WPCA NEWS
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# *Executive Summary*

## Making (No)Sense of TR Control Feedback Signals While Testing with SMPS

*By Rob Sosinski, Redkoh Industries*

Engineers and technicians may get caught up in the "feedback" world, and although kV and mA feedbacks can be critical for diagnosing problems, they can be confusing after the implementation of switch mode power supplies. ***Full Story….***

## Effluent Limitation Guidelines / Step 1. Minimize Effluent

*By Suzette Puski and Matthew Quitadamo, Babcock Power*

Reducing the quantity of wastewater sent to a treatment system by analyzing the overall plant water balance can have a significant impact on the overall design, selection, and cost associated with the final technology to be utilized to treat the effluent stream in accordance with the ELG. ***Full Story….***

## Aerodynamic Optimization of Solar Racks

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## Evaluation of Current HCl and HBr Stack Gas Measurement Methods For MATS Compliance

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## Commercial Operation of Electrostatic Precipitator High Frequency Energization in Intermittent Energization Mode at Labadie Energy Center, Unit 1 & 2

*By David Boll and Nicolas Pelech, Ameren; Mick Chambers and Hardik Shah, SEI; Gary Grieco, Air Consulting Associates*

ESP high frequency energization in intermittent energization mode (IE mode) is now in commercial operation at Ameren's Labadie Energy Center, Units 1 & 2. When operating in IE mode, the kW for each SMPS, was reduced nearly 40-50% when compared to operating in normal mode. ***Full Story….***

## Mercury Abatement – A Case Study

*By Michael Thiel, Nol-Tec Systems*

A next generation of mercury abatement technology has been developed which utilizes pressure technology to overcome the challenges which an eductor system simply could not do on its own. ***Full Story….***

## Case Study on Increasing Fabric Filter Life – Utility Coal Fired Boiler

*By Tim Stark, CLARCOR Industrial Air / BHA*

This article reviews a case history where an investigation was done to determine steps that could be taken to solve abrasion, bag cage connection joint wear, connection failures and blinding problems with the fabric filters being used in a coal-fired boiler baghouse. ***Full Story….***

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WORLDWIDE POLLUTION CONTROL ASSOCIATION

# MAKING (NO)SENSE OF TR CONTROL FEEDBACK SIGNALS WHILE TESTING WITH SMPS

*Written by Rob Sosinski, Redkoh Industries*

The Electrostatic Precipitator Industry's venture into Switch Mode Power Supplies (SMPS) has often proved to be an effective and advantageous means of improving precipitator efficiency.

The power supplies on the market today use frequencies on the precipitator ranging between 100 Hz and 50 kHz. These frequencies TYPICALLY result in a lower ripple, higher average voltage (kV) and higher ESP field current (mA). The anticipated performance improvement comes from additional power drawn by the precipitator.  BUT……. This is only one aspect of the power frequency change.

A prime example of how to become confused by looking purely at the change in kV after the implementation of an SMPS is shown below.

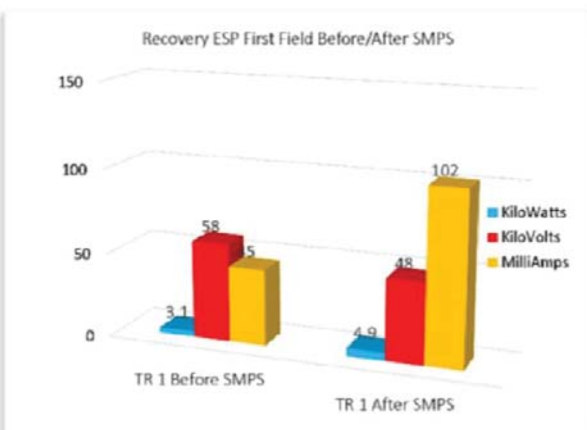



*FIGURE 1: Before the SMPS test, at 58 kV the field was able to pull only 45 mA. After the SMPS installation the field had far more current (102 mA) at a lower kV (48). How could this be?*

This Graph is taken from a set of data read from the controller interface and when analyzed, we see that apparently we are drawing more current when using the SMPS at 48 kV than we were on the standard controller at 58 kV.

Straight away this does not make obvious sense.

There could be any number of misleading numbers in our evaluation. Let's examine some of these:

- The original or newer controller is misinterpreting or averaging the voltage applied to the ESP and thus providing data over different periods giving us data that is inconsistent between the different frequencies.
- The original or newer controller may need its display and control parameters re-calibrated. Inconsistent current draw and spark rate limits may be an indication that the power supply is bumping up against a parameter or internal limitation.
- The SMPS, with its ability to respond to sparks so much more efficiently may be running at a spark rate higher than the original and with a different control averaging algorithm give the appearance of running at a lower output voltage.
- Quite simply: the data is constantly changing and while the engineer looked up to take one reading, a second later all the other readings have changed!
- Of course there's always the overwhelming possibility that the load makeup to the ESP may have changed….

- The list could go on and on, but at the end of the day, does it all really matter?

As engineers and technicians we get caught up in the "feed-back" world, and although kV and mA feedbacks can be critical for diagnosing problems, there's really only a couple of ways of determining the benefits of any power supply under test:

**HAS THE POWER IN THE FIELDS, AFTER THE FIELD UNDER TEST CHANGED?**

Presumably we have not touched these controls and so the prior and post data we read from them remains

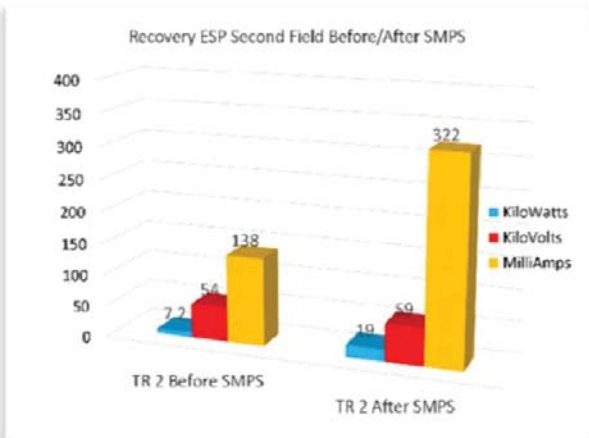



***FIGURE 2:** The second field proves our original theory that with more kV the field will draw more current. Before the SMPS installation on the inlet field, the second field sat at 54 kV and the field was able to draw 138 mA.*

***After the SMPS installation the second field was able to get more kV (59) and was able to draw far more current (322 mA).***

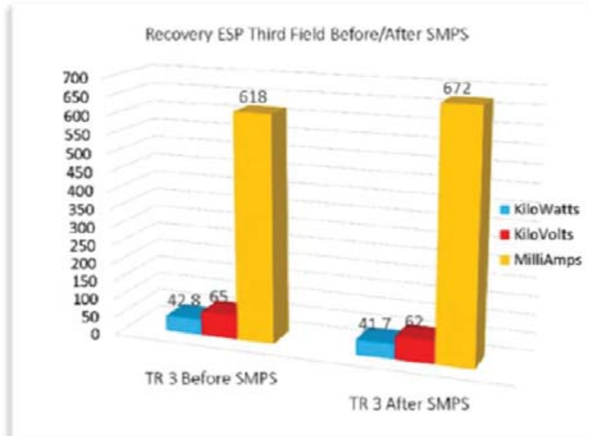
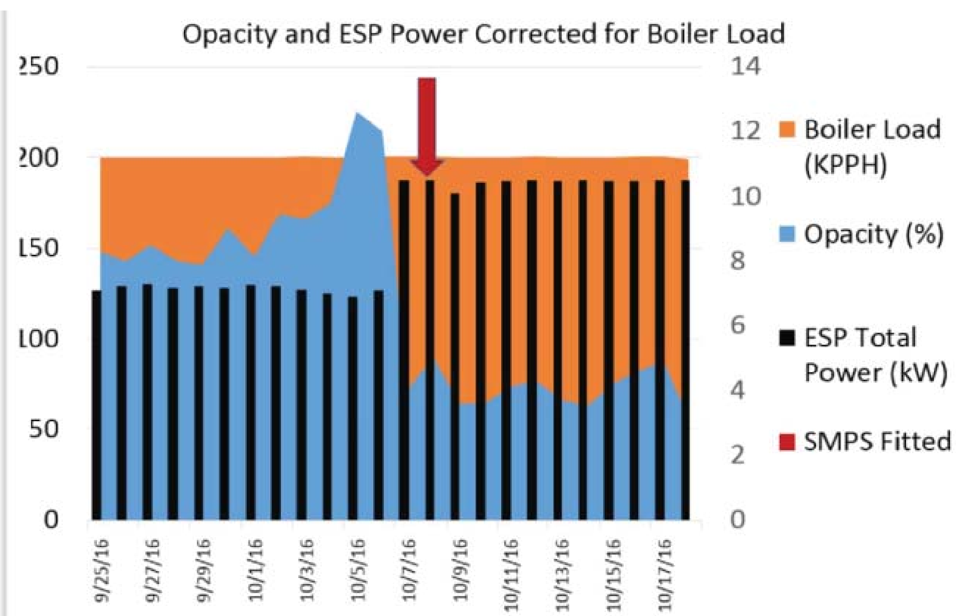



***FIGURE 3:** On the outlet field our theory has less relevance (After the SMPS was installed the field is drawing more current (672 compared to 618) at a lower kV (62 compared to 65)) and we can conclude that the gas reaching here is cleaner than before and so less volts are required to drive the current.*

**HAS THE OPACITY CHANGED - APPARENTLY SO!**

**FIGURE 4**



*For further information contact*
*Rob Sosinski at rob.sosinski@redkoh.com*

***BIOGRAPHY***

***Rob Sosinski is the Lead Product Technologist at Redkoh Industries where he specializes in the development and promotion of new technology. He graduated from Kutztown University in Pennsylvania with a bachelor's degree in Liberal Arts and Sciences in 2010. After graduating, he worked as a game day operations director for Madison Square Garden in New York City, New York. As a native New Jersian, he moved back to New Jersey and has been with Redkoh since 2011.***

# Effluent Limitation Guidelines
# Step 1. Minimize Effluent

*Written by Suzette Puski and Matthew Quitadamo, Babcock Power*

## INTRODUCTION

Power plants produce various wastewater streams, most notably ash transport water and WFGD purge (or blowdown). Regulations have been promulgated restricting the discharge and use of ponds to store these wastewater streams. Several mitigation techniques exist. Prior to deciding which mitigation technique to use, a review of the power plant's water balance is required. This will determine if the plant can be optimized to reduce the volume of wastewater produced and/or reduce the constituents in the wastewater to be managed dependent on the preferred treatment process.

