

**APPLICATION OF WET ELECTROSTATIC PRECIPITATION TECHNOLOGY IN THE
UTILITY
INDUSTRY FOR MULTIPLE POLLUTANT CONTROL INCLUDING MERCURY**

Presented By: Wayne Buckley

Authors:

Ralph Altman, EPRI

&

Wayne Buckley

Dr. Isaac Ray

Croll-Reynolds Clean Air Technologies

Abstract

Wet electrostatic precipitation technology can be used to control acid mists, sub-micron particulate, mercury, metals and dioxins/furans as the final polishing device within an multi-pollutant air pollution control system. Test results from coal –fired installations demonstrate >90% removal efficiencies on PM_{2.5}, SO₃, and near zero opacity. Additionally, wet ESP technology can be used for mercury removal. How wet ESPs work, what configurations they come in and some of the design considerations are described. New developments to wet ESP technology to reduce cost, (membrane WESP), make higher performing in less space (single pass dual field) and enhance mercury control (plasma-enhanced ESP) will also be discussed.

Introduction

Power utilities are coming under increased scrutiny from regulators, the public and environmental groups. The ready availability of information about power plant emissions, along with recognition of the effects of acid gases, fine particulate and toxic chemicals on the environment and human respiratory systems, are forcing utilities to control their emissions to a much greater degree than ever before. The U.S. Environmental Protection Agency (EPA) has issued regulations to control PM₁₀, NO_x and SO₂. New regulations to control mercury, PM_{2.5} and other hazardous air pollutants are being proposed. The trend is clear: EPA is seeking to control a multitude of pollutants that are comprised of smaller and harder-to-capture sub-micron particles, mists and metals.

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 1907. The technology has become a standard piece of process equipment for the sulfuric acid industry for over 50 years to abate SO₃ 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 PM_{2.5} and SO₃ mist, as well as for removal of toxic metals. Unfortunately, wet electrostatic precipitation is a relatively unknown technology to most industries and utilities because air regulations up to recently have not required high levels of control of sub-micron particulate.

Most utility facilities already have some sort of dry technology installed to control particulate emissions, such as a cyclone, fabric filter or dry ESP. Where acid gases or condensable particulate may be present

in a gas stream, a scrubber or gas absorber is typically in place. However, as regulations emerge requiring stringent control of sub-micron particulate—which includes acid mists, low and semi-volatile metals, mercury, and dioxins/furans—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.

ESP Operation

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 those sub-micron particles from the gas stream.

TABLE 3
PARTICLE DISPLACEMENTS IN STANDARD AIR DUE TO VARIOUS FORCE FIELDS
PARTICLE DIAMETER *Displacements in 1 sec. for force field listed*

Size in Microns	Feet	Cc*	Grav.**	Cent***	Elect.****	Brown.** ***
10.0	3.28 x 10 (-5)	01.016	.024	20.5	0.98	.0000057
1.0	3.28 x 10 (-6)	01.165	.00027	00.235	0.11	.0000194
0.1	3.28 x 10 (-7)	02.93	.0000069	00.0059	0.27	.0000972
0.01	3.28 x 10 (-8)	22.6	.00000053	00.00046	2.12	.0008540

- * Stokes Cunningham slip-correction factor-dimensionless
- ** Gravitational force field-downward linear displacements based on 32.2 ft./s² acceleration
- *** Centrifugal force field-outward radial displacements based on 862 g's acceleration
- **** Electrostatic force field-normal linear displacements based on 7500 volts/in. Field strength and a saturation charge on the particles.
- ***** Brownian movement-random linear displacements based on average values

Most importantly, whereas mechanical collectors exert their force upon the entire gas, ESPs exert their force only upon the particles to be collected. ESPs typically operate at around 0.5-1.0 inch pressure drop, regardless of air volume or particle size. Alternatively, a mechanical collector such as a venturi scrubber would have to operate at around 60 inches of water column to achieve 95 percent collection efficiency on 0.5-micron particles. This is a major reason why dry ESPs are predominantly used in the utility industry. Every inch of pressure drop translates into dramatically higher energy requirements for operating the ID fan. To achieve 95 percent removal efficiency on 0.5-micron particles in a 1,000,000 cfm air flow, 12,000 kW of energy is required using a venturi scrubber, while an ESP needs only 100-

200 kW of energy for I.D. fan operation.

