# Advanced Flue Gas Conditioning as a Retrofit Upgrade to Enhance PM Collection from Coal-fired Electric Utility Boilers

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# ABSTRACT

The U.S. Department of Energy and ADA Environmental Solutions are engaged in a project to develop commercial flue gas conditioning additives. The objective is to develop conditioning agents that can help improve particulate control performance of smaller or under-sized electrostatic precipitators on utility coal-fired boilers. The new chemicals will be used to control both the electrical resistivity and the adhesion or cohesivity of the fly ash. There is a need to provide cost-effective and safer alternatives to traditional flue gas conditioning with $SO_3$ and ammonia. During this reporting quarter, further laboratory-screening tests of additive formulations were completed. For these tests, the electrostatic tensiometer method was used for determination of fly ash cohesivity. Resistivity was measured for each screening test with a multi-cell laboratory fly ash resistivity furnace constructed for this project. Also during this quarter chemical formulation testing was undertaken to identify stable and compatible resistivity/ cohesivity liquid products.

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**(updated through 06/01)**

# INTRODUCTION

The objective of this program is to develop a family of cohesivity modifying flue gas conditioning agents that can be commercialized to provide utilities with a cost-effective means of complying with particulate emission and opacity regulations. Improving the cohesivity and agglomeration of fly ash particles is a proven means of increasing the collection efficiency of an electrostatic precipitator (ESP). Optimizing these properties in combination with control of electrical resistivity is vital to the overall collection efficiency of ESPs, and flue gas conditioning may provide the most cost effective means in today's deregulated utility market for plants to meet DOE's goals of 0.01 lb/Mbtu and 99.99% collection efficiency in the particle size range of 0.1 to 10 microns.

This new class of additives is needed because currently available agglomerating aids on the market require the storage and handling of large quantities of ammonia, which under recent legislation has been classified as extremely hazardous and necessitates extensive risk assessment and emergency response plans. There are also operating conditions and coals where the ammonia-based technologies are not effective and treated ash may be unusable for recycle applications or difficult to dispose due to ammonia vapor off-gas.

This quarterly report covers technical work undertaken on the project from April through June 2001. During this period work was underway on Task 2, *Selection and Evaluation of Candidate Additives,* and Task 4, *Long-term Site Selection*. Under Task 2, formulation development work continued. This involved additional preparation of trial batches of a combined resistivity/cohesivity formulation designated ADA-43. Physical specifications, chemical stability, and Material Safety Data Sheets were developed in preparation for a planned full-scale application later in 2001. On Task 4, discussions and proposals to two potential plants for a long-term demonstration were prepared during the quarter. Figure 1 shows duct and ESP arrangement at one of these potential long-term sites.

**Figure 1: Inlet Duct and ESP at Potential Long-Term Site**

# EXPERIMENTAL

## Additive Formulation

In the prior reporting quarter two additional polymers had been investigated for cohesivity and chemical compatibility with the resistivity modification chemicals. One of these is commonly used as a lubricant in numerous materials and is also used as a food additive (preservative). The second polymer is a common water treatment chemical. Both of these chemicals exhibit low toxicity and are temperature stable to more than 350°F. They are also stable in solution with the ADA-43 resistivity chemical, making them good candidates for a combined additive.

During this quarter a final blended mixture of these chemicals was developed. Physical testing was conducted for development of Material Safety Data Sheet and product specification. In addition, samples were diluted in samples of power plant service water to check for bacterial and biological growth.

## Fly ash Resistivity

Cohesive properties of fly ash conditioned with various polymers, moisturizers, and other materials has been evaluated previously in the laboratory using test methods adapted from prior work at the Southern Research Institute.[1,2,3] Results of the cohesivity screening have shown that the best resistivity-modification additives do not show any significant cohesive properties when tested with the reference PRB fly ash.[1] This may be in part a result of the lower resistivity overcoming intra-layer electrostatic holding forces.

Conversely, the best-performing cohesion agents that have been evaluated to date either have no effect on electrical resistivity or can tend to increase resistivity in the surface conduction temperature region below 400°F. Therefore the final formulations need to be further evaluated in the laboratory for resistivity effect prior to commitment to a full-scale evaluation.

Additional fly ash resistivity tests were completed to verify the performance of the combined additive formulations with fly ash obtained from a potential test site. Tests were run for a western subituminous ash at two different levels of conditioning. Samples were conditioned in the ADA-ES Additives Spray Chamber. Fly ash resistivity was then measured in the laboratory furnace as previously described.[1,4]

# RESULTS AND DISCUSSION

## Fly Ash Resistivity

Additional resistivity tests were completed for the final blended additive, ADA-43, as shown in Figure 2. In addition, a baseline test of the fly ash resistivity without flue gas conditioning was completed. Tests were carried out with a western subituminous fly ash from a plant that is a potential long-term test site.

