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Air preheater leaks: Mind the gap

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It is well known that air preheater leakage is a major factor in the loss of boiler efficiency, but it is routinely viewed as a low-priority issue. ***Pavan Kumar Ravulaparthy*** *argues that there needs to be a change in attitude and explains the benefits of employing adaptive brush seals.*

The design of radial, axial and circumferential seals installed on rotary, regenerative air preheaters (APHs) have not evolved significantly from the original metal strip arrangements that date back to the inception of the Ljungström preheaters nearly a century ago. However, these metallic strip seals tend to start to degrade immediately following installation, allowing excessive air-to-gas leakage, which translates to increased fuel consumption and fan power draw over the life of the seals.

The well-known heat transfer, temperature and efficiency-related benefits for rotary APHs make them a key component of any power plant. As a critical contributor to overall plant efficiency, APHs deliver upwards of 12 per cent of the heat transfer in the boiler process at only 2 per cent of the investment. For every 20°C decrease in the gas outlet temperature of the air heater, boiler efficiency rises about 1 per cent, with inherent fuel consumption reductions. APHs operating at optimal conditions also help reduce fan power consumption and control flue gas volume, temperature and velocity.

That said, air-to-gas and gas-to-air leakage paths through the APH seals, as shown in Figure 1, have several consequences. Leak rates with properly designed and installed seals should be well below 10 per cent, but rates of 15-20 per cent are typical and rates of >30 per cent are not uncommon.

Furthermore, leak rate increases can be gradual and often go unnoticed. Leakage negatively impacts heat rates, parasitic power losses with increased fan power consumption, and downstream air pollution control (APC) equipment because of higher gas flow rates and pressure drops.

Flue gas velocity through a typical selective catalytic reduction is approximately 5-6 m/s, but higher velocities because of air-to-gas leakage will decrease residence time and therefore affect ammonia injection rates and slip. In flue gas desulphurization systems, lower residence time can affect lime or limestone injection rates and thus SO2 removal efficiency. Finally for particulate matter control systems, higher air-to-cloth face velocities in fabric filters can lead to decreased bag life. Pulverizer capacity can also be negatively impacted with lower air volumes and temperatures due to air-to-gas leakage.

The optimisation of APH performance, often not considered a priority, is truly a low-cost, easily implemented solution to decrease the consequences of leakage. A key component of APH optimisation is the upgrade of its radial, axial and circumferential seals.

Conventional rigid metal strip seals, in common use since the introduction of the Ljungström rotary APHs in the 1920s, are vulnerable in the surrounding harsh environment. Repeated thermal expansions and contractions in the large rotors (up to 18 metres in diameter) in constant motion lead to continual changes in gap sizes. At operating temperatures, the outer edges of large APHs can droop or turn down by 7.5 cm or more compared to under cold conditions. However, because they are unable to yield to the warpage of sector plates, the conventional metal strip seals are prone to stress and breakage.

An interesting alternative are brush seal products, which are witnessing increased adoption as radial, axial, circumferential/ bypass and rotor seals on Ljungström rotary regenerative APHs on fossil fuel-fired boilers. Brush seals are in fact ideally suited for replacing strip steels on rotary, regenerative APHs. As radial, axial, and circumferential seals, they provide a high degree of abrasion resistance, adaptability to operating conditions and bend recovery not possible with rigid strip seals. Rigid strip seals rapidly wear down to the smallest gap size allowing leakage to occur at wider gaps. The strip seals are also vulnerable to damage at high differential pressures and expansion because of temperature increases where induced drag can shut down the rotor.

A brush seal, in contrast, produces an extremely dense barrier as thousands of filaments nestle tightly together to create a high-integrity seal. Each bristle is independent and flexible allowing deflection to conform to any irregularities and gap variations, and recovery to its original position. Several distinct features are incorporated into the brush seal design.

A malleable alloy foil membrane is nestled within the brush filaments to enhance sealing by up to 80 per cent. This resilient barrier to- leakage feature provides 2-5 times greater functional sealing life (Figure 2).

Soot blowing can splay the sealing surfaces due to steam blasts of 205°C. To prevent this direct impingement, an angled holder with an extended protective flange has been incorporated as a soot blower shield. The resilience to soot blower impacts is achieved by minimising dwell time in the soot blower steam path. This design further improves bend recovery and seal contact.

A further design enhancement, shown in Figure 3, is a two-component Quick-Lock system allowing for the removal of just the brush component during an outage. The holder component is re-used as on the initial install it remains locked down to the appropriate gap. During outages, the timeconsuming process of seal realignment is eliminated as the brush itself can be removed and replaced quickly. Avoiding gap setting and bolting of holders at each replacement contributes to low life-cycle cost as seal replacement time can be reduced by 50-60 per cent.

Quantifiable benefits

Since APH leakage has historically been a low priority maintenance outage issue with many fossil fuel power plant engineers, plants often experience leakage rates in excess of 15-20 per cent, with extreme leakage rates up to 40 per cent measured. These levels are often tolerated because they are often underestimated or completely overlooked.

