, which comprise a primary and secondary seal, are used widely in petroleum production and pipeline operations, and are 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 start-up. The three of particular note are discussed in the sections that immediately follow.

Functional gap at sealing elements

The functional gap (**Figure 2**) 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 to be 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 millimetre. This is a tough challenge to manufacture because variation in the gap height is influenced by temperature and pressure, and has to be minimised. To achieve this, extensive FE-calculations were carried out by EagleBurgmann prior to finalising the design.

Stability under high forces

At ultra-high-pressure levels there are tremendously high 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

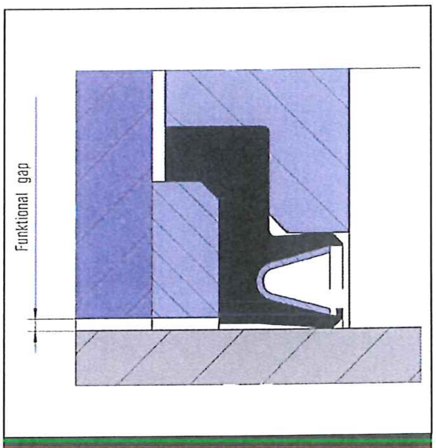

Figure 2. Functional gap of a PDGS.

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 (see **Figure** 3).

Material selection

Because of the extreme mechanical loads at ultra-high-pressure –such as great torque at start-up when the seal faces are still in contact – special emphasis has been given to the selection

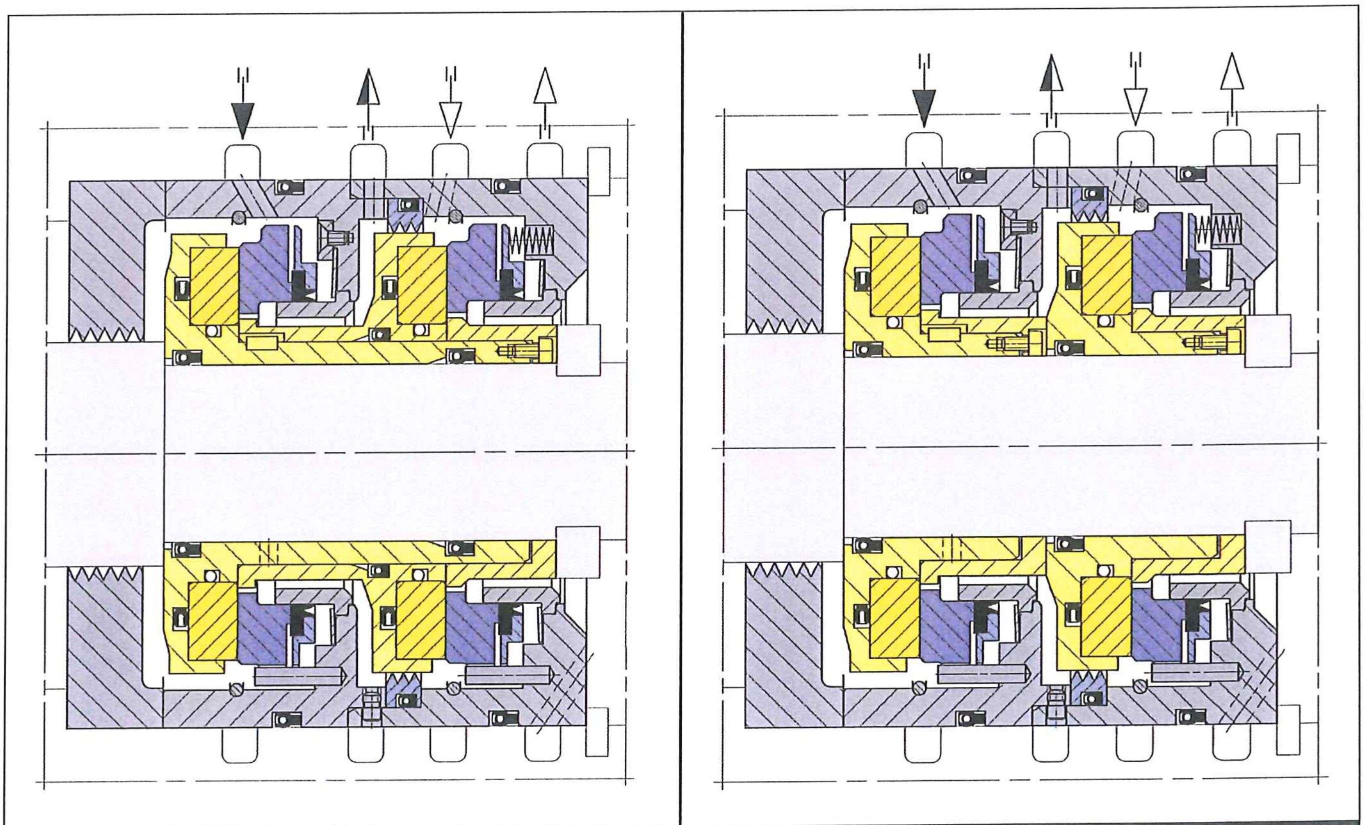

Figure 3. Low-pressure seal design with one shaft sleeve (*left*) and high-pressure seal design with two sleeves (*right*).

