

**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 SO₃ and ammonia. During the fourth reporting quarter, laboratory-screening tests of more than 20 potential 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 new multi-cell laboratory flyash resistivity furnace constructed for this project. An initial field trial of three additive formulations was also conducted at the City of Ames, Iowa Municipal Power Plant.

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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 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 October through December 2000. During this period work was underway on Task 2, *Selection and Evaluation of Candidate Additives*, and Task 3, *Short-term Testing*. Laboratory screening of more than 20 cohesivity candidate additives was completed using the previously developed Electrostatic Tensiometer. Fly ash resistivity was tested for additional samples conditioned with the candidate additives. The first full-scale testing of additives on the project was completed on a municipal power plant in Ames, Iowa.

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 During this reporting quarter a total of more than 40 cohesivity-screening runs were completed with the refined ET technique.

Methodology

All tests started with the identical flyash, a low-carbon PRB (North Antelope). The ash was conditioned by co-injection with an aqueous spray of various chemical additives. Water evaporated from the aqueous additives droplets and the resulting particles were captured onto a fabric filter with the flyash, as previously described.¹

The flyash samples were conditioned at a higher rate than would be necessary in full-scale application in order to maximize the differences between conditioners. A target rate of 1.0% by weight additive-to-ash (ATA) was used for cohesivity screening. The typical expected range of additive application at full-scale is expected to be in the range 0.05 – 0.25% ATA, or 0.2 to 0.8 lbs/ton coal. An additional sample was also generated at the lower additive-to-ash rate, typically 0.2% ATA, for each candidate additive. This second sample was used to measure the flyash resistivity, since for an effective resistivity additive, the higher dosage would have yielded unrealistically low values.

The conditioned flyash was then quantitatively recovered. A 5 gm. uncompacted sample layer of the conditioned ash was prepared onto the bottom electrode of the electrostatic tensiometer. The electrostatic tensiometer was housed in a heated, humidified laboratory oven. The oven had a large view window that was used for visual observation and for digital photography.

The ash layer was allowed to equilibrate at a constant temperature of 165°C for all of the screening tests. Humidity was controlled at between 12 - 15% by volume by means of feedback temperature control of a humidity generator. The humidity generator incorporated a feedback exhaust gas loop from the ET oven. The exhaust gas was continuously monitored for temperature and relative humidity. The volume flow of carrier air through the heated water bath and the bath temperature was adjusted as necessary to yield the target moisture content.

Once the ash layer was fully equilibrated at the target temperature and moisture, oven circulation fans were shut off. Then a direct voltage was applied across the parallel plate electrodes in increasing potential of 1KV increments from 5 KV up to spark-over potential (typically above 30 KV). Electric field strength ranged from 2 to 10 KV/cm, realistically matching actual ESP electrical conditions.

At each voltage step a high-resolution digital photograph was taken of the ash deposition onto the upper (negative) electrode. The resulting series of digital photographs was computer enhanced for maximum resolution. Figures 1 – 5 are examples of the images obtained at 15 KV potential (4.3 Kv/cm field strength). Once these photographs were uniformly sized and enhanced, an equal-area grid pattern was projected onto each photograph. Then for each successive voltage step, the number of grid areas showing particle deposition was counted. This, in effect, yielded a cumulative distribution of the area of deposition onto the upper electrode with increasing voltage (and the corresponding area of particle repulsion from the lower flyash layer).

This data was used to determine two somewhat arbitrary levels of layer tensile strength for each sample. 10% coverage of the total grid area was defined as the initial “onset” of particle ejection. Layer tensile failure was defined as the point where particle loss is observed across the entire layer, as specified by SRI.^{2,3} This was calculated at the point of 90% or greater deposition of the grid area on the upper electrode.

Additive Selection

Previous reports have described the additive chemicals to be investigated.¹ These include the following general classes of chemicals:

- Adhesives:

Manufactured materials that exhibit sticky and binding properties including glues, gums, waxes, adhesives and resins. Bonds formed with these materials can be either chemical or mechanical in nature and can range from being very brittle to elastic. Common compounds used in formulating these materials are phenol-formaldehyde, neoprene and nitrile rubber, polyvinyl butyral, silicates, gelatins, cellulose, latex, and acetates.

- Moisturizers, humectants, and emollients:

Chemical additives to increase and retain moisture in a wide range of pharmaceutical and food products. Possible additives for this purpose include humectants (common in the food industry), moisturizers or emollients (pharmaceutical and cosmetic industries), and hydrogels (medical and other industries). Both synthetic and naturally occurring substances can fall into these categories of compounds.

- Hydrate-forming compounds:

Hydrates with bound moisture may also serve the purpose of increasing the moisture content of ash. Alums are a common group of materials that readily form hydrates. Common alums include those formed with sodium, potassium, aluminum, calcium, magnesium, zinc and iron.

- Synthetic organic polymers:

This group includes primarily non-cellulose viscosifiers and flocculants. Such polymers are commonly applied in oil recovery, industrial and water treatment processes. Anionic polyacrylamide (PAM), used widely for agricultural soil erosion control, was tested.

- Natural water-soluble polymers including two subgroups:

Inherently adhesive (“sticky”) carbohydrate polymers including sugars, carbohydrates, dextrans, and starches. Most of these materials are water-soluble and can be conveyed easily using conventional spray technology. These materials are reasonably available in various grades through commodity markets. Chemical and thermal stability within the flue gas environment are possible detriments to effective use. Current large-scale industrial uses (non-food) of these types of materials are in paper and board manufactured products. Agricultural sources of the raw materials for these compounds are corn, potatoes, cane, beets and wheat.

Cellulose polymers including sodium carboxymethylcellulose and related compounds such as hydroxypropyl methylcellulose were also evaluated. These compounds had been previously investigated for cohesive properties.⁴ One unusual characteristic of these compounds is their ability to thermally gel. These compounds are used as thickeners, binders, film formers, water-retention agents, suspension aids, surfactants, lubricants, and emulsifiers in a wide variety of products.

- Ammonia substitutes:

While not a focus of the screening tests, several water-soluble compounds that decompose at temperature to ammonia were considered. These could find application in combination with existing SO₃ conditioning where flyash is not recycled.