For any given system, the wastewater rate and composition are functions of several design and operating factors, such as unit size, boiler type, fuel fired, reagent used, makeup water sources, particulate capture type and efficiency, WFGD type, equilibrium chloride concentration, byproduct specification, and the use of any other upstream air quality controls system (AQCS) equipment (e.g. SCR, DSI, ACI). As a result, wastewater streams can exhibit a high degree of variability: both from plant to plant and within individual units. The first step towards minimizing effluent is to determine how much wastewater requires treatment and what is in it. To accomplish this, an engineering study should be completed to:

- Evaluate the impact of processing other wastewater sources through the Wet Flue Gas Desulfurization (WFGD) system
- Evaluate the impact of operational changes
- Evaluate the impact of additional equipment
- Evaluate the impact of upstream sorbent injection systems
- Evaluate the impact of fines removal
- Evaluate the salability of fly ash and gypsum byproduct

## KEY CONSIDERATIONS WHEN MINIMIZING EFFLUENT

The following sections provide some high level discussion identifying the major parameters to consider when evaluating typical methods to reduce existing wastewater generation from coal fired power plants.

Bottom Ash Water

Even when bottom ash systems are retrofitted with a submerged scraper conveyor a slip purge stream may be required to maintain the recycle water pH. In most cases, characteristics of this water are considered acceptable for reuse as WFGD process water (e.g. reagent preparation, absorber makeup). The availability of this water for use in a WFGD process is dependent on key components such as Al and F.

Chlorides

A majority of the chlorides come from HCl in the flue gas and subsequently a large fraction of HCl is removed from the flue gas in the WFGD system. Most of the chlorides leave the process through the wastewater purge stream. Dependent on the marketability of the gypsum, a significant fraction of the chlorides can also leave with the byproduct if the gypsum cake remains unwashed.

In addition, it is feasible to remove HCl upstream of the WFGD system. If HCl is removed upstream of the WFGD system then the purge stream can be reduced proportionally. The extent of the reduction for a given system is dependent on several factors. The plant must complete an evaluation of the O&M costs of removing HCl upstream of the WFGD system versus the mitigation system chosen to treat the WFGD purge stream.

Removing HCl upstream of the WFGD process can provide other benefits as well dependent on the technology utilized. Benefits include flue gas mixing to improve SCR performance and reduce air heater downtime required for equipment flushing.

Maximizing the Use of Reclaim in WFGD

There are several ways reclaim can be reutilized in the WFGD process including using it as a source of flush water or as makeup to the lime/limestone preparation system. Process chlorides should be cycled up to a safe margin below the limit of materials of construction.

Fines

Fines in the WFGD process water originate from fly ash carryover to the scrubber, limestone inerts, makeup water, and gypsum. Reclaiming process water will increase the fines concentration in the process. Excessive fines can lead to dewatering issues from blinding of the vacuum belt filter and erosion issues in rotating equipment including agitator and pump impellers.

There are several options to minimize the fines in the process including utilizing secondary hydrocyclones to concentrate fines in the purge stream or clarifiers and filter presses to remove fines from the process.

Plant Capacity and Load Variability

It is important to understand how units will be operated as the water balance is reduced at the plant. For example, instantaneous water usage during mist eliminator wash cycles can cause a positive water balance during low load operation. A review is required to determine how the system can be operated to account for the cyclic operation of the WFGD system.

## CONCLUSION

Whether it is real estate for the physical/chemical components, nutrients and man-power to maintain the biological components, or exotic materials of construction and energy costs for the crystallizer/evaporator components, reducing the quantity of wastewater sent to a treatment system can have a significant impact on the overall design, selection, and cost associated with the final technology to be utilized to treat the effluent stream. By looking at the overall plant water balance and system operation, the effluent stream can be minimized to provide cost effective alternatives to meet the new ELG guidelines reducing the capital and O&M costs required for a treatment system.

*information contact*
*Suzette Puski at SPuski@babcockpower.com*
*Matthew Quitadamo at mquitadamo@babcockpower.com*

***BIOGRAPHY***

***Suzette is a chemical engineer with 20 years in the environmental field. Her experience includes engineering design, startup and commissioning of new and upgraded environmental systems. Currently she works on the technical aspects of proposals for Babcock Power Inc. Her focus is on air and water quality systems.***

***Matthew Quitadamo currently serves as Technical Advisor for Environmental Technology at Babcock Power Environmental Inc. (BPEI). In this role, he has been responsible for environmental technology development projects, engineering quality procedures for environmental technologies, and managing the development of design standards. Since joining BPEI in 2002, Matthew has held various***

***positions in the field of air pollution control, including Process Engineer, CFD Engineer, and Product Manager of Wet Flue Gas Desulfuration. Matthew has a Bachelor of Science in Chemical Engineering, a Master of Science in Mechanical Engineering, and a Master of Science in Environmental Engineering from Worcester Polytechnic Institute.***



# Aerodynamic Optimization of Solar Panel Racks

*Written by John D. Nitz, Airflow Sciences Corporation*

The falling price of silicon photovoltaic (PV) solar panels is making large scale installations an economically viable option for renewable energy production. Arrays of PV panels are being installed on the roofs of large buildings, such as factories and warehouses, to provide supplemental power for the facility. A typical installation is shown in Figure 5.

***FIGURE 5: Roof-top PV array (Montgomery County, MD)***

On flat roofs, the PV panels are mounted on freestanding racks with south-facing inclinations to maximize the amount of solar power that is harnessed. Ballast is applied to each rack to provide stability in winds up to 120 mph. To minimize the ballast requirements, and therefore the total load on the roof, the racks must be designed to minimize the aerodynamic lift force. In a worst case scenario, with high winds from the north, the inclined panels may experience lift forces on the order of hundreds of pounds.

To reduce the lift force under these conditions, the racks are designed with wind deflectors and baffle plates. Figure 6 shows a CAD model of the panels.

Airflow Sciences worked with Solar Mounting Solutions of Newburgh, NY to provide Computational Fluid Dynamics (CFD) modeling in support of their design optimization efforts. Rack systems, either singularly (Figure 7) or in larger arrays, were modeled under various wind conditions to determine the optimal size, placement, and number of deflector plates.

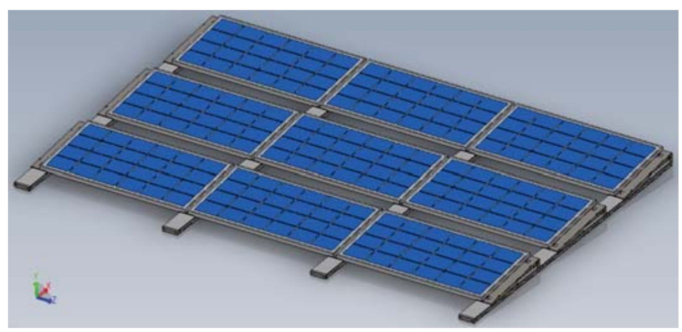


***FIGURE 6: PV panel array CAD model***

One goal was to establish the optimal length of a deflector plate positioned on the windward edge of the rack. The single panel CFD model was used for this analysis, with a wind from the north. The length of the deflector plate (as measured from the top edge of the rack, Figure 8) was increased incrementally from 0 to nearly length H, the height of the top edge of the rack above the roof. CFD results of the calculated lift force at various deflector lengths are shown in Figure 9. For this particular panel configuration and incline, the lift force calculations indicated that a deflector would in fact reduce the aerodynamic forces. The lift force dropped

significantly at a length approximately ½H, with the optimal length identified in the graphs as O.

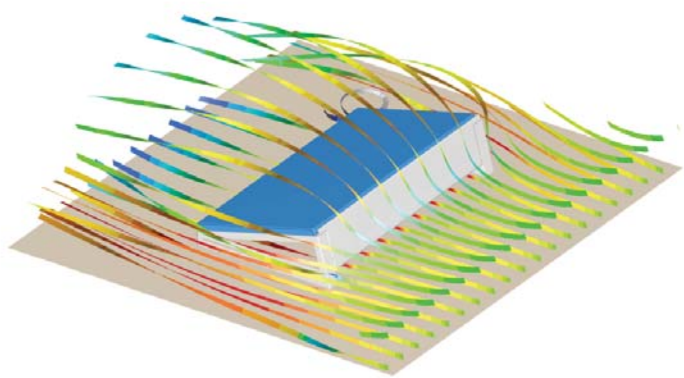


***FIGURE 7: CFD results show pathlines colored by velocity over a single rack system.***

One goal was to establish the optimal length of a deflector plate positioned on the windward edge of the rack. The single panel CFD model was used for this analysis, with a wind from the north. The length of the deflector plate (as measured from the top edge of the rack, Figure 8) was increased incrementally from 0 to nearly length H, the height of the top edge of the rack above the roof. CFD results of the calculated lift force at various deflector lengths are shown in Figure 9. For this particular panel configuration and incline, the lift force calculations indicated that a deflector would in fact reduce the aerodynamic forces. The lift force dropped significantly at a length approximately ½H, with the optimal length identified in the graphs as O.

Simulations of larger panel arrays were conducted to determine the variation of aerodynamic forces at different positions within the array. A side view closeup of the velocity contours over the first two panels is shown in Figure 10.

Because the lift force decreases with each downwind panel, the next goal was to determine how many rows of panels required deflector plates. The setup being evaluated consisted of five (5) rows of solar panels. Five (5) CFD analysis runs were conducted, starting with a single deflector panel on the windward (north) side and ending with all rows having deflector panels.

The lift forces were calculated for each panel for each run. Having deflector panels on the first two (2) rows was beneficial, but additional rows had diminishing returns. The static pressure for this ideal configuration is shown in Figure 11.

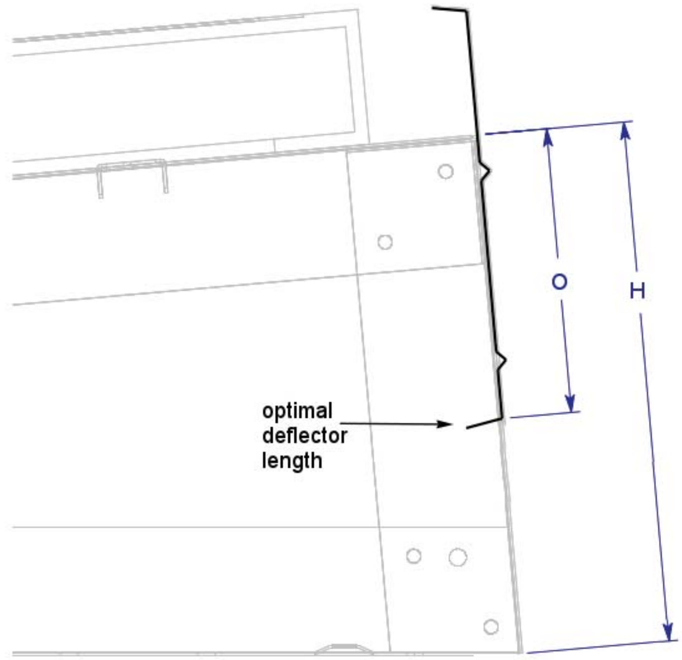



***FIGURE 8: The range of deflector lengths for this study incremented from being flush with the top edge (0) to a length almost equal to the distance H to the roof.***

