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 has begun 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 flyash. 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 flyash cohesivity. Resistivity was measured for each screening test with a multi-cell laboratory flyash resistivity furnace constructed for this project. Also during this quarter chemical formulation testing was undertaken to identify stable and compatible resistivity/cohesivity liquid products.

TABLE OF CONTENTS

LIST OF GRAPHICAL MATERIALS

FIGURES

TABLES

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 flyash 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 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 January through March 2001. During this period work was underway on Task 2, *Selection and Evaluation of Candidate Additives,* and Task 4, *Long-term Site Selection*. Laboratory screening of several additional cohesivity candidate additives was completed using the electrostatic tensiometer. Fly ash resistivity was tested for the additional samples and for several combined formulations. Formulation development work was also completed during the quarter. On Task 4, a significant effort was made to identify and qualify candidate host sites for long-term testing.

EXPERIMENTAL

Cohesivity Screening

In earlier work on this project, the electrostatic tensiometer (ET) cohesivity method was refined and adapted to the specific requirements of the flue gas conditioning (FGC) additives development. Details of the method have been previously described.[1,2,3] During this reporting quarter a number of additional cohesivity-screening runs were completed with the refined ET technique. Tests of combined resistivity/cohesivity formulations were completed to verify performance of our expected finished products.

Additive Selection

Two additional polymers were investigated during the quarter in addition to follow-up testing of a class of byproduct natural polymers. One of these is commonly used as a lubricant in numerous materials and is also used as a food additive. A variety of molecular weights are commonly manufactured. The second polymer is another common water treatment chemical. Both of these chemicals exhibit low toxicity and are temperature stable to more than 350^{o}F. They are also stable in solution with the ADA-43 resistivity chemical, making them good candidates for a combined additive.

Flyash Resistivity

Additional flyash resistivity tests were completed to verify the performance of the combined additive formulations. In addition, some of the polymer-only samples were tested for effect on flyash resistivity. Flyash resistivity was measured in the laboratory furnace as previously described.[1,4]

RESULTS AND DISCUSSION

Cohesivity Screening Results

Table 1 summarizes the laboratory screening tests for all chemicals evaluated on the project. Note that the majority of screening tests were run at a high conditioning rate to clearly define the differences between conditioners. Figure 1 plots this data for the candidate additives considered to be viable for further development. Tests completed this reporting quarter are included at the end of Table 1.

Fly ash conditioned with Polymer #7 and Polymer #8 exhibited higher tensile strength than baseline. Polymer #8 in combination with ADA-43 increased the flyash tensile strength compared to baseline at a conditioning rate of only 0.3% ATA. This rate is expected to be similar to what will be required for full-scale conditioning.

Flyash Resistivity

Additional resistivity tests were completed for selected formulations as shown in Figure 1. Resistivity of fly ash conditioned with Polymers 7 and 8 showed significantly higher resistivity than the baseline at temperatures below 400^{o}F. The ash was conditioned at a higher rate to accommodate cohesivity screening. Therefore the impact on fly ash resistivity would not be as significant at the expected application rate. A final test of Polymer #8 in combination with ADA-43 at 0.3% ATA gave satisfactory resistivity results.

Table 1: Results of Laboratory Cohesion Tests

Trial Additive	Conditioning Rate (% Additive-To-Ash)	Onset of Particle Ejection (N/m^2) (1)	Layer Tensile Failure (N/m^2)	Normalized Tensile Failure (N/m^2) (2)
Baseline #1	0	26	35	35
Baseline #2	0	18	46	46
Baseline #3	0	18	46	46
Baseline, High Moisture	0	59	87	87
Hydrate #1 (3)	1.27	46	163	128
Resistivity #1	0.83	26	46	56
NH3 Subst. #1	0.95	26	72	76
Polymer #1	1.10	35	87	79
Natural Polymer #1	0.97	26	59	60
NH3 Subst. #2	0.90	35	72	80
Polymer #2	0.62	26	59	94
Polymer #3 (3)	1.10	46	104	95
Polymer #4	0.79	72	142	179
Moisturizer #1	1.03	26	46	45
NH3 Subst. #3	1.02	18	46	45
Moisturizer #2	0.84	26	46	55
Resistivity/NH3 Subst.#2	1.05	72	185	176
Natural Polymer #2	0.93	46	122	131
Hydrate #2	0.92	18	59	64
Resistivity/Polymer #4	1.30	7	35	27
Polymer #5	0.30	46	87	273
Polymer #6	1.80	142	416	234
Natural Polymer #3 (3)	0.80	87	163	203
Natural Polymer #4 (3)	1.50	104	289	193
First Quarter 2001				
Baseline Repeat (PRB)	0.0	18	46	46
Polymer #7(4)	1.0	35	72	72
Polymer #7(4)	0.5	35	87	162
Polymer #8(4)	0.8	26	72	89
Resistivity/Polymer #8(4)	0.3	26	59	225

Notes:

