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FLUE GAS CONDITIONING FOR IMPROVED PARTICLE COLLECTION IN ELECTROSTATIC PRECIPITATORS

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PROGRAM OBJECTIVES

The purpose of this research program is to identify and evaluate a variety of additives capable of increasing particle cohesion which could be used for improving collection efficiency in an ESP. A three-phase screening process will be used to provide the evaluation of many additives in a logical and cost-effective manner. The three step approach involves the following experimental setups:

1. Provide a preliminary screening in the laboratory by measuring the effects of various conditioning agents on reentrainment of flyash particles in an electric field operating at simulated flue gas conditions.
2. Evaluate the successful additives using a 100 acfm bench-scale ESP operating on actual flue gas.
3. Obtain the data required for scaling up the technology by testing the two or three most promising conditioning agents at the pilot scale.

The objectives of this program are addressed in ten tasks defined in the Management Plan. During the three months covered by this report, work was focused in Tasks 3 and 4.

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ACTIVITIES COMPLETED DURING CURRENT REPORTING PERIOD

TASK 3. INITIAL SCREENING OF ADDITIVES

Modification of the Laboratory Test Apparatus

Flyash Feeding System

The laboratory flyash feeding system was modified to produce more consistent results. This was important because of the reaction between SO_3 and the flyash required maintaining a relatively constant ratio between the quantities of these materials being injected.

Variation of the flyash feed rate and pluggage of the screw feeder even after modification to the supplied 1/4 inch diameter feed screw continued to present a problem with the laboratory apparatus. Another manufacturer of screw feeders was identified that produced 1/8 inch diameter single pitch feed screw. A 1/8 inch diameter feed screw was purchased and retrofitted into the screw feeder unit. Stirring whiskers or whips were also added in the solids hopper to prevent compaction of the flyash prior to feeding. A positive pressure purge of 15 standard cubic centimeters per minute of dry air was also plumbed into the solids feeder hopper to prevent any potential back flow of the simulated wet flue gas into the solids hopper were condensation might occur. The final modification to the screw feeder unit was the addition of a small electric solenoid rapper on the end of the feed tube where the flyash enters the simulated flue gas flow path. This rapper prevents bridging clumping of the flyash promoting a more uniform feed rate.

These modifications to the solids feeder unit resulted in a significant improvement in flyash feedrate. Figure 1 is a graph of the screw feeder calibration after retrofitting the 1/8 inch diameter feed screw. The screw feeder is now operating at nominally 80 rotations per minute (1/4 inch screw operated at 0.75 RPM) to provide approximately 3 grains per minute of feed. Control of the flyash feedrate is much finer and reasonably predictable. The flyash loading in the simulated flue gas mix entering the resistivity apparatus is visibly improved and more uniform.

Additive Injection System

The first several attempts at injecting additives into the simulated flue gas via the injection chamber revealed that the ultrasonic humidifier system was producing inadequately low liquid feed rates. The ultrasonic humidifier had been characterized and calibrated previously in room air with several of the potential additives. A 1.5 inch diameter uptake tube similar to that used on the bottom of the injection chamber was used on these test. Use of the

ultrasonic humidifier with the heated flue gas stream was expected to increase the feedrate due to increase liquid evaporation at higher temperatures. Several modifications were made in an attempt to increase the liquid feedrate of the ultrasonic humidifier with minimal success.

