# Statement of Work

The overall 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 is vital to the overall collection efficiencies 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 as effective and the treated ash treated is difficult to dispose of because of the odor produced by ammonia.

**Approach**

The primary objective will be achieved through a series of technical tasks that begin in the laboratory, followed by a short "proof of concept" demonstration at a utility plant, optimization of the conditioning technology through the combination of laboratory and full scale evaluation and finally, longer term demonstrations at various sites to prove the viability of the technology over a broad range of applications. The successful completion of this work requires both proper equipment and skills. As detailed in later sections, ADA-ES has the majority of laboratory and demonstration equipment in-house and has a proven track record of corporate experience dedicated to supporting technology development. The technical tasks are summarized below.

**Task 1. Upgrade Existing Laboratory Test Apparatus:** Improve the capability of existing equipment to directly measure cohesivity and tensile strength.

**Task 2. Identify and Evaluate Candidate Cohesivity Enhancement Additives:** Perform screening tests to identify the most promising candidate additives, followed by an intensive series of parametric tests to assure the additives meet the requirement in terms of performance, ability to integrate easily with the plant process and cost. The classes of additives to be tested will include various synthetic anionic and cationic polymers.

**Task 3. Demonstrate Performance at Full Scale and Optimize Product:** Prepare and install equipment for the demonstration of the most promising additive or additives on at least a portion of a full-scale ESP. This test will confirm anticipated performance and identify properties that can not be simulated in laboratory tests.

**Task 4. Identify Potential Longer Term Demonstration Sites:** To meet DOE's goal that the newly developed technology be applicable for a variety of coals and configurations, demonstrations will be conducted at several sites. In this task additional test sites will be identified and contacted.

**Task 5. Conduct Demonstrations to Confirm Performance for Different Coals and Configurations:** Additive performance will be evaluate at several different sites. The coals will be representative of types widely used. The two primary groups of interest are Powder River Basin Sub-bituminous and a low sulfur washed eastern bituminous with ash silica-alumina content above 85%. Also of interest is a site that fires a high sulfur bituminous coal with a scrubber-ESP configuration.

**Task 6. Determine Waste Characteristics:** Determine the effect of the additive on flyash disposal and reuse properties.

**Task 7. Perform Economic Analysis:** Develop the economics of the conditioning technology following EPRI approved techniques, where costs are presented as normalized busbar costs.

**Task 8. Management and Reporting:** Define project schedule, milestones and costing for internal project tracking. Prepare and submit DOE required reports.

**Quality of Data**

The most important components in any development effort are the abilities to 1) effectively simulate the test conditions and 2) accurately measure the variable in question. With initial help through DOE funding, ADA-ES personnel have developed the tools, skill and knowledge for the timely development and commercialization of innovative flue gas conditioning agents. The acceptance by utility users to demonstrate the newly developed agents and to purchase commercial equipment and annual additive contracts verifies that the data obtained from the existing laboratory test apparatus can be scaled-up to utility installations.

Laboratory evaluation techniques have been improved since the initial DOE funded programs and limitations have been identified. One limitation is the accurate measurement of cohesivity. Previous techniques were found to not be reliable when the conditioning agent was taken to full scale. The first task of the test plan addresses limitations by upgrading the system to measure cohesivity of flyash at flue gas conditions using an electrostatic tensiometer (Pontius and Snyder, 1991) and at ambient temperatures using a commercially available COHETESTER. The system will also be upgraded to inject flue gas constituents such as NO, $SO_2$, and $SO_3$.

ESP performance results from the full scale demonstrations will be obtained from plant CEMs and ESP operating systems, such as those supplied by Forry Controls, Neundorfor Inc., or BHA, Inc. Chemical injection parameters will be logged by an ICL data acquisition system that is located on the ADA-ES injection skid. The data obtained with this system during the past 3 years has been found to be reliable and accurate (Dharmarajan et. al., 1996, Baldrey et. al. 1997, Durham et.al., 1998).

Waste disposal properties will be measured both in-house and at industry accepted laboratories (CTL Thompson, Hazen Laboratories).

**Test Methods and Schedules**

In Task 2 the candidate additives will be evaluated using the laboratory additive screening test apparatus, Figure 1. The primary performance parameters will be tensile strength and cohesivity. Testing will be conducted over a range of operating temperatures (220 to 450 $^{o}$F) and with flyash from two coal sources; one high in alkaline constituents, like a PRB coal, and one that has more acidic properties of an Eastern low sulfur coal with high silica and alumina content. Flyash resistivity will also be measured.

**Figure 1. Laboratory Additives Screening Apparatus**

Baseline data of the flyash will be obtained with no conditioning. A second set of data will be obtained while conditioning with $NH_3$ and $SO_3$ to compare performance with a known cohesivity modifier.