- Resistivity:

Water-soluble chemicals primarily applied to lower electrical resistivity. Several of these were tested for cohesive effect either separately or in combination with the cohesivity additives.

Flyash Resistivity

Many of the materials tested for cohesion were evaluated for effect on electrical resistivity with the same PRB flyash. Some additives were tested in combination with the previously identified deliquescent salt resistivity additives in order to test compatibility.

A second set of conditioned flyash samples were generated at an additive-to-ash rate of 0.2% ATA. FGC effects on flyash resistivity are easily detectable at this rate and it realistically simulates actual application. Flyash resistivity was measured in the laboratory furnace as previously described.^{1,5}

Field Screening Tests

During the quarter a brief field screening of 3 candidate FGC additives was conducted at the City of Ames Municipal Power Plant, Ames, Iowa. Several of the cohesivity additives from the lab screening trials were evaluated in addition to the resistivity additive, designated ADA-43.

Ames Municipal Power Plant Unit 7 is a 35 MW pulverized coal boiler burning a low-sulfur sub-bituminous coal. This unit also fires up to 20% by BTU value Refuse Derived Fuel (RFD). This unit is a stand-by peaking unit that is used primarily in the summer and early winter. The particulate control device is a 1967 American Standard Industrial electrostatic precipitator (ESP). The Specific Collection Area is 130 ft²/kcfm and the ESP has three mechanical and three electrical fields. The ESP is in good mechanical condition. This undersized ESP provides marginal particulate collection efficiency, even with a 40% opacity limit. The unit is currently grandfathered with respect to NSPS standards but will be required to upgrade particulate controls within two years. For the interim, there is an interest in inexpensive ESP performance fixes to avoid opacity-related de-rates.

Several years ago a commercial liquid based flue gas conditioning product supplied by Calgon was evaluated. This product improved performance and a similar liquid based technology, referred to in this report as “Plant FGC”, is still in use. The existing injection system, with the addition of a second pump, was used for our tests. The spray nozzles and lance spacing of this system were considered to be less than optimal in terms of distribution and droplet atomization. However, by maintaining the identical equipment the performance of the ADA-ES additives could be compared directly to the Plant FGC conditioning agent.

RESULTS AND DISCUSSION

Cohesivity Screening Results

Screening tests were completed for representative chemicals from the various listed chemical categories. The flyash was conditioned at a nominal 1.0% additive-to-ash weight ratio for the cohesivity tests. However, there were a number of conditioning runs with either higher or lower than the desired rate. In the extreme example, a water-treatment polymer was injected at a much higher (1.8%) additive-to-ash ratio due to a malfunction of the flyash feed part way through the test. Cohesivity for this test was measured at more than 400 N/m². The sample layer could be turned upside down and shaken with no particulate loss. A comparison of the deposition to the top electrode for this test (Figure 3) to the baseline (Figs. 1 and 2) is an excellent example of the striking visual differences from 40 N/m² to 400 N/m². While outside the range of feasible application rate, this test demonstrates the validity of the ET screening method and the high flyash tensile strength that can be achieved with chemical conditioning.

Table 1 and Figure 6 summarize the laboratory screening tests through the end of the reporting quarter. Candidate additives are identified sequentially by chemical class. The measured tensile strengths range from less than 40 N/m² to more than 400 N/m². Ash with no chemical conditioning (baseline) is at the low end of the range, < 50 N/m².

The tensile strength measured by the electrostatic tensiometer compared to other published measurements for flyash is expected to be lower because the layers are not pre-compacted. Therefore, comparisons of ET data with the Hosakawa Micron Cohetester or ring-shear data are not directly applicable but it is expected to follow the same relative trends. Previous investigations of cohesion with ESP rapping re-entrainment, for example, have found that fine particle rapping re-entrainment can increase almost exponentially for dust tensile strength below 50 N/m². Dusts with a tensile strength of 500 N/m² and greater showed minimal rap re-entrainment in a pilot-scale study.⁶ The reported values were derived from Cohetester data.

Another aspect of the data generated is the sensitivity to conditioning rate. We attempted to maintain consistent rates for comparison but the flyash feed system did not always cooperate. As a way to qualitatively compare additives at the same application rates, the data generated was further normalized to a uniform 1% ATA. This gives a qualitative indicator of which additives are more effective at lower application rates. The clear winner in this regard was Polymer #5, a high molecular weight anionic polymer soil conditioner known to bond with and to form direct bridges between clay particles. Figure 4 shows the deposition pattern for Polymer #5 with conditioning at only 0.3% ATA.

Table 1: Results of Laboratory Cohesion Tests

Trial Additive	Conditioning Rate (% Additive-To-Ash)	Onset of Particle Ejection (N/m²) ⁽¹⁾	Layer Tensile Failure (N/m²)	Normalized Tensile Failure (N/m²) ⁽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 ⁽³⁾	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 ⁽⁴⁾	0.80	87	163	203
Natural Polymer #4 ⁽⁴⁾	1.50	104	289	193

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. Selected for field screening tests.
4. Not evaluated in time for Ames field screening.

Flyash Resistivity Results

Resistivity tests were completed for selected trial additives over a full range of temperatures from 250°F to 800°F. The critical temperature region for combined cohesivity and resistivity FGC is the surface conditioning range below 400°F. Figure 6 shows the measured resistivity for selected additives. As can be seen, none of the cohesivity chemicals significantly reduced resistivity and one test, conditioning with polymer #5, was significantly higher than the baseline PRB flyash. The best resistivity chemical continues to be the previously identified deliquescent salt, shown as ADA-43 on Figure 6.

Selection of Chemicals for Field Trial

Selection of chemicals for the initial screening opportunity was based on the cohesivity screening performance, cost, and compatibility with an aqueous FGC injection system. Other considerations were handling characteristics, health effects, and potential for formation of harmful or toxic byproducts. In general, materials with significant health or toxicity risk were eliminated from consideration prior to the laboratory screening tests.

