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

Quarterly Technical Report
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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, performance testing of flue gas conditioning was completed at the PacifiCorp Jim Bridger Power Plant. The product tested, ADA-43, was a combination resistivity modifier with cohesivity polymers. The product was effective as a flue gas conditioner. However, ongoing problems with in-duct deposition resulting from the flue gas conditioning were not entirely resolved. Primarily these problems were the result of difficulties encountered with retrofit of an existing spray humidification system. Eventually it proved necessary to replace all of the original injection lances and to manually bypass the PLC-based air/liquid feed control. This yielded substantial improvement in spray atomization and system reliability. However, the plant opted not to install a permanent system.

Also in this quarter, preparations continued for a test of the cohesivity additives at the American Electric Power Conesville Plant, Unit 3. This plant fires a bituminous coal and has opacity and particulate emissions performance issues related to fly ash re-entrainment. Ammonia conditioning is employed here on one unit, but there is interest in liquid cohesivity 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 April through June 2002. During this period work was underway on Task 5, *Conduct Demonstrations to Confirm Performance for Different Coals and Configuration*. Full-scale testing of flue gas conditioning was conducted at Jim Bridger Power Plant, Unit 1. The performance results were positive; however, hardware problems that resulted in deposition within the ductwork developed. Testing was discontinued and the injection system was modified to overcome the application problems.

EXPERIMENTAL

FGC Performance Test at Jim Bridger

The final phase of FGC testing at Jim Bridger was conducted on Unit 4. Prior reports have presented data on ESP performance on Units 1 and 2 with ADA-43 conditioning[1]. The injection system was also installed on Unit 4 and was utilized throughout the spring of 2002 on that unit, primarily during episodes of poor (low sodium) coal quality. Since Unit 4 was not included in the test program for the DOE additives, long-term ESP performance and stack opacity data was not available.

Injection Lance Development

Previous project reports have detailed spray nozzle development work[1]. Work during this reporting period involved adapting the ADA-ES proven atomizing nozzle into a straight tube lance configuration, (J-Core series from Jackson Machine Co.). The lance design and nozzle adaptation was contracted through Jackson Machine. Energy Research Consultants evaluated spray performance of the nozzle and lance configuration independently. Testing confirmed that performance parameters in terms of spray size, air and liquid flow were equivalent to the same ADA-ES nozzle in other lance designs.

The end result was a single-nozzle lance with exceptional spray performance in a tube size of less than ¾" (1.9 cm.) diameter. Such a lance will not create flow disturbances and has minimal cooled surface area. It will be particularly useful for small and tight duct configurations. A total of twelve J-Core lances were installed at Jim Bridger, Unit 4. A brief trial of the new injection lances was conducted prior to a major outage. The lances were installed vertically downward in the existing injection ports, as seen in Figure 1 (penetration approximately 2' downward, vertical downward spray).

