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Rely on excellence

PDGS for high temperature application

As prodigious consumers of electricity, steel mills have a strong incentive to recycle furnace gas in cogeneration plants to improve their overall energy efficiency and lower emissions. While industrial cogeneration is a mature concept, component suppliers like seal manufacturers are breaking new ground meeting the operational demands of very large power plants fueled by blast furnace gas.

EagleBurgmann designed and manufactured the world's largest dry gas seal (DGS) in an actual operating environment for the fuel gas compressors in a 240 MW combined cycle power plant that went online in December 2009 at the Wuhan Iron & Steel Group mill in China. It also was the world's first large DGS rated for temperatures up to 250 °C (482 °F).

Wuhan Iron & Steel Group is one of the world's largest steel producers and number three in China. The Wuhan plant uses non-cooled furnace gas from pig iron production to power two 120 MW gas turbines. Gas compression is required to raise the pressure of the furnace gas to the turbine combustion chamber pressure. Large cogen plants in steel mills typically employ very large horizontally split compressors to achieve high flow rates at relatively low delivery pressures, in this case 20 barg (290 PSIG). It wasn't cost-effective to pre-cool the furnace gas prior to compression or use more than two compressors per turbine. Each of the two compressor power trains was planned with a pair of centrifugal compressors with horizontally split casing, one with a 390 mm (15.35") shaft diameter, the other a 330 mm (12.99") diameter. The larger compressor would be the largest of its type ever built, requiring dry gas seals with the same 390 mm (15.35") shaft diameter designed for high temperature operations. Such a seal didn't exist yet.

Compressor train at Wuhan plant

EagleBurgmann experience with ultra-large dry gas seals

Dry gas seals are the most sophisticated type of sealing technology and play a major role in allowing compressor manufacturers to increase the capacity and efficiency of their products, especially in demanding operating conditions. With their ability to maintain a gap of only a few microns between the rotating seal and stationary seal face, they are most efficient at minimizing the leakage of compressed gas or entry of air into the compressor case at shaft ends. EagleBurgmann had collaborated with one of the world's largest compressor manufacturers in developing a 390 mm (15.35") DGS for LNG plants, a product certificated but not deployed operationally. That same manufacturer selected EagleBurgmann to supply the seals for the compressors at Wuhan, based on that LNG experience and the seal maker's highly sophisticated design tools.

Basic criteria and challenges

Developing a 390 mm (15.35") DGS for the high heat environment of Wuhan had unique design, manufacturing and testing challenges. The design had to accommodate all issues related to high heat operation, both from the process media and from high compressor speeds. Generally, dry gas seals are designed for top temperatures of -20 °C ... 160 °C (-4 °F ... 320 °F). Since fluctuating operating temperatures at Wuhan could be very high, a DGS was needed that would be rated up to 250 °C (482 °F), the estimated worst case scenario. Manufacturing DGS that large requires adherence to extremely strict geometrical tolerances to ensure stable gas film properties. And the high temperature seals would have to prove themselves in testing that would mimic the operational characteristics of a fuel gas compression chain in round-the-clock operations.

EN110701 / E1 / 1.000 / 09.11/ 9.7.5 / © EagleBurgmann Group Marketing, Germany
Article by Francesco Grillo, EagleBurgmann Italy and Daniel Goebel EagleBurgmann Germany.

EagleBurgmann Germany GmbH & Co KG
Aeussere Sauerlacher Strasse 6-10
D-82515 Wolfratshausen / Germany