The laboratory screening showed that many of the potential additives had a beneficial effect on ash cohesion. However, a review of price and availability immediately ruled out several of the chemicals. For example, the manufacturer of Polymer #6, an advanced boiler water treatment chemical, was further contacted for firm pricing and availability. This particular chemical, which had appeared promising, was available only on a special order basis. Price was quoted at more than \$4/lb. Polymer #5, while readily available from several suppliers, was \$3.50/lb. in bulk quantity. Even with the superior results at low application rate, this was considered expensive for the application. Another drawback with Polymer #5 was a characteristic formation of viscous gels at very low concentration. It was determined that it could not be injected in a conventional aqueous FGC system at more than 3% concentration in water. Similarly, several of the cellulose-based polymers could not be formulated in aqueous solutions above 5% concentration.

Ammonia substitute chemicals were ruled out for field-testing due to the concerns with ammonia in flyash and because ammonia is readily available as a conditioner in less expensive forms. These chemicals could, however, have application in situations where vapor ammonia is too hazardous for conditioning.

The resistivity chemicals tested alone did not show any cohesive tendencies, a somewhat surprising result. It had been expected that these deliquescent salts, which obviously do attract moisture into the surface flyash layer, would improve layer cohesion in combination with resistivity reduction. As a result of this finding it will be important to test the compatibility of the best-performing cohesive chemicals in combination with the resistivity additives. Further lab tests and formulation stability tests will be undertaken in the near future.

Three cohesivity chemicals were selected for the initial field screening. The first was a common hydrate-forming compound (Hydrate #1). It is widely available as a bulk chemical at prices of less than \$.30/lb in 50% solution. The second was one of the water-soluble natural polymer group (#3). It is available in several grades as a common food additive. Price for food grade is about \$1.20/lb but other grades could be substantially cheaper. The final chemical selected was a commercially available water treatment chemical that was a combination polymer/aluminum chloride (Polymer #3). Bulk pricing was quoted at \$.60/lb in 40% solution.

A further group of natural byproduct chemicals (Natural Polymers #3 and #4) were investigated too late to be included in the field screening at Ames, Iowa but appear very promising both from a performance and cost standpoint. Figure 5 shows ET results for Nat. Polymer #3. This family of chemicals will be further investigated in the near future.

Field Screening Results

The Ames field screening trial yielded some data on additive resistivity performance and on material handling and formulation issues. However, results of effect on ash cohesion were inconclusive due to difficulties in maintaining controlled test conditions and to site-specific ESP operating practices (rapping frequency). Test of several additive formulations in addition to the Plant FGC conditioner were conducted over 3 weeks. The additives tested had been previously tried in the laboratory (Table 1). Chemicals selected were as follows:

- ADA-43 – combination of deliquescent salts for resistivity modification.
- Hydrate #1 – bulk metal hydrate primarily applied as a water treatment chemical. Available in concentrated aqueous solution.
- Polymer #3 – combination synthetic polymer flocculent and inorganic metal salt. Significantly less expensive than similar polymers.
- Natural Polymer #2 – carbohydrate polymer, food grade additive for trial, cheaper grades available.
- Plant FGC.

During the trial a resistivity conditioner, either ADA-43 or the Plant FGC, was injected at all conditions. This was a necessity in order to keep the ESP operating and to maintain opacity compliance. The cohesivity additives were then co-injected through a second metering pump. Application rates for resistivity chemicals ranged from 0.3 to 0.7 lbs/ton fuel. Application rates for the additional cohesivity modifiers ranged from 0.2 to 0.6 lbs/ton coal. In terms of actual chemical consumption this corresponds to about 0.6 to 1.3 gph injection rate for each chemical for this small 35 MW capacity unit. While application rates for liquid-based flue gas conditioners are highly sensitive to site-specific factors such as ESP condition and FGC chemical distribution, these rates are considered realistic and economical for most of the small, undersized ESPs targeted in this project.

Data was available from the ESP AVC readouts on an instantaneous basis. However, no AVC data logging or averaging was available. Electrical and process data was logged manually on 15-minute intervals during the test. This was sufficient to identify major shifts in ESP power and operating characteristics, but did not permit detailed trending or show short-term indications of ESP response to FGC. Resistivity was the predominant factor limiting ESP performance, as seen in suppressed secondary currents and power at full load in the first two fields. Rapping re-entrainment was quite pronounced. Baseline opacity ranged from 20 – 35% with frequent spikes that corresponded to outlet field rapping. Opacity trended higher while burning the refuse-derived-fuel (RFD). This was likely due to an overall increase in particulate loading and likely to a higher flyash resistivity.

Our initial assessment of the Ames Unit #7 ESP was that it provided an ideal opportunity to improve opacity by application of a cohesivity additive. The ESP certainly exhibited rapping re-entrainment problems that could potentially be reduced through cohesivity conditioning. In common with most undersized ESPs of the same vintage, it also had a high face velocity and likely had ash scouring from collection plates during peak generation periods. Despite these conditions, it became apparent after several days testing that operating conditions and practices were not well suited to testing of cohesivity conditioning.

Rapping Schedule

Frequency of plate rapping is an important variable that must be optimized in order for cohesivity to be effective. In this case it was learned after the trial started that the rapping frequency was extremely rapid compared to standard operating practice for most utility ESPs. The entire ESP was rapped in less than 4 minutes with double hits in rapid succession on each plate rapper. First and second field plates and all wire rappers were rapped on 49-second intervals. The outlet field was completely rapped every 3.5 minutes. In more typical ESP operation with a small ESP, the final field plates would be rapped on a 4 to 8 hour interval or even longer cycle. This allows a defined ash layer to build up that is then sheared off by the rap and falls into the hopper as sheets or large agglomerate particles.

While the process of rapping particulate from collection plate to hopper is complex, it is commonly recommended that if severe rapping spikes are observed, increasing the time between raps will reduce re-entrainment⁷. At other sites with fast rapping (though none as extreme as this) “puffing” is often observed. The freshly collected ash is released by rapping and immediately re-entrained into the outlet flue gas. Ash does not have a chance to build into a cohesive layer.

It is believed that the fast rapping at this plant significantly diminished the impact of any cohesivity conditioning. In this situation the existing Plant FGC flue gas conditioning was primarily effective as a resistivity control.

Fuel Throughput

A further difficulty in structuring a short-term comparative test at this site became apparent after several days operation. The standard operating procedure when firing RDF was to maximize RDF feed while maintaining opacity within compliance. Thus any improvements in opacity led to a higher rate of RDF. For this short-term test there was no good method to monitor or control RDF throughput. This made any direct comparisons between periods of operation with different FGC chemicals problematic.