As can be seen, the baseline resistivity was only $10^{10}$ ohm in the expected temperature range of 300 – 350°F (150 - 177°C). This is comparatively low and does not agree with the operational experience at the plant with this coal and fly ash. However, it is a common experience that laboratory resistivity often fails to match in-situ results. For an ascending resistivity/temperature curve the laboratory results can be lower by an order of magnitude or more. One further factor in this instance was that the fly ash sample had been stored in open air for several months prior to analysis. The tests are run at constant humidity but the ash may have retained additional adsorbed moisture during the lengthy storage period.

Although the absolute level of resistivity is expected to be higher than laboratory tests indicate, the relative change with flue gas conditioning is consistent with expectations for resistivity modification. The conditioned samples were typically more than an order of magnitude lower than the baseline in the temperature range of interest. This confirms that the blended additive, ADA-43, with cohesivity polymers will be effective as a resistivity conditioner for this fly ash. Not surprisingly, the plant reports that $SO_3$ conditioning is similarly effective (although high temperature excursions present problems).

Overall, the laboratory test data and plant experience with flue gas conditioning are consistent. Resistivity modification can substantially improve ESP performance during episodic periods of poor coal quality or high temperature process excursions. Additional ash cohesivity will also be beneficial to reduce rapping and non-rap re-entrainment once optimized. Given the significant changes to opacity compliance procedures that will be required at this plant (see below) and the recognized need for supplemental flue gas conditioning with some coals, this appears to be an ideal long-term test site for this program.

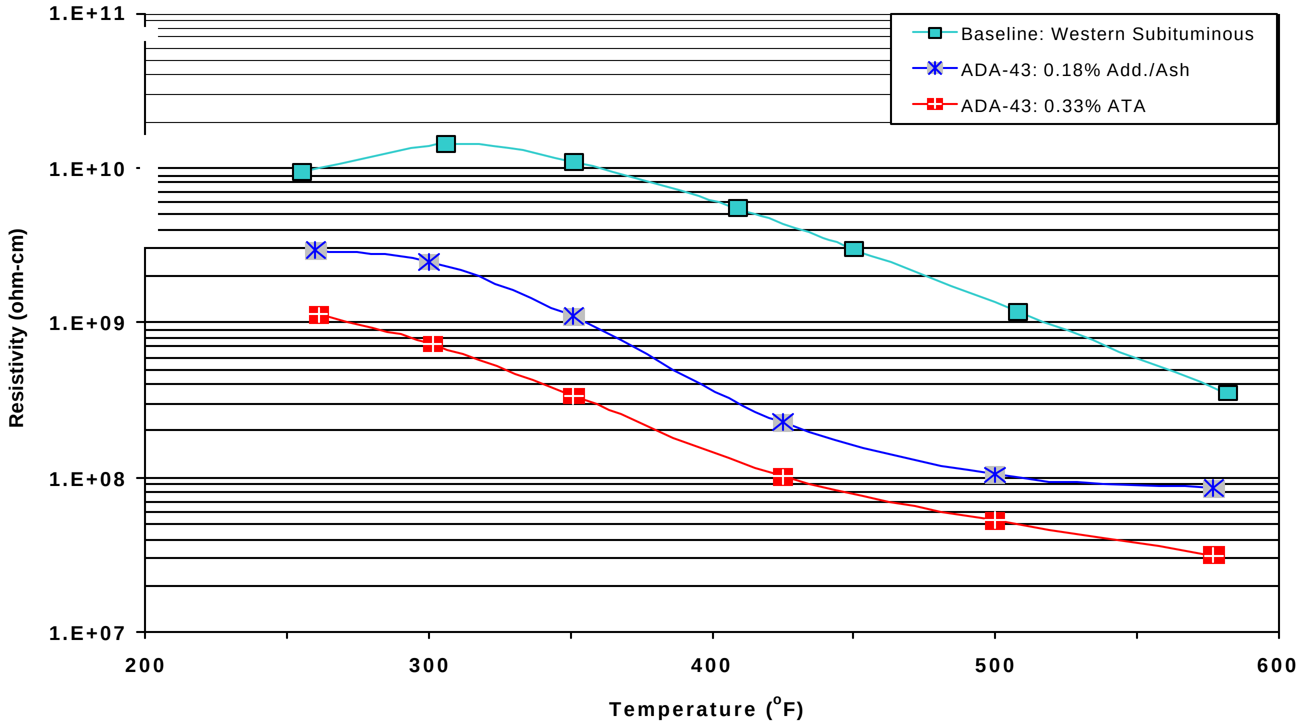


**Figure 2: Fly ash Resistivity with ADA-43 Final Blend**

## Additive Formulation

A combined additive blend consisting of ADA-43 in combination with Polymers #7 and #8 was evaluated for performance and long-term stability during this reporting quarter. Target concentration of the final product was 40% by wt. in aqueous solution. Diluted samples were prepared with service water from several power plants to determine the need for additional biocide. Long-term results over more than two months indicate that the blend is stable as formulated and should not require specific biocide (one of the polymers is commonly used as a preservative in food products). Thus, in this instance the cohesion component is also an effective biological growth inhibitor. A final Material Data Safety Sheet will be developed for this product and it will be the initial product to be tested full-scale.