Dry ESPs

Dry ESPs consist of a series of parallel vertical plates, which act as the collecting electrodes, with a series of discharge electrodes in between the plates spaced some distance apart. As the contaminated flue gas passes through the ESP, negatively charged ions form near the tips of the sharp points of the ionizing electrode (corona discharge). These negatively charged ions move toward the positively charged collecting electrode surface and charge the contaminated particles passing through the ESP. These charged particles become attracted to the positively charged collection plate, where they accumulate on the surface. The collected particulate builds up on the dry collection surface and forms a layer of particles or “cake” that has insulating properties.

Dry ESPs perform best when particle deposits on the collecting plates have a resistivity greater than approximately 10^7 ohm-cm, but less than 2×10^{10} ohm-cm. If resistivity is less than 10^7 , the electrostatic force holding the dust particles on to the dust layer is too low and re-entrainment of particles in the flue gas can become a serious problem, reducing efficiency. If resistivity exceeds 2×10^{10} ohm-cm, the voltage drop through the particle layer to the grounded electrode becomes significant, lowering field strength in the space between the ionizing electrode and the top of the dust layer. This can cause a breakdown in the electrical field and “back corona” can take place, again lowering efficiency. Resistivity becomes a limiting factor to the amount of electrical power that can be achieved within a dry ESP.

To dislodge the dust from the collecting electrode surface and into the bottom hopper, mechanical rappers or sonic horns are employed. However, portions of the particles remain suspended in air and get re-entrained in the gas stream. This secondary re-entrainment requires the use of another dry ESP field to collect the re-entrained particulate plus those particles not captured in the first field.

Dry ESPs have been used successfully for many years in industrial and utility applications for coarse particulate removal. Dry ESPs can achieve 99+ percent efficiency for particles 1 micron to 10 micron in size. However, they have several limitations that prevent their use in all applications:

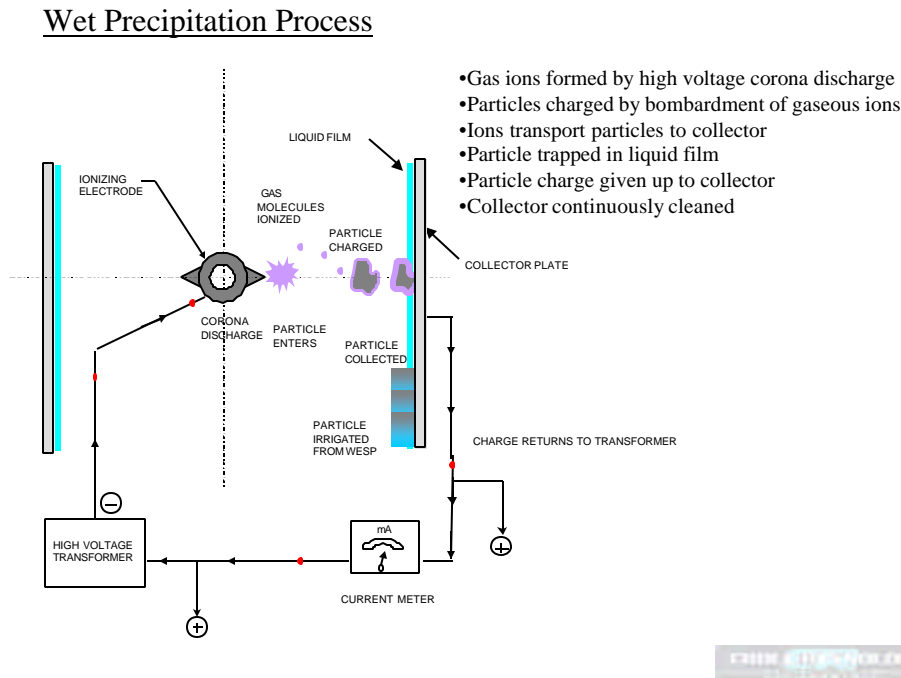
- Dry ESPs are not capable of removing toxic gases and vapors that are in a vapor state at 400°F.
- Due to their low corona power levels because of resistivity of the particulate cake, dry ESPs cannot efficiently collect the very small fly ash particles.
- Dry ESPs cannot handle moist or sticky particulate that would stick to the collection surface.
- Dry ESPs cannot remove oxidized or elemental mercury
- Dry ESPs require a lot of real estate for multiple fields due to re-entrainment of particulate.
- Dry ESPs rely on mechanical collection methods to clean the plates, which require maintenance and periodic shutdowns.