As a result, plants can experience capacity losses, increased heat rates, higher parasitic losses associated with fan horsepower, and higher pressure losses for downstream APC systems. A plant that has experienced ‘running out of fan’ can conclude with a high degree of certainty that they have excess preheater leakage and are suffering from costly side effects.

To give an example, a 500 MW coal-fired plant operating at an 85 per cent annual capacity factor would consume 5000 tonnes of coal per day, assuming an average heat rate of 10,550 kJ/kWh and an average coal heating value of 5500 kcal/kg. If increases in boiler efficiency due to improved APH sealing reduce fuel consumption by 1 per cent, the annual savings in fuel cost amounts to nearly $1.5 million, assuming a delivered coal cost of $80/tonne.

APH leakage can also account for significant increases in parasitic power draw from the boiler fans and this translates into revenue losses from unsalable power. If a 500 MW coal-fired plant has 8595 kW of installed fan power with two primary, two secondary and two ID fans (excluding an AQCS system), and two APHs originally designed with 10 per cent air heater leakage (AHL), an additional 10 per cent increase in AHL would cost a 13 per cent increase in fan power consumption.

In other words, for every 1 per cent increase in AHL the plant essentially sacrifices116 kW, which is unavailable for sale, or 1.16 MW for every 10 per cent increase in AHL. If the sale value of a MWh is $30 off-peak and $150 peak, the plant operating on an 85 per cent capacity factor running six hours a day peak and 18 hours a day off-peak would stand to lose a sizeable $520,000 per year.

Views from the field

In June 2007, Sealeze, a subsidiary of Jason Incorparated, was authorised to manufacture and supply a simple yet innovative axial and radial brush seal design for both the hot and cold ends of the Unit 1 Ljungström APH at Bicent Power’s 119 MW Hardin power plant in Montana, in the US.

The radial and axial stainless steel brush seals were inspected the following year and were found to be in very good condition. Some splaying of the brush was evident on the cold end due to soot blower blasts of 205°C steam. To prevent direct soot blower impingement, the brush seals mounted in the path of soot blower blasts were redesigned to incorporate an angled orientation and an integral protective shield.

Now, with over five years in service, the high-performance brush seals continue to outperform the original strip steel seals. Further. the brush seals are expected to continue performing through a predicted design life of at least four outage cycles.

According to Kevin Calloway, a plant engineer at Colorado Energy, which operates Hardin on behalf of Bicent Power: “The brush seals have reduced air leakage considerably, and as a result we have reduced operational costs through fuel savings.” Further, the plant has been able to postpone two scheduled APH outages.

In another example, radial and circumferential brush seals were installed on two 8-metre diameter horizontal APH (APH-A/B) at a 300 MW power station in the US in

2010. The plant reports leakage rates well below 10 per cent, with tests showing leakage rates of 5 per cent and 7 per cent on APH-A and APH-B, respectively.

Also in 2010, radial and axial brush seals were installed on a 10-metre diameter vertical Ljungström APH at a 750 MW plant in US. Both the radial and axial brush seals remained intact over 2.3 million impacts to the sector plates following 490 days in service. The brush profiles are essentially the same as the installed condition.

Seal integrity remains intact as the seal conforms to gap size variations and surface irregularities. Shown here are radial seals after 135 days in service and 642,000 contacts.

The effect of boiler side parameters of any coal-fired power plant is linked to a host of factors including excess air, unburned carbon and coal moisture. However, two parameters that have a major impact on plant performance is flue gas temperature and boiler efficiency. In a 500 MW coalfired power plant, the effect of heat rate per °C deviation can be 1.2 kcal/kWh and 25 kcal/kWh per 1 per cent deviation of boiler efficiency. Nevertheless, these two parameters are closely related to air heater performance.

The major air heater performance indicators are air-in leakage, flue gas temperature drop, air-side temperature rise and air/gas side pressure drop. The leakage of the high-pressure air to the low-pressure flue gas because of the differential pressure, termed as AHL, is the major contributor for reduction in boiler efficiency. Increased AHL reduces air heater efficiency, increases fan power and produces higher gas velocities and a loss of fan margins. AHL is associated with poor air heater seal performance, such as increased seal clearances in hot condition, seal erosion, inappropriate seal material and improper seal settings.

An adaptive brush type air heater seal is a demonstrated technology that provides an extended functional service life with measurable improvement in performance and an increased control for plant operators with low total cost. The calculated payback on efficiency improvements alone has been demonstrated to provide ROI valued at many times the cost of the adaptive brush seal and installation. Added to this, savings related to pollution control systems performance is a nice multiplier. AHL reduction, therefore, is a low-risk, low-cost, high-return-value modification to rotary air heater systems, so effective sealing through innovative approaches such as brush seals is highly recommended to improve O&M practices.

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