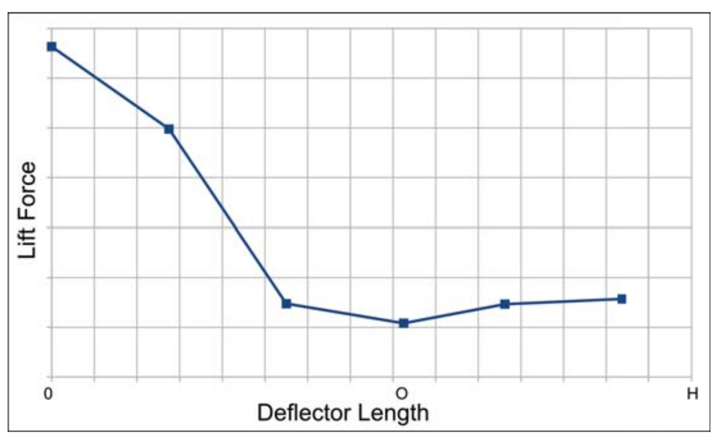



***FIGURE 9: CFD results of the lift force as a function of deflector length were used to determine the deflector length that would minimize aerodynamic forces.***

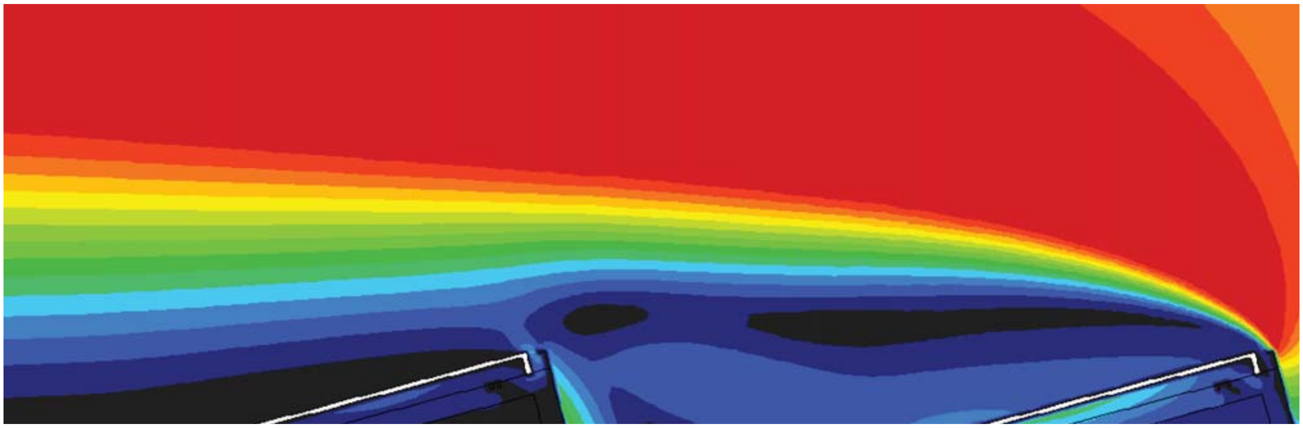


*FIGURE 10: The velocity magnitude contours caused by the wind indicate the different effects on the panels in the first two (2) rows.*

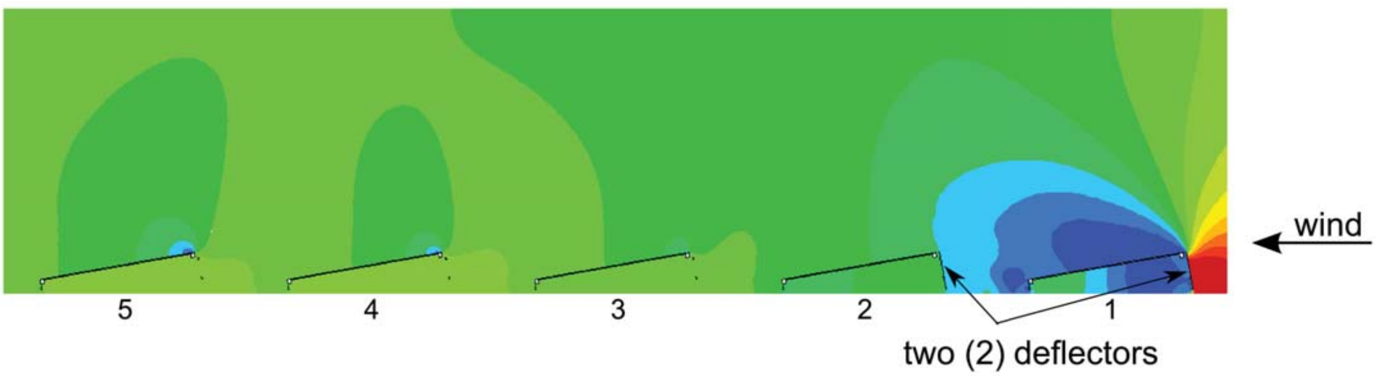



*FIGURE 11: Deflectors for the first two (2) rows provided the most aerodynamic benefit without adding undue weight, as indicated by the static pressure determined with CFD analysis.*

Worst case lift forces may occur on panels at the edges of the arrays, or on interior panels, depending on the row spacing and panel geometry. In most cases, the lift forces can be reduced by a factor to 2-3 times with an optimal deflector design.

*For further Information contact*
*John D. Nitz at jnitz@airflowsciences.com*

***BIOGRAPHY***

***Mr. John D. Nitz, P.E., Project Engineer, has been with ASC since October 2008. Mr. Nitz has performed computational fluid dynamics (CFD) modeling for a variety of industrial applications including air quality control systems, food processing equipment, combustion, and steel heat treatment. He also has extensive experience in the computational modeling of metal casting processes, solidification, and metallurgy of non-ferrous alloys, and has been granted four U.S. Patents for innovations in metal casting technology.***

***Mr. Nitz received a B.S.E in Mechanical Engineering from Michigan State University in 1991, and a M.S.E in Mechanical Engineering from the University of Michigan in 1994 with a specialization in heat transfer.***

# Evaluation of Current HCl and HBr Stack Gas Measurement Methods For MATS Compliance

*Written by Anthony Milianti, Clean Air Engineering*

## BACKGROUND

This article describes an EPRI-funded laboratory study to investigate the performance of two EPA reference methods used to measure halogens in stack gases. Specifically, the study determined the precision and accuracy of EPA Methods 26 and 26A, and examined the impact of changes to gas composition and sampling procedures on method performance. This study has direct relevance to compliance testing and monitoring by fossil-fuel-fired power plants and other industries such as Portland cement manufacturing.

Acid gases are produced when fuels containing halogens are combusted. Hydrochloric acid (HCl) is produced during coal combustion and in lesser amounts from combustion of other fuels such as fuel oil or natural gas. Recent changes to U.S. environmental regulations require many fossil-fuel-fired power plants to limit HCl emissions and to monitor concentrations in emitted stack gas on a regular basis. The concentration of hydrogen bromide (HBr) in stack gas is also of interest because bromine may be added to the fuel or boiler to increase mercury oxidation thereby improving the efficiency of mercury removal in pollution control devices. Power plant owners may therefore wish to measure levels of HBr to evaluate the efficacy of control measures.

Currently, two U.S. Environmental Protection Agency (EPA) reference methods are used for the sampling and analysis of halogens in stack gases: Method 26 (non-isokinetic) and Method 26A (isokinetic). Method 26 can only be used in "dry stacks", meaning those that do not have suspended water droplets in the flue gas, and Method 26A can be used at any combustion source. Both methods collect halides by bubbling the collected flue gas through a series of impingers containing a sulfuric acid solution and analyzing the halide ion content with Ion Chromatography (IC).

## DESIGN of STUDY

The ability of Methods 26 and 26A to accurately and reliably measure HCl emissions from coal-fired power plants at or below the emission limits mandated by the 2012 Mercury and Air Toxics Standards (MATS) rule is of interest to utility power plant owners/operators. EPRI initiated a laboratory study to evaluate the performance of Methods 26 and 26A under controlled conditions using synthetic flue gases in the laboratory. For the study, investigators used gas compositions similar to those expected of coal-fired power plant units complying with the MATS limit for existing units (i.e., less than 1 ppm HCl concentration). The flue gas simulator, shown in Figure 12, used a combination of compressed gas

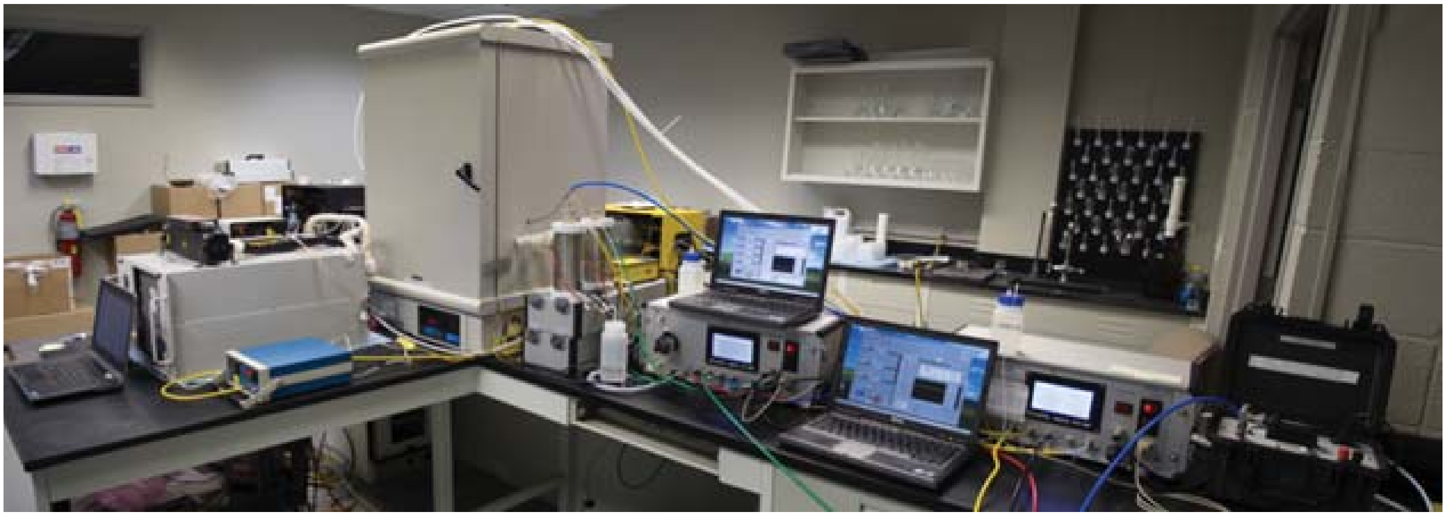


*FIGURE 12: Flue Gas Simulator*

cylinders, mass flow controllers, evaporative gas standards generators, and gas permeation tubes to generate the simulated flue gas.

