

New Robust Sealing Technology

For subsea applications, all parts of a pump have to be designed for the highest process security, reliability, and robustness. The pump seals have to withstand high absolute pressures and high temperatures. A newly developed mechanical seal can perform reliably at up to 1 000 bar a (15 000 psia) and 180 °C (350 °F).



1 External pressurized seal with cooling jacket and DiamondFace® seal surface.

The exploration of subsea oil fields — those more than 3 000 m (9 842 feet) below sea level — provides the oil and gas industry with a host of challenges. The mechanical sealing of subsea boosting pumps is not exempt from these challenges. For a new generation of subsea pumps, Sulzer and EagleBurgmann co-developed a mechanical seal that withstands the high absolute pressure and high temperatures (HP/HT) of subsea oil discoveries.

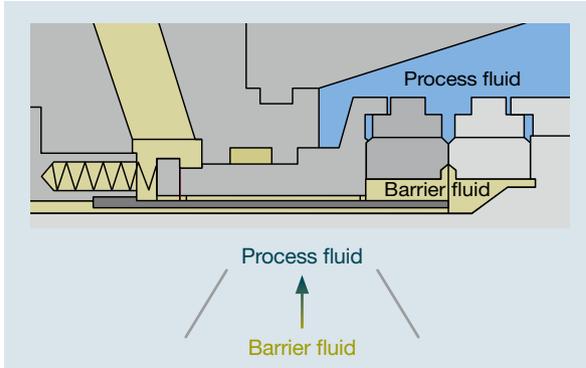
Sealing a hot process

The oil temperature of the subsea oil discoveries corresponds with the recovery depth and tectonic area of the oil field. It ranges from 70 °C to 180 °C (160 to 350 °F).

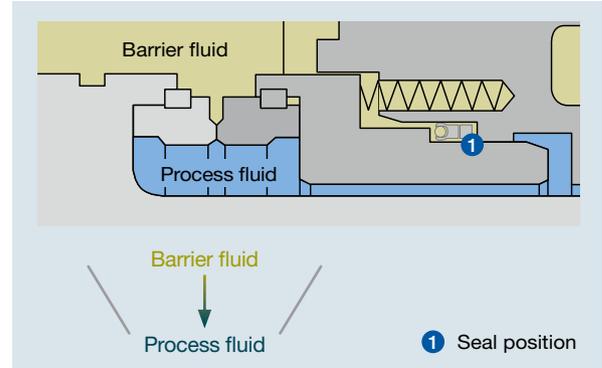
The high temperature of the pumped media raises the temperature in the seal and can cause the pump barrier fluid to degrade or can cause deflection of the seal faces. In a joint project, the engineers of EagleBurgmann and Sulzer optimized a seal for HP/HT applications (Fig. 1). Other industry sponsors backed the project as well. The goal was to develop an improved HP/HT solution and overcome the limitations of traditional mechanical seal design for subsea applications.

The following aspects were analyzed and enhanced:

- Pressurizing direction of the seal faces
- Secondary seal design
- Seal face material and mounting of the seal faces.



2 Internal pressurized seal.



3 External pressurized seal.

The new seal is a novel combination of an external pressurized seal, with a new secondary seal design, a cooling jacket, and a diamond coated seal face material. The new combination provides good results for high-pressure and high-temperature applications.

Pressurizing direction of the seal faces

Traditional subsea seals are internal pressurized seals. These seals offer excellent fluid film generation under moderate temperature applications. Any process-borne particulates are centrifugally flushed from the seal faces. In case the subsea oil discovery has a high temperature or high gas content, internal pressurized seals have limitations. With higher temperatures, a deflection of the seal faces occurs and the lubrication barrier fluid, which also cools the system, cannot enter the seal (Fig. 2).