Additive Comparison

Data collected over the entire trial was examined for periods of operational stability. For each conditioner, periods of from 2 – 8 hours were identified with relatively stable load, fuel blend, and boiler operation. Opacity response was selected as the primary indicator of performance. The variation in opacity response is a combined function of ash resistivity (ESP electrical) and ash cohesion. Insufficient ESP data was available to assess differences in electrical response to different conditioners for the short periods of stable operation.

Within each of these stable periods the 1-minute opacity response was tabulated within frequency ranges. This data was then compared as an indicator of FGC effect for each chemical. Figure 8 shows the results. The combination of ADA-43 and Hydrate#1 at a high rate was the most effective, while the Plant FGC and ADA-43 with Polymer #3 was the least effective. Conditioning with ADA-43 with no cohesivity additive was as effective as the current Plant FGC. This was an expected result since ADA-ES had previously tested the resistivity response of ADA-43 compared to the commercial conditioner in use at Ames. Laboratory resistivity response of ADA-43 was found to be superior for a western sub-bituminous fly ash.

Natural Polymer #2 was not injected due to formulation problems. The toll blender could not produce a stable, water-soluble blend. The chemical was delivered at 30% solution, but it rapidly precipitated out of solution. In addition, the remaining liquor rapidly fermented. This additive, if used in the future, will require some form of biocide and additional work on formulation.

The trial at Ames was discontinued due to the above difficulties with rapping and plant operation. Since this trial was an invitation only to substitute for existing FGC, plant operations could not be adapted to accommodate parametric testing. Optimizing rapping with flue gas conditioning, while potentially very beneficial to plant operations in the long-term, was outside the scope and time constraints of the test.

Fly ash samples were collected but to date have not been analyzed due to the inconclusive performance results. All ash collected from the ESP during the trial was land filled so there was no need from an operational standpoint to evaluate ash characteristics.

CONCLUSION

During the quarter, laboratory-screening tests were completed for more than 20 candidate additives by the Electrostatic Tensiometer method. Additives for screening were selected from a variety of water-soluble chemical classes including compounds forming metal hydrates, moisturizers, synthetic polymers, cellulose and other carbohydrate-based natural polymers, adhesives, and several ammonia-producing chemicals. Additives were co-injected with flyash in a heated, humidified spray chamber, realistically simulating actual liquid-based flue gas conditioning. A number of the additives increased the tensile strength of the test fly ash layers compared to baseline tests with no conditioning. Measured tensile strength ranged from 40 N/m² for the unconditioned baseline tests to as high as 400 N/m². The comparative difference between these two extremes was readily visible in digital photographs of the deposition off the test layer at an applied field strength of 4.3 Kv/cm field strength (Figures 1 through 5).

The results from laboratory cohesivity screening to date have been very promising. A number of chemicals have been proven to improve ash cohesivity. In particular, a class of byproduct chemical tested after the first field trial appears to have good performance at low application rate (Nat. Polymer #3 and #4). Price and availability are both favorable. Further work is needed to develop formulations that can be injected as a combined aqueous chemical. Further full-scale testing is essential once a stable product is developed.

Flyash resistivity was also measured for selected ash samples conditioned with the candidate additives. At a conditioning rate of 0.2% by wt. additive-to-ash none of the cohesivity chemicals lowered resistivity compared to the baseline.

Previously identified deliquescent salts that do effectively control resistivity were tested for cohesive effect and found to have little effect on ash tensile strength compared to baseline with no conditioning. This finding is surprising because it is believed that the mechanism for resistivity modification is binding moisture to the flyash.

If the resistivity modifiers do nothing to improve ash cohesion, then for most applications a combined cohesivity/resistivity additive will be required. Chemical compatibility and formulation between the deliquescent salts and cohesivity additives will be a key priority in further development.

Also during this quarter a full-scale trial of several of the candidate additives was conducted on a small municipal power plant. An existing FGC injection system was used. All of the additives were injected successfully with the exception of one trial batch of a carbohydrate polymer that solidified and then fermented.

A direct comparison of the different additives was difficult due to the variability in fuel content and throughput. In addition, the ESP rapping system was set to an extremely fast rapping schedule that effectively negated any benefits from cohesivity conditioning. Conclusions that could be drawn from the trial, based on opacity response during comparable and stable operation were as follows:

- ADA-43 was at least as effective as a resistivity modifier as the existing Plant FGC.
- A combination of ADA-43 and Hydrate #1 cohesivity additive appeared to give better performance than any other combination or than injecting resistivity chemicals alone (see Figure 8).
- Polymer #3 did not appear to be effective.

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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