The primary objective of this study was to determine the bias and precision of EPA Methods 26 and 26A (the "reference methods") when used to measure HCl and HBr emissions from a typical coal-fired, MATS-compliant electric utility stack. In addition to determining performance at a base set of conditions, the study also examined how the bias and precision of the study methods varied with respect to:

- Sulfur dioxide ($SO_2$) concentration in the flue gas
- Presence of free halogens, free ammonia ($NH_3$) and different types of fly ash
- Temperature at which ash filtration occurs
- Determination of whether the sample filter is preconditioned with flue gas
- Duration of sampling and total volume of gas collected during a sampling run

The study also examined the relative difference in bias and precision between the two study methods and the ability of Method 26 to differentiate between hydrogen halides (HCl and HBr) and free halogens ($Cl_2$ and $Br_2$). Paired sampling trains differing in one or more aspects (for example, test method and gas composition) were used to compare performance under various conditions. Fourier Transform InfraRed spectroscopy (FTIR) was used as the referee method for HCl and HBr analysis.

### METHOD PRECISION and BIAS

At the baseline conditions for this study, Method 26 appears to give more precise results than Method 26A, a relative standard deviation (RSD) of 11% vs. 22% at 0.5 ppmv HCl and 5% vs. 11% at 0.2 ppmv HCl. Method 26A exhibited no bias compared to the FTIR reference concentration at either 0.5 ppmv or 0.2 ppmv HCl. Method 26 exhibited a 25% high bias compared to the reference concentration at 0.2 ppmv and no significant bias at 0.5 ppmv..

### METHOD PERFORMANCE in the PRESENCE of HALOGENS (CL$_2$ and Br$_2$)

Method 26 was unable to differentiate between (speciate) $Cl_2$ and HCl; thus HCl results were biased high. This result is consistent with previous studies reported in the literature, which showed that molecular chlorine converts to HCl in the sampling system at typical coal-fired source conditions. The main driver for this conversion is the presence of $SO_2$ in the flue gas at concentrations higher than HCl in the flue gas. Previous studies showed that speciation between $Cl_2$ and HCl cannot be achieved when $SO_2$/HCl flue gas ratios

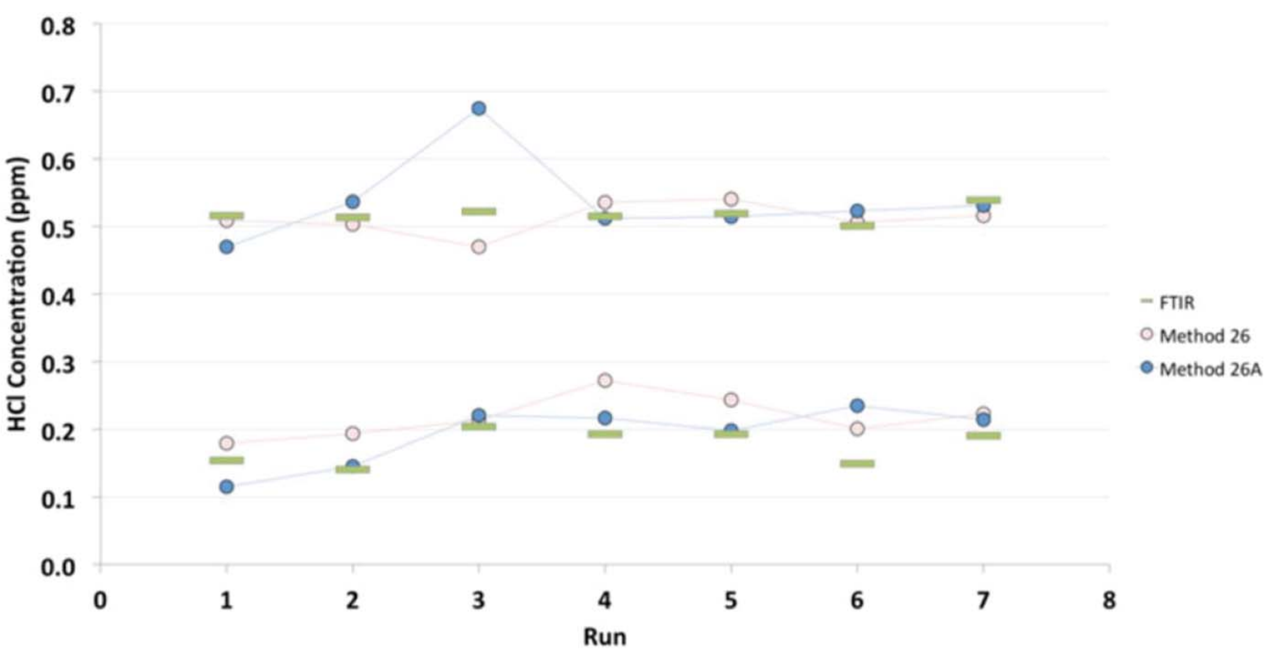



*FIGURE 13: Comparison of Method 26, Method 26A, and FTIR at baseline conditions.*

are greater than 8:1. In this study, the $SO_2$/HCl flue gas ratios were at least 10 times greater than this.

The method had the same problem in speciating molecular Bromine ($Br_2$)— all added bromine was measured as HBr. $Br_2$ also appeared to have an effect on the measurement of HCl concentration. When $Cl_2$ was present, HCl results were biased high. When both $Cl_2$ and $Br_2$ were present, HCl results were still biased high but to a lesser degree. The study concludes that when bromine and/or HBr are present in the flue gas, even at low levels, it is difficult to predict speciation.

## Effect of FLYASH

Both reference methods use a heated filter to collect particulate matter, including halide salts, prior to the absorbing solutions in the sampling train. Application of several fly ashes of different coal ranks to the particulate filter ahead of the Method 26 sampling train did not appear to significantly affect the results in a 30-min run. However, with a 180-min run, minor differences in method precision and in bias (ranging from 8% negative bias to 10% positive bias) were observed at some filter temperatures and with some fly ash types.

## EFFECT of FILTER TEMPERATURE

In this study, the filter temperature was much higher than the estimated acid gas dew point. As a result, variations in the filter temperature had no impact on the method performance. If the flue gas temperature were closer to the acid dew point, it is possible that these results would have been different. However, experience with the sample delivery system indicates that temperatures closer to the acid dew point result in sample loss, or low bias.

## FUTURE RESEARCH

Additional research into the impacts of fly ash and ammonia on method performance would be useful, as only limited testing was conducted with these flue gas components. A

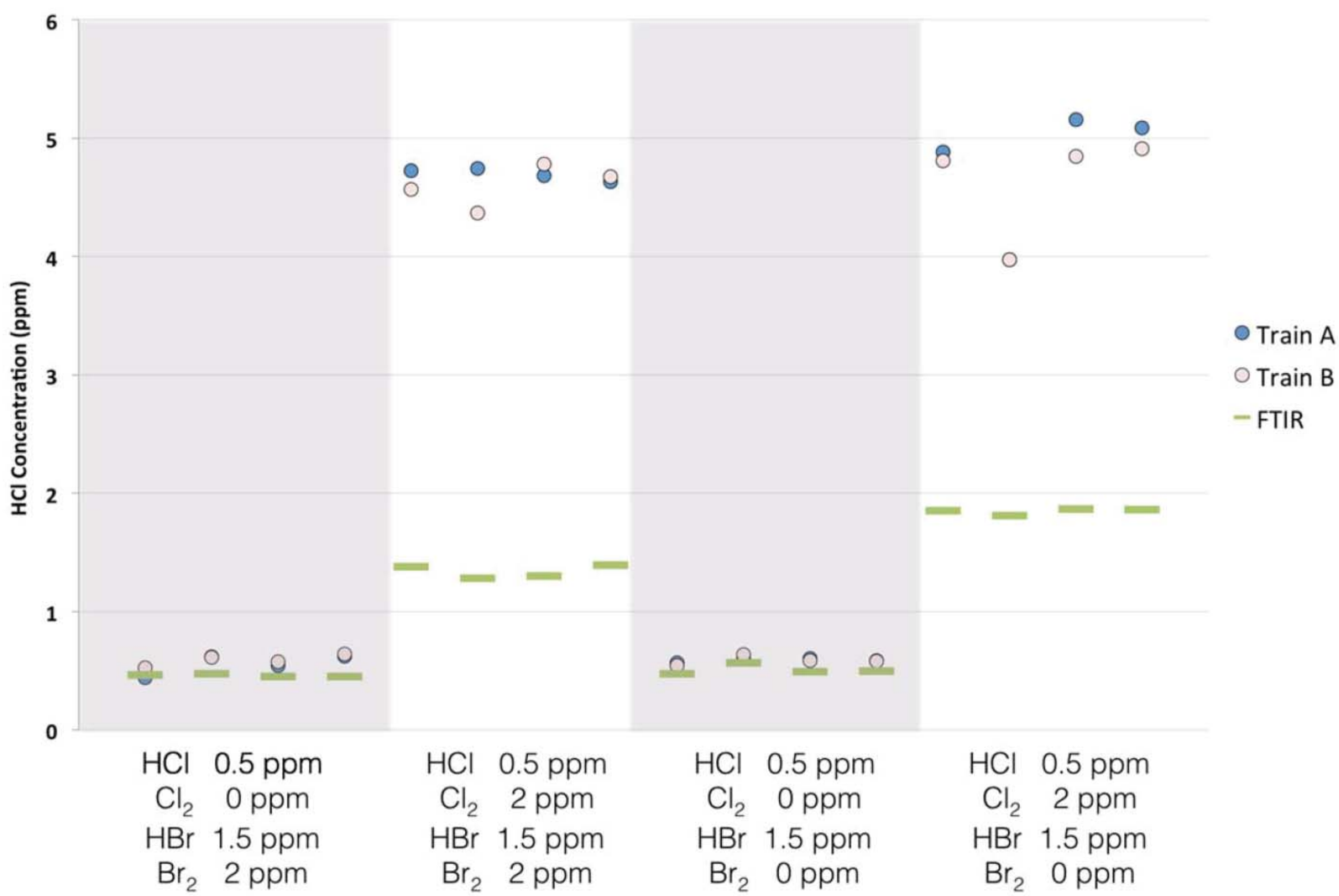



***FIGURE 14: High bias in the reference methods when halogens are present. High bias in FTIR when HBr and $Cl_2$ are present.***

temperature-focused study would also improve our understanding of the role of temperature on acid gas measurements.

Bromine addition to facilitate Hg removal is a growing trend in the power generation industry; thus, the observed conversion between $Br_2$ and HBr and its effect on both method performance and control technology performance should be studied further. A study of varying $Br_2$ and HBr concentrations, along with varying temperatures and flow rates, could help characterize typical kinetic behaviors of bromine in a flue gas stream.

Additional findings and best-practice recommendations for acid gas sampling can be found in the full report available through the EPRI website: http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002003347

*For further Information contact*
*Anthony Milianti at amilianti@cleanair.com*

***BIOGRAPHY***

***Anthony has been with Clean Air for three years and is currently a Project Engineer. He has been actively involved in the management and execution of innovative industry research. Currently, he is involved in research pertaining to emissions control design, new applications for FTIR measurements, and development of new measurement technologies. He holds a Bachelor of Science degree in Chemical and Biochemical Engineering with focuses in Bioengineering, Life Sciences, and Environmental Engineering from the Colorado School of Mines.***

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***Brandon Bettinger,***
***East Kentucky Power Cooperative***

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# Commercial Operation of Electrostatic Precipitator High Frequency Energization in Intermittent Energization Mode at Labadie Energy Center, Units 1 & 2

*Written by David Boll, Ameren; Nicolas Pelech, Ameren; Mick Chambers, Southern Environmental; Hardik Shah, Southern Environmental; Gary Grieco, Air Consulting Associates*


## SUMMARY

Electrostatic precipitator (ESP) high frequency energization in intermittent energization mode (IE mode) is now in commercial operation at Ameren's Labadie Energy Center, Units 1 & 2.