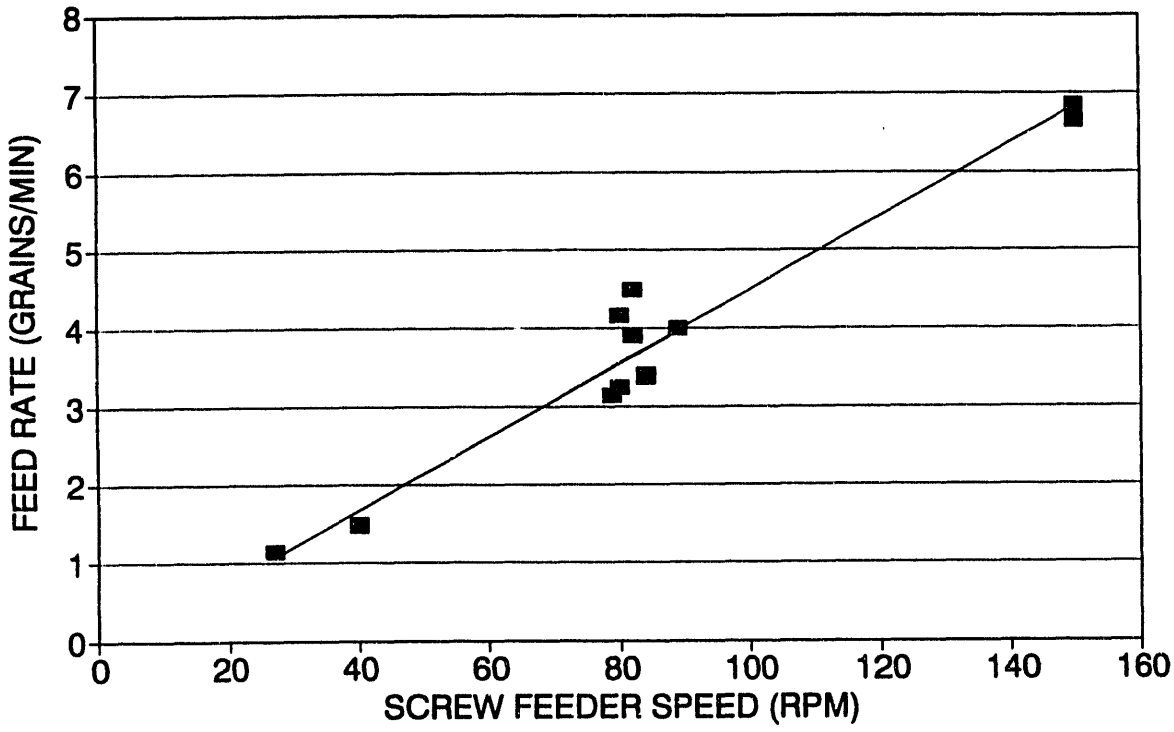


Figure 1. Calibration of the 1/8th inch Diameter Screw.

Under Task 4.2 Design of Additive Injection System, a dual fluid atomizing nozzle had been specified and ordered for use on the bench scale system and potentially the pilot scale system. The nozzle specifications show a minimum liquid flow capacity that was 1-2 orders of magnitude greater than what was need on the laboratory apparatus. Since modifications to the ultrasonic humidifier system were proving unsuccessful, a test of the bench-scale dual fluid nozzle was conducted to determine if it might be suitable for use on the laboratory apparatus.

A test of the nozzle was performed in which the minimum design atomizing air flow, 10,000 sccm (0.35 scfm), was supplied to the nozzle while the desired laboratory feedrate of liquid, 0.5 cc/min (0.008 GPH), was fed via a peristaltic pump. The minimum design liquid flow rate of the nozzle is 8.8 cc/min (0.14 GPH). The atomizing nozzle performs quite well at these extremely low liquid flow rates most likely as a result of the excessive amounts of atomization air. After visual and tactile examination of the spray plume the nozzle was inserted into the laboratory injection chamber. Complete evaporation of the injected liquid is occurring as there is no evidence of wall wetting or solids deposits in the main body of the injection chamber which has an inside diameter of 3.8 inches.

The gas mixing spreadsheet used for the laboratory flue gas simulator was modified to account for the 10,000 sccm of air injected into the chamber via the atomizing nozzle. The humidifier water bath temperature was adjusted accordingly to maintain the 10% moisture content desired as a baseline operation.

Initial Additive Test Results

Figure 2 shows the configuration of the experimental apparatus after all of the modifications were made. The combination of the improved flyash feed rate and improved temperature control provided a system in which consistent test conditions could be produced. In addition, use of the dual fluid atomizing nozzle for injection of candidate additives has simplified the daily operation of the laboratory apparatus lessoning the turn around time between tests and increasing the reproducibility of the test results.

Laboratory tests reported in the previous quarter demonstrated that the rate of precipitation increased for higher resistivity conditions. This indicates that the lower resistivity leads to increased reentrainment which limits the rate of precipitation. Since precipitation rate appears to be a method of discriminating between two cases with different amount of reentrainment, it was decided to use this parameter as a criteria to judge the effectiveness of the additives.

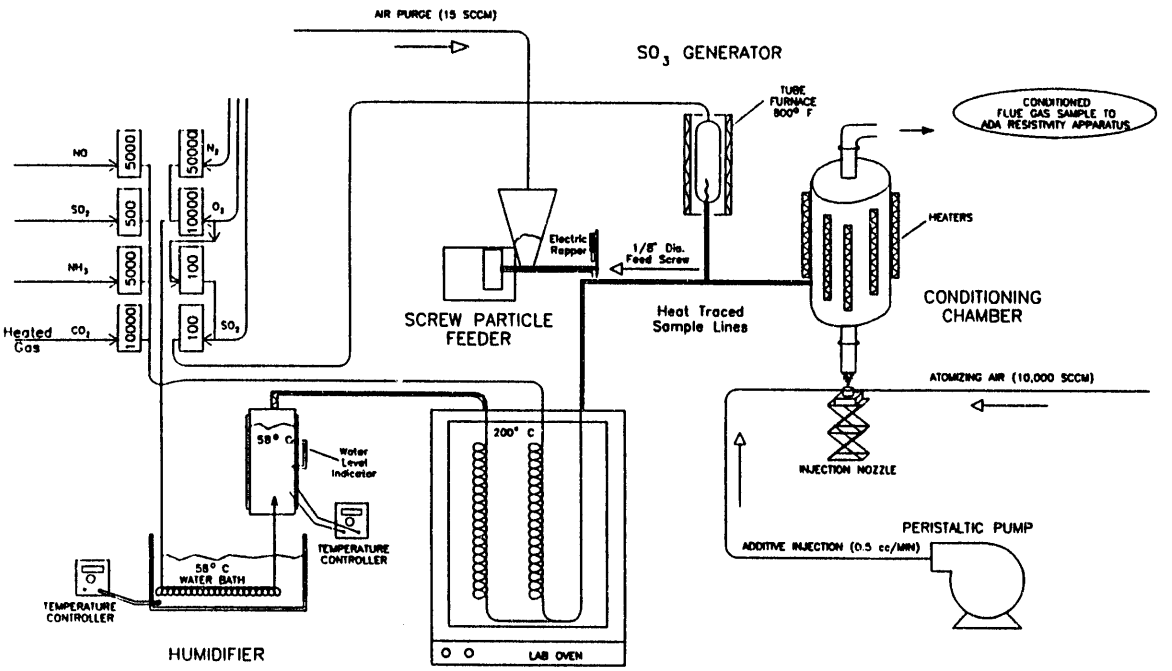


Figure 2. Final Configuration for the Laboratory Experiments.

