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Improve seal designs for 'dirty' services

Environmental rules require increased reliability for pumps in flue-gas applications

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The Cross-State Air Pollution Rule (CSAPR) is at the center of the regulatory debate in the US. The Environmental Protection Agency (EPA) rule replaces the 2005 Clean Air Interstate Rule (CAIR), tightening caps on sulfur oxides (SOx) and nitrogen oxides. Regardless of the Appeals Court stay in early January, equipment reliability is now more important with regard to efficient utilization of existing pollution control technologies.

In December 2011, the Department of Energy (DOR) outlined "near-term compliance pathways" highlighting the need for increased utilization and reliable performance of wet and dry flue-gas desulfurization (FGD) units.[1] Selecting reliable mechanical seals is of most critical importance and is the subject of this article.

Industry convention is of interest. The industry custom is to fit single-type, heavy-duty mechanical seals in FGD applications, thus sealing the lime slurry and preventing its exiting at the rotating shaft region of pumps and other fluid movers. Often, the seal is the first component to fail, and seal performance can be unpredictable.

How have FGD distinct operating parameters been addressed by industry standards? Standards are written collaboratively by industry experts to apply to a wide range of applications. The unique issues in FGD units encourage the plant reliability professional to produce an add-on company standard or purchaser's amendment to ensure predictable sealing performance.

Single vs. dual designs. The referenced single-type, heavy-duty mechanical seal design, as shown in Fig. 1, has a single set of precision-lapped silicon-carbide components (faces) to contain the lime slurry. Stability of the fluid film between the face set is essential for long-term performance. Failure margins narrow when operating conditions impact the stability of this fluid film.

Failure mechanisms. Operating practices necessary for optimum FGD efficiency may adversely affect seal performance. The utilization efficiency of the FGD unit is improved with fine pulverized limestone and forced oxidation. High-speed pumps are used to feed rotary atomizers, in the case of dry FGD. These variables impact the stability of the seal's fluid film. Adding proprietary sorbents with reagent enhancers or additives and the resulting unknown fluid properties make seal performance even more unpredictable.

As detailed by Mohamad Hassibi, Chemco Systems, LP, "For SO_2 capture with ground limestone in wet FGD, much of the coarser particles never react with the gases. Because of a short contact period, many of these particles are basically wasted. For limestone to react with SO_2 gas, there should be some dissolution of limestone so that it can ionize. Fine pulverization generally improves the rate of dissolution, thus increasing SO_2 capture efficiency."[2] This applies to dry FGD installations, as well. The greatly increased surface area in fine-micron particles means less absorbent is required. At one facility, particle distribution sampling determined that approximately 50% of the particles were 8 microns or less. The small particles enter into the micro-gap between the seal faces, thus leading to unpredictable seal performance.

Air injection is used to ensure a fully oxidized gypsum product. Oxidation may be through a sparging grid system or through air lances mounted near side-entering agitators. Air injection can be problematic for the seal face set. The cost of a maintenance event on large equipment can be as much as \$50,000 per occurrence. Managing these costs has led some

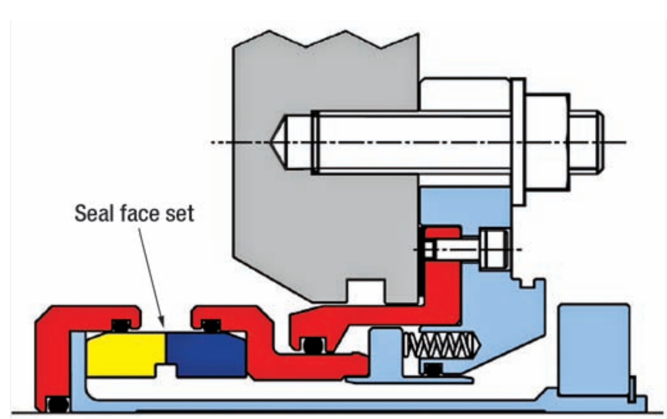

FIG. 1 Single-type, heavy-duty mechanical seal for limestone slurry service. Source: AESSEAL, Rockford Tennessee, and Rotherham, UK.

utilities to try horizontally split mechanical seals with a single set of faces. Retrofitted to existing large-bore bell housing designed seal chambers, it is believed that an external flush water injection [American Petroleum Institute (API) Piping Plan 32] will protect the seal faces. However, experience-based industry guidelines state that this strategy is impractical.

In dry FGD applications, higher-speed pumps generate pressure (head) for the rotary spray atomizers. In one example, a 6-in. suction/4-in. discharge pump were specified to operate at 1,800 rpm. The pump thrust loads are balanced by back vanes (pump-out vanes) in the pump impeller. The industry practice is to modify the back-vanes to accommodate operating limitations of single-slurry mechanical seals.