Therefore, dry ESPs may not be the best practicable control device to meet the proposed PM_{2.5} standard, or as a final mist eliminator for acid gas mist on FGD systems in order to reduce opacity levels to near zero.

Wet ESPs

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

(Figure 1).



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 and 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 H₂SO₄
- The temperature of the gas stream is below the dew point.

Because 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 reentrainment are the main reasons a wet ESP can collect sub-micron particulate more efficiently.

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. This reduces the need for multiple fields, as in a dry ESP where additional fields must be added to capture re-entrained particles from the previous field.

Wet ESPs are most effective for submicron particulate control. Smoke plume from a stack is the clearest sign of the presence of sub-micron particles in a gas stream. Due to refraction of sunlight, 0.5-micron particles are the most visible. Additionally, the surface area of the smallest particles in a flue gas is greater than the surface area of larger particles. One gram of 0.1-micron particles has 10 times the surface area as a gram of 1.0-micron particles (60 m^2 vs. 6.0 m^2). Toxic vapors however, condense uniformly on the surface area of all particles. That is why the capture of a gram of 0.1-micron ash particles is 10 times more effective at removing toxic pollutants than the capture of a gram of 1.0-micron ash particles.

In wet ESPs, the delivery mechanism for the irrigating liquid is critical to maintain thorough wetting of the collecting electrode surface to avoid corrosion issues without degrading the electrical system.

Collection Efficiency

For a given particulate or droplet size and concentration, ESP efficiency can be calculated by using the exponential Deutsch-Anderson equation. Field experience has shown that, with some modification, the same equation can also be applied to wet ESPs. The Deutsche-Anderson equation is:

$$\text{Eff} = 1 - \text{Exp}(-Aw/V)$$

Where the collecting electrode surface area, A , and volumetric flow rate, V , are calculated from the known geometry of the ESP and the process design data. The drift, or migration velocity, w , is determined by the operating power and particle size distribution.

There are two types of charging processes at work in an ESP. For particles greater than 1 micron, “field-charging” is primary and refers to particles being charged through the collision of negative ions as they follow the electric field lines to the surface of the particles. The peak operating voltage is the most important factor in field charging. For particles smaller than 0.5 micron, “diffusion-charging” is primary and occurs because of the random motion of the sub-micron particles and their collision with negative ions. The current density injected into the ESP is the most important factor in diffusion charging.

Wet ESPs are capable of removing sub-micron particles, droplets, and mists as small as 0.01 micron in size up to 99.9+ percent efficiency depending upon the number of fields employed and can achieve near zero opacity levels.

Tubular vs. Plate

Wet ESPs can be configured either as tubular precipitators with vertical gas flow or as plate precipitators with horizontal gas flow (Figure 1). For a utility application, tubular wet ESPs would be appropriate as a mist eliminator above a FGD scrubber, while the plate type could be employed at the back end of a dry ESP train for final polishing of the gas in a hybrid ESP. In general, tubular precipitators are more efficient than the plate type and take up less space due to simple geometry. A tubular wet ESP is just a horizontal ESP turned vertical with all four sides enclosed to act as collection surface. Other differences between the two types are:

- For a given efficiency, a tubular precipitator may be operated at twice the gas velocity of a plate precipitator of equal electrode length
- For a given efficiency, a tubular precipitator has a smaller footprint than a plate type precipitator.