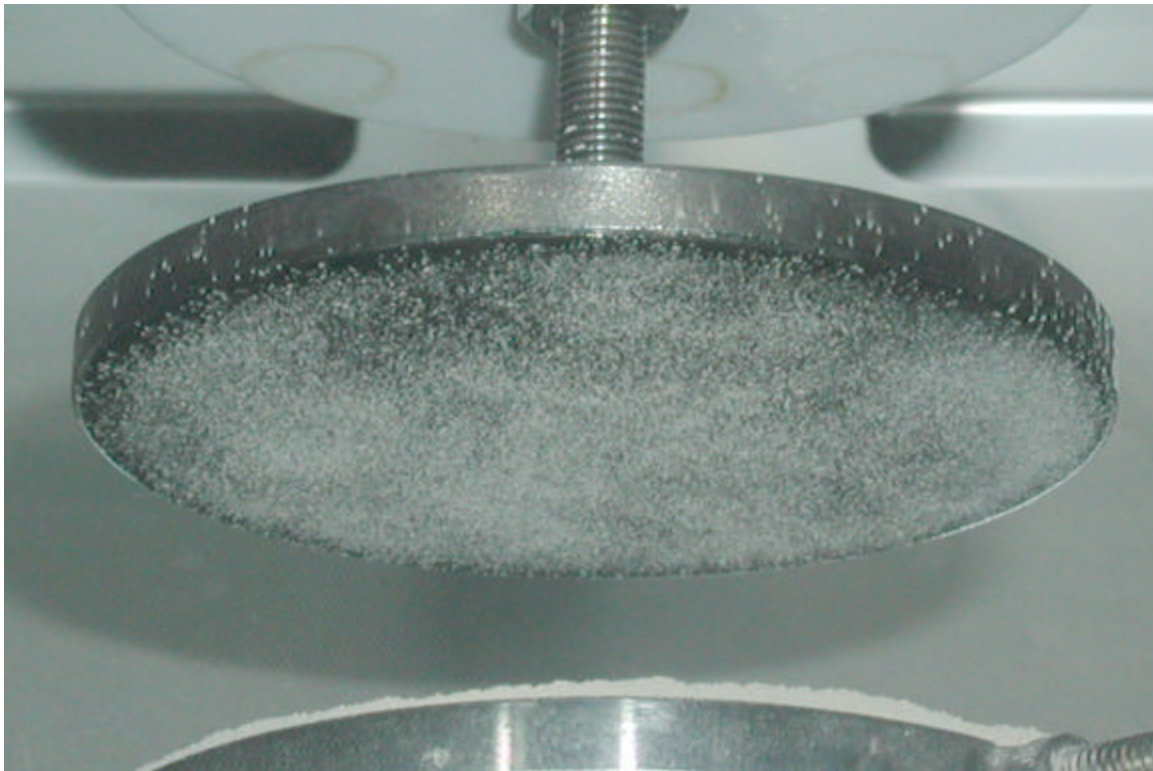


Figure 1: Unconditioned Flyash, Baseline, Photographed at 4.3 Kv/cm

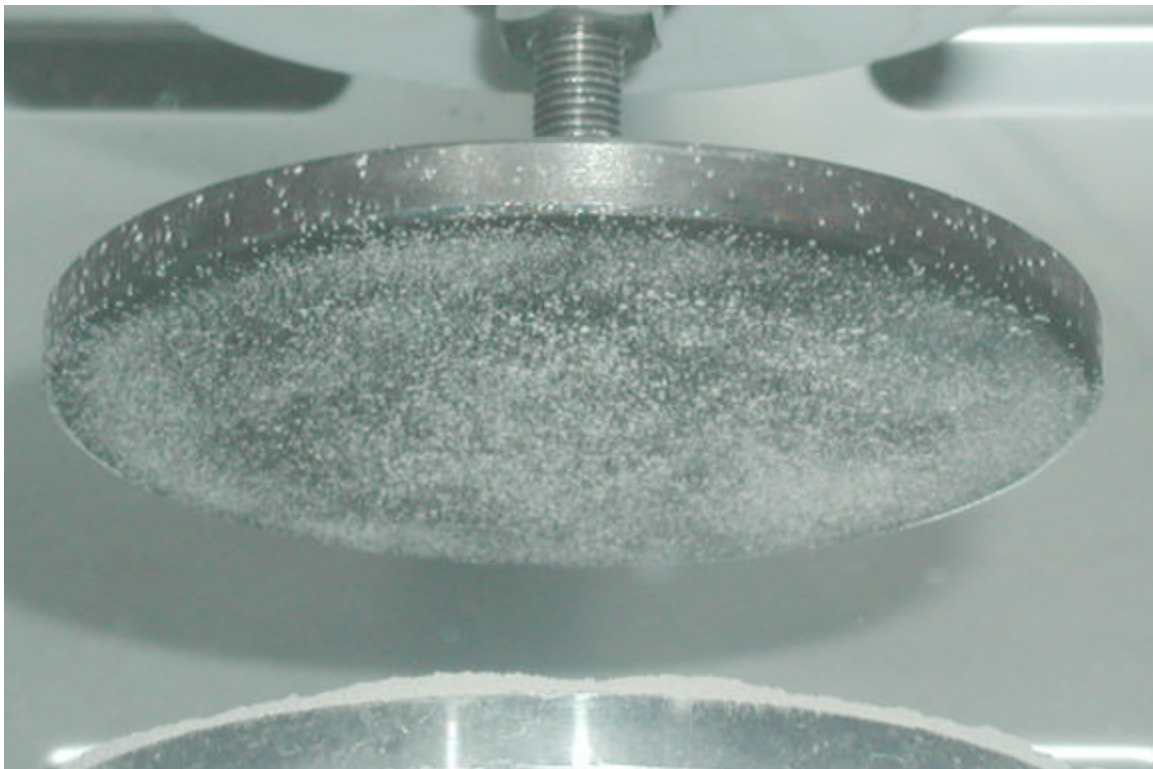


Figure 2: Baseline Repeat (Unconditioned) at 4.3 Kv/cm

