SO_3 Control and Wet ESP Technology

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Summary

New EPA $PM_{2.5}$ for existing sources and New Source Performance Standards for new coal fired plants will require control of both filterable and condensable particulate. Additionally, the Regional Haze Rule will likely require control of fine particulate and condensables to improve visibility in areas with National Parks. Finally, where Selective Catalytic Reduction technology has been installed for NOx control, increased oxidation of SO_2 to SO_3 has increased visible plume and created neighborhood and operational issues.

While utilities have installed dry ESPs and baghouses to collect course particulate and FGD systems to scrub SO_2 acid gas from the flue gas, none of these APC devices can effectively control SO_3. SO_3 exists as a vapor at temperatures above 300°F where a dry ESP or baghouse is typically located and passes right through these devices. With no FGD installed, upon exiting the stack the SO_3 mixes with ambient air, cools and condenses into H_2SO_4, typically seen as a trailing blue plume. If a wet FGD system is installed, the SO_3 condenses within the absorber vessel. However, because sulfuric acid mist is uniformly 0.1-0.5 microns in size the FGD scrubber cannot effectively collect these size particles and the majority exits the FGD. Wet Electrostatic Precipitator Technology offers the ability to control both solid and condensable particulate, including sulfuric acid mist to meet these new standards and reduce visible plume. In fact, several new coal-fired power plants are requiring a Wet ESP in the air pollution control system as the final polishing device after the FGD system.

The first ESP developed was actually a wet ESP to remove a sulfuric acid mist plume from a copper smelter designed by Dr. Cottrell in 1908. The technology has since become a standard piece of process equipment for the sulfuric acid industry for over 50 years to abate SO_3 mist, a sub-micron aerosol. In the past twenty years, wet ESP technology has been employed in numerous industrial applications for plume reduction associated with PM2.5 and SO_3 mist, as well as for removal of toxic metals. While there are hundreds of installations worldwide in industrial facilities and close to thirty installed in Japanese utilities, wet electrostatic precipitation is a relatively unknown technology to most U.S. utilities because air regulations up to recently have not required high levels of control of sub-micron particulate or condensibles. However, as regulations emerge requiring stringent control of sub-micron particulate—which includes acid mists, metals, and mercury—wet ESP technology is increasingly attractive due to its low pressure drop, low maintenance requirements, high removal performance and reliability as a final polishing device.

Electrostatic precipitation consists of three steps: (1) charging the particles to be collected via a high-voltage electric discharge, (2) collecting the particles on the surface of an oppositely charged collection electrode surface, and (3) cleaning the surface of the collecting electrode. As particles become smaller, gravitational and centrifugal forces become less powerful, while electrical and, to a lesser degree, Brownian forces become greater, especially for 0.1 to 0.5-micron particles. Consequently, electrical collection is an effective method for separating sub-micron particles and mists from a gas stream.

Wet ESPs operate in the same three-step process as dry ESPs—charging, collecting and finally cleaning of the particles. However, cleaning of the collecting electrode is performed by washing the collection surface with liquid, rather than mechanically rapping the collection plates. While the cleaning mechanism would not be thought to have any impact upon performance, it significantly affects the nature of the particles that can be captured, the performance efficiencies that can be achieved, the design parameters and operating maintenance of the equipment. Simply stated, wet ESP technology is significantly different than dry ESP technology.

Because wet ESPs operate in a wet environment in order to wash the collection surface, they can handle a wider variety of pollutants and gas conditions than dry ESPs. Wet ESPs find their greatest use in applications where gas streams fall into one or more of the following categories:

- The gas in question has a high moisture content;
- The gas stream includes sticky particulate;
- The collection of sub-micron particulate is required;
- The gas stream has acid droplets or H_2SO_4
- The temperature of the gas stream is below the dew point.

Because true wet ESPs continually wet the collection surface area and create a slurry that flows down the collecting wall to a recycle tank, the collecting walls never build up a layer of particulate cake. Consequently, there is no deterioration of the electrical field due to resistivity, and power levels within a wet ESP can be dramatically higher than in a dry ESP. The ability to inject much greater electrical power within the wet ESP and elimination of secondary re-entrainment are the main reasons a wet ESP can collect sub-micron particulate more efficiently than a dry ESP. Wet operation also prevents re-entrainment. The captured particulate flows down the collection wall in suspension to a recycle tank for treatment and never gets re-entrained into the flue gas.

At Northern State Power's Shirco Station, which has two 750 MW boilers, eleven modules of wet ESPs were installed after each FGD absorber vessel. Opacity was reduced from over 40% to less than 10% with all twenty-two Wet ESP modules in service

At First Energy's Penn Power's Bruce Mansfield Plant (BMP), located in Shippingport, PA., a pilot WESP was installed using a slipstream of flue gas from the exhaust of the FGD system on boiler unit No. 2, which has a rated capacity of 835MW and burns 3% sulfur coal. The plant installed the pilot WESP to test for PM2.5 and SO_3 mist removal as a potential control technology to reduce visible emissions.

The November 2001 test showed removal efficiency of 96% for PM2.5 and 92% for SO_3. The November 2002 SO_3 test was consistent with the previous year with 89% removal reported. The July 2003 testing showed 93% removal of PM2.5 and 88% on SO_3. Differences in reported results are attributable to test method inaccuracies, test personnel experience and instrument calibration.

The important points are:

- The WESP achieved relative high removal efficiency on both solid particulate and SO_3
- The results by two different testing parties were consistent with one another
- Results from three different time periods were consistent with one another.
- Removal efficiency for PM2.5 was always slightly higher than for SO_3 mist, likely due to particle size distribution.

Wet ESP technology is a proven, well-known technology that can achieve greater than 90% removal of sub-micron SO_3 acid mist, solid particles and aerosols with low pressure drop and minimum maintenance. Opacity, a function of $PM_{2.5}$ and SO_3 concentration, can be reduced to less than 10%. Additionally, pilot testing has shown particulate and oxidized mercury were collected with > 80% efficiency while elemental mercury can be partially oxidized. As a final polishing device in an air pollution control system, a WESP offers excellent multi-pollutant control capability that can meet new EPA regulations for solid particulate and condensables.