High frequency energization provides a low-ripple secondary waveform that allows for ESP operation at higher secondary voltage and current. IE mode then superimposes corona on/off-times onto this low ripple D-C waveform. High frequency energization in IE mode provides two primary advantages:

1. It overcomes the debilitating effects of high resistivity particulate matter (PM) and is applicable when PM resistivity is mid E+10 ohm-cm, with the degree of effectiveness increasing as PM resistivity increases
2. Owing to frequent waveform off-times, ESP electric power consumption is reduced, and hence ESP operating cost is lower.


The ESP systems at Labadie Energy Center, Units 1 and 2 are competitively-sized and considered "SCA-efficient" ESPs. By contract, performance testing took place with two (2) of the installed PowerPlus™ sets out of service. The Unit 2 system was tested with one (1) set off-line in each ESP, while the Unit 1 system was tested under a significantly more rigorous condition: two (2) sets energizing ESP C, both located within the same cell (gas lane), were out of service during the performance test program.

The Units 1 and 2 ESP systems were individually performance tested and produced similar stack PM emissions rates. More extensive field testing and data analysis was conducted

*FIGURE 15: ESP System Overview*

on the Unit 1 ESP system and so, for the most part, the Unit 1 test results are reported on and discussed in this paper.

Unit 1 has a PM emissions rate of 0.00904 lb/mmBtu (57.1 lb/hr) and a stack opacity of 8.1%. Fly ash resistivity was determined to be 4.5E+10 ohm-cm by means of a modified version of the Bickelhaupt computer program. Air heater outlet/ESP inlet fly ash mass median diameter (MMD) was determined to be 5.6 microns, as measured in-situ by Anderson cascade impactors. Stack PM emissions were similarly measured and found to have a MMD of 1.3 microns. ESP fractional collection efficiencies were determined and these are listed on Figure 19.

Unit 2 was tested with and without benefit of IE mode and stack PM emissions decreased from 0.0109 lb/mmBtu in DC Mode to 0.00850 lb/mmBtu in IE mode. This data determines an ESP migration velocity enhancement factor (w'/w) of 1.158 at a fly ash resistivity of 5.1E+10 ohm-cm. A literature search failed to uncover an IE mode enhancement factor of this magnitude associated with a fly ash resistivity of only 5.1E+10 ohm-cm.

When operating in IE mode, the kW for each SMPS, as collected through Ameren's data acquisition software, was reduced nearly 40-50% when compared to operating in normal mode.

## DESCRIPTION of LABADIE ENERGY CENTER, UNITS 1&2

Units 1 & 2 at Ameren's Labadie Energy Center, located in Labadie, Missouri, are subcritical pulverized coal-fired units, each having a gross generating capacity of 625 MW when firing Powder River Basin (PRB) sub-bituminous coal. Figure 15 shows the overall layout of the plant; Units 1 & 2 are on the left hand side of the photograph.

Units 1 & 2 are dry bottom, tangentially-fired boilers installed by Combustion Engineering in 1966, and each unit has a gross heat rate of 6,300 mmBtu/hr. PRB coals are shipped in from various mines but all have low sulfur content (0.21% on average, by weight). Due to the low sulfur content of the PRB coal, Labadie Energy Center is not equipped with SO2 scrubbing. Figure 17 lists a typical ultimate coal analysis for PRB coal delivered Labadie Energy Center.

Each of Labadie Energy Center's four boilers originally discharged into dry, weighted-wire type electrostatic precipitators (ESPs A & B) arranged in a chevron flow configuration. In 1979 a new rigid-frame type dry ESP (ESP C) was retrofitted in parallel with ESPs A & B. ESP C treated approximately 35% of the total flue gas flow. This upgraded arrangement produced an ESP system PM collection efficiency that was sufficient to meet stack emissions standards in effect at that time provided that $SO_3$ flue gas conditioning was employed to condition the high resistivity fly ash.

Because all three ESPs were installed as stand-alone casings their inlet and outlet ductwork had an unusual geometry, as shown in Figure 15. ESPs A & B were located on the riverside of the plant, while the retrofitted ESP C was (and still is) located on the coal storage side of the plant.

Recently Southern Environmental Inc. (SEI) deployed Synergy ESP technology as an additional upgrade to limit filterable PM emissions to 0.015 lb/mmBtu and stack opacity emissions to less than 10%. In so doing this new ESP system operates without benefit of $SO_3$ flue gas conditioning. There are currently no gas stream additives utilized, although Ameren has made provisions for the future injection of activated carbon and Trona.

Several approaches were investigated to accomplish this more stringent PM emissions and stack opacity goals, with the following two upgrade concepts deemed most favorable:

1. A general upgrade of the A, B, and C ESPs using new high frequency power supplies, wide (16-inch) collecting plate spacing and new ESP internals, in conjunction with improvements to ESP gas flow distribution and also a possible re-biasing of flue gas flow between the three upgraded ESPs.
2. An upgrade of the C ESP by retrofitting new high frequency power supplies in conjunction with construction of a new D ESP in parallel with the upgraded C ESP. For this approach the A and B ESP's would be bypassed and retired. The D ESP was designed with NWL PowerPlus™ high frequency power supplies, 16-inch plate spacing and SEI/ELEX discharge electrodes. The C ESP was retrofitted with NWL PowerPlus™ high frequency power supplies, but otherwise unmodified.

Enlargement of the A & B ESPs for optimum performance was deemed infeasible due to space limitations between the boiler building and ID fans. The D ESP retrofit approach was selected due to superior construction access and greater freedom to properly size a new D ESP. This arrangement is shown in Figure 16; the abandoned A & B ESPs are on the right hand side of the stack, the New D ESP is at the far left

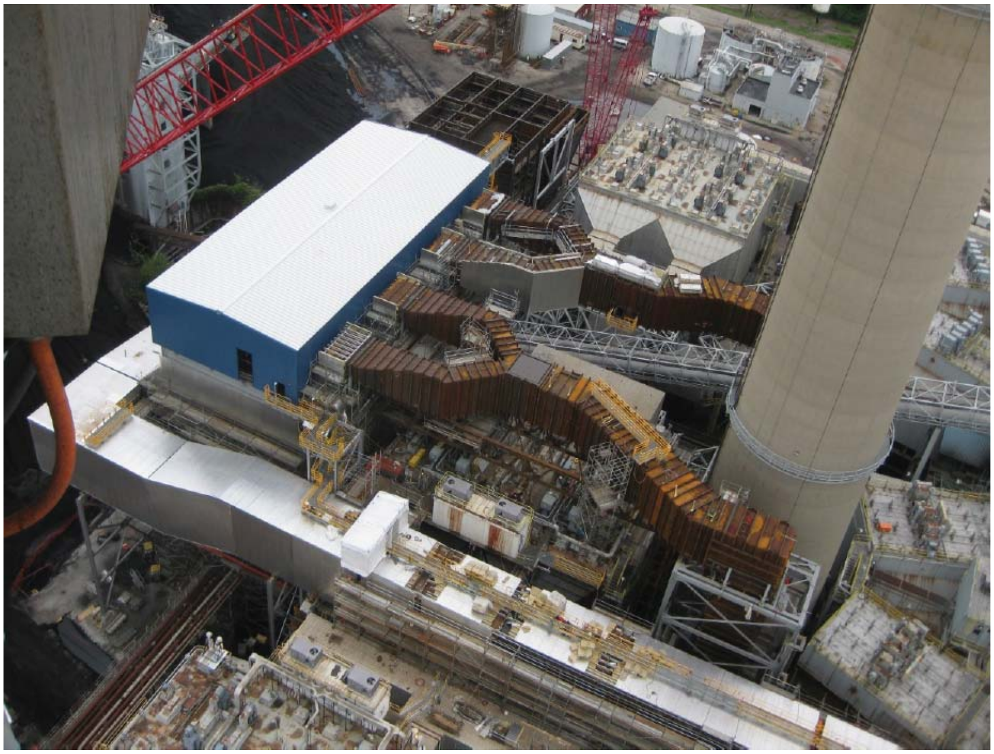

*FIGURE 16: Overall Layout of ESPs A, B & D*

of the photograph, and the C ESP is located beneath the (as yet uninsulated) duct run connecting the outlet of the D ESP to the stack.

## PRB COAL ANALYSIS

Typical coal ultimate and ash mineral analyses for the PRB coals delivered to Labadie Energy Center are detailed on Figure 17 & 18.

| Ultimate Analysis (As-Received Basis) | (%) |
|---|---|
| Moisture | 25.95 |
| Ash | 4.51 |
| Sulfur | 0.21 |
| Carbon | 50.67 |
| Hydrogen | 4.92 |
| Nitrogen | 0.73 |
| Oxygen | 13.01 |
| Total | 100.00 |

*FIGURE 17: Typical Coal Analysis*

The PRB coal's combination of low sulfur and relatively low sodium produce fly ash resistivities between 3.9E+10 and 5.2E+10 ohm-cm at an operating flue gas temperature range of 300 to 360 deg F. This temperature window straddles the peak of the PM resistivity versus gas temperature's bell-shaped relationship.

ESP inlet PM loading was moderately light, ranging from 3.1 to 4.8 lb/mmBtu, which is typical of tangentially-fired boilers originally designed to fire Eastern bituminous coal but were converted to PRB coal firing.

| Ash Mineral Analysis | (%) |
|---|---|
| Silicon Dioxide, SiO2 | 35.27 |
| Aluminum Oxide, Al2O3 | 17.66 |
| Titanium Dioxide, TiO2 | 1.49 |
| Iron Oxide, Fe2O3 | 6.44 |
| Calcium Oxide, CaO | 19.81 |
| Magnesium Oxide, MgO | 4.11 |
| Potassium Oxide, K2O | 0.47 |
| Sodium Oxide, Na2O | 1.38 |
| Sulfur Trioxide, SO3 | 8.76 |
| Phosphorus Pentoxide, P2O5 | 0.90 |
| Manganese Oxide, MnO2 | 4.14 |
| Undetermined | - |
| Total | 100.43 |

*FIGURE 18: Typical Ash Mineral Analysis*

## ESP System Startup and Tuning

During ESP system startup the tenacity of this "pure" PRB fly ash demanded that special care be taken with regard to rapping cycle frequency and intensity. Also the gas flow split between the C and D ESPs was adjusted to ensure maximum performance relevant to the capability of these very differently designed ESPs.