For the new seal, the engineers of EagleBurgmann and Sulzer choose an external pressurized seal design. The V-form of the gap between the seal faces allows the barrier liquid to enter easily. Thus, the robust design resists seal-closing deflections (Fig. 3). Sulzer

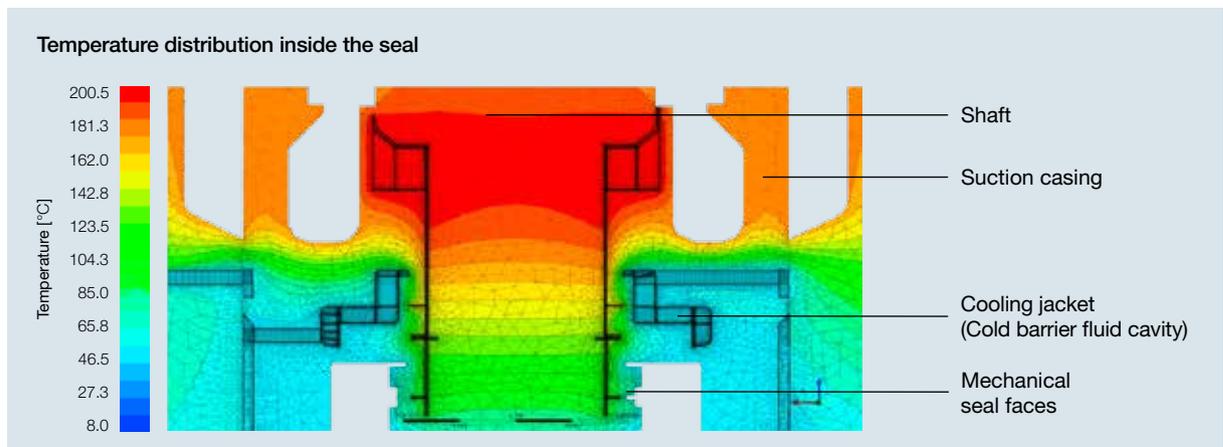
contributed to the design of a cooling jacket (patents pending). Placed around the seal, it prevents a temperature increase of the barrier fluid and reduces deflection of the seal faces.

The functioning principle of a cooling jacket is easy: near the seal faces, a cavity filled with barrier liquid enables the rapid heat transfer to the cooling system of the subsea pump. The temperature distribution graphic (Fig. 4) shows that the cooling is able to reduce the temperature at the seal faces.

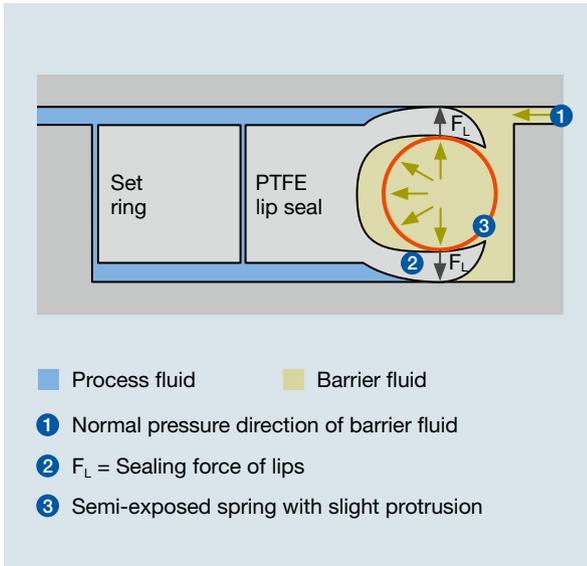
During the project, many CFD and FEA calculations were performed to predict the seal face lift-off deflection and the interaction with the surrounding structure under all operational conditions. Based on these calculations, the engineers tailored the design of the seal geometry accordingly.