# COMMERCIALIZATION ACTIVITY

ADA-ES has been actively promoting and seeking utility partners for the full-scale test and demonstration phase of this project. Table 1 summarizes the activity to date for the project. Recently, site visits and detailed proposals have been completed at two plants, Wisconsin Electric Power Company (WEPCO) Port Washington in Wisconsin and PacifiCorp's Jim Bridger Power Plant in Wyoming. At the time of this report proposals were under consideration. A summary of each of these is presented below as an illustration of the real-world problems and applications that liquid flue gas conditioning and the technologies being developed through this program can address.

## WEPCO Pt. Washington

Port Washington consists of four 85 GMW units located near Milwaukee Wisconsin. These are older (late 1930s design) Riley indirect fired units in a down-fired configuration. ESPs were retrofit in the 1950s and then completely rebuilt by Research-Cottrell with wide plate spacing (16 inch centers) in the early 1990s. The ESPs are downstream of the ID fans and thus are under positive pressure. Units 1-3 share a common stack but have individual duct opacity monitors. Unit 4 has a dedicated stack. Units 1 and 3 inject sodium bicarbonate upstream of the ID fans for $SO_2$ control. Units 2 and 3 are equipped with Chemithon $SO_3$ injection systems, which are no longer in operation. The flue gas entering these ESPs is hot. Full load gas temperatures leaving the air heaters range from 385 to 425°F (195 to 220°C). $SO_3$ injection is ineffective above 350°F (175°C). Liquid flue gas conditioning with ADA-43 is not temperature-limited. The units at Port Washington are scheduled for decommissioning starting with Unit 1 in 2002 and all four by 2004. Therefore, the range of options available must be limited to lower capital costs.

Until approximately one year ago, the opacity at Port Washington was maintained below 5% at most times, without any $SO_3$. In early 2000 they began to have occasional periods of higher opacity on seemingly random units. In mid January 2001 the problem suddenly became much worse. Units 1-3 have been constantly derated by 15 to 25 MW. Fuel is the suspected root cause. The once consistent fuel supply has been changing recently. One mine has run out and coal is now being burned from a number of different sources. These are all Eastern bituminous coals that are fairly close in ultimate analyses and ash mineral make up. Opacity traces do not indicate severe re-entrainment although additional ash cohesion could be beneficial, in common with most small ESPs.

## PacifiCorp Jim Bridger Power Plant

Jim Bridger Power Plant is located in south central Wyoming and fires subituminous coals from several nearby mines. The plant has four 520 MW units, all of which have FGD scrubbers installed. Particulate control equipment consists of cold-side ESPs of intermediate size (Flakt, 488 $ft^2$/kacfm specific collection area, rigid discharge electrodes). Unit 3 has an $SO_3$ conditioning system installed and operational. The plant has periodic episodes of poor ESP performance, primarily due to low sodium coal from various seams within the mines. In addition the plant will soon be required to re-install compliance opacity monitors downstream of the wet FGD scrubbers. Due to this regulatory change and periodic episodes of poor coal quality, there is a need for supplemental flue gas conditioning to maintain acceptable precipitator performance.

In this instance the primary FGC requirement is for resistivity modification. However this is also an opportunity to evaluate cohesivity effects of conditioning. The duct opacity monitors installed between ESP and FGD scrubber can be maintained as non-compliance monitors. This will allow a detailed assessment of real-time rapping and re-entrainment with and without flue gas conditioning. In addition, a full-scale trial will provide an opportunity to evaluate chemical handling and storage, fly ash characteristics, and other critical information that must be developed and tested full-scale in order to introduce any new commercial FGC product.

Initial site visits and proposal have been presented to plant management and engineering. Technically, this is an excellent site for liquid flue gas conditioning due to the size and arrangement of ductwork leading to the electrostatic precipitator. Figure 1 shows a side view of the ducting arrangement for three of the units. There are existing injection ports with as much as 40 ft. (10.2 m) of open duct prior to turning vanes and other flow obstructions. In addition, the plant has an existing mothballed spray humidification system that may be adaptable for flue gas conditioning.