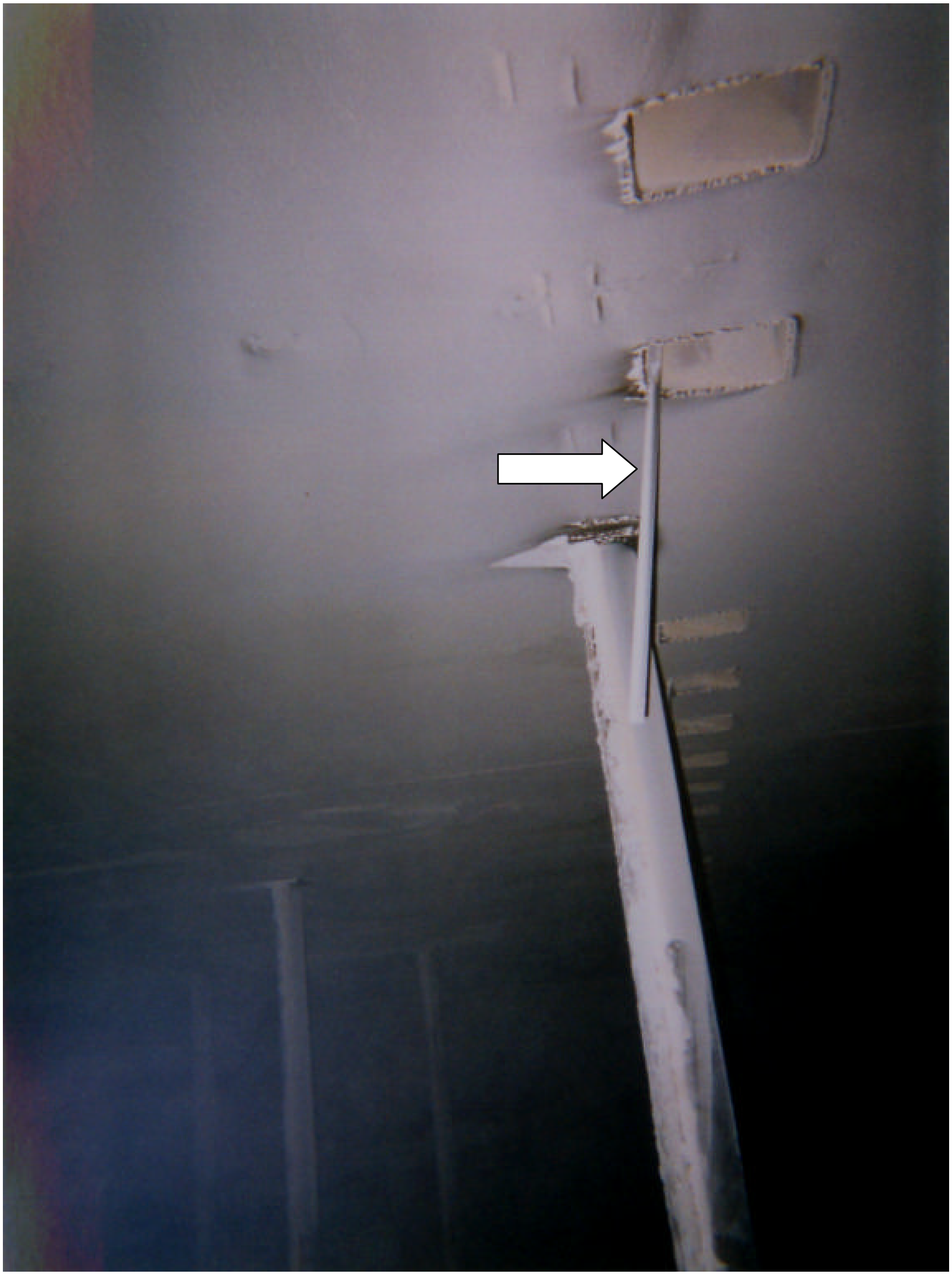

Figure 1: ADA-ES/J-Core Lance Installed Vertically In ESP Inlet Duct

RESULTS AND DISCUSSION

PacifiCorp Jim Bridger: Injection System Test

A test of the newly developed injection lances (J-Core) was conducted on Unit 4 prior to a schedule major unit outage. The humidification system control was extensively modified for this trial. A booster pump with backpressure recirculation loop was installed in the feed water system. This enabled operation of the injection array with steady inlet liquid pressures of more than 100 psig (70,300 Kg/m^2). Liquid flow meters were installed to individual lances to control the chemical rate and pressure. These changes allowed operation at much higher and steadier liquid and air pressures, contributing to improved atomization. Total liquid flow rate was reduced to 1.2 gpm (4.5 lpm). Air-to-Liquid ratio was increased from 0.9 to 1.7. Despite this increased air, the total air consumption was reduced as a result of less total liquid. Table 1 summarizes the previous and modified injection parameters. Figures 2 and 3 illustrate the spray drop size reduction achieved in terms of Sauter (surface) mean and large droplet fraction.

The Sauter mean diameter is a performance indicator of the overall spray distribution, while the DV_{90} is a measure of the maximum droplet size and the maximum time to evaporate. The maximum droplet size is the primary parameter that will influence deposition past the spray zone. Even with a clean lance the largest droplets produced with the existing (humidification) lances were likely too large to evaporate before reaching downstream duct features. This contributed to wall wetting and deposition into the ESP. The new lances maintained a DV_{90} of less than 30 microns.

Table 1: Comparison of Nozzle Performance at Actual Conditions

		Air Flow scfm (m^3/hr)		**Air Pressure psig (kg/m^2)**	**Sauter Mean Diameter (µm)**	**Max. Droplet Size, DV90 (µm)**
Humidification	32	450 (765)	>4.0 (15.1)	50 (35,100)	46	82
J-Core w/ADA-ES Nozzles	12	235 (399)	1.2 (4.5)	90 (63,300)	17	27

