FLUE GAS CONDITIONING FOR IMPROVED ELECTROSTATIC PRECIPITATOR AND FABRIC FILTER PERFORMANCE

MICHAEL DURHAM, PH.D., JEAN BUSTARD, KENNETH BALDREY
TIMOTHY EBNER, RICHARD SLYE
ADA TECHNOLOGIES, INC.
302 INVERNESS WAY SOUTH, SUITE 365
ENGLEWOOD, CO 80112
(303) 792-5615

Abstract

The overall objective of two separately funded Department of Energy Pittsburgh Energy Technology Center programs was to develop an improved technology to enhance fine particulate control and overall collection efficiency of electrostatic precipitators (ESPs) and fabric filters using non-toxic, novel flue gas conditioning agents. In the four years of program funding, over 200 candidate additives were screened and many evaluated at both lab- and pilot-scale. One agent, ADA-23, has proven to be more versatile and as effective as the state-of-the-art flue gas conditioning technologies. The agent is injected as an aqueous solution upstream of the particulate control device to increase ash cohesivity, porosity, and tensile strength. It has also been shown to reduce flyash resistivity over a wide range of temperatures.

Since July 1995 all of the testing efforts have been focused on ADA-23. Testing has been conducted at laboratory, pilot, and full-scale on a variety of coals and flyashes. The most significant findings from these tests include:

- Resistivity measurements made on several Powder River Basin coals and low-sodium/low-sulfur eastern coals demonstrated that the additive could effectively reduce the resistivity by two orders of magnitude at temperatures of 650 to 800°F.
- Increased ESP power levels, decreased stack opacity, and decreased flyash resistivity were documented during a full-scale trial on a 270 MW hot-side ESP at a utility in Texas;
- At 450 °F, resistivity could be reduced to 10^{10} ohm-cm from an unconditioned value of 10^{12} ohm-cm. This is important for many cold-side ESP applications, since SO_3 conditioning typically becomes less effective above 350°F.

Introduction

Development of a cost-effective technology to decrease outlet emissions, and associated particulate air toxics, is driven by a comprehensive plan in Title III of the Clean Air Act Amendments of 1990 to achieve significant reductions in emissions of hazardous air pollutants from major sources. The mandate to reduce air toxics will require upgrading particulate control equipment such as electrostatic precipitators and fabric filters, since many of the toxic metals exist as fine particles. Concentration of trace metals in the fine particle fraction may force utilities to achieve very high overall particle collection efficiencies. This presents a challenge to users of existing particulate control equipment to identify modifications or upgrades which increase the collection efficiency of fine particles.

The Department of Energy (DOE) Pittsburgh Energy Technology Center funded two programs at ADA Technologies to identify, develop, and evaluate cost-effective, alternative ESP and fabric filter conditioning agents to increase removal of fine particle air toxics from coal-fired combustion flue gas streams. This goal can be met in ESPs by reducing reentrainment losses of collected ash and in fabric filters by modifying the cohesive characteristics of the ash. One additive was discovered that not only met these goals, but also solved a long standing problem in the utility industry of poorly performing hot-side ESPs. With support from outside funding sources, two full-scale demonstrations of this new flue gas conditioning agent have been completed on hot-side ESPs. A third full-scale demonstration co-funded by DOE, the Electric Power Research Institute (EPRI) and Public Service Company of Colorado is scheduled to get underway this summer. In this demonstration, testing will be conducted on a cold-side ESP filtering flyash from a low sulfur western coal.

HISTORY OF ADDITIVE DISCOVERY

This promising additive mixture was first tested in the laboratory with fabric filters and was identified in previous DOE presentations as ADA-14.[1] ADA-14 increased particle cohesion and created a more porous dustcake, which reduced the penetration of particles through the fabric filter by greater than a factor of ten. These results duplicated the effect obtained from similar tests with dual conditioning by SO_3/NH_3. In addition to decreasing particle emissions, subsequent bench-scale tests demonstrated that the pressure drop across the baghouse was reduced by the more porous dust layer resulting in a decrease in bag cleaning frequency by as much as a factor of five.

Because of ADA-14's similar performance to SO_3/NH_3 in a fabric filter, tests were conducted to measure its impact in an ESP. In these tests a second additive was mixed with ADA-14 and the combination was immediately seen to be successful as a resistivity modifier in laboratory trials. The new combination of additives is referred to as ADA-23. This finding led to several additional field tests on flue gas slipstreams at different sites and with different coals.[2]

While the results from these tests were excellent and it appeared that ADA-23 would provide an alternative to SO_3/NH_3 conditioning, a new technical challenge came to mind. Would this additive work at hot-side ESP temperatures (greater than 600°F)? The problems unique to hot-side ESPs have been virtually without solution for the past 20 years. Some additives do improve performance, but not nearly as effectively as dual flue gas conditioning applied to cold-side ESPs. Other hot-side options to meet particulate removal requirements include a cold-side retrofit or installation of a baghouse. Although hot-side units were not initially considered in the development of this additive, successful testing at these temperatures has shifted the focus for the first targeted end-user of this new technology to hot-side ESPs.