It is concluded that the laboratory tests should be conducted at high levels of SO_3 such that the resulting resistivity is in the range of 10^7-10^8 ohm-cm. There are several reasons leading to this conclusion. At SO_3 concentrations of 30 ppm and greater, the curves for both dew point and resistivity are relatively flat so that changes in gas phase SO_3 will have minimal impact on particle characteristics. In addition, the electrostatic forces are relatively flat in this range so that changes in flue gas conditions will that result in a change in resistivity by up to two orders of magnitude will have little effect on the magnitude of reentrainment. Finally, at the very low resistivity conditions, reentrainment will be the highest. Since the purpose of the laboratory resistivity tests is to determine the relative ability of the various additives to reduce resistivity, the greater the reentrainment, the easier it will be to measure an improvement.

Tests were conducted by first operating at baseline conditions with no additives and then repeating the test with additives. In order to produce the identical gas stream characteristics under both baseline and additive conditions, the injection nozzle was operated for both cases. During baseline testing with no additive injection, a 0.5 cc/min feed of clean water is injected through the nozzle into the chamber. A 250 ml flask acts as the liquid reservoir to the peristaltic pump. To start an additives injection test the a 250 ml flask containing an additive concentration is exchanged on the fly with the baseline water flask. At the completion of an additives injection test the process is reversed and a second baseline measurement can be performed. Tests are run for a constant duration. The data collected during each test includes the resistivity of the material, the thickness of the collected dust layer, and subjective indications of the dust characteristics.

Seventeen of the most promising additives have undergone preliminary screening in the laboratory apparatus. The candidate additives were from the polymer group, cellulose derivatives, starches and gums, and oils. No waxes or synthetic compounds have been tested to date in the laboratory apparatus.

Of the seventeen additives tested, eight appeared to have a positive impact on either the ash layer thickness or the physical appearance of the dust layer. Excessive deposits on the discharge electrode resulted during injection of some of the additives. Three of the additives resulted in significant deposits in the injection chamber. The build up on the electrode was interpreted as a positive indicator of increase particle adhesion. The initial observations and comments for the eight additives are listed in Table 1.

ADDITIVE	CONCENTRATION	EFFECT	COMMENTS
Polyvinylpyrrolidone	2%	Test resulted in visible change in flyash entering the chamber and precipitation rate with excessive buildup on the needle. Precipitation voltage increased steadily as solids built up on the needle.	The most promising of the additives at this point.
Xanthan Gum	1%	Looked good; Uniform build-up on disc--Very fine, but thick.	Very good candidate--The fact that the ash was not as chunky as others could prove to be an advantage.
Locust Bean Gum	1%	Much like Xanthan Gum, but thinner ash layer. When the test was run, the solids flow appeared to have slowed dramatically, which could account for lower precipitation rate.	May have promise--A retest would be beneficial.
Carboxymethylcellulose	2%, 0.5%	At 0.5% concentration, there was no visible change over baseline, but 2% yielded a heavy buildup on the needle and base.	Heavy buildup may have been the result of increased solids flow (> 10 grains/min).
Airvol 523	2%	Light buildup on base with indentation directly below upper disc. Precipitation rate was just slightly better than baseline.	An adequate choice, but far from the best.
Corn Starch	2%	2.5 hours of injection resulted in large deposits of a damp, gummy nature. No significant difference in precipitation rate.	Need to retest.
Jaguar 8801	1%	Appeared to result in slightly larger particles, as well as slight increase in precipitation rate. Buildup occurred on needle, but not in additives chamber or nozzle.	Best of the Jaguars. Need to retest

Methylcellulose	2%	One hour of injection resulted in wet deposits in 1.5" spray tube. Appeared to be collecting well with an indentation evident directly below upper disc, however there was no significant change in measured precipitation rate.	Resistivities were climbing toward 10^10, possibly losing SO3 injection--Need to retest.

The additives that had little or no observable effect in the laboratory apparatus included: guar gum; Jaguar T-4542, 8012, 8710, and 8707; Soy Oil; Colloid 121, 202; and hydroxypropyl methylcellulose.

The eight promising additives will be retested in the laboratory apparatus at similar conditions to confirm repeatability of the initial results. Photographs will be used to document any unique ash layer characteristics or build-ups on the discharge electrodes.

TASK 4.0 BENCH-SCALE TESTING

Subtask 4.1 Comparison of Insitec Instrument with Impactors

Introduction

ADA Technologies recently acquired a laser particle size and velocity measurement system: the Particle Concentration, Size, and Velocity instrument, model E (PCSV-E). The equipment is sold by Insitec Measurement Systems of San Ramon, California. The hardware consists of a U-shaped bridge unit that houses the optics for a laser transmitter and receiver, a signal processing unit, and an advanced personal computer that performs the computations and displays measurement results. Insitec has also packaged software with the instrument to control the optical alignment, data acquisition and analysis functions from the keyboard of the PC.

In conjunction with the PCSV-E system, shipping cases for both the bridge unit and the electronics/computer system were purchased. These are designed to protect and cushion the hardware during transportation to test sites.