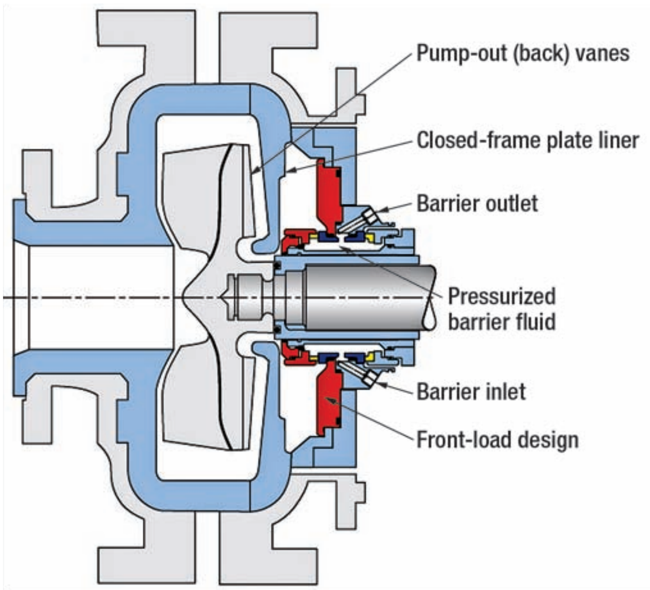

FIG. 2 A dual-mechanical seal. The space between the shaft sleeve and the bore diameters of both sets of seal faces is filled with a barrier fluid, usually water. Source: AESSEAL, Rockford, Tennessee, and Rotherham, UK.

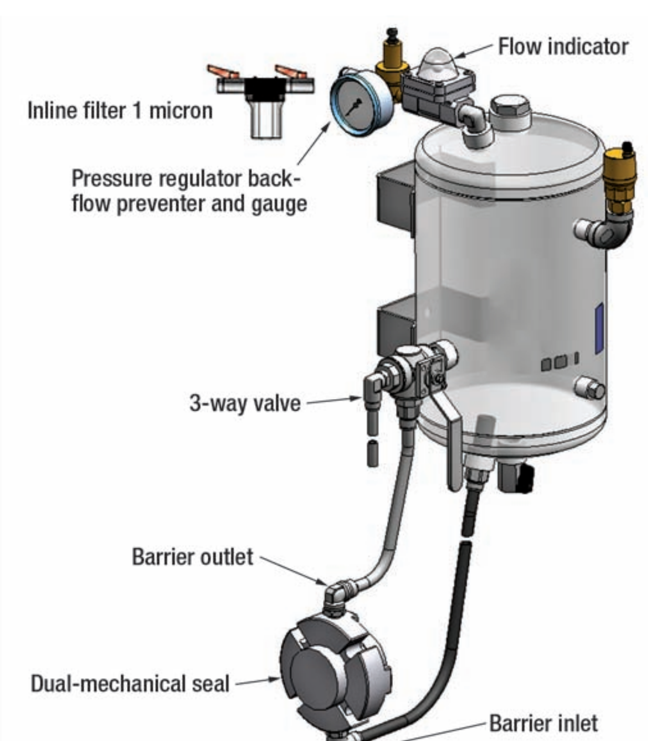

FIG. 3 Pre-engineered seal-contained water management system for dual seals in FGD slurry services. Source: AESSEAL, Rockford Tennessee, and Rotherham, UK.

Industry standards. The industry standard for rotodynamic equipment is the American National Standards Institute (ANSI) /Hydraulic Institute (HI) Rotodynamic (Centrifugal) Slurry Pump Standard ANSI/HI 12.1-12.6-2011.[3] This comprehensive document is recognized as the authoritative reference for slurry pumps. Written collaboratively by HI members who are experts in the industry, the standard covers a wide range of topics. Section 12.3.8 describes general arrangement details for mechanical shaft seals. With respect to this section, a number of cautionary statements highlight the difficulties associated with predictable seal performance.

Summarizing the cautionary statements in Section 12.3.8, industry practice is to use "… bell housings, large tapered bore seal chambers, or large tapered bore seal chambers with vortex breakers (to) improve seal life by preventing a buildup of the slurry around the sealing faces that can cause excessive erosion …" The standard goes on to state: "If air bubbles surround the seal faces, the seal can run dry, leading to seal face damage and potential seal failure … the slurry concentration and particle size limits (100 microns to 1,000 microns/0.004 in.–0.04 in. for d50 particle size at 50% concentration) when using an external injection are only limited by the ability of the injection system to exclude the slurry from the seal chamber. The associated product dilution needed to accomplish this task needs to be assessed … (with) large-diameter shafts; this is normally not practical as the required bushing radial clearances to account for shaft deflections will result in excessive flowrates or dilution into the product."

The standard continues and notes: "… dual pressurized seals have the advantage of providing enhanced lubrication to the faces with a pressurized barrier fluid. This arrangement prevents process fluid leakage to the atmosphere to improve safety … dual pressurized seals are used when the limits (of heavy-duty single mechanical seals) are exceeded, when there is a potential for entrained air in the slurry, or when large volumes of air can be introduced into the pump."