Tubular precipitators can be designed as either up-flow or down-flow. In up-flow tubular ESPs, flue gas enters at the bottom of the ESP and flows upwards. The wash nozzles are located at the bottom spraying up into the ESP, co-current with the gas. In some cases, nozzles that spray down into the field are added above the field. In down-flow designs, the flue gas enters the top of the wet ESP and flows downwards. Similarly, the sprays are mounted on top, spraying down co-current with the gas.

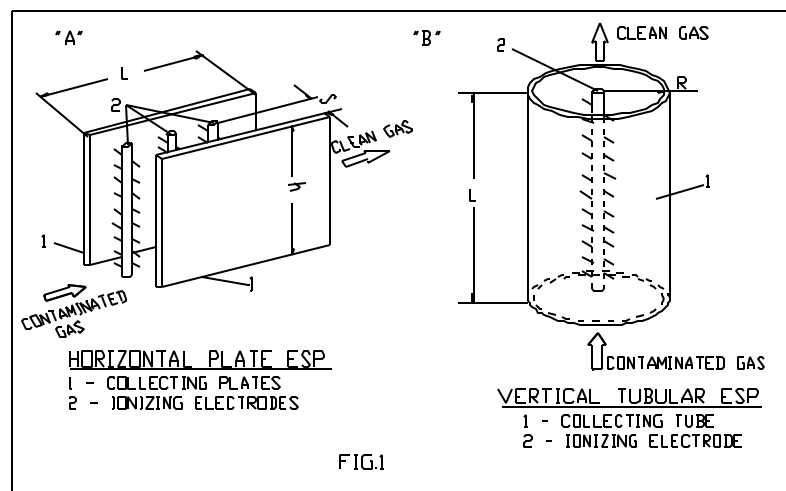


Figure1: The comparison of a tubular WESP vs. a plate type WESP shows that, for a given efficiency, a tubular WESP can operate at twice the velocity of a plate type WESP, resulting in a smaller footprint (Applicable mostly for new construction).

While in some installations a down-flow design may minimize inter-connecting ductwork, it will require a mechanical mist eliminator to capture the water mist that has been carried along with the flue gas before entering the stack. Conversely, an up-flow, tubular wet ESP is an excellent mist eliminator due to its ability to capture sub-micron droplets and requires no mechanical mist eliminator.

Air Distribution

Distribution of the flue gas throughout the wet ESP is a critical design function. Overloading a section of

the wet ESP will negatively impact collection efficiency. While perforated plates below the electrical section will aid in proper air flow distribution, an alternative is using some sort of scrubber in front of the wet ESP. This accomplishes multiple purposes:

- Removal of any acid gas present, which reduces corrosion in the wet ESP and allows for less expensive materials of construction to be used (i.e., FGD application)
- Removal of particulate larger than 2 microns, which reduces the particulate loading on the wet ESP and allows for smaller size of the wet ESP
- Cooling of the gas, which reduces the gas volume and cuts down on the size of the wet ESP
- Saturation of the gas, which enhances condensation within the wet ESP
- Enhanced airflow distribution throughout the wet ESP due to limited pressure drop.

Sparking

Since wet ESP efficiency is directly proportional to the electrical power conveyed to the moving gas, each time a spark occurs, the voltage, and consequently the particulate collection efficiency, is reduced. Sparking rate for a given inter-electrode spacing is a function of the inlet loading (mist, droplet, or particulate) and alignment of the discharge electrodes. Additionally, the power level and efficiency of a wet ESP can be dramatically increased by properly designing the automatic voltage control system. While the industry average seldom goes beyond 50 percent conduction (i.e., the ability to deliver 50 percent of the available power to the gas), the proper selection of the transformer-rectifier (T/R), automatic voltage controller (AVC) and current limiting reactor (CLR) can deliver much greater conduction.

Corona Current Suppression

If there is a high loading of charged particles, corona current is diminished due to the low mobility of charged particles in the inter-electrode space. This phenomenon is called current suppression or space charge effect. A high concentration of fine particles, a typical scenario for space charge effect, can reduce the corona current by a factor of 50 or more.