The PCSV system was acquired in order to make fly ash particle size, concentration and velocity measurements in flue gas streams both in the field and in the ADA laboratory. An initial test was scheduled to assess the performance of the instrument in comparison to conventional particle size and concentration sampling techniques; specifically, a modified EPA Method 17 for total particulate loading determination, and particle impactors and cyclones for size fractionation. Testing was to be performed on the inlet and outlet of a pilot-scale electrostatic precipitator (ESP) operated by Consolidation Coal Co. at their Research and Development Laboratory's Combustion Research Facility.

The comparison testing was performed on inlet and outlet ductwork to the ESP modified to accommodate measurements with the PCSV-E. While the laser instrument was in operation, simultaneous measurements were made with a modified Method 17 sampling

system, cyclone sampler, and both Anderson and University of Washington cascade impactors. Since the laser-based PCSV measurements are non-intrusive, the laser access ports were installed upstream of the sample ports for the standard methods. The laser access ports consisted of four inch pipe flanges on opposite sides of the ductwork, each fitted with a glass viewport for transmission of the laser beam across the interior of the duct. A focal point in the laser beam defined the sample volume of the PCSV instrument in the duct interior, at the approximate center of the duct.

Modified Method 17 samples and size fraction impactors and cyclones were run on the inlet and outlet of the ESP during data acquisition with the Insitec instrument. The extractive samples were taken over 10-minute to two-hour intervals, while the PCSV laser measurements each required about five minutes to complete. Data was reduced by the organizations that operated the respective equipment, and was assembled by ADA so that comparisons could be made among the several types of equipment used.

Test Procedures

Several days were required for setup and installation of the equipment at the Consolidation Coal Co. Research and Development Labs. The most extensive effort was required for the layout and fabrication of platforms to support the PCSV-E optics bridge at the inlet and outlet from the ESP. These were built by welding Unistrut structural steel tubing to the ESP frame, and then using threaded rod inserted into Unistrut fittings to suspend a plywood platform on which the PCSV-E optics bridge was positioned. The window flanges were installed in 4 inch couplings previously welded into the eight inch flow duct.

The PCSV-E system was also unpacked, assembled, checked out and calibrated in this set-up period. The system was found to have survived the transportation to the test site, and required only a minor adjustment to the calibration. This recalibration was accomplished on-site with the calibration reticle supplied as part of the instrument hardware.

Since this was the first field test of the PCSV-E system for ADA, arrangements were made to have a factory technical representative on site to provide guidance and support in the operation of the system. The representative was present for the first two days of testing, and proved to be most valuable in providing insight into the optimization of system parameters during data acquisition with the instrument.

During initial operation of the PCSV-E on the inlet to the ESP, problems arose over the strength of the laser signal passing through the two viewports that sealed the flue gas flow

from the ambient environment. These were planned to be optical quality quartz windows, but the vendor was unable to ship the components on time for initial testing. Windows fabricated from commercial float glass were used instead, and the attenuation of the laser beam was significant. A thinner type of float glass was installed, which brought the laser beam intensity up to a minimal level required for normal operation of the PCSV system.

The optical quality quartz windows were delivered on the second day of testing, and were immediately installed. The laser intensity rose by about 50%, to operational levels that provided improved instrument resolution. Tests were conducted on both the inlet and outlet of the ESP with the quartz windows.

A second problem arose during Insitec measurements at the inlet to the ESP, where particle concentrations in the flow combined with the extended path length across which scattering could occur (recall that these measurements were made in an eight inch diameter duct). Signal levels from scattered laser light were so high that the system electronics were reaching saturation, and only a fraction of the particles were being counted. To address this problem, a modification was made to the quartz window installation flanges. A two inch diameter tube was welded to the window support flange to reduce the path length in which fly ash particles attenuated the laser beam. The tubes extended about one inch into the flow path, and were flushed with dry nitrogen to reduce the particle count in the light path of the instrument. The external side of the fused quartz windows were maintained at elevated temperatures by directing a stream of air from a heat gun at each window. This eliminated the potential for condensation to form on the windows, which would attenuate the scattered light signal to below detectable levels.

In order to make measurements over a wide range of particle sizes, the Insitec instrument is built with two sets of laser optics. One set provides a larger diameter beam to obtain data on particles in the range of 5 to 150 microns, and the second forms a smaller diameter beam for measurement of particles from 0.4 to about 3 microns in diameter.

A full data run with the Insitec instrument requires the acquisition of four separate data samples. Because the velocity of particles in the flow is a term used in the deconvolution of the scattered laser light intensity signal, velocity measurements are made with both the large and small laser beams to comprise two of the four data samples. The remaining two samples (one taken with each size laser beam) acquire scattered light intensity data that is separated into bins that represent discrete levels of intensity of the scattered light. The deconvolution algorithm is then applied to the scattered intensity arrays to compute particle size and

concentration distributions. Another algorithm is used to interpolate between the minimum size measured with the large beam and the maximum size of the small beam.

Test Results

A total of 66 runs were made with the Insitec instrument, where measurements were made on both the inlet and outlet ducts of the CONSOL ESP. Of these, 25 runs were conducted on the outlet, and 41 runs on the inlet of the ESP. The inlet runs were divided into two groups, one where float glass windows were used (18 runs) and the scattered light signal was at minimum acceptable levels, and a second group of 23 runs where the optical quartz windows were installed, and the light levels increased by about 50% over the minimum level of the earlier measurements.