Candidate cohesivity additives will include various synthetic anionic and cationic polymers selected for their effect on cohesivity. Previous applications of polymers for flue gas conditioning have focused primarily on resistivity modification. However, there are numerous applications of polymers that depend on properties that may improve flyash cohesion. In particular, high molecular weight temperature-stable polyacrylamide (PAM) salts, which are widely used for viscosification and flocculation of clay minerals, will be evaluated.

The results from this first phase of screening will be based on changes in cohesivity and how these changes compare to those obtained with known cohesivity modifiers. A sample test matrix for these laboratory tests is presented in Table 2.

The most promising of the additives from the first screening will then be put through a more extensive set of parametric screening tests. The parameters of interest in this series include:

- Sensitivity of additive concentration to cohesivity
- Sensitivity of the additive to different coal sources (several PRBs, Texas Lignite, To be determined)
- Impact of additive on flyash mineral analysis
- Impact of additive on key flyash properties (concrete set time, available alkali)
- Requirements for storage
- Requirements of injection system
- Cost

Following the laboratory tests, s short term (2 –4 week) evaluation will then be conducted at a utility site with the new conditioning agent or agents. It is expected that the host site will have a cold-side ESP with an SCA between 200 and 400 ft /kacfm and fire a low sulfur western or PRB coal. A typical test schedule for a full scale evaluation of one additive and two coal sources, or two additives and one coal source is presented in Table 3. The length of time at each condition can vary from several hours to several days. However, the industry experience with flue gas conditioning on cold-side ESPs is that the impact on performance is seen very quickly (within hours) and 24 hours of operation at one condition provides adequate screening. Based on the schedule in Table 3, it is estimated that this test series can be completed in 3 – 4 weeks. Data to be collected during the short term tests are presented in Table 4.

The measures of success for the short term tests will be a quantifiable reduction in outlet opacity and collection efficiency, and no impact on flyash reuse or other plant equipment. The ultimate goal is to achieve the DOE criteria of collection efficiencies of 99.99% for particle sizes from 0.1 to 10 micron. If undesirable side effects are discovered, an effort to identify the cause of the problem and to develop an acceptable solution or alternative additive will be conducted. Previously proven methods using both internal and external experts and testing with the ADA-ES test apparatus will be followed.

After the short term measures of success are satisfied, arrangements will be made to demonstrate this new technology for longer periods at 2 to 3 different sites in Task 4.. The goal of these tests is to show that the new additives offer a means to improve ESP performance to a broad segment of coal fired utility boilers. It is assumed that one of these sites will be the site from Task 3. The demonstrations will be structured so that the host site has minimal risk. The technology must be capable of meeting both DOE’s criteria and addressing plant needs. If the technology does not meet plant needs, such as any impact on ash resale, the test will be ended and equipment removed. If the technology does meet their needs, arrangements will be made to continue use until long term performance concerns can be answered. It is desirable that once short-term performance is confirmed, that the system is operated for a minimum of 6 months. It is expected that this task will take up to 15 months.

The injection scheme (chemical rate, load following, intermittent injection, etc.) will be determined from the short-term tests and the needs of the host site. The same parameters listed in Table 4 will be monitored. For this longer term test, daily operation of the system will be turned over to plant personnel. Operating manuals will be distributed and instruction classes held prior to passing over operating responsibility to the plant. ADA-ES will monitor data daily via modem and will visit the site at least once per month to gather data and inspect equipment.

**Table 3. Short Term Full Scale Test Schedule**

| Step | Test Description | Injection Rate | Boiler Condition | Coal Source |
|---|---|---|---|---|
| 1 | Baseline 1 | None | Maximum | Coal 1 |
| 2 | Baseline 1a | None | Low | Coal 1 |
| 3 | Rate 1 | Low | Maximum | Coal 1 |
| 4 | Rate 2 | Medium | Maximum | Coal 1 |
| 5 | Rate 3 | High | Maximum | Coal 1 |
| 6 | Rate 4 | Optimize | Maximum | Coal 1 |
| 7 | Rate 5 | Optimize | Low | Coal 1 |
| 8 | Repeat first 7 steps for second coal or additive | | | |

**Table 4. Full Scale Performance Parameters**

| Parameter | Method | Location | Frequency |
|---|---|---|---|
| Chemical Injection Rate | Coriolis Flow Meter | Injection Skid | Continuous |
| Flue Gas Temperature | Thermocouple | Before and After Injection Lances | Continuous |
| Boiler Load | Plant Signal | Boiler | Continuous |
| ESP Voltage and Current | ESP Controllers | TR Sets | Depends on System |
| Opacity | CEM | Stack or Individual Duct | Continuous |
| Coal Samples | Manual | Pulverizer | Daily |
| Ash Samples | Manual | ESP Hoppers | Daily |
| ESP Collection Efficiency | Manual | ESP Inlet and Outlet | At Specified Conditions |

Tasks that will be on going throughout the development and demonstration process will include waste (Task 6) and economic (Task 7) analyses.