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 because of the shearing action of the high-density gas.

The seal design and choice of materials is such that a tremendous amount of power is easily dissipated by the surrounding gas and metal parts.

Refinements

There have been notable advances in re-injection technology since 2000, as new fields have been brought into production in Oman, the Caspian Sea and now off-shore Brazil.

This has spurred EagleBurgmann to develop ultra-high-pressure derivatives of its tried and tested DGS used widely in petroleum operations. The company has been able to progressively raise the DGS design pressure with refinements to the existing DGS design and materials without compromising operational reliability and integrity.

For example, the sour gas (natural gas with high levels of hydrogen sulphide, an aggressive corrosive gas) content of the Caspian oil fields 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% hydrogen sulphide 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 (6163 pis) and maximum shaft speed of 12 373/min for the Caspian projects – milestones surpassed by the Tupi 4 seal.

Balancing multiple objectives

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 start-up/shutdown scenarios, as well as continuous operations at full load, assuring compressor integrity with minimal controlled leakage, despite the great pressure exerted.

Development is not stopping there: research being done by EagleBurgmann continues to focus on enhancements for re-injection operations at an even higher pressure – up to 550 bar (7975 psi) – whilst ensuring optimum safety and reliability.

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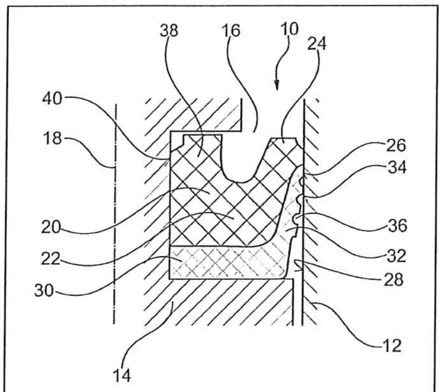
PATENTS

Seal for a hydraulic piston–cylinder arrangement

Applicant: **Schaeffler Technologies Ag & Co Kg, Germany**

A seal (10) has been developed, in particular, for a hydraulic piston–cylinder arrangement within a hydraulic path for clutch or brake actuation. It incorporates a first sealing element (20) that has a main body (22) and has at least one first sealing lip (24). The latter has a first sealing contour (26) which makes contact with a first surface (28) of the piston–cylinder arrangement so as to impart sealing action, and has a reinforcement (30) that bears against the main body (22) of the first sealing element (20), and at least one projection (32). The first sealing lip (24) is produced from silicon or from a material that is composed of silicon.

Patent number: WO/2014/108122
Inventors: P. Wagner and D. Regending
Publication date: 17 July 2014



This invention, detailed by patent WO/2014/108122, relates to a seal for a hydraulic piston and cylinder arrangement – preferably within a hydraulic line for clutch or brake application.

Expandable seal assembly for a downhole tool

Applicant: **Omega Completion Technology Ltd, UK**

Details are disclosed of an expandable seal assembly for a downhole tool, such as a downhole packer. An exemplary expandable seal assembly comprises an elastically deformable primary component made from a first material, and a seal component made from a second material, which has a modulus of elasticity that is less than that of the first material. The primary component is at least partially encased within the seal component. In use, the seal assembly is radially expandable between an unexpanded configuration, where the seal component is not in contact with a downhole surface, and an expanded configuration where it abuts the downhole surface. The seal assembly describes an inner diameter. And this inner diameter in the expanded configuration is greater than the inner diameter in the unexpanded configuration.

Patent number: WO/2014/108692
Inventors: M. Buyers, D.G. Martin and S.P. Anderson
Publication date: 17 July 2014

High-pressure sealing structure for slip control braking pump

Applicant: **Kelsey-Hayes Co, USA**

This invention relates to a hydraulic pump for a vehicle's braking system. In particular, it covers an improved seal configuration for such hydraulic pumps. The hydraulic braking pump includes a sleeve that has an inner bore defining an inner-bore surface, and a piston with a stop collar and ramped seal-face. The stop collar, ramped seal face and the inner bore cooperate to define a seal pocket in which is "trapped" a high-pressure seal. The ramped seal-face ensures that the contact of the high-pressure seal with the sleeve inner bore is proportional to the fluid pressure acting on the seal.

Patent number: WO/2014/113262
Inventor: J.A. Starr
Publication date: 24 July 2014

Coil springs with complex configurations

Applicant: **Bal Seal Engineering Inc, USA**

Coil springs are used in several applications, such as seal energisers, mechanical connectors and electrical contacts. Typically, their