Data from the Insitec instrument is available immediately after completion of the data samples, while the standard techniques require significant effort to reduce the data to usable numbers. The Insitec information is saved to a computer file, which can be transferred to a spreadsheet for additional analysis and comparison to the physical sampling results.

The sampling crew from CONSOL obtained samples on all three days where Insitec data was taken. Their tests included 7 modified Method 17 total particulate samples, 3 cyclone size distribution samples and 3 Anderson impactor size distribution samples. The modified Method 17 data was reduced immediately, and is included in the data presented here. The EPA standard for Method 17 sampling specifies that the filter be inside the duct being sampled; this was not practical for the 8 inch diameter duct at CONSOL, so the filter was located in a heated housing external to the duct. The modified Method 17 probes were traversed across the duct at specified locations to obtain a representative sample in the flow.

ADA Technologies also performed extractive sampling, running a total of 7 University of Washington (UW) cascade impactors. Two of the impactor runs proved to be non-isokinetic, and were eliminated from the data set. Impactors are run at a single location in the flow because the size cuts of the various stages are functions of the flow through the device, which must remain constant throughout the run in order maintain constant size cuts among the stages.

Data Analysis

Summaries of the comparison of results from the modified Method 17 samples and the Insitec instrument are presented in Tables 2 and 3. Inlet data are shown in Table 1, where 3 Method 17 total particulate samples are presented, along with corresponding Insitec runs.

Comparison of Method 5 and Insitec Particle Loading Data
for CONSOL Combustion Lab ESP Inlet

Sample ID	Measured Loading (gr/dscf)	Measured Loading (g/cc)	Standard Loading (mg/dscm	Measured Velocity (m/s)	Corrected Loading (mg/dscm)
Method 17 #2-Inlet	0.6886		1575.8	5.8	1575.8
Insitec C06 [Total]		7.71E-06	12197.7	4.9	10304.9
Insitec C07 [Total]		6.22E-06	9840.4	4.9	8313.4
Insitec C08 [Total]		6.98E-06	11042.8	5.0	9519.6
Insitec C09 [Total]		7.95E-06	12577.4	4.9	10625.7
Insitec C06 [<10 um]		6.01E-07	950.8	4.9	803.3
Insitec C07 [<10 um]		6.47E-07	1023.6	4.9	864.8
Insitec C08 [<10 um]		7.8E-07	1234.0	5.0	1063.8
Insitec C09 [<10 um]		4.63E-07	732.5	4.9	618.8
Insitec Avg. [<10 um]					837.7
Inlet #2 [<10 um]			1575.8		1008.5
Method 17 #3-Inlet	0.6837		1564.6	5.8	1564.6
Insitec C13 [Total]		9.25E-06	14546.2	5.0	12539.8
Insitec C14 [Total]		1.15E-05	18084.5	4.9	15278.3
Insitec C15 [Total]		9.51E-06	14955.1	5.0	12892.3
Insitec C13 [<10 um]		6.97E-07	1096.1	5.0	944.9
Insitec C14 [<10 um]		5.02E-07	789.4	4.9	666.9
Insitec C15 [<10 um]		7.88E-07	1239.2	5.0	1068.3
Insitec Avg. [<10 um]					893.4
Inlet #3 [<10 um]			1564.6		1001.3
Method 17 #7-Inlet	0.6172		1412.4	6.2	1412.4
Insitec C52 [Total]		4.41E-06	6895.8	4.7	5227.5
Insitec C53 [Total]		4.83E-06	7552.6	4.7	5725.3
Insitec C54 [Total]		4.74E-06	7411.8	4.9	5857.7
Insitec C55 [Total]		5.49E-06	8584.6	4.9	6784.6
Insitec C52 [<10 um]		5.13E-07	802.2	4.7	608.1
Insitec C53 [<10 um]		4.35E-07	680.2	4.7	515.6
Insitec C54 [<10 um]		4.12E-07	644.2	4.9	509.2
Insitec C55 [<10 um]		4.56E-07	713.0	4.9	563.5
Insitec Avg. [<10 um]					549.1
Inlet #7 [<10 um]			1412.4		903.9

Create Date 1/5/93

Comparison of Method 5 and Insitec Particle Loading Data
for CONSOL Combustion Lab ESP Outlet

Sample ID	Measured Loading (gr/dscf)	Measured Loading (g/cc)	Standard Loading (mg/dscm	Measured Velocity (m/s)	Corrected Loading (mg/dscm)
Method 17 #4-Outlet	0.0243		55.6	5.9	55.6
Insitec C20 [Total]		2.38E-08	38.5	5.6	36.6
Insitec C20 [<10 um]		2.38E-08	38.5	5.6	36.6
Outlet #4 [<10 um]			55.6		49.5
Method 17 #5-Outlet	0.0090		20.6	6.0	20.6
Insitec C27 [Total]		1.6E-08	26.1	5.4	23.5
Insitec C28 [Total]		8.32E-09	13.6	5.4	12.2
Insitec C29 [Total]		1.22E-08	19.9	5.3	17.6
Insitec C30 [Total]		1.9E-08	31.0	5.4	27.9
Insitec C27 [<10 um]		1.58E-08	25.8	5.4	23.2
Insitec C28 [<10 um]		8.32E-09	13.6	5.4	12.2
Insitec C29 [<10 um]		1.22E-08	19.9	5.3	17.6
Insitec C30 [<10 um]		1.87E-08	30.5	5.4	27.5
Insitec Avg. [<10 um]					20.1
Outlet #5 [<10 um]			20.6		18.3
Method 5 #6 Outlet	0.0126		28.8	6.6	28.8
Insitec C31 [Total]		2.83E-08	45.1	5.3	36.3
Insitec C32 [Total]		1.26E-08	20.1	5.4	16.4
Insitec C33 [Total]		1.8E-08	28.7	5.3	23.1
Insitec C34 [Total]		2.08E-08	33.2	5.3	26.6
Insitec C31 [<10 um]		2.8E-08	44.7	5.3	35.9
Insitec C32 [<10 um]		1.26E-08	20.1	5.4	16.4
Insitec C33 [<10 um]		1.8E-08	28.7	5.3	23.1
Insitec C34 [<10 um]		2.05E-08	32.7	5.3	26.3
Insitec Avg. [<10 um]					25.4
Outlet #6 [<10 um]			28.8		25.7