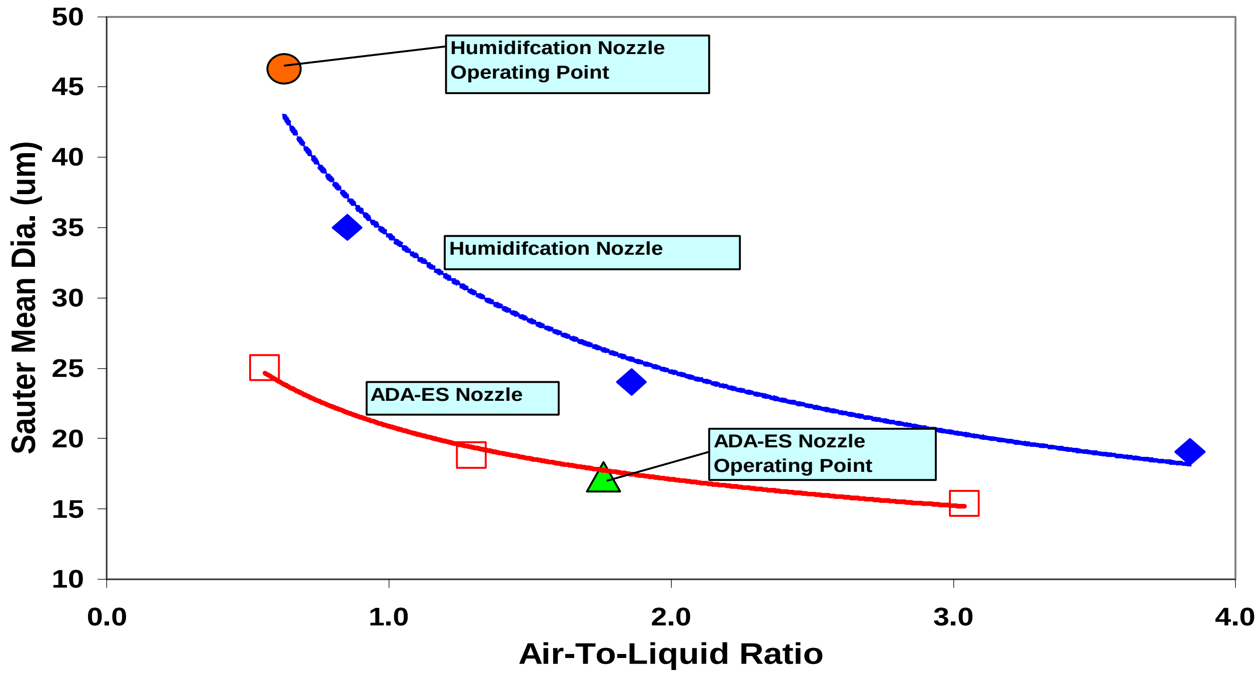

Figure 2: Comparison of Mean Droplet Fraction

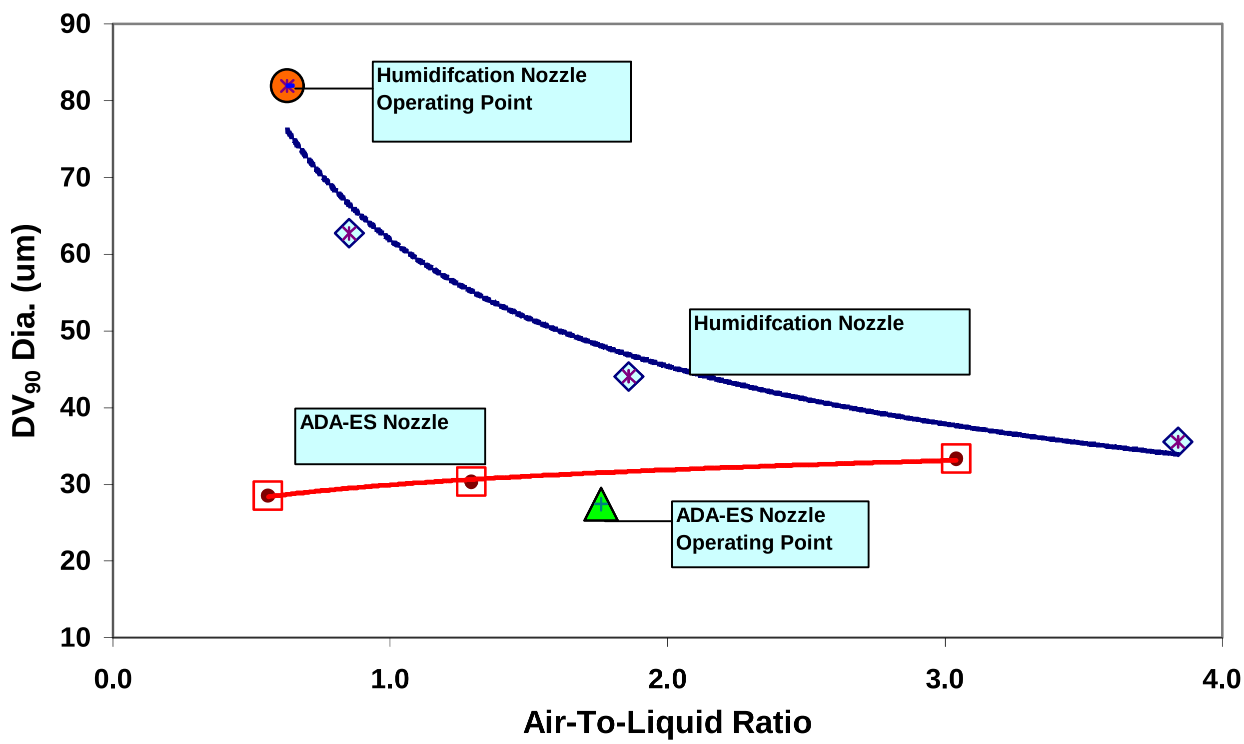

Figure 3: Comparison of Large Droplet Fraction

Injection System Performance

The test of the spray injection system with the new lances was conducted for approximately 4 days prior to unit outage. With the new lance configuration, the spray distribution in the duct was substantially altered from a total of 32 nozzles spraying co-current with flue gas to 12 nozzles spraying vertically downward.