Secondary seal design

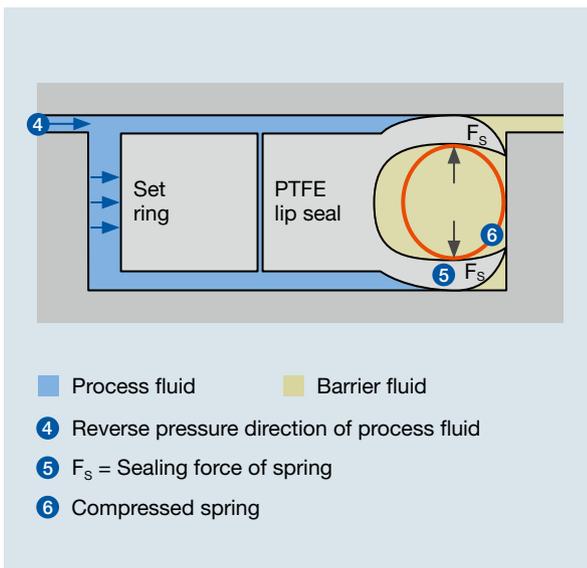
The function of the secondary seal is to allow relative axial movement between the stationary and rotating



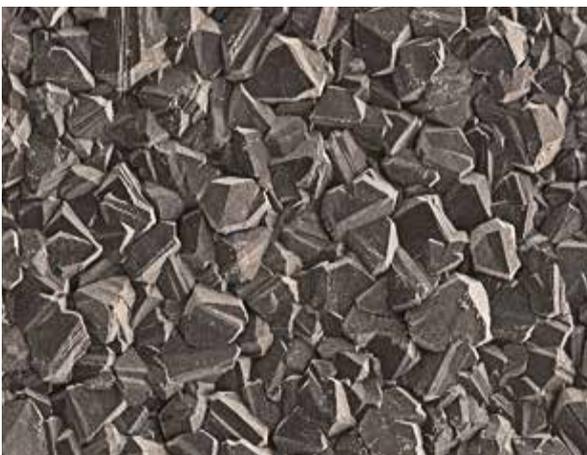
4 Temperature distribution with low temperature at the cooling jacket and seal faces.



5 Seal function with normal pressure direction.



6 Seal function with reverse pressure direction.



7 Seal surface with DiamondFace® for increased lifetime.

parts of the seal but still seal between the process and barrier fluid. The sealing not only has to work properly under normal pumping conditions but it also has to survive unusual reverse pressure situations. Elastomeric O-rings are excellent for sealing in both directions but have the tendency to shrink under high pressure and high temperature. For this HP/HT application, such O-rings are not a suitable solution for a secondary seal. The engineers developed a spring-energized non-elastomeric seal made from polytetrafluoroethylene (PTFE) material. The seal has a U-Cup form. Under standard operating conditions, the normal pressure of the barrier fluid generates enough force to open both lips of the secondary seal radially (Fig. 5).

But in a reverse pressure situation, the system pressure of the barrier fluid would not open the seal lips. The force of the spring in the middle would not be sufficient to provide sealing. The solution is a semi-exposed spring seal. During reverse pressure scenarios, the spring seal shuttles to the opposite side of the cavity. The semi-exposed spring is axially compressed against the cavity wall and more in an oval shape. This generates sufficient radial force to ensure the sealing. This seal design is also called a self-energizing seal (Fig. 6).

Seal face materials and mounting of the seal faces

Grown diamond is a significantly harder material than any carbide. Mechanical seals with DiamondFace® have an increased lifetime that has been proven in numerous applications. They can tolerate accidental dry running conditions and an increased number of solid particles.

Conventional, internal-pressurized seals have the carbide seal faces shrunk into a carrier bandage. After fitting the face into the bandage, the seal faces are ground to the final geometry needed. Because of their extreme hardness, DiamondFace cannot be polished afterwards. Therefore, a new assembly method had to be developed for HP/HT seals.

The solution was to use floating rings where the seal faces are not constrained but rather loose fitting. To ensure longevity with a loose fit, the engineers examined the hydraulic balance of the seal faces in detail. The optimized seal design with minimized contact forces ensures an extended lifetime. The structure of the grown DiamondFace is shown in Fig. 7.