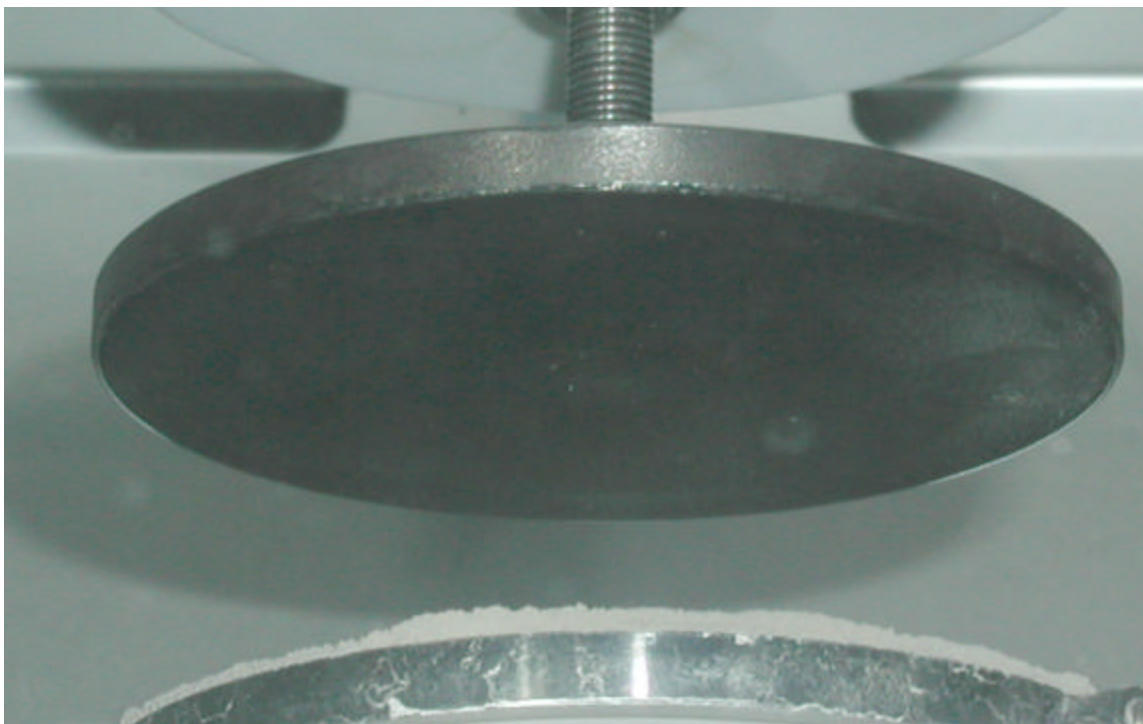


Figure 3: Polymer #6 Conditioning at 1.8% ATA, 4.3 Kv/cm

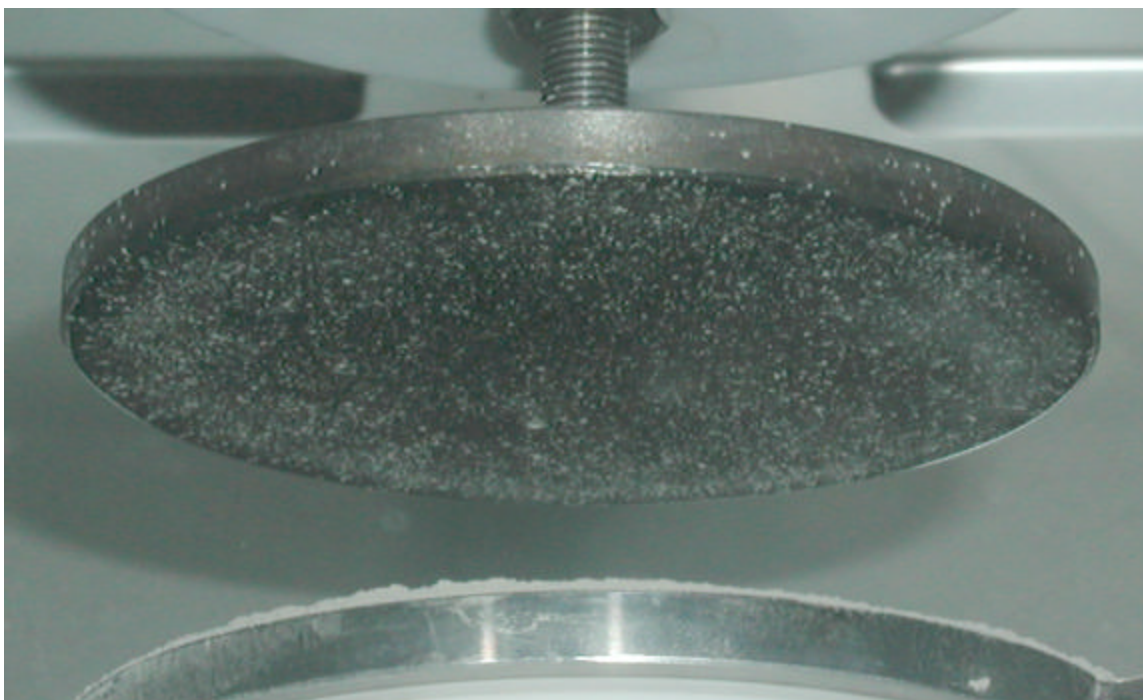


Figure 4: Polymer #5 Conditioning at 0.3% ATA, 4.3 Kv/cm