The Insitec data are reported as grams of particulate matter per actual cubic centimeter of flue gas, and is therefore recalculated to match the milligrams per dry standard cubic meter in which the Method 17 data are reported. The calculation is performed by accounting for the sampling conditions at the time that the samples were taken. These were included in the data set for the Method 17 samples, so that it was possible to restate the Insitec values. It must also be noted that the "Measured Loading" column for the Insitec samples reports values that assume a particle density of 1 gram per cubic centimeter; this is not the correct density for the flyash at CONSOL, but was used so that a density correction could be determined from a flyash sample and easily applied to the data when the analysis was performed. A sample of ash was analyzed in the ADA laboratory using a helium pycnometer and determined that the density of the flyash particles was about 2.5 g/cc. This density and the corrections to standard conditions are applied to obtain the values in the column labeled "Standard Loading".

An additional correction was applied to the data from the Insitec instrument. The instrument measures the frequency distribution of particle sizes over a timed interval, and then computes the concentration by calculating the total volume of particulate matter, multiplying the volume by the particle density input to the software, and using the Insitec-measured velocity to determine the volume passing the sample location in the timed interval. It was noted that the Insitec instrument consistently reported velocities in the duct that were about 20% below pitot measurements at the inlet and about 10% low at the outlet. To account for this difference, the Insitec data was corrected in the final column of the tables by multiplication of the "standard loading" by a ratio of the Insitec velocity to the measured pitot velocity.

Each modified Method 17 sample is grouped with the Insitec runs taken during the time period over which the Method 17 sample was obtained. Recall that a typical Insitec run takes about 5 minutes, while the modified Method 17 samples ran about an hour.

At first glance, the Insitec instrument appears to measure much greater concentrations than the Method 17 samples at the inlet. This is due to a factor first reported by Holve, et al. [1988], where large flyash particles appear to scatter laser light more like transparent particles than opaque particles. The result is that the Insitec deconvolution algorithm calculates the sizes of these more-efficient scattering particles as larger than their actual dimension. The impact is further aggravated by the fact that many of these large particles are unburnt carbon or spherical shells rather than high-density flyash material [Bonin and Queiroz, 1992]. The

particle fraction greater than 10 microns in diameter thus is reported as oversized by the Insitec and also as comprising a very large fraction of the total mass loading at the inlet.

In order to make a more meaningful comparison of the Insitec and modified Method 17 results, the size distribution information of the Insitec was employed. In an ESP, the most significant size region in terms of collection is the fraction below 10 microns in diameter. Those particles greater than 10 microns are almost certain to be collected because of their relatively large size and ease of charging; the particles that resist collection are invariably those below 10 microns. This is confirmed in the Insitec measurements made on the outlet from the ESP. The largest particles reported by the Insitec for the runs that corresponded to the modified Method 17 samples at the outlet were between about 7 and 13 microns in diameter; this is in great contrast to the inlet where particles greater than 100 microns in size were routinely reported in the Insitec data sets.

For the inlet to the CONSOL ESP, there were multiple Insitec runs for each modified Method 17 sample. Table 2 lists the corresponding Insitec results for each Method 17 sample, and also presents the fraction of particulate matter below 10 microns in diameter for the Insitec runs. The data files for the Insitec runs present a tabulated distribution of mass loading as a function of particle size. Information for the table was taken directly from the Insitec tabulated data. A 10-micron cut value for the modified Method 17 sample was calculated by visually fitting a log-normal distribution to impactor data for the inlet, and finding the mass fraction value where the fit-line crossed the 10 micron line on a log-probability graph. This fraction was found to be 0.64 for the inlet UW impactor runs, which was then multiplied by the total standard loading for the modified Method 17 sample to obtain a mass fraction less than 10 microns.

The mass fraction less than 10 microns in diameter are seen to compare quite well. In almost all cases, the Insitec values are less than the modified Method 17 numbers. The averages of the Insitec data are within 20% of the modified Method 17 measurements for the first two samples, and within 40% for the final sample. The modified Method 17 samples showed about a 10% difference between the largest and smallest measured loading, so that there is some natural variation present in the flow stream. This variation is emphasized in the Insitec samples because of their relatively short time duration. The hour-long sample time of the modified Method 17 samples tends to average more transient oscillations in the flyash concentration; the Insitec runs take about 5 minutes, where 2 minutes is actual data acquisition time for the particle sizing data.