Certain criteria should be met in order to prevent the deterioration of removal efficiency in the presence of a space charge effect. The level of current suppression that will be experienced in a particular application is related to the total surface area of the suspended particles and the designed corona current density within the given volume of the wet ESP collection section. For example, particles of 0.6-micron diameter have 100,000 cm²/gram of surface, whereas particles of 0.3-micron diameter have more than 10 times the surface area per unit weight (1,100,000 cm²/gram). For a given grain loading, the finer the particle, the more potential there is for current suppression to occur.

In the case of multiple fields in a wet ESP, collection efficiency can be maintained even in the presence of current suppression. The first pass will operate in “suppressed” conditions at a somewhat reduced efficiency level, but will condition the gas for the second pass, which will operate at its full design potential.

Materials of Construction

A wet ESP's collection section can be made out of any conductive material. However, the material chosen must be corrosion resistant to any acid mist contained in the flue gas. Wet ESPs have been made out of conductive fiberglass, carbon steel, various stainless steels and various high-end alloys depending upon the duty intended. Most multi-pollutant applications for wet ESPs typically employ some sort of scrubber in front of the wet ESP to remove corrosive acid gases. Material selection should be based upon a "worst-case" scenario analysis in order to protect the equipment against upset conditions. Alternatively, the water sprayed into the ESP can be treated to neutralize acids collected within the ESP. Proper pH control is essential to maintain integrity of the equipment.

Modular

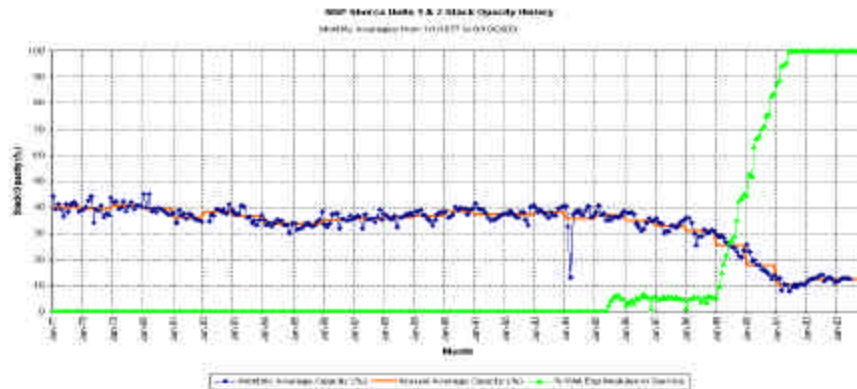
Like dry ESPs, wet ESPs can be modular. Each field is limited in size to the power of the available transformer. The largest transformers available today are 70,000 V @ 2500 mA of installed electrical power. Depending on the specific application (large air flow or heavy inlet loading), multiple sections can be arranged together, either in series or in parallel, to achieve the required efficiencies.

Utility Application

Coal fired plants are starting to recognize the need for wet ESP technology to reduce opacity related to PM2.5 and SO3 concentrations in the flue gas as States start to mandate more stringent opacity limits.

Northern State Power's Shirco Station with two 750 MW boilers installed the first full-scale wet ESP in the country to reduce opacity. Eleven modules/unit of tubular, upflow wet ESP technology were installed after a FGD system and opacity was reduced to less than 10% with 22 Wet ESP modules in

Sherco 1 & 2 opacity over time



service.

In several instances where plants have installed SCR technology with ammonia injection on high sulfur coal and FGD systems are installed, increased plume resulted from higher levels of SO₃ and fine ammonia salt concentration in the flue gas. These plants are considering installing a wet ESP after the FGD system to capture the additional SO₃ and ammonia salts, which cannot be captured in the FGD

system due to their sub-micron nature. Therefore, for the 25% of coal fired plants that burn high sulfur bituminous coal that have FGD systems installed, installing a wet ESP is the next logical step to meet opacity, PM2.5 SO₃ and mercury standards.