Over a four week span, each of these parameters was fine-tuned in sequence until optimum ESP system performance was achieved. However it was noted that on hot summer days, when the flue gas temperature climbed above 340 deg F due to elevated ambient air temperature, stack opacity gradually crept up throughout the afternoon hours. Secondary voltage versus current (V-I) curves were obtained in order to evaluate the extent of back corona ionization. It was observed that hot afternoon V-I curves displayed signs of mild back corona when compared to V-I curves produced earlier in the day.

This investigation suggested that the implementation of IE mode would be of benefit. In this manner, the potential for developing back corona ionization was reduced, resulting in better and more consistent ESP performance. An additional benefit of IE mode is a reduction in ESP power consumption.

## High Frequency Energization in IE Mode

High frequency energization provides a low-ripple secondary waveform that allows for ESP operation at higher secondary voltage and current. IE mode then superimposes corona on/off-times onto this low ripple D-C waveform. When operated in IE mode, high frequency energization is capable of delivering "on-times" from 0.10 to 10 milliseconds and "off- times" from 0.10 to 99 milliseconds. This favorably compares to a one half cycle (8.33 milliseconds) on-time and a full cycle (16.67 milliseconds) off-time for conventional 60 Hz power supplies. Hence high frequency energization in IE mode provides significantly greater operating flexibility when compared to conventional energization.

Figures 19 & 20 compare a NWL PowerPlus™ set operating in DC mode versus IE mode. Note that this data was not taken at Labadie Energy Center but rather at a similar installation. Figure 19 is an oscilloscope trace of DC mode operation where kVavg = 29.4 and kVp = 30.7. Figure 20 demonstrates IE mode operation with 0.30 milliseconds on-time and 3.3 milliseconds off-time, where kVavg = 26.6 and kVp = 37.4. The 21.8% increase in kVp provides improved charging and precipitation of high resistivity particles without the onset of back corona ionization. Also, the 3.3 milliseconds off-time provides electric energy savings.

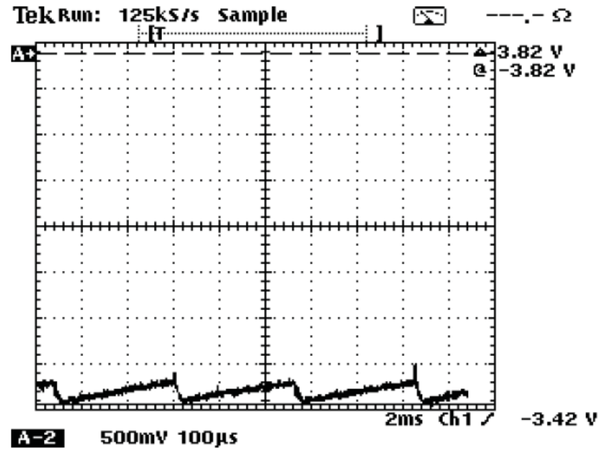


*FIGURE 19*
*DC Mode Operation (reference 3)*

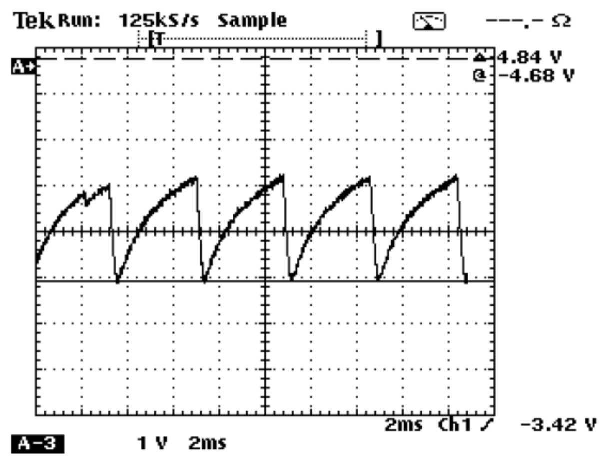


*FIGURE 20:*
*IE Mode Operation (reference 3)*

High frequency energization in IE mode has provided ESP enhancement factors of 1.23 when collecting coal fly ash with resistivities greater than 1E+11 ohm-cm.

## Labadie Unit 1 Performance Test Program

The Unit 1 ESP performance test program took place on February 10-11, 2015. A total of six individual test runs were conducted and then averaged together. Each test run included PM sampling at both ESP inlet test stations (USEPA Method 17) and at the stack test station (USEPA Method 5). In-situ particle size measurements were also conducted during three of the six test runs using Anderson cascade impactors. Particle sizing measurements were conducted at the inlets to the ESPs as well as in the stack. Figure 21 summarizes PM sampling and stack opacity results at Labadie Unit 1.

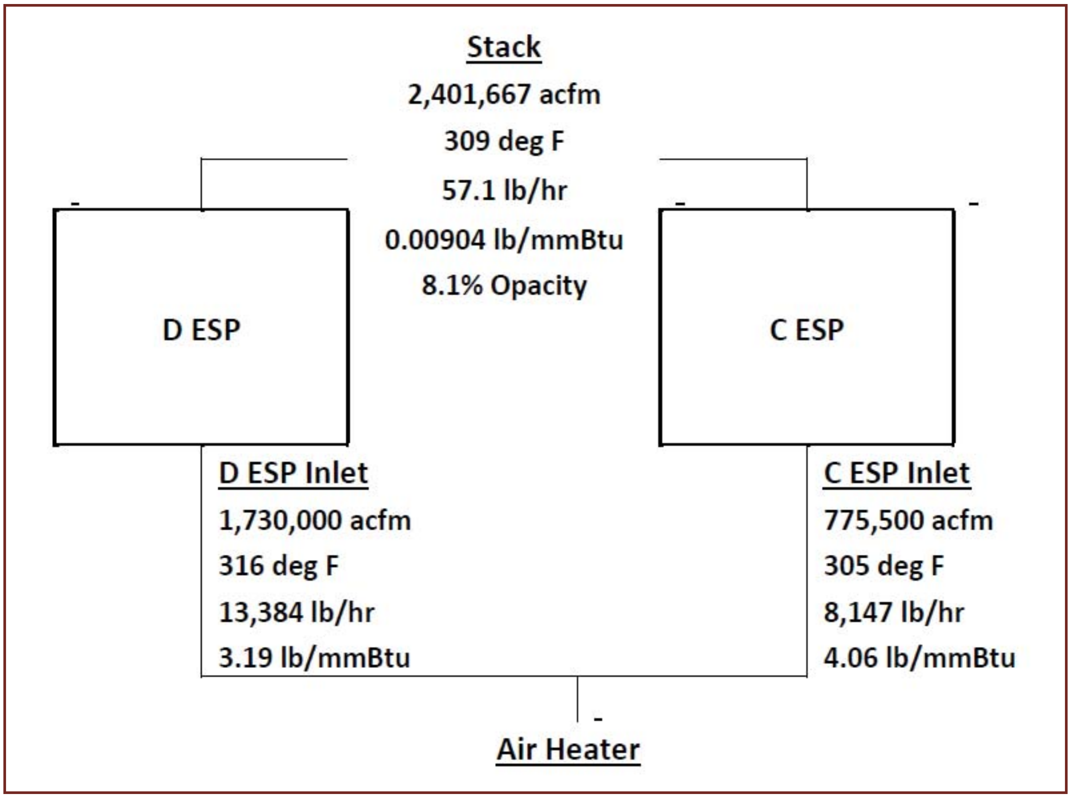


*FIGURE 21: Unit 1 PM Sampling Results (6-Test Run Averages)*

A total fly ash rate of 21,531 lb/hr entered the ESP system and 57.1 lb/hr was emitted, determining an overall ESP system collection efficiency of 99.735%.

The ESP system's design performance goals were 0.015 lb/mmBtu PM emissions and 10% stack opacity, while 0.00904 lb/mmBtu emissions and 8.1% opacity was measured.

| | Duck Creek<br>70% PRB/30% Bituminous<br>ESP in DC Mode | Labadie Unit 1<br>100% PRB<br>ESP in IE Mode |
|---|---|---|
| PM | 99.91 | 99.735 (0.00904 lb/mmBtu) |
| PM 10 | 99.73 | *** |
| PM 5 | *** | 99.54 (0.00713 lb/mmBtu) |
| PM 2.5 | 99.63 | 99.33 (0.00568 lb/mmBtu) |
| PM 1 | 99.37 | 98.68 (0.00393 lb/mmBtu) |
| PM 0.5 | *** | 98.67 (0.00200 lb/mmBtu) |
| PM 0.25 | *** | 98.36 (0.00182 lb/mmBtu) |

*FIGURE 22: Comparison of Duck Creek and Labadie Unit 1 Fractional Efficiencies*

Air heater outlet/ESP inlet fly ash mass median diameter (MMD) was determined to be 5.6 microns, as measured in-situ by Anderson cascade impactors. This is typical for tangentially-fired boilers originally designed to fire Eastern bituminous coal but subsequently were converted to PRB coal firing. Stack PM emissions were similarly measured and found to have a MMD of 1.3 microns. ESP fractional collection efficiencies were determined and are listed on Figure 22.

On Figure 22 Labadie Unit 1's fractional efficiency results are compared to Ameren's Duck Creek Station ESP, an SEI Synergy ESP collecting fly ash from a boiler firing a blend of 70% PRB and 30% Eastern bituminous coals (see Reference 5). While fractional efficiency values appear to compare unfavorably, these differences are solely due to the lighter, finer nature of the "pure" PRB fly ash exiting the Labadie Unit 1 boiler. Most impressive are the ultra-low PM emissions rates determined for PM1 and below.

## Labadie Unit 2 Performance Test with and Without IE Mode

Unit 2 was tested with and without benefit of IE mode and stack PM emissions decreased from 0.0109 lb/mmBtu in DC Mode to 0.00850 lb/mmBtu in IE mode. This data determines an ESP migration velocity enhancement factor (w'/w) of 1.158 at a fly ash resistivity of 5.1E+10 ohm-cm. A literature search failed to uncover an IE mode enhancement factor of this magnitude associated with a fly ash resistivity of only 5.1E+10 ohm-cm.

## Long-term Operation of ESP System

When operating in IE mode, the kW for each SMPS, as collected through Ameren's data acquisition software was reduced nearly 40-50%, when compared to operating in normal mode. The reduction in kW is attributed to the IE mode setting. If the set points were changed the kW reduction would also change.

Because the IE is most effective at high flue gas temperatures, Labadie also had to install logic to turn IE on and off automatically on start-ups and shut-downs based on air heater outlet temperature and stack temperature. It is important to note that to avoid exceedances, IE mode was turned on and off in groups of four SMPSs, in lieu of changing modes all at once. However, because each start-up and shut-down can be unique, Ameren later added logic to provide the operator manual control to turn IE on and off as desired.

