

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 SO₃ and ammonia.

During this reporting quarter, installation of a flue gas conditioning system was completed at PacifiCorp Jim Bridger Power Plant. Performance testing was underway. Results will be detailed in the next quarterly and subsequent technical summary reports. Also in this quarter, discussions were initiated with a prospective long-term candidate plant. This plant fires a bituminous coal and has opacity performance issues related to fly ash re-entrainment. Ammonia conditioning has been proposed here, but there is interest in liquid additives as a safer alternative.

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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 October through December 2001. During this period work was underway on Task 5, *Conduct Demonstrations to Confirm Performance for Different Coals and Configuration*. Construction and installation of the flue gas conditioning system at PacifiCorp Jim Bridger Power Plant was essentially completed. Some preliminary operational and performance data for the flue gas conditioning system was obtained.

EXPERIMENTAL

Flue Gas Conditioning System: Installation

Installation of the retrofit flue gas conditioning system was completed at Jim Bridger Power Plant during the reporting quarter. An available chemical storage tank was adapted to service for the ADA-43H chemical. A custom chemical metering skid was installed at ground level next to the system storage tank. From this chemical metering skid, chemical is pumped by an existing in-duct humidification skid (EnviroCare) atop the Unit 4 duct. The humidification skid was adapted to control and deliver dilute chemical to Units 1, 2 and 4. The humidification skid also controls compressed air delivery to the injection manifolds on each system. New chemical supply and compressed air piping were installed to the manifold headers on Units 1 and 2. All exposed liquid and compressed air piping were heat-traced.

Existing injection lances were modified to accommodate the low liquid flow rate of the FGC system. Low flow nozzles by the original manufacturer were installed on all lances. These MM1 nozzles are effective at a liquid flow rate down to about 0.15 gpm/nozzle. A total of eight lances per unit with 4 spray nozzles per lance were installed.



Figure 1: Chemical Metering Skid

Performance Test Plan

Use of the flue gas conditioning system at Jim Bridger Power Plant has been limited to short periods of approximately 48 to 72 hours while firing poor quality (low sodium) coal. A detailed evaluation of FGC performance will be completed as possible during periods when Units 1 or 2 require conditioning. Due to the intermittent usage, it is anticipated that several periods of test data will be obtained. The tests will be structured to compare ESP performance prior to, during and after conditioning (On/Off) or to compare Unit 1 to Unit 2 with and without conditioning. Test schedule is subject to the plant's requirements for flue gas conditioning on Units 1 and 2. Table 1 summarizes the data that will be collected.

Table 1: Preliminary Test Matrix

Parameters	Sampling Method	Data Frequency
Unit Load (gross MW)	Plant DCS	Six minute
Coal Quality	Splits, Coal Lab samples	At a minimum one representative sample with and one w/o conditioning per test.
Fuel feed rate	Plant DCS	Six minute
Air Heater outlet flue gas temperature	Plant DCS	Six minute
ESP electrical (Secondary Kv, Secondary Ma, kW, Spark rate for each field and overall)	1 minute data from ESP logging computer, units 1 and 2.	Hourly average or more frequent if available.
Injection System (Chem. Rate, Liquid Rate, Air Pressure)	Manual log	As necessary to document flow changes
Opacity	Stack Opacity Monitor	Six minute avg. or more frequently to evaluate rapping spikes and re-entrainment.
O ₂ /CO ₂	Unit CEM data, diluent component only from plant DCS	Six minute
Fly Ash	Representative silo samples by fly ash recycler	Sample once every two days, primarily at beginning of program.
Lance Inspection	Visual inspection, frequency to be determined. Manual log.	As necessary primarily at start of program. Also during routine maintenance inspections.
Injection System Operation	Visual inspection, manual log.	Daily or more frequently during critical test periods. Also during routine maintenance inspections.
Chemical	ADA-ES Product QA/QC Samples (as delivered)	Initial load, then monthly.

Spray Atomization

Injection lances of the humidification system experienced severe problems with deposition in the duct and on turning vanes and perf screens. The original nozzles have been replaced with a finer atomizing nozzle from the original manufacturer. In addition, the Air-to-Liquid Ratio (ALR) of the nozzles has been significantly increased. The retrofitted EnviroCare injection lances will be carefully monitored at startup for signs of deposition both on the lance surfaces and on downstream duct structures. If necessary, they will be replaced with injection lances designed specifically for flue gas conditioning for long-term operation.

Technology Transfer and Commercialization

The following technology transfer activities were conducted during the reporting quarter:

- Project technical meeting held at Jim Bridger
- Project presentation and site visit to eastern utility. Plant fires a mid-to-high sulfur coal and has an undersized ESP with re-entrainment problems.

RESULTS AND DISCUSSION

PacifiCorp Jim Bridger: FGC Results

Flue gas conditioning was turned on for several periods as necessary to condition fly ash during episodic firing of low sodium coals. To date, the plant has reported that the chemical is effective at opacity control at conditioning rates ranging from 0.4 to 0.8 lbs/ton coal. An upper limit of 0.5 lbs/ton coal has been fixed at the chemical metering skid in order to avoid over conditioning. This appears to be adequate for most coals. The upcoming testing of the FGC on Units 1 and 2 will be an opportunity to optimize chemical utilization and to fully evaluate ESP performance with conditioning.

Spray Atomization

ADA-ES inspected and monitored the injection lances with an in-duct camera during the initial trials of the FGC system. The injection lances have experienced significant problems with spray buildup onto the unshrouded lance surfaces. In order to minimize this, total liquid flow rate of diluted chemical has been reduced to less than 4 gpm per unit. In addition, compressed air volume and pressure has been maximized for the new, lower-flow spray nozzles. However, spray buildup onto the lances is still evident.