Tubular Pilot Wet ESP at First Energy’s Bruce Mansfield Station

Croll-Reynolds installed a pilot wet ESP at a major coal-fired plant in 2001. This plant burns 3% bituminous coal and has a FGD system installed for PM10 and SO₂ control. A 5,000 acfm slipstream, tubular pilot wet ESP was installed for PM2.5 and SO₃ control, the two primary contributors to stack plume. Speciated mercury testing was also performed to measure collateral benefits of installing wet ESP technology.

Summary of Pilot Wet ESP Test Results- Bruce Mansfield Plant –2001-2002									
	PM2.5		SO ₃ Mist Tests			Mercury			
						Particulate	Oxidized	Elemental	
Average of all Tests									
Test Series	Sep-01	Nov-01	Sep-01	Nov-01	Sep-01	Sept -01	Sept -01	Sept -01	
Airflow-acfm	8394	8235	8394	8235		8000	8000	8000	
Velocity – ft./sec.	10	10	10	10					
# of fields	1	2	1	2		1	1	1	
Power Levels	100%	100%	100%	100%		100%	100%	100%	
						ug/dscm	ug/dscm	ug/dscm	
Inlet	0.0292	0.0506	11.475	10.01		0.011	0.689	6.245	
Outlet	0.0063	0.002	2.7	0.85		0.004	0.158	3.474	
Removal %	79%	96%	76%	92%		64%	77%	44%	

An initial series of tests completed during Sept. of 2001 were performed in a single electrical field at approximately 8,000-cfm. Removal achieved at this higher than designed for airflow was 79% for PM2.5 and 76% for SO₃. Mercury testing during this time period showed 64% for particulate, 77% for oxidized and 44% for elemental. Removal levels for particulate and oxidized mercury were similar to that for PM2.5 and SO₃. Most importantly, 44% removal of elemental mercury was measured at the highest inlet concentration. Mercury levels were extremely low because most of the particulate and water soluble HgCl was already removed in the upstream FGD system. It is estimated that at higher inlet levels, higher removal efficiencies would be expected.

In order to improve removal efficiency within the wet ESP pilot, the electrical system was subsequently retrofitted from a single to a two-field configuration. New test results on PM2.5 and SO₃ improved to 96% and 91% respectively.

Observation Tube

In order to estimate opacity on this slipstream application, Croll-Reynolds supplied a 19’ long observation tube to that is the same diameter as the top of the stack. A light source provided at one end

with an observation port at the other allows for direct visual observation. The pictures below show the results at varying power levels.

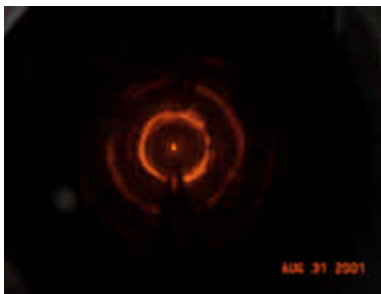


10,000 cfm wet ESP unit at Bruce Mansfield plant

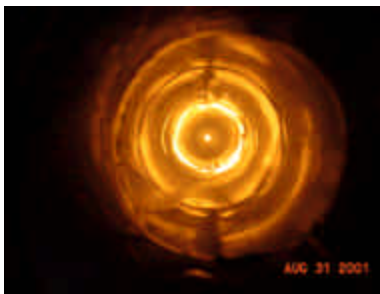
Observation tube – 19' long to simulate diameter of top of stack.



Pictures looking down the observation tube



Looking down observation tube with minimal power.



Looking down observation tube with some power on in the WESP.



Looking down observation tube with maximum power on in the WESP.

Hybrid ESP Design

However, the majority of coal-fired plants do not have a wet FGD system installed. Many are considering installation of fabric filters with injection of activated carbon for mercury control to meet new proposed mercury standards as well as removal of PM2.5. A viable, cost-effective alternative that offers multi-pollutant control is needed. Retrofit of a dry ESP last field with a wet field offers the potential to remove PM2.5, SO₃ mist, SO₂ and mercury without the drawbacks of activated carbon injection/fabric filter technology.

For those plants with undersized dry ESPs, retrofit of a dry ESP with a wet field offers the ability to meet opacity requirements with minimal cost and impact. The Electric Power Research Institute tested the concept of adding a wet ESP after a dry ESP in an unsaturated condition during 1994-1995 at pilot scale level on coal-fired flue gas, primarily for opacity abatement. Those results indicated that a single wet field could achieve very high collection efficiency, greater than 90 percent.