Table 3 presents the comparison of data for the modified Method 17 samples taken at the ESP outlet and Insitec runs made through measurement ports upstream of the outlet sample point. The format is identical to the earlier inlet data, with the Insitec data restated to standard conditions and corrected for a difference in measured velocity between the Insitec and a pitot probe at the modified Method 17 location. There is a value presented for the modified Method 17 fraction below 10 microns that is derived from a visual log normal fit to the ADA University of Washington impactor results. This fit predicted that 89% of the total captured mass was of a diameter below 10 microns. The total modified Method 17 mass loading was thus multiplied by 0.89 to compute the fraction below 10 microns.

The Insitec data for the outlet agrees quite well with the modified Method 17 results. Averages were calculated for multiple Insitec runs obtained during the 60 minute Method 17 sample period. These are included in the table, and are seen to be within 30% in the worst case, and within 1.5% for the best case. There is also an obvious significant variance in the outlet loading; this may be a function of rapping time with respect to sampling time for the modified Method 17 tests. There also appears to be better agreement at lower loading values. This is significant in the use of the Insitec to quantify performance of additives to enhance ESP performance, since a successful additive will reduce the outlet loading from the ESP over non-additive values.

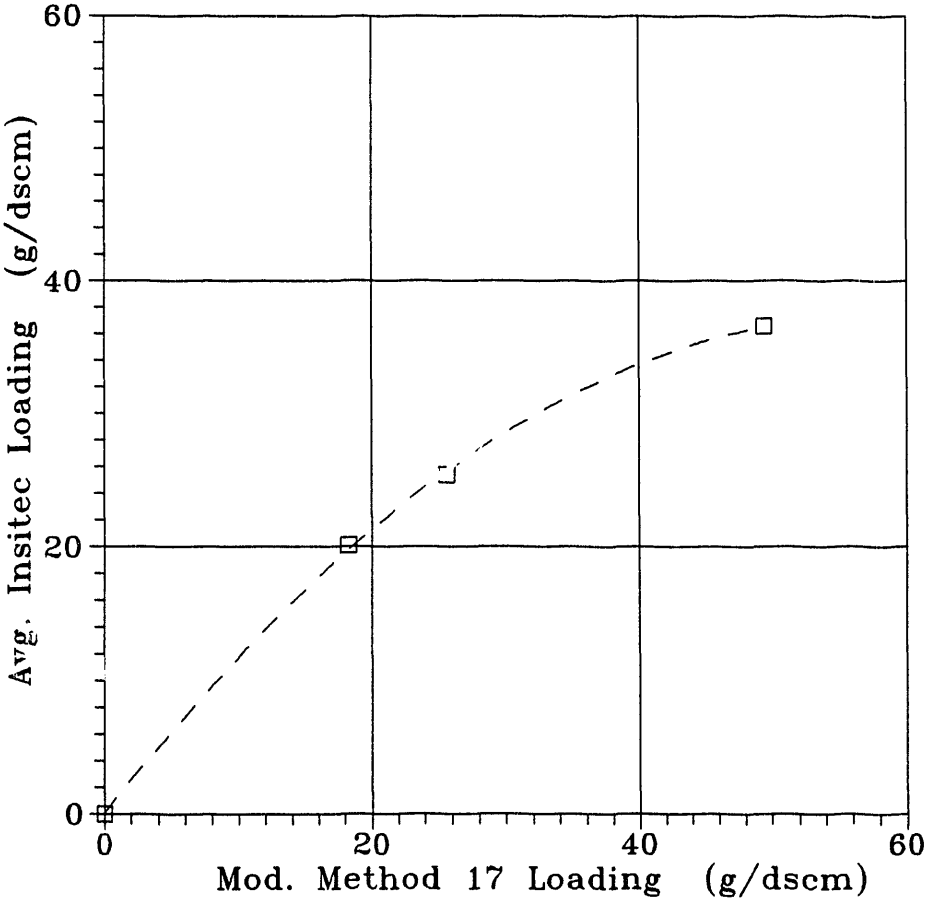
The modified Method 17 and Insitec comparisons are graphed in Figure 3. A second-order curve fit is shown, where the improvement of the agreement at lower loadings is evident.