LABORATORY EVALUATION OF ADA-23 AT HOT-SIDE ESP CONDITIONS

To test whether ADA-23 could be used to condition hot-side ESPs, laboratory resistivity tests were conducted using a flue gas simulator and additive injection chamber. Initial tests were run at 700°F with an ash sample from a hot-side ESP at a plant firing a western subbituminous coal. This ESP has historically exhibited severe performance problems associated with a low sodium content in the coal. Resistivity of fresh ash at hot-side operating temperatures has typically been measured in the 10^{10} - 10^{11} ohm-cm range; it is expected that the resistivity increases significantly for an aged ash layer. For this test, the additive and ash were injected at 700 °F in an air environment with 10% moisture content. The additive reduced resistivity at 700 °F by up to two orders of magnitude. The amount of the resistivity reduction could be controlled via the concentration of the additive. This test demonstrated that conditioning appeared to extend the range of temperatures for which flyash resistivity is controlled by surface-conduction to temperatures normally dominated by volume (bulk) conduction. This allows the additive to be effective at hot-side temperatures.

FULL-SCALE DEMONSTRATION TEST DESCRIPTION

A Texas utility that operates several hot-side ESPs became interested in the potential benefits that this flue gas conditioning agent could provide for their system. Their hot-side ESP performance degrades over time because of sodium depletion of the residual ash layer, which increases the resistivity of the ash on the collection plates. When this condition becomes severe collection efficiency drops off, opacity increases above compliance limits and the ESP must be brought off-line for washing, which results in lost generation and power sales. ADA-23 has the potential to control resistivity increases due to advanced sodium depletion and therefore to eliminate undesirable conditions such as back-corona and sparking at reduced voltage. Funding for this demonstration was a joint effort between EPRI, the host utility, and ADA Technologies.

The test began in August, 1995 and was organized into four phases, with the continuation of each phase dependent on positive results from the previous phase. A brief description of each phase follows:

Phase I: Conduct a laboratory evaluation of the effect of ADA-23 on resistivity of a host-site ash sample.

Phase II: Evaluate the effect of ADA-23 on ash resistivity when a slipstream sample is extracted from a host site hot flue gas duct and subsequently conditioned.

Phase III: Design, fabricate and install an additive injection system and conduct a short-term, 2 week demonstration on one half of an existing hot-side ESP.

Phase IV: Conduct a long-term demonstration of flue gas conditioning with ADA-23 to optimize injection parameters and document performance.

Phase I and II Description and Results

The objectives of Phase I and II were to demonstrate that resistivity of the host flyash at hot-side temperatures could be modified with ADA-23 in the laboratory as well as on actual flue gas at the plant. Changes in resistivity were measured using a modified, in-situ resistivity device[2] The resistivity sampler collected a flyash layer by filtration of a particle-laden gas sample across an electrically isolated metal frit. The resistivity chamber contained a high voltage electrode which was integrated with a precision micrometer to measure dust layer thickness. DC voltage was applied to the electrode during resistivity measurement from an external power supply. Current across the dust layer was measured via a picoammeter. Resistivity was typically reported at a standard 4 KV/cm field strength, which approximated the conditions of a 9 inch spaced wire/plate ESP.

Tests alternated between baseline and additive conditioning at several concentrations. Baseline tests consisted of the injection of pure water into the slipstream to demonstrate that any change in resistivity was due to additive, rather than humidification of the flue gas. Resistivity reduction as a function of conditioning was observed over a temperature range of 350 - 700 °F. At 650 °F, resistivity was lowered two orders of magnitude to a level of 1 x 10^8 ohm-cm. There were also qualitative indications of increased ash cohesivity and dust layer tensile strength. Tests at the host site in Phase II also showed that required additive injection rates could not be predicted from the laboratory resistivity tests. The degree of conditioning changes as a function of ESP condition, duct temperature, and particle loading. It was agreed among the participants that these results warranted Phase III testing.

Phase III Description

The objective of Phase III was to demonstrate that flue gas conditioning with this newly discovered agent improves full-scale ESP performance. The specific goals were to decrease resistivity, increase ESP total power levels, and decrease outlet duct opacity. The demonstration unit was nominally 270 MW in size with a flue gas flow of approximately 1,600,000 acfm at 750 °F.

