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.

This quarterly report summarizes project activity for the period April - June, 2003. In this period there was limited activity and no active field trials. Results of ash analysis from the AEP Conesville demonstration were received. In addition, a site visit was made to We Energies Presque Isle Power Plant and a proposal extended for a flue gas conditioning trial with the ADA-51 cohesivity additive. It is expected that this will be the final full-scale evaluation on the project.

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INTRODUCTION

This report presents supplemental results and conclusions from a trial of flue gas conditioning additives at the American Electric Power Conesville Plant, Unit 3. The developed flue gas additives were evaluated at full-scale in a unit that has moderate to severe reentrainment problems that are exacerbated by unburned carbon in the fly ash. Such conditions are representative of many other plants due to the widespread adoption of low-NO_x burners and other technologies that tend to reduce combustion efficiency and increase unburned carbon.

The Department of Energy National Energy Technology Laboratory (DOE NETL) and ADA Environmental Solutions (ADA-ES) are collaborating on a project to develop advanced commercial flue gas conditioning additives. The objective of this project is to develop advanced commercial flue gas conditioning additives that can help improve fine particulate control performance of electrostatic precipitators (ESP) on utility coal-fired boilers. Improvements in performance of existing ESPs may be necessary in coming years to meet a variety of new air pollution regulations including fine-particle (PM 2.5) and particulate air toxics. Secondary objectives related to commercialization of the technology include improving in-duct liquid delivery systems, characterizing conditioned fly ash for disposal or utilization, and development of accurate capital and operating costs.

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 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 to meet existing particulate emission standards and upcoming standards for fine particulate emissions.

In addition, cohesivity conditioning may be required in combination with emerging dry sorbent pollution control technologies. Dry sorbent injection for mercury capture (activated carbon, recycled ash) or for sulfur trioxide control (alkali and/or alkaline earth dry sorbents) may simultaneously increase ESP inlet particulate loading and reduce the cohesion of collected particulate. In such situations, cohesivity-specific conditioning may be required to maintain acceptable ESP performance.

The new class of non-toxic 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 report presents updated results of fly ash characterization from the full-scale trial of two cohesivity-specific additive formulations, ADA-44C and ADA-51, at the American Electric Power Conesville plant.

EXPERIMENTAL

Experimental activity this quarter was limited to completion of trial results from the AEP Conesville demonstration. Fly ash TCLP results were received and reviewed. Leachability of RCRA metals from slurried fly ash is of interest for plants with wet ash handling and disposal, such as Conesville. Any conditioning agent could, potentially, affect leachability by chemical alteration of the glassy fly ash matrix. While no effect was anticipated, testing was performed as a precautionary measure.

Further fly ash characterization is needed to confirm the suitability of ash conditioned with ADA-51 for concrete admixture. However, the Conesville Unit 5 ash is not useful for this testing due to the high unburned carbon content. The upcoming test at We Energies Presque Isle Power Plant may provide a higher pozzalanic content ash from which conditioned ash samples can be tested for concrete admixture. Carbon separation from the ash by non-thermal method may be required to complete these tests.

RESULTS AND DISCUSSION

AEP Conesville: Fly Ash Characteristics

One of the concerns of this or any cohesivity conditioning is the potential to generate "sticky ash" that can lead to ash buildup on the collection plates or hoppers. This can, for example, be a problem with dual SO_3/NH_3 conditioning if sticky ammonium bisulfate condenses on the ash. However, at the rates required to increase fly ash cohesion, sticky ash is typically not a problem except in episodes of severe over-conditioning. There were no reported problems with fly ash transport or with hopper emptying for any of the cohesivity additives for the Conesville tests. Another indicator of steady-state ESP operation with normal ash removal from the plates and electrodes was the relatively constant electrical characteristics over the long-term test.

During the program fly ash hopper samples were periodically collected and analyzed to document any changes due to conditioning or any fuel-related changes. Composite samples were taken from the front field hoppers (ESP Fields 1 and 2).

Selected hopper fly ash samples were analyzed for elemental composition and for Loss-On-Ignition (LOI). Results are summarized in Table 6. The most notable characteristics of this analysis were the consistently moderate LOI compared to pre-test expectations and the extremely high iron content of the ash. It was expected that LOI would approach 20% in the fly ash but, at least in all of these samples, it was much lower. One possible explanation for this is that the LOI carbon may be re-entraining from the front fields and hoppers and could be enriched in the outlet hoppers and stack particulate emission.

High iron can be indicative of a low resistivity fly ash, as explained above. This could be a contributing mechanism for the reentrainment problem on Unit 3. Low resistivity ash could result in plate scouring at the operating face velocity of 4.7 ft/sec.

Selected hopper fly ash samples have been analyzed for RCRA metals leachability via standard Toxicity Characteristic Leaching Procedure (TCLP)[1]. In addition, samples were analyzed for mercury leachability via an alternate and more rigorous protocol, Synthetic Groundwater Leaching Procedure[2]. Results of the leachability tests are presented in Table 7. The reported values are at lower detection limits for both conditioned and unconditioned ash and well below any regulatory limits. This indicates that conditioning with ADA-44C or with ADA-51 does not alter the leaching characteristics of the ESP hopper ash and that disposal of conditioned ash by wet ponding will not present any unusual concerns.