Overall, the laboratory test data and the plant's prior experience with flue gas conditioning indicate that resistivity modification can substantially improve ESP performance during episodic period of poor coal quality and/or during high temperature process excursions. Additional ash cohesivity will also be beneficial to reduce rapping and non-rap re-entrainment once optimized. Given the significant changes to opacity compliance procedures that will be required at this plant and the recognized need for supplemental flue gas conditioning with some coals, this appears to be an ideal long-term test site for this program.

## CONCLUSION

Formulation and long-term stability tests of a final trial blend of cohesivity additives with the best resistivity chemical were completed during the quarter. This blend, designated ADA-43, has also been evaluated for cohesive and resistivity properties in the laboratory. Conditioning of the reference PRB fly ash increased layer tensile strength and lowered resistivity of an ash layer conditioned at 0.3% ATA. This is close to expected full-scale application rate.

Additional commercialization activity is underway to secure a long-term test and demonstration site for this program. Two plants have recently been visited and proposals presented to management and engineering. One of these is considered high probability due to a changing opacity compliance situation and a stated need for flue gas conditioning capability by fall 2001. In addition to these proposals and continued follow-up with utilities previously contacted about this project, technical papers will also be given presenting some of the test results with the combined additive formulation ADA-43.

ADA-ES is now focusing efforts on full-scale testing and demonstration of the developed additives. These tests will provide data on chemical handling characteristics, performance in a flue gas environment and on any effect on conditioned fly ash. ESP performance data and post-injection duct condition are two other key characteristics that can only be evaluated full-scale.

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2. Pontius, D. and Snyder, T., "Measurement of the Tensile Strength of Uncompacted Dust Aggregates" in Powder Technology, 1991, pg. 159 –162.
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4. IEEE Standard 548- 1984; IEEE Standard Criteria and Guidelines For the Laboratory Measurement and Reporting of Fly Ash Resistivity, 1984.

# LIST OF ACRONYMS AND ABBREVIATIONS

ATA – Additive-to ash weight ratio, %

CMC - Carboxymethylcellulose

$D_{max}$ - Maximum spray droplet physical diameter, microns

DOE – U.S. Department of Energy

ESP – Electrostatic Precipitator

ET – Electrostatic Tensiometer powder and fly ash cohesive measurement method

FGC – Flue gas conditioning for particulate control

FGD – Flue Gas Desulfurization

IEEE – Institute of Electrical and Electronic Engineers

KV – kilovolt

MW – megawatt

PAM – Polyacrylamide polymer

PM – Particulate matter

PRB – Powder River Basin coals and resulting fly ash

SRI _ Southern Research Institute

V/I – Voltage/current

## Table 1: Commercialization and Demonstration Activities (updated through 06/01)

| Utility | Plant | Phone/Letter Contact | Meetings/ Headquarters | Meetings/ Plant Visit | Proposal | Follow-up | Status |
|---|---|---|---|---|---|---|---|
| Ameren CIPS | Coffeen<br>Newton | X | X | X | X | X | Installing SO3 conditioning, no immediate application. |
| City of Ames, Iowa | Ames Municipal Power Plant | X | X | X | X | X | Test completed, additional chemical ordered |
| City Utilities of Springfield | Springfield Mo. | X | | | | X | Possible interest |
| Central Louisiana Electric Co. | Dolet Hills | X | X | | | X | Currently using ammonia conditioning, no immediate need. |
| Duke Power | Corporate & Belews Creek | X | X | | | X | Oh hold, no immediate applications. |
| Dynegy Midwest Generation | Hennepin Station | X | X | X | X | X | Possible application as combined FGC or as supplement to SO3. |
| Electric Energy Inc. | Joppa Generating Station | X | X | | | X | Installed humidification, no immediate application. |
| Great River Energy | Coal Creek Station | X | X | X | X | X | Does not appear that FGC will fix immediate problems. |
| Indianapolis Power and Light | Corporate/Various | X | X | | | X | Considering FGC, no immediate applications. |
| Pacificorp | Jim Bridger | X | X | X | X | X | New interest, high probability |
| Public Service Electric and Gas | Mercer Generating Station | X | | | | X | Follow-up and site visit required. |
| Sikeston Board of Municipal Utilities | Sikeston Station | X | | | | X | Possible interest |
| Southern Co. | Corporate<br>Harley Branch Gadsen<br>Mitchell | X | X | | | X | Possible interest |
| Wisconsin Electric Power Co. | Corporate & Port Washington Plant | X | X | X | X | X | Mechanical upgrades and rapping optimization corrected immediate problems. |
| Xcel/Northern States Power | Black Dog<br>King Station | X | X | X | X | X | Several plant visits, pending outcome of staged ESP mechanical upgrades. |