An injection system capable of reliably and uniformly distributing the conditioning agent into the flue gas stream was designed and fabricated. The main components were 1) an injection skid, 2) interconnecting piping, 3) a purge air system, and 4) lances with dual fluid atomizing nozzles. The injection skid was generically designed to be mobile and to accommodate a wide range of agent flow rates. This skid is owned by ADA Technologies and will be used at several different test sites. Water, agent, and compressed air flow are monitored and controlled on the skid by a Campbell Scientific Micrologger. Automatic shutdown logic was included to allow for unattended operation.

The other three components were custom designed specifically for the site. The host utility installed the interconnecting piping between the skid (located at ground level) and the manifold system (located on top of the ductwork). In the manifold system a main liquid line was connected to a header which fed the five lances. Similarly, a main air line and header supplied compressed air to the lances. To prevent buildup around the nozzles and to cool the liquid lines, a large purge air blower was mounted near the manifold system with a flexible connection to each lance. The lances were made up of nozzles and fluid lines housed within a 6-inch pipe.

In January of this year a two-week test was completed and all of the performance goals were successfully met. Figure 1 presents measured flyash resistivity as a function of conditioning agent concentration. Measurements were made using the same equipment and procedures as Phase II and were extracted from the duct at a location approximately 80 feet downstream of the injection lances. Conditioning lowered resistivity from nominally 3x10^{11} ohm-cm to 5x10^8 ohm-cm, similar to the results from Phases I and II. The conditioned value was well within the optimum resistivity range for good ESP performance. Figure 1 also shows that no additional improvement is observed when concentration is increased above a certain level.

Figure 2 compares hourly averages of power levels in the first 4 electrical fields of the ESP during baseline (untreated) operation and during additive injection. The baseline data show typical hot-side performance when boiler load and flue gas temperature decrease at night. If resistivity weren't the limiting factor, the ESP should work better at lower temperatures because of decreased flue gas volume and increased density. This is not the case, however, because resistivity increases at the lower temperatures and causes a degradation in performance. This is reflected by the decrease in ESP power at night. However, when the ash is conditioned, resistivity no longer limits electrical conditions in the ESP, and power levels actually increase at low loads.

Figure 3 shows how increased power in individual electrical fields was reflected in overall ESP power levels and better collection efficiency. ESP total power was significantly increased from 80 kW to 150 kW. At the same time, outlet duct opacity decreased from 17% to 11%. Based on these results, approval was granted to proceed with Phase IV and a request was made for pricing of a commercial system. Phase IV testing will begin the week of June 24 1996.

CONCLUSIONS

A DOE objective to improve removal of fine particle air toxics from coal-fired combustion flue gas streams has been satisfied with the successful full-scale demonstration of ADA-23. This flue gas conditioning agent is intended for use in both ESPs and fabric filters. Two short-term full-scale demonstrations of this technology were recently completed with positive, quantifiable results. Data from the first two-week test showed flyash resistivity was reduced, ESP performance was improved and outlet opacity was reduced. A long-term (3 - 6 month) test will begin in June 1996.

A short-term demonstration on a cold-side ESP is planned for August, 1996. This test is co-funded by DOE, EPRI and Public Service Company of Colorado. The goals of this test are to confirm performance of ADA-23 at cold-side temperatures on a low sulfur coal flyash.