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*For further Information contact*
*David E. Boll at dboll@ameren.com*
*Nicolas Pelech at npelech@ameren.com*
*Hardik Shah at hshah@sei-group.com*
*Gary J. Grieco at ggrieco@aol.com*

***BIOGRAPHY***

***David E. Boll of Ameren Missouri has 35 years of experience in the power generation industry. His primary focus has been in the areas of coal-fired boilers and air quality control systems. David holds a B.S. degree in Mechanical Engineering from Washington University in St. Louis, and he is a licensed professional engineer in the States of Missouri and Illinois.***

***Nicolas Pelech has worked in the electric power industry and employed by Ameren for over 15 years with 10 years of pollution control experience. Nicolas holds a B.S. degree in Electrical Engineering from University of Missouri-Rolla and a Masters in Business Administration from Webster University, and is a licensed professional engineer in the State of Missouri.***

***Gary J. Grieco of Air Consulting Associates, LLC has 43 years experience in the air pollution control industry, a career encompassing engineering, R&D, management, and over 30 years as a consultant. His primary areas of interest include dry and wet electrostatic precipitators and novel concepts for particulate removal. Gary has published over 30 technical papers covering these topics. Gary holds a B.S. degree in Aerospace Engineering from Syracuse University and an M.S. degree in Mechanical Engineering from New York University, and he is a licensed professional engineer in the State of New Jersey.***

***Mick. Chambers is a 40+ year veteran of the power industry with the last thirty-five being in the environmental sector. Following studies in Chemical Engineering at the University of Connecticut, he joined the former Combustion Engineering in the mid 1960's, focusing primarily in commercial and business development areas.***

*Early experiences included participation in the development and marketing of first generation wet scrubbing systems, culminating with the sale of the first commercial wet scrubbing system project in the U.S. Following CE's acquisition of PC-Walther in 1977, Mr. Chambers joined that organization and began a long, on-again, off-again association with electrostatic precipitators, highlighted by the sale of two major ESP projects in the People's Republic of China in 1987 and another in the Republic of Indonesia.*

*After a long career with the CE/ABB Environmental Systems organizations, which included experience with wet and dry FGD, ESP, and multi-pollutant capture systems, Mr. Chambers moved to Southern Environmental, Inc. in 1997, serving as the Director of Precontract Operations.*

*Highlights of his time in that position were a significant increase in the company's sales volume and profitability, as well as the company's movement to a dominating position in the utility ESP market. Mr. Chambers retired at the end of 2016.*

*Hardik Shah of Southern Environmental, Inc. has over 11 years of experience in the air pollution control industry. His primary area of focus is applications work with Dry and Wet Electrostatic Precipitators. Hardik holds a B.E degree in Mechanical Engineering from M.S. University, India and M.S. degree in Mechanical Engineering from Ohio University.*

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Reinhold Environmental
3850 Bordeaux Drive
Northbrook, IL 60062 USA
1.847.291.7396
sreinhold@reinholdenvironmental.com


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# Mercury Abatement - A Case Study

*Written by Michael Thiel, Nol-Tec Systems*

## Introduction

As the MATS rule (Mereury and Air Toxics Standards) has taken effect, electric generating units (EGU's) nation wide were required to tighten up their emission standards of mercury. Many of these EGU's were designed and built many years ago before the notion of mercury abatement was conceived. That often made implementing a new mercury abatement injection system very difficult due to space constraints. Injection locations frequently varied from one injection location near grade level to twenty or more injection locations 100 feet or more above grade. With each site subject to such variation, the 'norm' of using eductors to convey powdered activated carbon (PAC) or new generation mercury abatement materials was becoming increasingly difficult. Eductors have advantages and can be a perfect solution for some EGU's with a short injection run, low injection rates, or a small number of injection locations. However, eductors also have many shortcomings and left a large demand for a new technology for those EGU's which require a more complex solution.

## Background in Mercury Abatement Technology

Many EGU's need mercury abatement across multiple units and ducts in order to be in compliance. As injection runs, injection rates, and injection locations increase, eductor sizes needed to increase in order to meet the pneumatic conveying demand. As the eductor size increased, convey pipe length, convey pipe diameter, and blower sizes needed to increase in proportion, due to the large pressure drop through the eductor. Even when these systems were scaled up, many eductor systems were not able to reach all units from a single location, due to the limitations of the technology. Too often, that meant an eductor system had to be designed for each of the EGU's units, which didn't allow all pneumatic equipment to be staged in a single, central location.This increased capital and operating expense.

In anticipation of the unique needs in the mercury abatement market, one leading pneumatic conveying provider had challenged its engineers to design a new single system that would have the capacity to deliver mercury abatement materials over long distances, using high injection rates, and supporting a large number of injection locations. Nol-Tec Systems developed a new generation technology which utilizes pressure technology to overcome the challenges which an eductor system simply could not do on its own. This next generation technology is a portable silo unit which uses a dual weigh hopper configuration. Each hopper uses a rotary valve to meter material into the convey line. What makes this system unique, is that each weigh hopper is pressurized to the convey line pressure, which nullifies the pressure differential between the convey line and the hopper. With no pressure differential across the rotary valve, there is no air leakage up through the rotary valve, which can cause inconsistencies in material flow at high line pressures.

This technology allows for a single system to convey material as much as 1,000 feet away, to 20 injection locations at injection rates of over 1,000 pounds per hour, while maintaining a four-inch main convey line size. With this system, convey piping and blower sizes are kept down, which reduces capital and operational costs. In addition, in today's mercury abatement market, many different sorbents are used which can vary greatly in bulk density. Since eductor systems are designed around a single bulk density, those systems are limited to the variety of sorbents that can be used. This next generation technology is much more flexible than an eductor system, in terms of using various sorbents, as the technology can overcome the differences in bulk densities. EGU's can now be provided with systems that offer the flexibility and reliability needed in a changing and developing market.

## Mercury Abatement Case Study

Challenged by a confidential client to take on one of the most demanding mercury abatement trials in their history, Nol-Tec set out to prove the effectiveness of this non-eductor technology. The challenge was to accurately and reliably inject five different materials used in mercury abatement over many different injection rates through twenty injection lances. The injection lances were located approximately 70 feet above grade, with the two end most injection lances being approximately 60 feet apart. Using approximately 500 CFM of motive air and without injecting any material, this particular configuration yielded a convey line pressure of approximately 3.5 PSI/g. During injection, convey line pressures were between 4 and 5 PSI/g, depending on the injection rate and material. Of the five materials that were injected,


*FIGURE 23: Displays 15 minute average injection rate for entire test run of sorbent #1*

the bulk densities of the sorbents varied from 18- 33 pounds per cubic foot.

The provider company's goal for their next generation technology was to achieve the target injection rate for each sorbent within± 5% of the target rate, and maintain the error margin for more than three hours. Sorbent #1 was tested for a total of eight days with four different injection rates in which were maintained for more than three hours: 400, 600, 800 and 1,000 pounds per hour. Figure 23 shows results and the actual injection rates, which are 15 minutes averages for the entire duration of that test run.

Sorbent #2 was tested for a total of four days with four different injection rates, which were maintained for more than three hours: 300, 600, 900 and 1,200 pounds per hour. Results are shown in Figure 24.

Sorbent #3 was tested for a total of three days with four different injection rates, which were maintained for more than three hours- 500, 600 and 1,400 pounds per hour. Results are shown in Figure 25.

Sorbent #4 was tested for a total of 519 minutes at various injection rates. The provider company was able to maintain

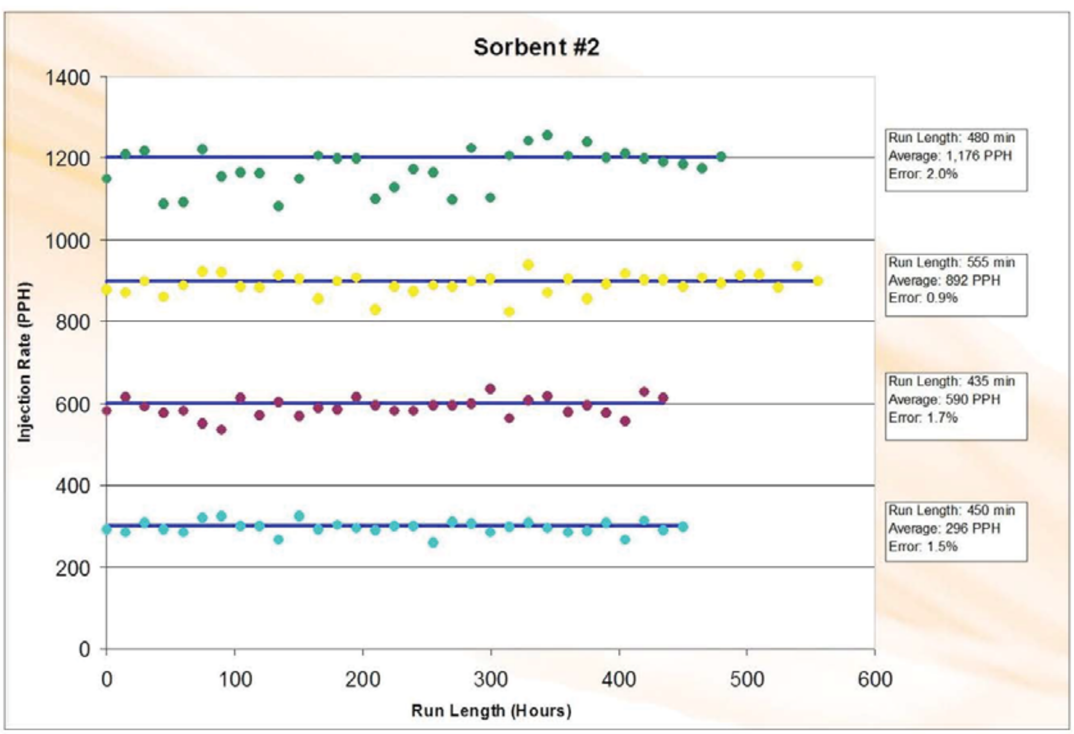


*FIGURE 24: Displays 15 minute average injection rate for entire test run of sorbent #2*

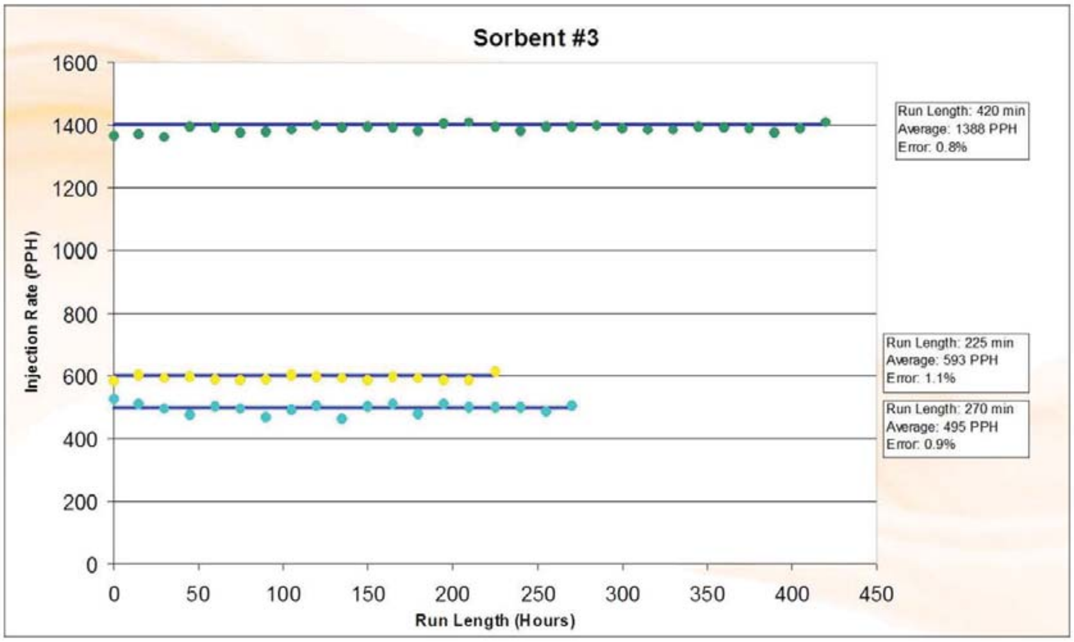


*FIGURE 25: Displays 15 minute average injection rate for entire test run of sorbent #3*

the error margin of less than 5%. However, none of the test runs met the three hour minimum run length and were not included in the injection error analysis.