Dual-seal designs. Fig. 2 shows a dual pressurized seal design. With two sets of seal faces, the process lime slurry is contained by an inboard set of faces, and a secondary barrier fluid (water) is pressurized higher than the process. The barrier fluid is contained by an outboard set of seal faces. The higher pressurization means the secondary barrier forms the inboard seal-face fluid film. Constraints caused by small micron particles and air injection are mitigated because the seal face is operating in clean and stable water.

Delivery of the water-barrier fluid is important. Traditional piping configurations are API Plan 53-A and API Plan 54. Plan 53-A is limited by a fixed volume of barrier fluid; a fluid-containing vessel or "seal pot" is externally pressurized by air or nitrogen. During upset process conditions, the pressurized fluid crosses the inboard seal face, and the seal pot must be recharged during operation. This recharging process is not operator friendly; there is a high probability that the seal will run dry. Plan 54 is a centralized water-barrier distribution system, usually through multiple pumps. This means the circulating system must always be pressurized at 15 psig to 30 psig above any seal chamber pressures to avoid cross-contamination of the barrier fluid.

Hybrid programs. Leading user companies have success with the suggested hybrid solution, which combines Plan 53 and Plan 54 with water delivery to a water-management system designed to control pressure and cool the seal faces. This system, as shown in Fig. 3, uses a regulator and a back-flow preventer to set the correct water-barrier pressure for the seal faces. The water is recirculated, thus reducing actual water consumption to just a few gallons per year. An inline filter, connected to the continuous source water, filters the barrier fluid to 1 micron absolute. A three-way valve on the line returning from the seal to the reservoir enables the operator to inspect the barrier fluid's condition in the seal without compromising performance. In the event that particles cross the inboard seal face, then the three-way valve is activated to flush the seal. An internal standpipe on the supply line to the seal protects the seal from contaminants. By connecting a valve and drain line to the bottom of the tank, an operator can purge contaminants from the reservoir while the connected water source automatically replenishes the system with clean water.

If process air bubbles accumulate at the seal face, the secondary liquid provides sufficient cooling to ensure consistent seal performance. Independent control of the seal environment broadens the success margin for the seal. An add-on company standard or purchaser's amendment couples specific operating conditions with available industry standards and provides for the optimum utilization of the FGD unit.

Bridging the gap. Plant reliability professionals will consider bridging the distinct operating parameters of FGD processes with existing industry standards for slurry sealing. Their add-on wording will incorporate the options outlined here. These options will constitute an important amendment to present equipment standards:

- The mechanical seal must be a heavy-duty, dual-cartridge mechanical seal suitable for slurry duty and designed to operate at a higher pressure than the process pressure at all times.
- Seal-internal cross-sections must have large radial clearances, and the inboard face set must be hydraulically balanced to the barrier fluid.
- Tungsten-carbide (TC) and/or silicon-carbide (SiC) faces paired with solid TC must be used when the pH is greater than 5; solid SiC must be used when the pH is 5 or less. Pin drives must be designed to minimize face fracturing.
- Large pump sizes must be configured to accept a front-load seal design that can be installed from the wet end of the pump to minimize overhaul costs.
- Wetted alloys must be abrasion resistance.
- Mechanical seals must perform equally with or without impeller back-vanes, and the user requests that back-vanes be incorporated in the equipment impellers.
- The seal chamber must be an open-frame plate liner with vortex breakers or a closed-frame plate liner designed to prevent excessive erosion.
- A mechanical seal support system must be provided as a pre-engineered turnkey system; it must include all instrumentation and fittings necessary to install at the site.
- The tank capacity must be a minimum of 25 l (6.6 gal) and self-filling. Inboard seal face integrity must be visually confirmable at the support system with a flow indicator.
- The system must deliver barrier fluid at pressure differentials 15 psig (minimum) above the process pressure in the pump stuffing box at all times.
- The seal system must include inline filtration of plant seal water to 1 micron. An internal standpipe on the supply leg, a three-way valve on the return leg, and a blow-off valve at the bottom of the tank must be included to allow clearing contamination from the system after the initial installation and during the service life of the application.
- As part of the initial supply package, documentation must include a heat-generation report for each installation. The report must refer to the operating conditions for the intended shaft diameter, speed, process/barrier pressure, temperature and induced flow. The data must provide the input for thermal equilibrium estimation and result in a calculation of the heat generated by the specific seal supplied in each case.

Better performance insurance. As regulatory legislation issues persist, a compliance strategy will drive solutions to optimize reliability of rotating equipment. This will lead to technology and revisions of current standards that meet increased demand for viable solutions. While in no way pre-empting the existing standard documents, this article gives experience-based guidance to FGD plants. The authors encourage reliability professionals to structure add-ons or amendments based on the feedback and recommendations contained in this article. **HP**

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