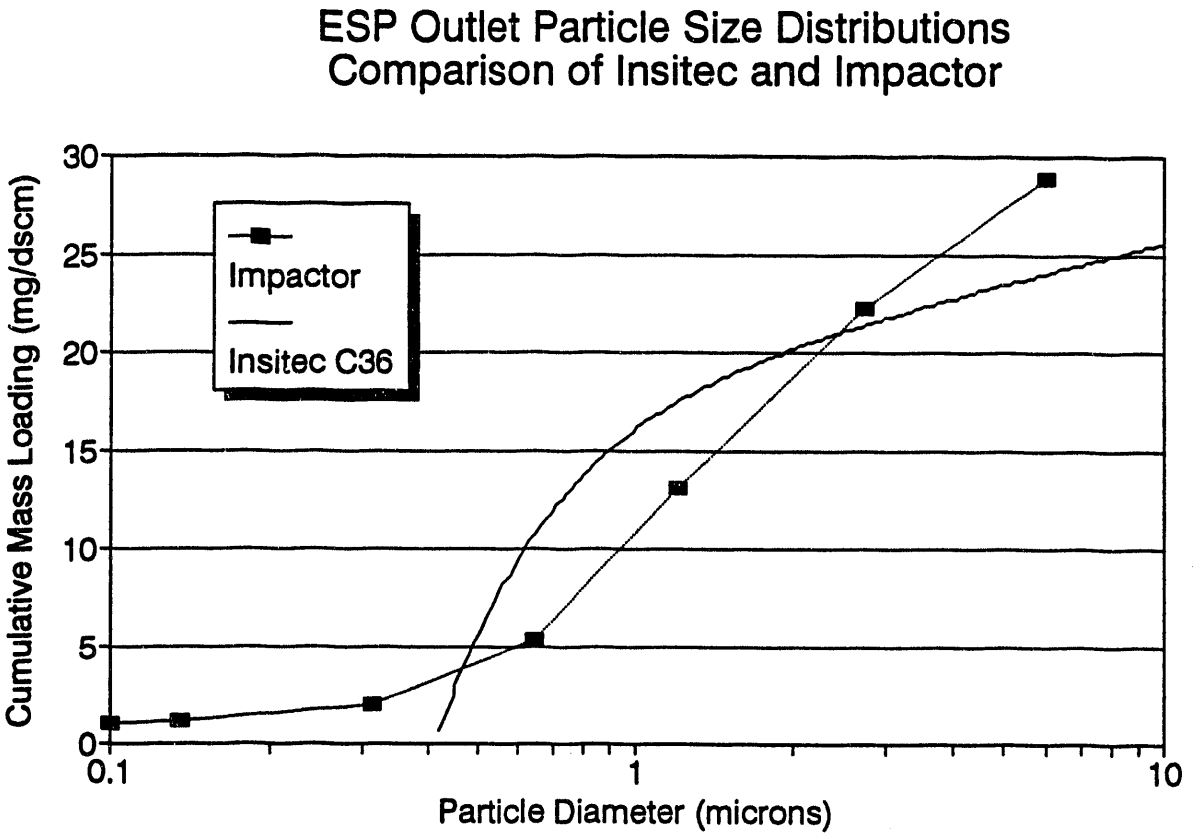
In Figure 4, the University of Washington impactor results with a corresponding Insitec distribution over the diameter range of interest of 0.1 to 10 microns. The distributions are comparable, although the Insitec measures higher loading in the region around 1 micron. It must be noted, however, that the impactor distribution is plotted for 50% cut points, so that there is some broadening in the size bands of the impactor data. Likewise, the largest size fraction of the impactor data is actually the sum of the initial two stages, and so includes larger diameter particles in some fraction. The lower limit of detection for the Insitec is about 0.4 microns, so there is no data available for comparison to the final two stages of the UW impactor.

Conclusions and Recommendations

The Insitec Particle Concentration, Size, and Velocity instrument was used to measure flyash particle size distributions and concentrations at the inlet and outlet of an operating ESP.

Comparison of modified Method 17 and Insitec Loadings <10 Microns for ESP Outlet




ESP Outlet Particle Size Distributions
Comparison of Insitec and Impactor
Impactor
Insitec C36
Cumulative Mass Loading (mg/dscm)
30
25
20
15
10
5
0
0.1
1
10
Particle Diameter (microns)

Conclusions and Recommendations

The Insitec Particle Concentration, Size, and Velocity instrument was used to measure flyash particle size distributions and concentrations at the inlet and outlet of an operating ESP. The results were compared with extractive samples taken following a modified EPA Method 17 protocol for particle loading measurements and cyclones and cascade impactors for size distribution data. The Insitec results at the inlet to the ESP present high values for mass loading, due to the detection of large numbers of large particles. This information is subject to interpretation at two levels: first, the larger particles in the flue gas stream tend to be unburned carbon or shell-type spherical particles which scatter the laser illumination of the Insitec instrument more like a transparent particle than an opaque particle that is assumed in the analysis routine. Second, these shell-type particles are most certainly not the density of the smaller particles, which form most of the mass and are used in the determination of density for the flyash. These large particles are thus not as large nor as dense as assumed in the Insitec computer analysis.

The results of these measurements are summarized in Table 4. The Insitec data was shown to be very consistent from run to run, and to compare favorably with the particle loading measurements at sizes less than 10 microns. This is the size range of interest, because larger particles are assured of capture in a properly operating ESP. Based upon these results it appears that the Insitec instrument would be very useful for providing real time data on both mass and particle size distribution for particles less than 10 microns.

Table 4. Summary of the Comparisons between Method 17 and Insitec for Particles Less than 10 Micrometers in Diameter.

	Method 17 (mg/dscm)	Insitec (mg/dscm)
Inlet	1008.5	832.7
Inlet	1001.3	893.4
Inlet	903.9	549.1
Outlet	49.5	36.6
Outlet	18.3	20.1
Outlet	25.7	25.4

References

Holve, D.J., P.L. Meyer, L.J. Musio, and G.H. Shiomoto, (1988). "On-Line, In-Situ Particle Measurements in a Large Scale Coal-Fired Furnace". Paper #88-60, Western States Section of the Combustion Institute, Salt Lake City, UT, March.

Bonin, M.P. and M. Queiroz (1992). "A Parametric Evaluation of Particle Phase Dynamics in an Industrial-Scale, Coal-Fired Boiler". Submitted for publication.

PLANS FOR NEXT QUARTER

During next quarter, the laboratory experiments will be completed and plans will be made to perform the bench-scale experiments at Consol.

END

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3/23/93