An ongoing maintenance and cleaning program has been implemented. The lances are cleaned on a weekly schedule when operational. This will help to prevent spray obstruction and deposition in the duct. A different lance style will be evaluated in the near future as a possible long-term solution. Figure 2 shows an interior view of the duct and spray lances. It is a relatively roomy location with more than 35 ft. to downstream turning vanes.

Fly Ash Utilization

All of the fly ash produced at Jim Bridger is sold for concrete admixture. Therefore, it is important to test the conditioned fly ash to ensure that the ADA-43 additive does not affect the ash specifications. Thus far, conditioned ash has been tested by the ash utilization contractor at the plant. A silo sample of fly ash was taken during sustained conditioning at a rate 0.65 lbs ADA-43/ton coal. The sample was submitted for ASTM C618 testing.¹ In addition, a proprietary “foam index” test was run in order to semi-quantitatively determine reaction to air entrainment chemicals in concrete. Final results of the ASTM C618 test are still pending, but most parameters measured are unaffected by conditioning with ADA-43. It is anticipated that there will be a slight increase in available alkali content, but final results are still pending. The foam index testing to date has indicated that the conditioned ash will be less reactive to air entrainment chemicals than unconditioned ash. This result may be due to changes in physical size and quantity of ash collected during conditioning or to surface passivation (oxidation) of residual unburned carbon in the ash by the additive chemical. This is an interesting result because conditioning may be beneficial to ash utilization for certain fly ashes that will meet ASTM specification for Loss-On-Ignition (LOI) but are still too reactive to air entrainment chemicals for use as a concrete admixture.

More detailed fly ash testing will be completed in the next test series. Ash will be tested at several different conditioning rates to ensure that all conditioned material can be safely used for concrete admixture.



Figure 2: Spray Lances Inside Duct

Technology Transfer and Commercialization

Inquiries and a site visit have been completed at an eastern utility plant firing a bituminous coal. This plant has a serious re-entrainment and opacity problem due primarily to undersized precipitators (<160 SCA). The plant is considering addition of an ammonia conditioning system but is very interested in a liquid conditioner. A presentation of this DOE developmental project has been made at the plant level.

CONCLUSION

Work began on Cooperative Agreement No. DE-FC26-00NT40755 in February 2000. Initial activities included holding a project kickoff meeting and various planning and administrative tasks. Development of laboratory instrumentation to support the project's objectives was the next task. This included adoption and further development of a lab-scale method to measure the tensile strength of uncompacted fly ash. This method and apparatus (electrostatic tensiometer) had been previously developed and patented by Southern Research Institute. Permission to build and operate the electrostatic tensiometer was obtained from SRI. A comprehensive laboratory-screening program for potential new flue gas conditioning agents was completed on schedule in the first year of the project².

In parallel with the lab-scale additive development work, commercialization and technology transfer activities have been on going since the program commenced. A number of potential industry partners have been contacted regarding program participation and full proposals with presentations have been prepared for seven sites thus far². Results of this effort to date include:

- A short-term FGC test program was run at the City of Ames, Iowa Municipal Power Plant on a 30 MW coal-fired unit with RDF co-firing. Tests confirmed effective resistivity control with the ADA-43 additive formulation developed on the project. Cohesivity effects were inconclusive due to a very aggressive rapping schedule on this ESP and non-uniform fuel feed and composition.
- A long-term demonstration is being conducted at Jim Bridger Power Plant, Units 1 and 2. This demonstration will evaluate ADA-43 as a combined resistivity/cohesion additive for a western sub-bituminous coal/ash type. It is expected to yield valuable comparative information on performance and costs compared to a standard SO₃ conditioning system on a sister unit at Jim Bridger.

Table 2 presents an updated summary of all commercialization and technology transfer activities on the project.

REFERENCES

1. ASTM C618, “Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete”, American Society for Testing Materials.
2. “Advanced Flue Gas Conditioning as a Retrofit Upgrade to Enhance PM Collection from Coal-fired Electric Utility Boilers”, Quarterly Technical Reports, Reporting Periods: Feb. – March 2000, April – June, 2000, July – Sept. 2000, Oct. – Dec. 2000, Jan – March, 2001 and April – June 2001. DOE NETL Contract No. DE-FC26-00NT40755.

LIST OF ACRONYMS AND ABBREVIATIONS

ALR – Air-To-Liquid Ratio

ASTM – American Society of Testing and Materials

CEM – Continuous Emission Monitor

DCS – Data Collection System

DOE – U.S. Department of Energy

ESP – Electrostatic Precipitator

FGC – Flue gas conditioning for particulate control

KV – Kilovolt

KW – Kilowatt

LOI – Loss on Ignition

MA – Milliamp

MW – Megawatt

NETL – National Energy Technology Laboratory

PM – Particulate matter

RDF – Refuse Derived Fuel

SCA – Specific Collection Area, $\text{ft}^2/1000$ acfm flue gas flow

SRI – Southern Research Institute

Table 2: Commercialization and Demonstration Activities (updated through 12/01)

Utility	Plant	Phone/Letter Contact	Meetings/ Headquarters	Meetings/ Plant Visit	Proposal	Follow-up	Status
Ameren CIPS	Coffeen 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	Long-term demonstration on Units 1 and 2
PacifiCorp	Naughton	X	X	X	X	X	Significant interest, technical problems
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 Harley Branch Gadsen 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 King Station	X	X	X	X	X	Several plant visits, pending outcome of staged ESP mechanical upgrades.
Confidential Inquiry	Eastern, firing bituminous	X		X	X		Requires cohesivity-only conditioning to suppress re-entrainment; ammonia considered