Table 6: Fly Ash Analysis

Sample	9/17/02	9/20/02	10/1/02	10/3/02	1/20/03
Ash Conditioning	None	ADA-44C	ADA-51	Ammonia	ADA-51
LOI (%)	10.6	12.4	10.9	11.1	16.7
Elemental Analysis					
SiO_2	49.7	47.3	41.2	44.9	42.7
Al_2O_3	22.1	18.9	19.4	21.3	18.8
TiO_2	1.21	1.0	1.1	1.2	1.1
Fe_2O_3	17.0	18.3	27.0	24.3	27.3
CaO	3.5	3.4	2.3	2.4	3.6
MgO	1.3	1.4	1.1	0.9	1.3
K_2O	2.1	1.7	1.5	1.6	1.4
Na_2O	0.8	0.7	0.5	0.5	0.5
SO_3	0.6	0.5	0.4	0.4	0.7
P_2O_5	0.3	0.2	0.1	0.2	0.2
SrO	0.05	0.04	0.04	0.04	0.05
BaO	0.04	0.05	0.04	0.04	0.05
MnO_2	0.06	0.05	0.07	0.07	0.1

Table 7: Leachability of Conditioned and Unconditioned Fly Ash

Fly Ash Sample	9-17-02	9-20-02	1-20-03
FGC Status	Unconditioned	ADA-44C	ADA-51
Metals			
Arsenic	<0.5	<0.5	<0.5
Barium	<2.0	3.7	<2.0
Cadmium	<0.1	<0.1	<0.1
Chromium	<0.5	<0.5	<0.5
Lead	<0.5	<0.5	<0.5
Selenium	<0.8	<0.8	<0.8
Silver	<0.05	<0.05	<0.05
Mercury (SGLP, µg/L) *	<0.01	<0.01	<0.01

* Analysis via Synthetic Groundwater Leaching Procedure

Technology Transfer

The project to date has proceeded from a screening of more than thirty potential additives to a successful full-scale trial with a final selected formulation, ADA-51. Of particular note, the full-scale results at AEP Conesville with ADA-51 indicated suppression of rapping reentrainment on a unit with high carbon content in the fly ash. ESPs collecting high carbon ashes with low layer cohesion are likely to be the most important application for this technology. Therefore, further and longer duration trials at full-scale with high carbon ashes are very important to full commercialization.

Presque Isle

A potential site for a final demonstration under this project was visited during the quarter. We Energies Presque Isle Power Plant (PIPP) in Marquette Michigan is seeking to make improvements in particulate collection and opacity performance on several units. PIPP currently has nine operating units with a total of 625 MW of electricity generation. Units 1 through 6 burn a mixture of approximately 90% bituminous Colorado coal blended with about 10% petroleum coke, while Units 7 through 9 burn sub bituminous Powder River Basin coal. Units 1 through 4 use a baghouse for particulate control while Units 5 and 6 use cold-side electrostatic precipitators. Units 3 through 6 currently have low-NO_x burners to control NO_x emissions.

Units 7 through 9 currently have hot-side electrostatic precipitators for particulate control. As part of a proposed upgrade at PIPP, a TOXECON (EPRI patented process) baghouse would be installed on Units 7 though 9 for multi-pollutant control including mercury. This project is currently under consideration through the DOE Clean Coal Power Initiative (CCPI)

Cohesivity conditioning is being considered for Units 5 and 6 in combination with other ESP improvements and possibly SO_3 conditioning. These units do have older SO_3 conditioning systems in place, although they are not currently required due to the petroleum coke in the blended fuel. Fly ash has high unburned carbon as a result of the low NO_x burners. Instantaneous opacity traces indicate reentrainment related opacity spiking. The proposed FGC trial would be one month duration on Unit 5 with ADA-51. Inlet/outlet particulate sampling would be conducted to evaluate ESP particulate performance. Rapping may be optimized with cohesivity conditioning.

CONCLUSIONS

Further conclusions from the AEP Conesville fly ash analysis are summarized as follows:

- Leachability of metals, including mercury, was not affected by conditioning with ADA-51 or ADA-44C in the AEP Conesville trial.
- Fly ash utilization is not anticipated to be a problem but this must be verified with a suitable conditioned ash .

On-Going Project Work

Work is proceeding on patent application for developed additives, economic assessment of the technology based on full-scale results to date, and on planning for a final full-scale trial at Presque Isle Power Plant.

REFERENCES

1. EPA Method 1311, "Toxicity Characteristic Leaching Procedure", 40 CFR 261, Appendix II.
2. D.J. Hassett, "*Synthetic Groundwater Leaching Procedure*" in Encyclopedia of Environmental Analysis and Remediation, John Wiley and Sons, 1998.

LIST OF ACRONYMS AND ABBREVIATIONS

acfm – Actual Cubic Feet Per Minute

AEP – American Electric Power Company

ALR – Air to Liquid Mass Ratio (spray parameter)

AVC – Automatic Voltage Control

DOE – U.S. Department of Energy

EPRI – Electric Power Research Institute

ESP – Electrostatic Precipitator

FGC – Flue gas conditioning for particulate control

ft^2 – Square Feet

gph – Gallons Per Hour

LOI – Loss on Ignition

lph – Liters Per Hour

mA – Milliamps

MW – Mega Watts

NETL – National Energy Technology Laboratory

NH_3 – Ammonia

PC – Pulverized Coal

ppmv – Parts-Per-Million by Volume

SCA – Specific Collection Area

SMD – Sauter Mean Diameter (mean droplet size, surface)

SO_2 – Sulfur Dioxide

SO_3 – Sulfur Trioxide

TOXECON – EPRI patented technology for multi-pollutant control (sorbent injection and fabric filter after ESP)