Sealing solutions for deep-sea extraction

“Deep-sea conveying equipment on the seafloor extracts oil at depths down to 3 000 m. This oil is pumped directly onto ships or onto land via underwater pipelines. Sealing systems in multi-phase pumps must reliably handle high pressures, high temperatures, and fluctuating compositions of the pumped media. Because recovering and repairing underwater pump units is extremely expensive, the seals also have to ensure maximum failsafe protection and extended maintenance intervals. The cooperation of EagleBurgmann and Sulzer engineers was inspiring, and it resulted in a smart sealing solution for industrial use.”

**Bernhard Gilch, Senior Product Engineer,
EagleBurgmann, Germany**

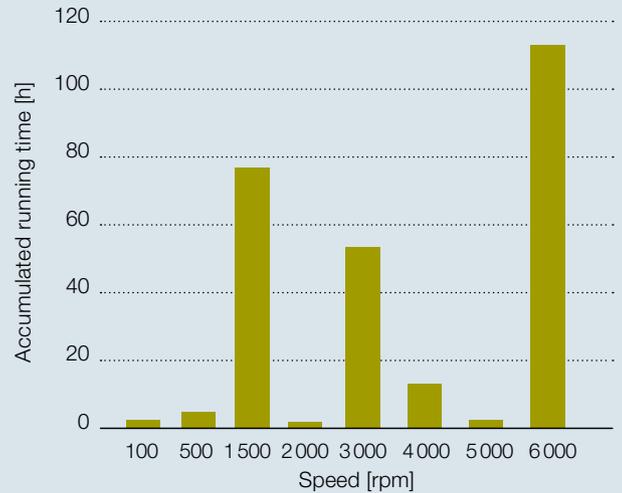
Qualified and tested

Following the analysis and concept studies, Sulzer and EagleBurgmann optimized and built the mechanical seal. It had to undergo an intensive bench test to be qualified for use in a subsea pump. The bench test was performed using both high-temperature liquid and gas on the process side of the seal at speeds up to 6 000 rpm and over 500 starts/stops (Figs. 8 and 9).

Dynamic seals are in use in all rotating equipment, such as pumps, agitators, and compressors. The HP/HT mechanical seal for 1 000 bara (15 000 psia) and 180 °C (350 °F) subsea boosting applications is available on the market now. The design and material of the new seal are optimized for these extreme conditions. The longevity of this seal can be of advantage for other pumping applications in the oil and gas industry as well.

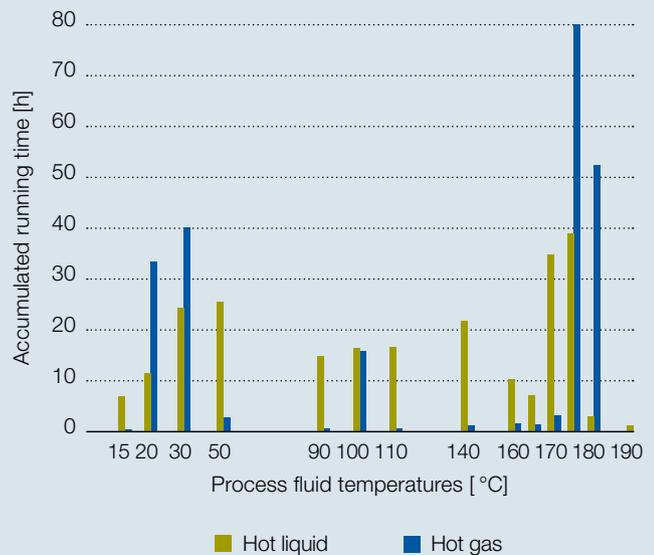
Author: Thomas Felix
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Seal bench test
 Total running time: 260 h



8 Running times during the bench test of the seal.

Seal bench test with hot fluids



9 Fluid temperatures during the bench test of the seal.