**Equipment and Facilities**

ADA-ES's laboratory and full scale demonstration equipment will used in this program. ADA ES has a 2,000 $ft^2$ laboratory for developing and testing additive formulations. It is equipped with a chemistry lab used for preparing formulations. For laboratory tests, the major component is the additives screening test fixture, Figure 1. This test fixture is sized for 10 acfm of flow. For the full scale tests, the additive injection skid is the most expensive piece of equipment needed. Existing skids will be used. The demonstration skid has the capability of injection rates from 1 to 40 gph. A process diagram of the skid is presented in Figure 2. Existing ADA-ES equipment that will be made available for these tests include:

**Laboratory Test Equipment**

- Resistivity Measurement Device
- Vicat Needle (ASTM C191)
- Heated Injection Chamber
- Humidification Chamber
- Integrated Test Fixture (not including upgrades)

**Full Scale Test Equipment**

- Fully Automated Chemical Injection Skid (commercial quality) with chemical metering pump
- Chemical Storage Tank
- Chemical Transfer Pump
- Chemical Hoses

**Figure 2 . Injection Skid Process Schematic**

Data will be reduced and analyzed using proven data reduction routines developed by ADA-ES. These routines are contained in spreadsheets that were developed so that daily updates on performance could be provided to utility customers in a timely, non-labor intensive manner. The programs are macro driven and quickly assimilate new data and provide graphing capabilities for quick analysis of opacity, power levels, boiler load and injection rate.

**Project Management**

A qualified project team and the use of proven management methods are crucial to the success of the proposed project. ADA-ES' management approach is based upon experience gained through 16 years of contract research and successfully commercializing the results of research efforts. Between ADA-ES and it's parent company Earth Sciences, Inc., the personnel available for this program have a proven history of technical expertise, commercialization experience, competitive business experience and government contract management. The key personnel, Ms. Jean Bustard and Dr. Michael Durham, together have over 30 years of experience working with particulate control equipment and have an international reputation for excellence. Those of Mr. John Wurster, Mr. Cameron Martin, Mr. Ken Baldrey, Dr. Ramon Bisque and Dr. Duane Bloom will complement their skills. An organization chart delineating responsibilities and lines of authority of the project team is presented in Figure 3.

**Schedules and Labor Distribution Plans**

**Table 5: Task Schedule and Work Breakdown Structure**

**Table 6: Labor Distribution Plan**

| | Senior Professional | Professional | Technical and Support | Total |
|---|---|---|---|---|
| Task 1 | 80 | 120 | 200 | 400 |
| Task 2 | 40 | 88 | 440 | 568 |
| Task 3 | 472 | 1,168 | 532 | 2,172 |
| Task 4 | 232 | 96 | | 328 |
| Task 5 | 620 | 816 | 1,520 | 2,956 |
| Task 6 | 88 | 120 | 120 | 328 |
| Task 7 | 108 | 96 | | 204 |
| Task 8 | 624 | | | 624 |
| Total for Projecet | 2,246 | 2,504 | 2,812 | 7,580 |

**Figure 3. Organizational Chart**

**REFERENCES**

Durham, M.D., Holstein, D.B., Rhudy, R.G., Altman, R.F., Burnett, T.A., Lepovitz, L, Blythe, G (1993). “Performance of ESPs with Small SCAs in Spray Dryer Retrofit Applications”, 10 Particulate Control Symposium, April 5-8, Washington, DC.

Pontius, D.H., Snyder, T.R. (1991). "Measurement of the Tensile Strength of Uncompacted Dust Aggregates", *Powder Technology*, 68 (1991) 159-162

Baldrey K.E., C.E. Martin, C.J. Bustard, M.D. Durham, S. Williams, and L. Jenkins (1997). "Duke Energy's Operating Experience with ADA-ES Flue Gas Conditioning Technology on a Cold-Side ESP", Power-Gen International '97, Dallas, TX, Dec 9-11.

Dharmarajan, N.N., Moore, B., Durham, M., Baldrey, K., Bustard, J., Martin, C., Chang, R., & Glover, R. (1996). Cost-Effective Alternative Solution for Hot-Side ESPs. *Presented at POWER-GEN '96, December 5, 1996—Orlando.*

Durham, M.D., Baldrey, K., Bustard, C., Martin, C., & Dharmarajan, N. (1997b). Cost-Effective Retrofit Technology For Enhanced ESP Performance On Low-Sulfur Coal. *Proceedings of EPRI-DOE-EPA Combined Utility Air Pollutant Control Symposium, August 25-29, 1997—Washington, D.C.*