Phone +49 8171 23 0
Fax +49 8171 23 1214

info@eagleburgmann.com
www.eagleburgmann.com

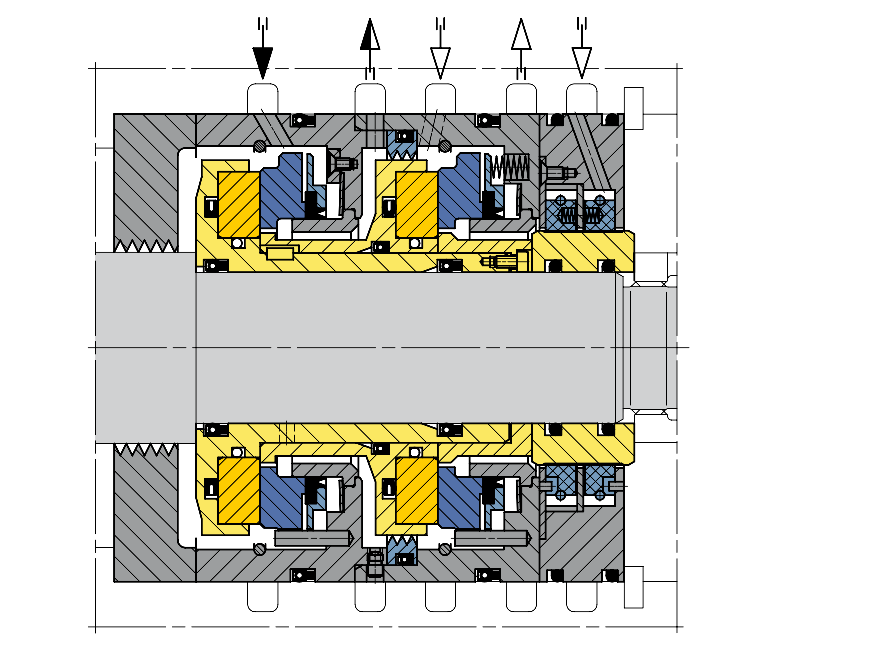
For the design, EagleBurgmann engineers had a template in the seal developed for LNG installations. The same tandem concept - two single seals with a labyrinth in between - was adopted for Wuhan. This provides an additional level of safety, as the secondary seal is capable of operating under the same conditions as the primary seal. During normal operation, the pressure is reduced through the process side seal to the primary vent pressure. The inert seal gas for the atmospheric side of the seal is typically Nitrogen. The slight pressure difference across the intermediate labyrinth ensures the process gas is guided safely only to the primary vent. Nitrogen leakage to the atmospheric side seal, together with the leakage of the oil barrier seal, is guided to a safe location via the secondary seal.

Wuhan had nearly the same compressor requirements, safety and emissions considerations as the LNG seal, except that the LNG seal was intended for extreme cold – as low as -170 °C (-274 °F). In a high heat operating environment, the most critical design consideration for a DGS is heat transfer. Materials were used that absorb created heat and conduct it away from the sealing gap to the housing and ring environment. Of potential materials for this application, sintered silicon carbide has by far the highest thermal conductivity coefficient and the highest capacity to remove the created heat from the sealing gap. Accordingly, the best materials combination for the facing materials was EagleBurgmann's standard SiC hard/hard combination with a DLC (Diamond like Carbon) coated sealing face.

It's essential the opposing seal faces always form a parallel gap, ensuring optimal stiffness of the gas film, minimizing the risk of contact while controlling leakage. In the case of changing temperatures, the shaft sleeve material will contract or expand more than the rotating seat, because of the thermal expansion coefficient of silicon carbide is about a third that of stainless steel. Due to the resulting relative movement on the contact surface of the rotating seat and sleeve a friction force is initiated that causes ring torsion and leads to gap distortion. Leakage increases immediately.

That's why proper tapering of the seal face is a critical part of designing a DGS for extreme temperature applications. Predicting seal face deformation is a fundamental requirement in achieving the seal face design with the proper taper. The unique EagleBurgmann solution is to size the seal face taper at room temperature for optimal geometry under ordinary operating conditions, while applying our validated calculation codes and extensive experience to get the optimum result for high heat, then submitting the design for further verification and fine-tuning through extensive testing.

PDGS10/390 after successfully passing tests at compressor manufacturer's facilities


PDGS Tandem seal with intermediate labyrinth

Heat transfer also affects secondary sealing elements. The EagleBurgmann design for extreme temperature applications achieves optimal gap behaviour between the dynamic, secondary sealing element and the balance sleeve by using a support ring fitted to the secondary seal to serve as a guide. The secondary seal is made of Polytetrafluoroethylene (PTFE), spring-energized and designed to withstand extreme temperature. The guiding device always keeps the secondary sealing element in the correct position. The guiding device, like the sleeve material, is made of tungsten carbide. Since they have the same expansion co-efficient, the gap is maintained within the tolerance range, despite temperature variations.

Testing and acceptance

Large seals are the most challenging to manufacture because the geometrical tolerances have to the same as they are for smaller seals. The Wuhan design passed all test procedures, including static and dynamic tests under full load, several start/stop cycles, slow roll operation and an extreme temperature test where the seal maintained stable leakage behavior from 20 °C (68 °F) to 250 °C (482 °F), in perfect condition. It passed test stand trials and full operating trials with flying colors. The first compressor train in the Wuhan plant was successfully started up in December 2009 and has received positive feedback from the customer, confirming the design's robustness even at extreme temperatures and its suitability for pairing with large capacity compressors in similar industrial CHP applications.