1. Onset defined at 10% area deposition of upper electrode.
2. Qualitative indicator defined as tensile failure at 1% additive-to ash. Assumes proportional change in tensile strength with conditioning rate.
3. Further development & test full-scale as cohesivity-only additive
4. Further development & test as combined FGC additive

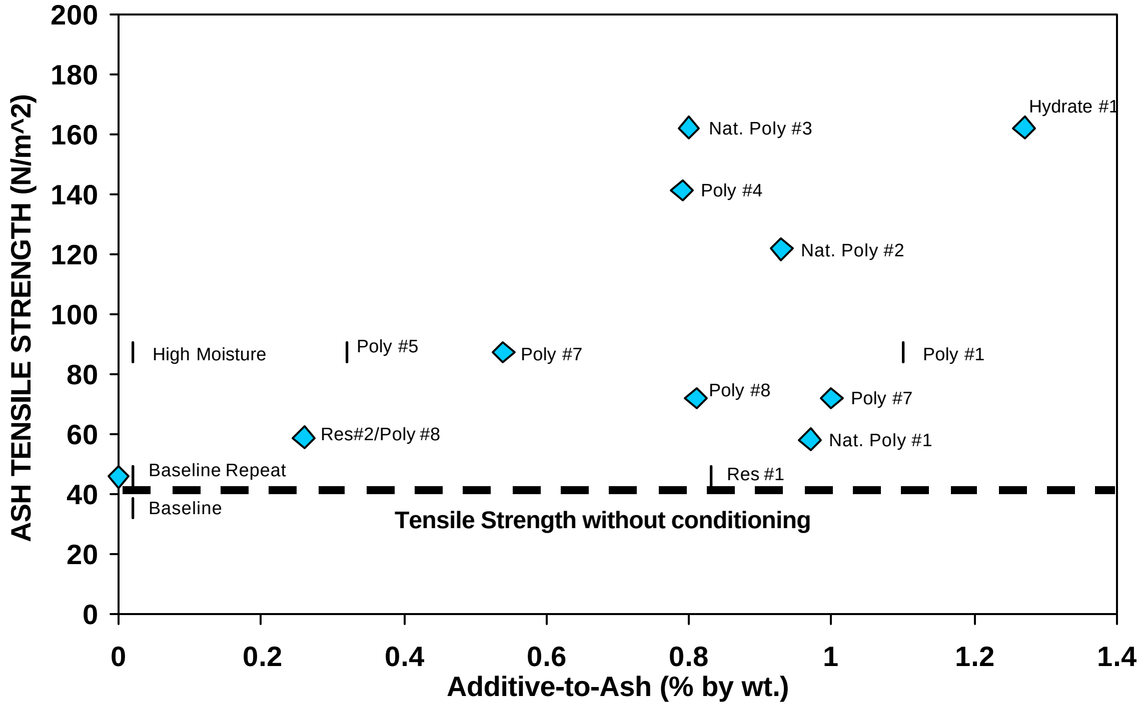

Figure 1: Cohesivity Screening Results

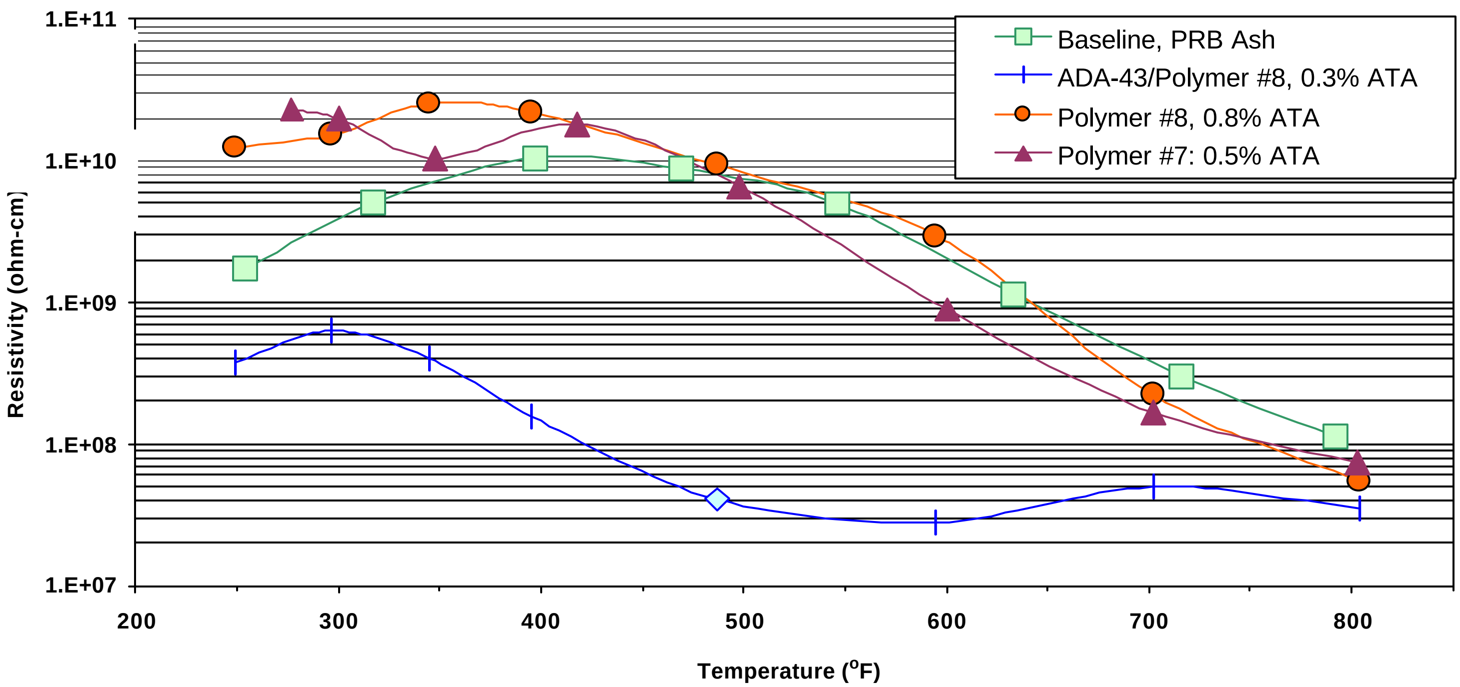

Figure 2: Flyash Resistivity for Polymers #7 and #8

Formulation Stability Tests

Previous results of 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 region below 400^{o}F.

A number of the best-performing additives were mixed in aqueous solution with ADA-43 and observed over a period of weeks. Target concentration of the final product was 40% by wt. Based on results thus far, the best-performing cohesivity additives are not compatible with the resistivity chemicals. Many reacted over a period of days to weeks and formed precipitates. None of the economically viable additives, including Hydrate #1 and Natural Polymers #3 and #4, could be formulated with the resistivity chemicals. This finding prompted a further round of cohesivity screening and the identification of two additional polymers (#7 and #8) that are stable in solution with ADA-43 and similar resistivity chemicals.

Commercialization Activity

ADA-ES has been actively promoting and seeking utility partners for the full-scale test and demonstration phase of this project. Since August 2000 a number of utilities and specific plants have been contacted about participation. Several have expressed interest in participation and a number of proposals are under review. Table 2 presents a summary of the commercialization, marketing and demonstration activities undertaken by ADA-ES for the project to date. In addition to the listed utility prospects, ADA-ES has presented the project at a number of trade seminars and air pollution specialty conferences. Interest level has been high and further work is continuing. A key objective for the project is to seek out additional industry partners for full-scale demonstration of the cohesivity additives.

CONCLUSION

Formulation tests of cohesivity additives with the best resistivity chemical were completed during the quarter. The economically viable cohesivity additives proved difficult to combine with the resistivity chemicals. This led to a further round of additive laboratory screening. Two additional polymers were identified that are stable in solution with the best resistivity chemical. A combined additive with these components 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.