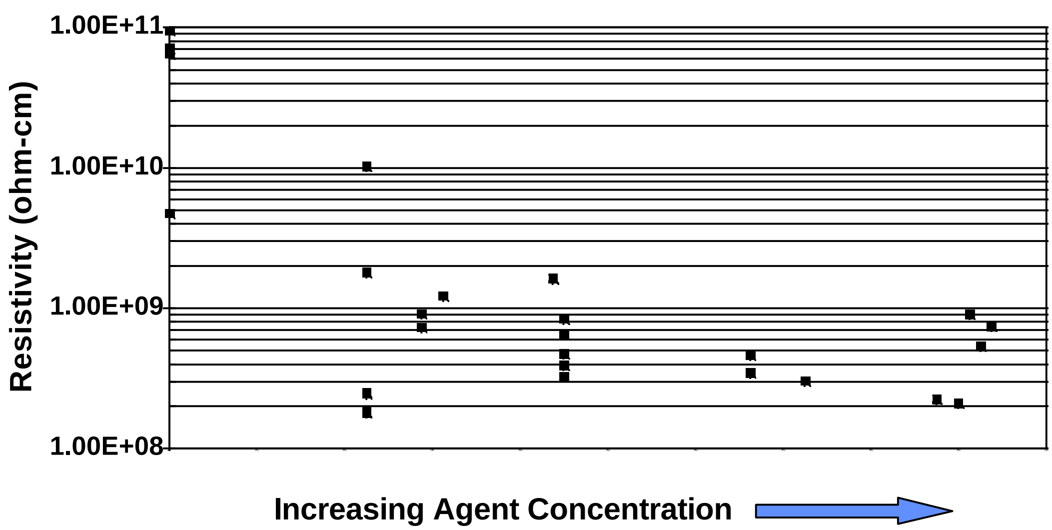

Figure 1: Effect of Conditioning on Flyash Resistivity

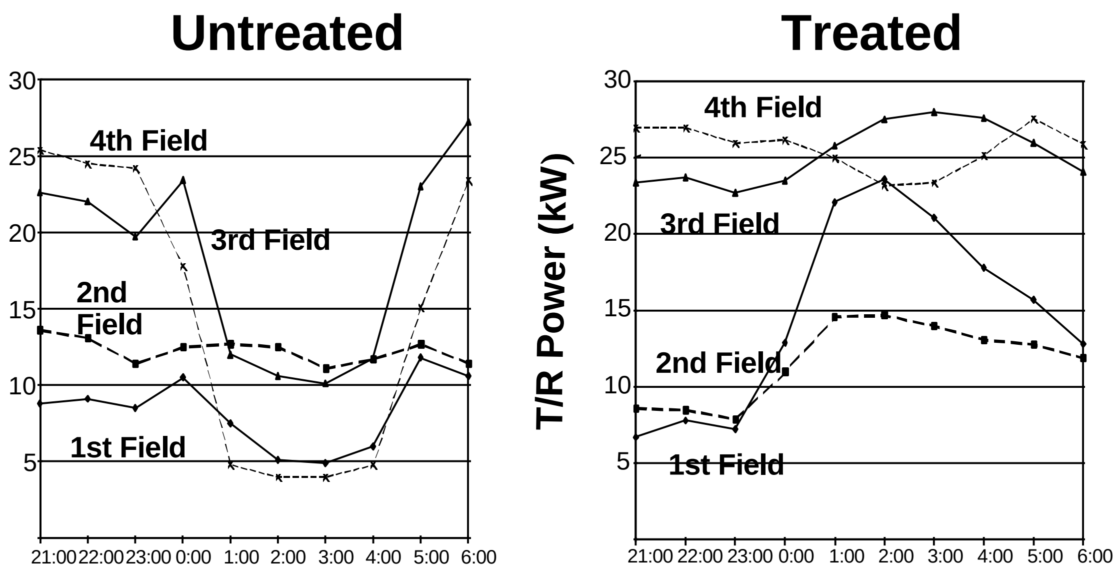

Figure 2: T/R Power with and without Conditioning

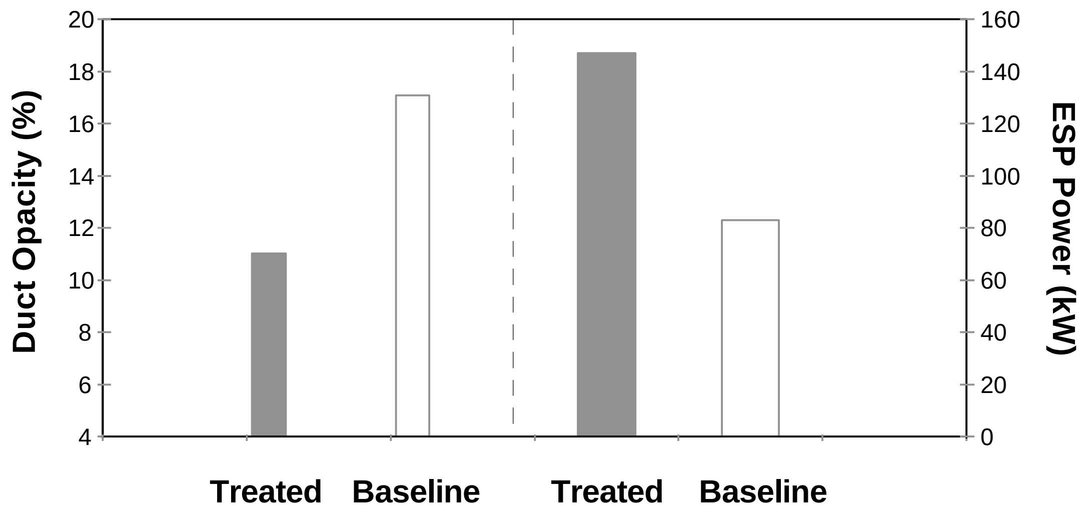

Figure 3: Effect of Conditioning on Opacity and ESP Power

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