In terms of outlet emissions, the tests indicated that a dry ESP emitting more than 0.1 lb/MMBtu before conversion would emit less than 0.03 lb/MMBtu after conversion to a wet field. This high efficiency results from the high power levels possible when fly ash electrical resistivity is no longer a controlling factor. Furthermore, the water wash system in the wet field eliminates the need for traditional mechanical rapping and thus virtually eliminates all re-entrainment losses. The EPRI tests also established that a wet ESP could be successfully operated with the flue gas temperature well above the moisture dew point. This method of operation means that equipment downstream of the converted ESP will not have to be operated under saturation conditions.

Finally, the EPRI tests demonstrated that the conversion to wet operation partially reduced SO₂, HCL and HF along with some oxidized mercury. Measured results from the pilot showed the following removal levels across the wet ESP.

- Particulate matter: 95%
- Sulfur dioxide: 20%
- Hydrogen chloride: 35%
- Hydrogen fluoride: 45%
- Oxidized Mercury: 50%
- Total mercury 30%*

(*Outlet elemental mercury was measured at higher levels than inlet Hg^o. It is estimated that some of the oxidized mercury degassed back to elemental mercury in the water solution due to improper pH control/water chemistry.)

In 2000-2001, EPRI participated in a full-scale demonstration of this concept at Mirant's Dickerson Station for opacity reduction. While performance testing reported high collection efficiency on PM_{2.5} and SO₃ with opacity as low as 10%, mechanical issues associated with the wet ESP design, which could have been corrected if non-technical issues had not limited the length of the project, prevented continued implementation of this approach. No mercury testing was performed at this site.

Croll-Reynolds has since designed and installed a horizontal, plate wet ESP at slipstream pilot scale that overcomes the mechanical issues experienced at Dickerson. A patented water header system prevents splashing, a unique plate design assures thorough water coverage to avoid dry spots and a drainage system eliminates arcing and mist carryover downstream.

Benefits

Adding a wet ESP field behind an existing dry ESP or retrofitting the last field offers several benefits to traditional methods for removing PM_{2.5}, SO₃ mist and some fraction of SO₂ and mercury:

- Less pressure drop than a fabric filter or FGD system. Typically ½" w.c. pressure drop across a wet ESP, similar to that of a dry ESP field.
- There are no moving parts since a wet ESP is self-cleaning, reducing maintenance.
- Less real estate is required. A wet ESP field can be retrofitted to an existing dry ESP, thereby avoiding the problem of trying to find space for new equipment within the confines of a plant.
- The wet ESP field can operate above the saturation point, thereby avoiding costly upgrading of downstream duct and stack materials of construction. The wet ESP section would be constructed of a high-grade stainless steel.
- Capital costs are significantly less than a fabric filter or full FGD system, typically in range in the \$25-\$35/kw depending upon difficulty of the installation.
- Operating costs are minimal with less than 3 watts/cfm-power usage within the wet ESP.
- There is no impact on existing upstream air pollution control equipment or process.
- Multiple pollutant control is possible. While primarily a particulate control device, similar to a fabric filter, a wet ESP retrofit offers the collateral benefit of being able to abate acid mists (SO₃), oxidized mercury, some acid gas (SO₂, HCL) as well as some elemental mercury.
- Opacity can be reduced to 10% or less due to removal of PM_{2.5} and SO₃ mist.
- There is no contamination of fly ash. The wet ESP section is located downstream of the dry ESP.
- Fuel blending/switching can be accommodated to minimize fuel costs while meeting emission standards.
- There is no sorbent injection system. Installation, handling, injection of sorbent plus disposal issues of mercury-laden carbon are eliminated.
- Any mercury collected in the wet ESP slurry can be treated in a wastewater treatment system to remove the mercury from the water, concentrating the waste and reducing handling and disposition of a hazardous waste.

- Wastewater from the wet ESP can be recycled, minimizing water-related issues.