Long-term ESP electrical and stack opacity data was not available to this program for Unit 4 since it was not originally included in the additives test plan. However, according to control room operations, comparable ESP power increases and opacity reductions were observed when ADA-43 conditioning was applied with the J-Core lances compared to the same rates with the humidification lances. This indicated that spray distribution with the ADA-ES/J-Core lances was effective.

Lances were inspected after 48 hours spray and found to be free of ash and spray buildup. In addition, duct coupons inserted at 20 ft. (6.1 m) downstream of injection lances were checked daily for buildup. None was observed.

A final inspection of the duct interior was conducted at unit outage. Interior duct surfaces within 50 ft. (15 m) downstream of the injection location were entirely clear. However, a minor incipient coating was observed at a section of turning vane in the inlet ESP duct. This material was very hard and not typical of spray deposition from water and fly ash. It may have formed as a result of chemical reaction of ash with the cohesivity additives in the ADA-43 blend. Based on this observation, it appears that a component of the cohesivity polymer is reacting with the fly ash to produce hardened deposits. This effect has not been observed either in laboratory tests or in the previous full-scale trial at the Ames Municipal Power Plant (PRB coal).

Technology Transfer and Commercialization

During the quarter, a project kickoff meeting was held and planning continued for a long-term test of the cohesivity additives at the American Electric Power Conesville Unit 3. Installation of equipment will be completed in July 2002. Actual testing will begin later in the summer of 2002. Test schedule may be delayed past peak summer generation.

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 project.

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 far. Two full-scale trials have been completed to date:

?? 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. The plant has continued to use ADA-43 after the conclusion of the trial.

?? A long-term trial of the ADA-43 blended additive was completed at PacifiCorp Jim Bridger Power Plant. Performance of the additive was successful but problems with injection precluded long-term acceptance.

?? A full-scale test will be completed in 2002 at AEP Conesville Unit 3.

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

REFERENCES

1. "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. 2001, Oct. – Dec. 2001, Jan. – March 2002. DOE NETL Contract No. DE-FC26-00NT40755.

LIST OF ACRONYMS AND ABBREVIATIONS

DOE – U.S. Department of Energy

ESP – Electrostatic Precipitator

FGC – Flue gas conditioning for particulate control

FT - Feet

GPM – Gallons per minute

kg/m^2 – Kilogram per square meter

LPM – Liters per minute

M - Meter

m^3/hr – Cubic Meters per hour

PLC – Programmable Logic Controller

PM – Particulate matter

psig – Pounds per square inch gauge

? m – Micro meters

Table 2: Commercialization and Demonstration Activities (updated through 06/

Utility	Plant	Phone/Letter Contact	Meetings/ Headquarters	Meetings/ Plant Visit	Proposal	Follow-up	
Ameren CIPS	Coffeen Newton	X	X	X	X	X	Installing SO3
City of Ames, Iowa	Ames Municipal Power Plant	X	X	X	X	X	Test completed
City Utilities of Springfield	Springfield Mo.	X				X	P
Central Louisiana Electric Co.	Dolet Hills	X	X			X	Currently usin im
Duke Power	Corporate & Belews Creek	X	X			X	Oh hold, nc
Dynegy Midwest Generation	Hennepin Station	X	X	X	X	X	Possible applica sup
Electric Energy Inc.	Joppa Generating Station	X	X			X	Installed hur
Great River Energy	Coal Creek Station	X	X	X	X	X	Does not appea
Indianapolis Power and Light	Corporate/Various	X	X			X	Considering FG
PacifiCorp	Jim Bridger	X	X	X	X	X	Long-term den
PacifiCorp	Naughton	X	X	X	X	X	Significant in
Public Service Electric and Gas	Mercer Generating Station	X				X	Follow-up
Sikeston Board of Municipal Utilities	Sikeston Station	X				X	P
Southern Co.	Corporate Harley Branch Gadsen Mitchell	X	X			X	P
Wisconsin Electric Power Co.	Corporate & Port Washington Plant	X	X	X	X	X	Mechanical upgr correctec
Xcel/Northern States Power	Black Dog King Station	X	X	X	X	X	Several plant visi ESP m
American Electric Power	Conesville	X	X	X	X	X	Installations unde