Sorbent #5 was tested for two days with two different injection rates, which were maintained for more than three hours-400 and 800 pounds per hour. The 400 PPH run was tested for 390 minutes continuously, achieving an error margin of 0.9%. The 800 PPH run was tested for 268 minutes continuously, achieving an error margin of 0.7%.

## Conclusion

In the final analysis, the next generation technology achieved the goal of under 5% error margin for all five sorbents. Without changing any equipment or convey routing, the provider company was able to overcome the differences in bulk density and material characteristics between the five different sorbents and inject reliably and accurately. Mercury abatement regulations can be met with greater flexibility and efficiency with this new, next generation technology and test results fully support the claim.

*For further Information contact*
*Michael Thiel at michaelthiel@nol-tec.com*

***BIOGRAPHY***

***Michael Thiel is a Sales Manager with Nol-Tec Systems, Inc. in Uno Lakes, MN. Nol-Tec is a supplier of pneumatic conveying systems and dry sorbent injection technology known as Sorb-N-Ject®. For more information about Nol-Tec's testing process, please contact Michael at MichaelThiel@nol-tec.com or 651.780.8600. For more information, go to www.nol-tec.com.***

# Case Study on Increasing Fabric Filter Life - Utility Coal Fired Boiler

*Written by Tim Stark, CLARCOR Industrial Air | BHA*

## Introduction

This case history is based on a 740 MW boiler burning PRB low Sulphur coal. The system includes a 3 catalyst layer SCR, air heater, carbon injection system using 8% brominated PAC for Hg removal, a two vessel SDA and a baghouse. The baghouse consists of:

- 14 compartments
- 16,800 filter bags; 8 meters long with 2 piece cages

The original filters were fiberglass media. These were changed to PPS media with a PTFE bath treatment. After 3 years of operation, the filter pressure drop rose to a level that caused the plant to go into off-line cleaning mode during low loads. The plant also was continuously changing failed filters due to abrasion and this became the highest cost of operation for the entire scrubber. The abrasion appeared to be caused by several sources.

## Failure Modes Experienced

Abrasion:

The first failure mode was at the top snap band connection of the filter to the tube sheet. The abrasion in this area is from two sources-the movement of the bag top against the cage top, and the abrasion from the pulse cleaning energy.

Another abrasion failure was where the filters would rub against each other and against compartment structures. These failures would occur in the first two bags of each row and the 20th and 21st row where the compartment is split in half.

The next area of failure was the outside corners, where build-up of hard deposits on the bottom 2 feet of the media would lead to splits in the filter bags.

Cage Joint Wear:

The middle point of the filter bags where the two-piece cage connection is made would also lead to excessive movement in that region, leading to failures.

Snap Band Cuff Wear:

Wear at the top snap band connection of the filter to the tube sheet came from two sources-the movement of the bag top against the cage top, and the abrasion from the pulse cleaning energy. As with the other failure modes, when this type of failure leads to dust in the clean air plenum, the problem is amplified from the dust getting pulsed back into the top of the filters.

*FIGURE 26: Failure at top snap band cuff*

Blinding:

Moisture conditions coupled with carry-over of ammonia bisulfate (ABS) led to blinding of the filter media and high pressure drop across the filters, forcing off-line cleaning to maintain air flow.

## Addressing the Issues

There were several different approaches taken to address these issues:

- Extended filter bottom cuff from 4” to 8”
- Changed snap band top material of construction
- Changed cage top design
- Included mid-bag wear strip band at two piece cage

connection

- Modifications to the compartment inlet design to decrease velocity levels
- Filter fabric style, weight and finish

The solution that answered each of the issues ended up being a switch to pleated elements versus the standard bag & cage arrangement. The first two rows of bags and cages in front of the inlet of each compartment were replaced with pleated elements in 2012. In 2013, the front three rows were replaced with pleated elements. At that point, the majority of the failures migrated to the 4th and 5th rows in each compartment. In 2014, one entire compartment was re-bagged with pleated elements and in March of 2015, the remainder of the entire baghouse system was re-bagged with the pleated elements.

The pleated element one piece design addressed several of the issues:

- Top design keeps filter from swaying in the tube sheet-eliminates bag-to-bag contact and cage-to-snap band contact.
- Single piece design-eliminates cage joint movement.
- While the pleated elements are shorter than the 8 meter filters, the pleated design maintains the same cloth area-eliminates the velocity issues at inlet and the problems with material build-up in the corners
- Using the shorter pleated elements removed filtration surface from the high velocity area directly in front of the inlet to each compartment, decreasing overall movement of the filters.
- The shorter element design created a large drop-out zone below the filters that leads to lower velocity levels. This allows for more drop-out of particulate and less grain loading to the filters.

**Results/Cost Justification**

- Labor & Material costs: Labor costs are less with the pleated design. This approach also eliminates the cost of the cage.
- Life Expectancy: Current estimates are 25% increase in filter life in addition to elimination of the monthly maintenance costs of replacing failed filters.
- Pulse Air usage: Standard filters required 50 to 75 psi, causing the plant to install a 2nd compressor. Pleated filters to-date are requiring 43 psi to maintain pressure drop.
- ID Fan: Pleated elements are running a consistent lower pressure drop than the filters, leading to a reduction in energy usage.
- Inspection & Replacement: Pleated elements requiring yearly versus quarterly inspections leading to savings in labor & materials plus avoiding the potential of a load derate.

***FIGURE 27: Pleated Element to replace filter bag and cage assembly***

*For further Information contact*
*Tim Stark at timothy.stark@clarcor.com*

***BIOGRAPHY***

***Currently the sales director for CLARCOR Industrial Air | BHA, Tim Stark brings 30 years of industrial filtration expertise to customers. He has served in a variety of capacities allowing him to gain a wide breadth of experience troubleshooting industrial ventilation systems in the power generation industry, as well as most industrial manufacturing industries. Tim helps customers improve their operation, providing application knowledge and filtration insights.***

***Tim frequently works with customers on-site helping to train maintenance supervisors, technicians, plant engineers and managers on filtration and dust collection. He is the company's industrial filtration specialist for power generation applications. He holds a bachelor's of science degree in electronic engineering technology from Pittsburg State University, and is Lean/Six Sigma Green Belt certified.***

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**WPCA Chairman**
**Susan Reinhold,**
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**Reinhold Environmental Ltd.**
3850 Bordeaux Drive, Northbrook, IL 60062 USA
Email: sreinhold@reinholdenvironmental.com

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**Global Director, Environmental Controls**
**Stock Equipment Company**
16490 Chillicothe Rd, Chagrin Falls, OH 44023
Email: jason.horn@stockequipment.com

**WPCA Treasurer**
**Robert Mudry,**
**President**
**Airflow Sciences Corporation**
12190 Hubbard Street, Livonia, MI 48150 USA
Email: rmudry@airflowsciences.com

**WPCA Vice President**
**Nate White,**
**Director, Business Development of APC**
**Haldor Topsoe, Inc.**
5510 Morris Hunt Dr., Fort Mill, SC 29708 USA
Email: tnw@topsoe.com

**David Novogoratz,**
**Manager of Environmental Products**
**Babcock & Wilcox**
20 S. Van Buren Ave., Barberton, OH 44203 USA
Email: dmnovogoratz@babcock.com

**Clayton Erickson,**
**Manager, Process Engineering**
**Babcock Power Inc.**
5 Neponset Street, Worcester, MA 01606 USA
**cerickson@babcockpower.com**

**Allen Kephart,**
**President**
**CleanAir Engineering**
110 Technology Dr., Pittsburgh, PA 15275
Email: akephart@cleanair.com

**Mark Ehrnschwender,**
**Vice President**
**Steag SCR-Tech**
304 Linwood Rd, Ste.102, Kings Mountain, NC 28086 USA
Email: mark.ehrnschwender@steagscrtech.com

**Tim Stark,**
**Director - Industrial Filtration Sales**
**CLARCOR Industril Air**
11501 Outlook St., Ste. 100,
Overland Park, KS 66211 USA
Email: timothy.stark@clarcor.com

**Michael Hatsfelt,**
**General Manager**
**Southern Environmental, Inc.**
6690 West Nine Mile Rd., Pensacola, FL 32526
Email: mhatsfelt@sei-group.com

**Blake Stapper,**
**Business Manager**
**AECOM**
9400 Amberglen Blvd., Austin, TX 78729 USA
Email: blake.stapper@aecom.com

**Curt Biehn,**
**Director of Marketing**
**Mississippi Lime**
3870 S. Lindbergh Blvd., St. Louis, MO 63127
Email: crbiehn@mississippilime.com

**Paul Ford,**
**President**
**Redkoh Industries**
300 Valley Road, Hillsborough, NJ 08844 USA
Email: paul.ford@redkoh.com

**Sharon Sjostrom,**
**Chief Product Officer, Market Strategy**
**ADA-ES, Inc.**
9135 S. Ridgeline Blvd., Ste 200,
Highlands Ranch, CO 80129 USA
sharons@adaes.com

**Erik Johnson,**
**Executive Vice President - CMO**
**Nol-Tec Systems, Inc.**
425 Apollo Drive
Lino Lakes, MN 55014 USA
Email: erikjohnson@nol-tec.com

# WPCA Officers

**WPCA President**
**Melissa Allen, Environmental Systems Manager,**
**TVA**

**WPCA Vice President**
**Grant Hilbers, Engineering Supervisor**
**DTE Energy**

# WPCA Advisors

**Greg Betenson,**
**Principal Engineer,**
**PacifiCorp**

**Melanie McCoy,**
**Superintendent**
**Sebewaing Light & Power**

**Ebrahim Patel,**
**Senior Consultant - APC,**
**ESKOM-GTD**

**Bruce Salisbury,**
**Engineering Supervisor,**
**Arizona Public Service**

**Scott Williams,**
**Principal Engineer,**
**Duke Energy**

**Darren Hanby,**
**Principal Engineer,**
**AEP**

**Brandon Bettinger**
**Chemical Engineer**
**East Kentucky Power Cooperative**