New Hybrid Pilot Demonstration

Because this approach offers so many potential benefits and there has not been sufficient testing of the concept and resolution of mechanical issues associated with the approach, the Electric Power Research Institute and Croll-Reynolds intend to construct a mobile 10,000 cfm slip-stream pilot wet ESP for installation after a dry ESP. One plant using PRB coal with high elemental mercury emissions has already committed to being a host. The plant is installing SCR technology for further NO_x abatement. Testing for PM_{2.5}, SO₃, SO₂ and mercury removal will be performed.

The pilot wet ESP consists of stainless steel plates with a patented water feed system that promotes uniform and thorough water coverage while minimizing the potential for plugging, splashing and mist carryover. Custom designed ionizing electrodes are configured to suit the electrical profile required for various flue gas concentrations.

Mercury Control –Plasma Enhanced ESP Technology

Mercury adsorbed onto particulate and oxidized forms of mercury are readily removed from the flue gas using a wet scrubber or flue gas desulfurization system. However, the remaining elemental mercury vapor passes through the air pollution control devices unabated. Most mercury research has focused on sorbent injection followed by a baghouse for those plants without an FGD system, typically where low sulfur coal is used.

Tests of wet ESP technology at the Bruce Mansfield pilot plant indicate that a wet ESP can remove both oxidized and particulate forms of mercury at similar levels to that for PM_{2.5} and SO₃. Mercury testing showed 64% for particulate, 77% for oxidized in the single electrical field configuration. Most importantly, 44% removal of elemental mercury was measured at the highest inlet concentration. Mercury levels were extremely low because most of the particulate and water soluble HgCl was already removed in the upstream FGD system. It is estimated that at higher inlet levels and /or a dual electrical field configuration, higher removal efficiencies would be expected.

To increase elemental mercury removal efficiencies using wet ESP technology, MSE Technology Applications, Inc. and Croll-Reynolds Clean Air Technologies, Inc. developed a technology that uses the central electrode of a standard wet electrostatic precipitator to inject a mercury oxidizing reagent gas directly into a flue gas stream. As the reagent gas passes through this corona discharge, reactive species are formed that subsequently oxidize elemental mercury into fine particulate. The mercury particulate acquire a negative charge in the electrical field and are attracted to positive electrodes where they are adsorbed into the liquid layer and are removed from the process in the washdown cycle. Under test conditions where the flue gas temperature was maintained well above the saturation temperature, the mercury oxidation efficiency of the technology increased to 79%.

Membrane Based Wet ESP technology

Ohio University, Southern Environmental and Croll-Reynolds have patented and developed a new membrane based Wet ESP with dramatically reduced cost and weight compared to metallic wet ESPs.

Cleaning of the corrosion resistant fabric membranes is facilitated by capillary action between the fibers, providing even water distribution, & continuous flushing which removes collected material without spraying, so the entire precipitator remains on line.

DOE's National Energy Technology Laboratory has awarded SEI/CRAT and Ohio University a grant to compare metallic and membrane based wet ESP technology in a pilot unit at First Energy's Bruce Mansfield Plant in Shippingport, Pa. Testing will begin this summer on the membrane wet ESP.

Conclusion

Wet ESP technology is a proven, well-known technology that can achieve very high removal of mists, particles and aerosols with low pressure drop and minimum maintenance, if properly designed and built. Whereas it has traditionally been installed after a FGD system in a saturated flue gas as a final wet electrostatic mist eliminator, it can also be retrofitted to an existing dry ESP last field to increase collection of PM_{2.5}, SO₃ and mercury and reduce opacity.

New improvements to the technology include enhancing its removal capability adding electrical fields within the same physical envelop, oxidizing elemental mercury using plasma and reducing cost by using membrane collection material.

Successful demonstration of these various developments will offer coal-fired plants using either bituminous, sub-bituminous or lignite coal a reliable control technology that has multi-pollutant capability for reducing PM_{2.5}, SO₃ mist, mercury with the co-benefits for some SO₂ and HCL trim control.

Key Words

Wet electrostatic precipitation

Wet ESP

Hybrid ESP