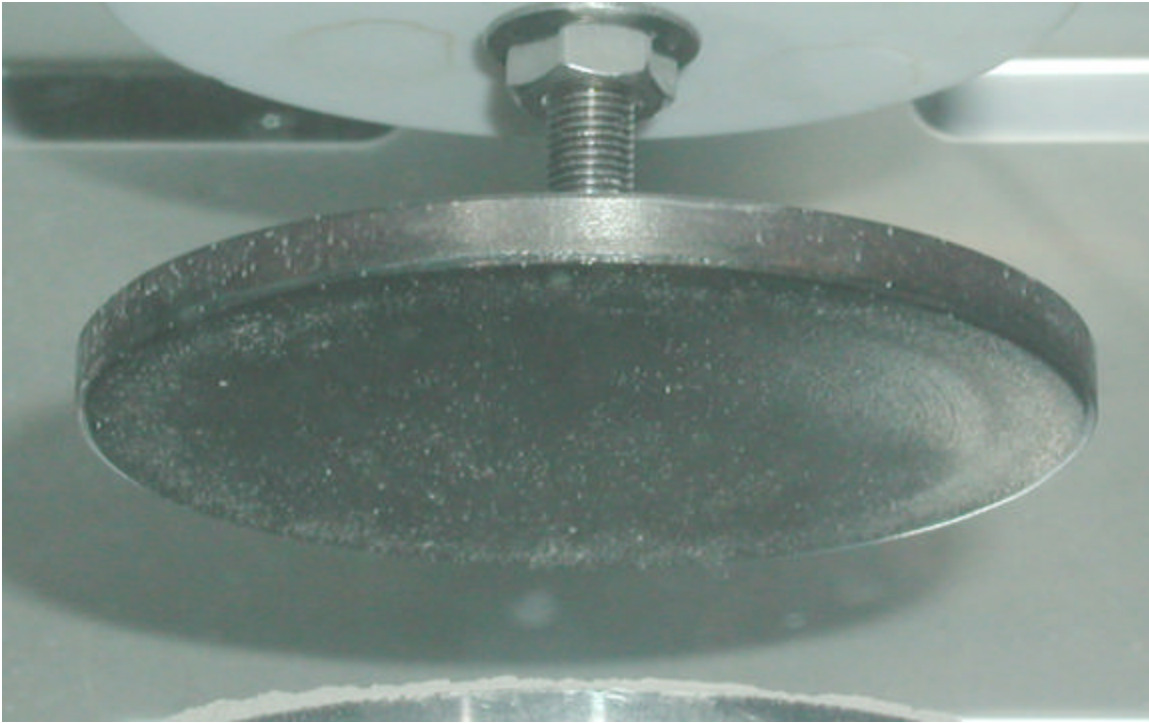


Figure 5: Natural Polymer #3, Conditioning at 0.8% ATA, 4.3 Kv/cm

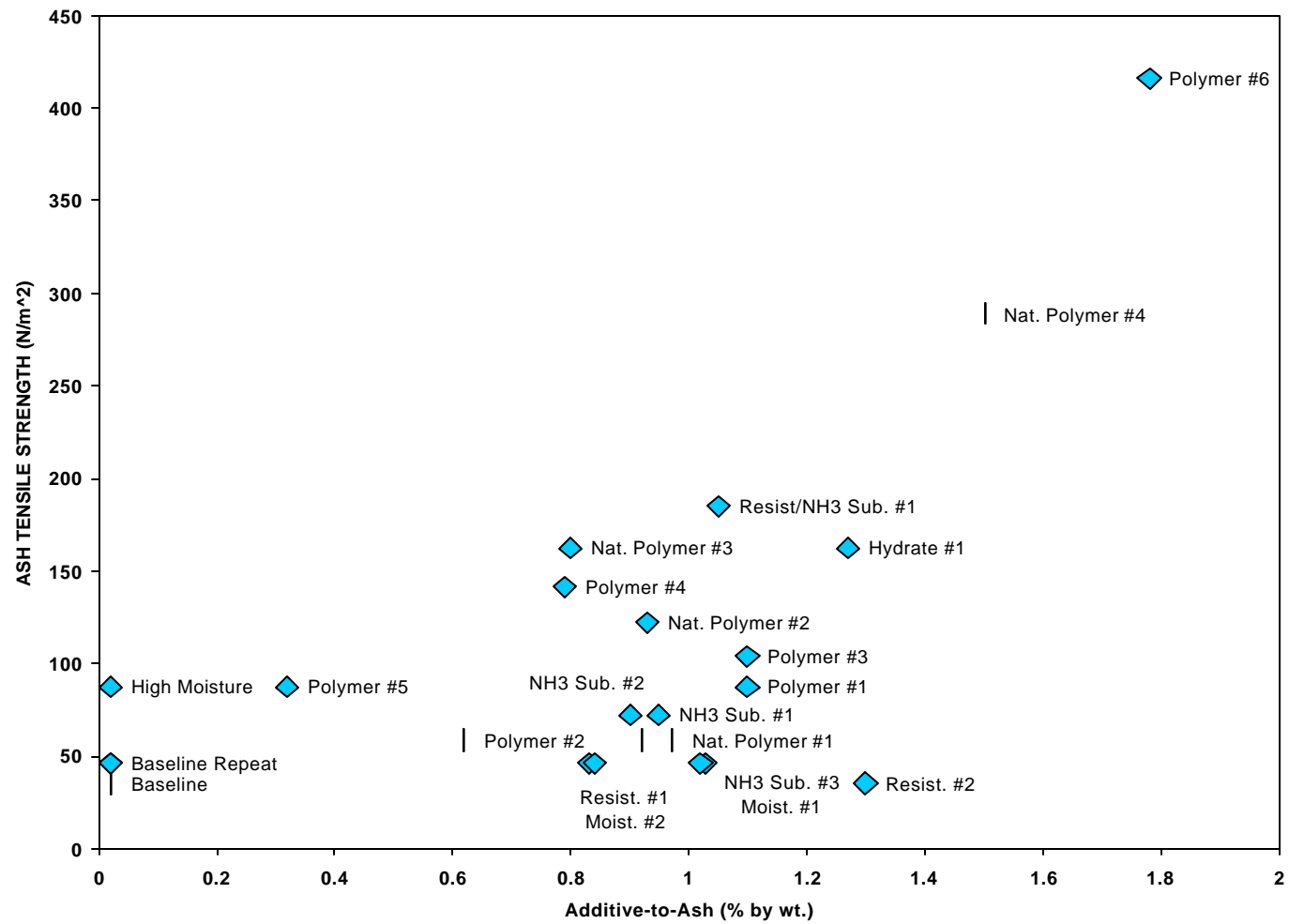


Figure 6: Cohesivity Screening Results