Formulation of an FGC additive into a single, concentrated aqueous solution is not an absolute requirement for successful commercialization of new FGC products. However, it is the least complicated application of the technology and it has the advantage of fully developed injection equipment and distribution system. The other alternative is separate injection of cohesivity additives, either in conjunction with SO_3 conditioning or with a liquid resistivity modifier. There are some technical advantages to a separate conditioner, including the ability to fine-tune cohesivity conditioning. Also, they represent a potential market as a stand-alone product.

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 flyash. ESP performance data and post-injection duct condition are two other key characteristics that can only be evaluated full-scale.

It is expected that there will be two eventual products, depending on the need for resistivity conditioning. For the cohesivity-only product, attention will be given to finding a site with SO_3 conditioning that may require additional cohesive FGC. Of the additives evaluated to date, natural polymers #3 and #4 and Hydrate #1 have shown excellent performance in laboratory tests and the economics are very favorable. However, a full-scale trial is required to see if they will perform in an actual flue gas environment. The combined FGC additive, as currently formulated with Polymers #7 and #8, will also be evaluated at one of the next test sites.

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. 2000, Oct. – Dec. 2000 DOE NETL Contract No. DE-FC26-00NT40755.
2. Pontius, D. and Snyder, T., “Measurement of the Tensile Strength of Uncompacted Dust Aggregates” in Powder Technology, 1991, pg. 159 –162.
3. Pontius, D. and Snyder, T., “ Method And Apparatus For Measuring The Tensile Strength of Powders”; US Patent Number 5,386,731 assigned to Southern Research Institute, 1995.
4. IEEE Standard 548- 1984; IEEE Standard Criteria and Guidelines For the Laboratory Measurement and Reporting of Fly Ash Resistivity, 1984.
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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

IEEE – Institute of Electrical and Electronic Engineers

KV - kilovolt

MW - megawatt

PAM – Polyacrylamide polymer

PM – Particulate matter

PRB – Powder River Basin coals and resulting flyash

SRI _ Southern Research Institute

V/I – Voltage/current

Table 2: Commercialization and Demonstration Activities

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
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.
Dynergy 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	Have humidification, no immediate application.
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
Wisconsion 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.