Increasing Power Plant efficiency for safe “wet stack” Operation

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Introduction

Elektrárny Opatovice a.s. is one of the leading suppliers of Electricity and Heat in the Czech Republic and the owner of the 698 MW lignite firing Opatovice Power Station (Figure 1). The power plant was built between 1959 – 1960 and is located 100 km eastwards of Prague. The Czech Republic has a large number of coal and lignite fired power stations that have been retrofitted with flue gas desulphurization (FGD) plants in the early 1990’s. Opatovice Power Plant has FGD systems since 1998. Many FGD plants of this generation are now reaching a point where they need to be modernized. Many stations have the option of not renewing their reheating system and switching to “wet stack” operation.

Elektrárny Opatovice a.s. decided to refurbish its Opatovice power plant with two new wet limestone FGD systems (Figure 2), to eliminate its reheating system and to operate wet stack. It was also decided that the existing concrete chimney with sectional brick flue would be re-used.

Omega Teplotechna a.s. Praha was the contractor for the Opatovice wet stack modification project. Hadek Protective Systems supplied the PennguardTM lining materials and the Quality Supervision for all PennguardTM lining activities. Alden Research Laboratory performed a detailed flow model study with recommendations for Opatovice Power Station to achieve environmentally acceptable wet stack operation.

Figure 1: 698 MW lignite firing Opatovice Power Station

Figure 2: New wet limestone FGD’s left and right from the chimney

Figure 3: Outside surface brick flue attacked by acidic condensate
Risks of wet stack operation

The first risk of operating wet stack is using the existing chimney. Elektrárny Opatovice a.s. decided to re-use its 142 m high chimney with 7.9 m diameter sectional brick flue for wet stack operation. By eliminating the reheat system, the plant operates with 100% treated, wet flue gas of 60 ºC, which means low temperature, acid condensing operation. Brick flues are permeable for acidic flue gas condensate. Figure 3 is an example picture showing the outside surface of a brick flue attacked by acidic condensate, caused by wet stack operation. If the brick flue would be left unprotected, the structural integrity of the whole chimney would be at risk in the end.

The customer decided to use the PennguardTM Block Lining System (Figure 4) to seal the brick chimney flue from the acidic condensate. The PennguardTM Block Lining System has been proven durable and reliable for ‘wet stack’ operating conditions for over 30 years. The system is completely resistant to sulfuric acid, impermeable to acidic flue gas and condensate, strongly insulating and lightweight. A PennguardTM lining is tolerant for imperfect substrates. Brick chimney flues have many imperfections, such as the many joints which may vary in width and depth.

The installation process of the PennguardTM Block Lining System can be summarized as follows (Figures 5 - 7):

Step 1: Gritblasting of the brick flue to remove all dirt, deposits and other loose particles;

Step 2: Application of the PenntrowelTM Epoxy Primer;

Step 3: Application of the PennguardTM Blocks onto the brick surface with the PennguardTM Adhesive Membrane by semi-skilled brick layers and under supervision of Hadek’s QA Inspectors.
The second risk of wet stack operation is the risk of entrainment of acidic condensate droplets into the gas flow (which is called spitting) and the deposition of acidic droplets near the chimney. This is caused by a two-phase flow interaction of gas and liquid. There are three main sources of liquid in a wet stack, Figure 8. The first is droplet carryover from the absorbers mist eliminators and from re-entrainment of droplets off the absorber outlet duct walls. The second source is thermal condensation within the stack liner and the third is adiabatic condensation of liquid out of the saturated gas flow due to pressure drop within the liner. All of these contribute to the formation the liquid film on the liner wall which naturally wants to flow downward due to gravity.

The main factor contributing to droplet re-entrainment from this liquid film is the velocity of the flue gas flow within the liner which imposes a vertical shear force on the downward flowing liquid film. As the flue gas velocity increases, the magnitude of the vertical shear force increases slowing the downward flow of the liquid film. At a critical velocity, the gravitational and gas shear forces are balanced and the liquid film stops flowing downward. As more liquid condenses on the liner wall, the resulting liquid film gets thicker and thicker until the surface of the film becomes unstable and droplets are re-entrained back into the gas flow. The critical velocity at which this occurs is dependent of the type of liner material used and is a function of the surface smoothness and construction methodology used to construct the liner.

Figure 9 presents the liner flue gas velocities recommended in the EPRI/CICIND Revised Wet Stack Design Guide. As can be seen in this Figure, Borosilicate Block commercially known as the PennguardTM Block Lining System has the highest recommended favorable design flue gas velocity. This is due to two important properties of the material. First PennguardTM is made from closed cell foamed borosilicate glass which results in a significantly higher surface area inside the liner to which the down flowing liquid film can adhere. It is estimated that the actual surface area of the PennguardTM material is greater than twice the surface of a smooth surface as would be the case for an alloy or FRP liner. Second, PennguardTM is inherently an excellent insulator which prevents heat loss thus reducing condensation on the inner surface of the liner.
significantly reduces the amount of thermal condensation experienced within the liner. A general rule of thumb for the impact of insulating a liner is that for every 51 mm of insulation, the quantity of thermal condensation is reduced by a factor of four. Because of this, the rate of liquid formation on the liner surface is significantly lower as compared to an uninsulated alloy or FRP liner.

The insulation properties of Pennguard™ are particularly noticeable during start up where the quantity of thermal condensation is significantly reduced because the hot flue gases do not come in contact with a cold liner. This effect can be clearly seen in Figure 10 which presents the result of a study evaluating the total amount of direct film condensation vs. time in cold liners of various materials during plant start-up.

Alden Research Laboratory was contracted by Hadek to perform a wet stack flow model study of the Opatovice power station with the objective of developing an effective liquid collection system for the prevention of stack liquid discharge (SLD). A physical flow model was built of the unit from the mist eliminator outlets of the plants two new WFGD absorbers.
through the absorber outlet ducting to a point in the stack liner approximately four liner diameters above the roof of the breach openings, Figure 11. The model was built to a scale of approximately 1:16 and was constructed primarily of Plexiglas to allow for flow observations. The liner itself was fabricated from a specially prepared fiber board to ensure that the surface in the liner model had the same wetting properties at the actual liner material. This is very important to ensure that the liquid film flow patterns are accurately modeled.

To evaluate the performance of a wet stack system, the model must be run at two different flow rates to evaluate two different sets of physics. The first condition is designed to evaluate droplet trajectories within the system, the second is to evaluate the motion of the collected liquid films on the duct and liner surfaces. Using this information, liquid collectors and drains are designed and optimized both within the absorber outlet ducting and within the stack liner. These collectors and drains are designed to remove collected liquid as quickly as possible while minimizing the potential for droplet re-entrainment back into the gas flow. Typical liquid collection system components are shown in Figure 12. As can be seen in this Figure, gutters are located on the duct walls, to direct collect liquid to the floor then into strategically placed drains.

Within the liner, gutters are located around the breach opening and a ring collector is placed in the liner to collect all the liquid flowing downward from the upper portions of the stack. The liquid collection system designed for the Opatovice power station is expected to operate very well given the long duct runs between the absorbers and the liner which are good for wet operation. The liner is also operating at a very favorable liner velocity of 14.6 m/s which is significantly below the recommended maximum liner velocity of 18.3 m/s recommended for the PennguardTM Block Lining System.

**Conclusions**

- Coal fired power plants operate more efficiently without flue gas reheat;
- PennguardTM linings can be used to make existing chimneys suitable for non-reheated wet stack operation;
- Wet stack flow model studies are a necessary tool to make “wet stacks” operate without discharge of acidic droplets.