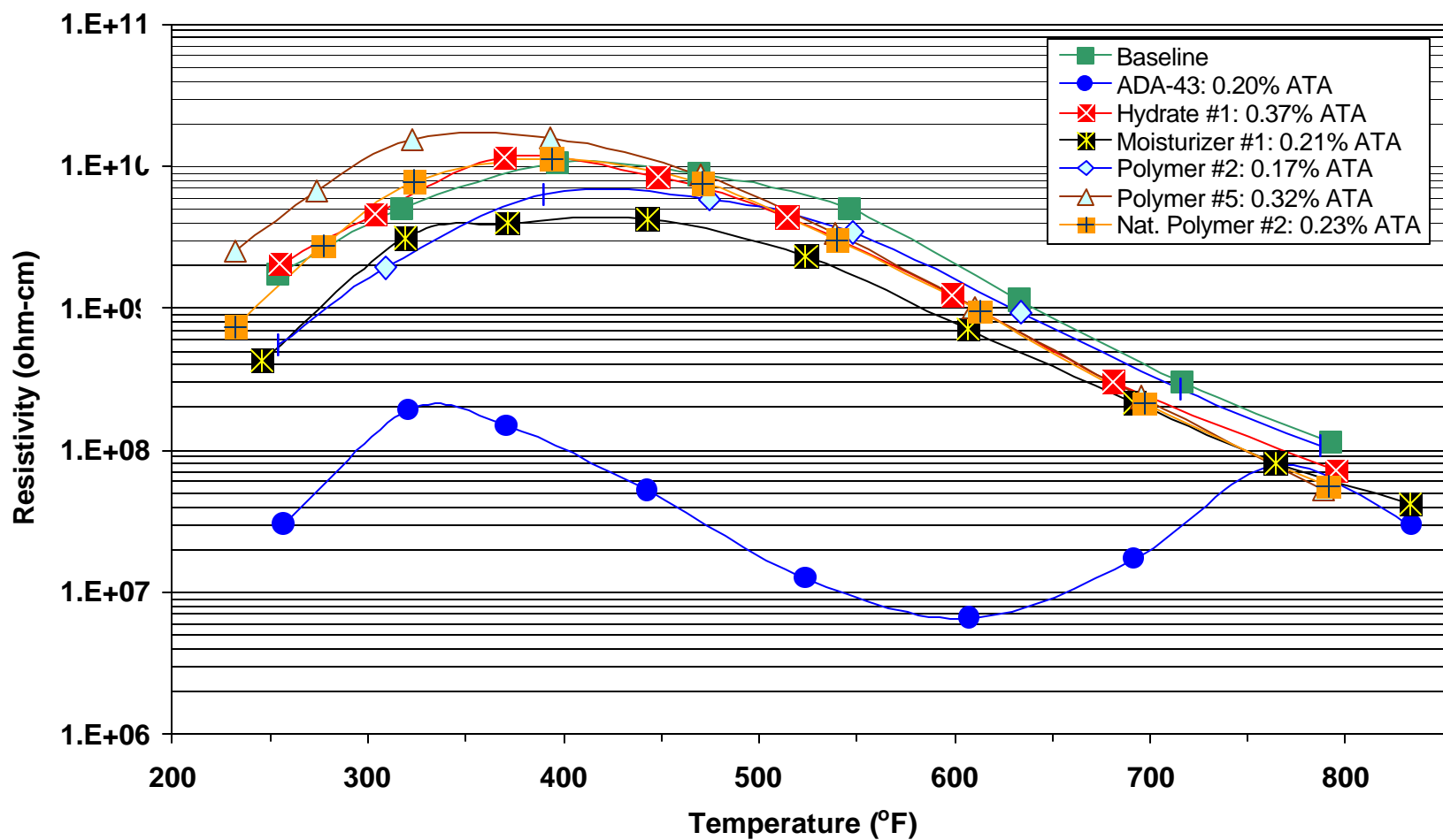


Figure 7: Resistivity Screening Results

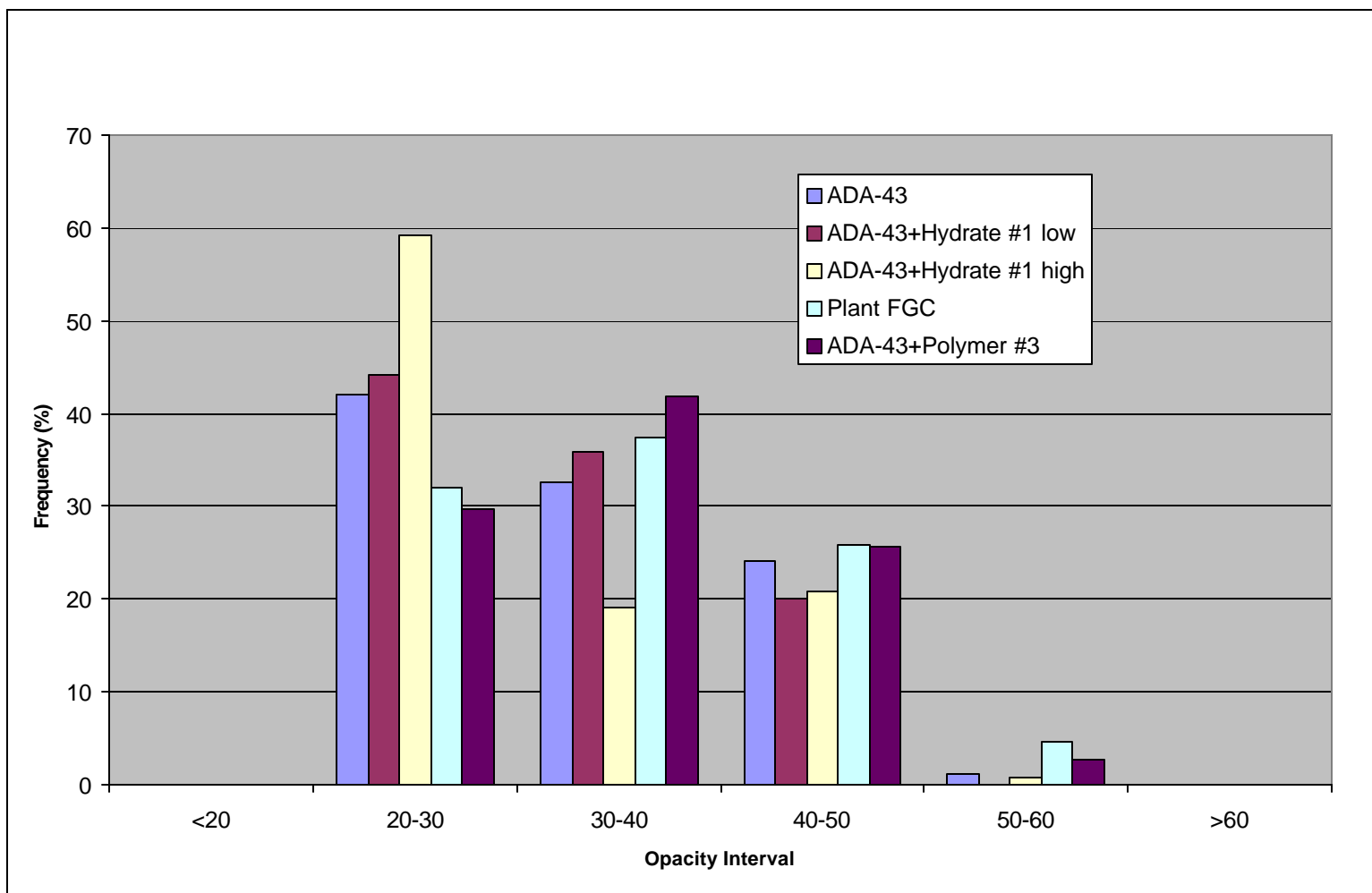


Figure 8: Ames Unit 7, Opacity During Stable Operation with Different FGC