Integrated System to Control Primary PM 2.5 From Electric Power Plants

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For the Period

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Introduction

The pilot-scale Advanced *ElectroCore*™ Field Prototype was installed at Alabama Power Company's E.C. Gaston Unit #4 to evaluate its performance when located downstream of a hot-side ESP. The unit was designed to process a slipstream with a nominal flowrate of 6,000 acfm and a specific separating area (SSA) of about 100 ft^2 per thousand acfm. The unit was built under a contract from DOE (DE-FC26-00NT40757) and received additional testing support under an EPRI contract (EP-P4245/C2075). The U.S. EPA also provided testing support in conjunction with mercury removal performance. In addition, Southern Company Services, Inc. along with its affiliate, Alabama Power Company provided excellent host site and technical services to support this test effort.

The Advanced ElectroCore Field Prototype was tested for particulate and mercury removal performance from November 12th though the16th and for mercury removal only on November 26th though the 28th. PM testing was performed by an independent testing firm, Armstrong Environmental of Dallas, Texas. Mercury testing was performed by Southern Research Institute of Birmingham, Alabama.

Summary

Mercury measurements were made by Southern Research Institute and conformed to the Ontario Hydro Method. EPA's current Reference Method 29A is for total mercury, whereas the Ontario Hydro procedure is capable of identifying the composition and species of the total mercury. One of the disadvantages of the Ontario Hydro Method is that it requires several weeks to complete the full analysis due to its extensive laboratory procedures.

Mercury measurements were also obtained with a PS Analytical Continuous Emission Monitor (CEM) owned by the U.S. EPA and contributed to this project by EPA's fine particulate group in Research Triangle Park. The PSA CEM functions on the principle of atomic fluorescence and is capable of measuring trace concentrations of mercury in water or air. The instrument was setup to monitor elemental and total mercury at the dry scrubber inlet and ElectroCore outlet. Each cycle required about 20 minutes to complete. Thus, the monitoring was not in "real time" in a strict sense, but did provide mercury tracking in continual batch processing.

Particulate measurements were determined by EPA Method 5 as well as with a P5A continuous monitor. The P5A is on loan to the project through EPA and SRI. Calibration factors for the device were provided by SRI. All particulate data was analyzed and interpreted by LSR Technologies, with technical input from Armstrong Environmental and SRI.

Discussion

During the week of November 12-16, a total of fourteen (14) Advanced ElectroCore tests were performed using EPA Method 5 and three (3) tests for particulate sizing with University of Washington cascade impactors. The test conditions during these tests are shown in Table 1. Figure 1 shows an elevation view of the system and shows the locations of the test planes. The same test planes can be seen on the system schematic diagram shown in Figure 2. In addition to the particle size and concentration measurements, some mercury sorbents were injected to determine mercury removal. These tests were performed by Southern Research Institute (SRI), and the results are not expected to be ready until January 2002. Mercury removal testing will be reported separately.

It is important to note that due to scheduling constraints from the various participants in these tests, the Advanced ElectroCore unit did not have a rigorous shakedown and checkout prior to its initial operation. Specifically, flow distribution within the Advanced ElectroCore module and characterization of the precharger and separator transformer rectifier (TR) sets were not optimized prior to the testing period. Thus, it is believed that the conditions that existed during these tests were not optimum, and that the results obtained were not necessarily the best that could be achieved. Nonetheless, the overall performance of the Advanced ElectroCore during this week of testing was very encouraging.

A Test Plan, dated September 7, was followed to the extent possible. On the first day of testing, a rubber boot in the precharger cooling water line failed. Therefore, test numbers 3 through 6 were run without cooling water. Also, the high voltage power cable for the Advanced ElectroCore module TR set began to spark and had to be replaced. While this was being repaired, test numbers 2 though 6 were run without power to the Advanced ElectroCore module's central electrodes.

The EPA Method 5 tests were used and compared with data from the P5A continuous emission monitor. The P5A was calibrated against the Method 5 measurements by SRI, since the instrument readings depend on the particle size and other physical properties of the solid material.

Table 2 summarizes the Advanced ElectroCore efficiency measurement data. The data show that the particle separation efficiency of the unit averaged about 85 percent when using EPA Method 5 and about 95 percent when using the P5A to measure the particulate concentration at the clean flow outlet. This difference is probably due to the fact that the P5A has a reduced sensitivity to particles above about 7 micrometers in stokes diameter. The only impactor run conducted at the clean flow outlet shows that about 60 percent of the particles are above 7 micrometers. The outlet size distribution is shown in Figure 3. Both the outlet size distribution and the disparity between EPA Method 5 and the P5A suggest that there may be a significant amount of particle agglomeration taking place within the Advanced ElectroCore system.

The first step in being able to use the P5A data to estimate the concentration of particles in the clean flow outlet is to run simultaneous P5A and Method 5 tests. Figure 5 shows the Method 5 results plotted as a function of the P5A output voltage. The data from the first two test days show an excellent straight-line correlation with an R^2 value of over 0.99. The data from the final three days shows poor correlation. The most significant difference in the operation of unit over the two time periods is that electrodes in the separator were energized during all tests in the last three days but energized only during one test during the first two days. It is supposed that energization of the electrodes in the separator encourages particle agglomeration by the phenomenon known as the "pith ball effect" described in *Electrostatic Precipitation* by Oglesby and Nichols.

For the purposes of analysis, the correlation from the first two days was used to correlate the P5A output to the EPA Method 5 results. This causes the P5A determined efficiency to be greater than the Method 5 efficiency for those tests where the Advanced ElectroCore electrode is energized. It represents an estimate of the efficiency if the agglomeration process could be controlled or eliminated.

Figure 6 and Figure 7 show examples of the P5A output traces. Figure 6 shows the trace for Test 2, which had the lowest outlet emission of all tests conducted and Figure 7 shows the trace for Test 4 which had the highest outlet loading. The first trace shows a consistently low output level with only eight significant spikes, all but one of short duration. The middle spike correlates to the midpoint of the Method 5 test where the probes are taken out and inserted into the sampling port 90 degrees away. The second trace shows the output is very unsteady with many peaks saturating the P5A output. Observations during the test indicated that the plant was having combustion problems as indicated by periodic puffs coming from the Unit 4 stack.

Table 1: Summary of Advanced ElectroCore Field Prototype Test Conditions

Test No.	*Clean Flow [acfm]*	*Clean Flow Gas Temp [°F]*	*Specific Separating Area [ft²/kacfm]*	*Bleed Flow Ratio [percent]*	*Average Precharger Voltage [kV]*	*Precharger Current Density [nA/cm²]*	*Average Advanced ElectroCore Voltage [kV]*	*Comments*
1	6064.2	156.5	88.4	9.42	-50	735.5	-60.5	Test ended early when HV cable failed
2	6161.8	176.7	87.0	8.22	-50	639.5	N/A	Joint on water-cooled precharger failed
3	5918.2	182.7	90.6	10.28	-45	495.6	N/A	Test conducted with cascade impactors
4	5870.4	189.6	91.3	9.08	-39.5	319.8	N/A	Still no precharger cooling water
5	5346.3	190.1	100.3	11.20	-38	247.8	N/A	100% of bleed flow directed to precharger
6	5151.4	186.4	104.1	10.83	-37	215.8	N/A	50% of bleed flow directed to precharger
7	5999.5	179.5	89.4	10.42	-40	279.8	-61.4	Cooling water and HV cable restored
8	4831.7	183.4	111.0	29.31	-40	279.8	-62.1	Test conducted with high bleed flow ratio
9	5327.1	188.3	100.6	11.19	-40	287.8	-60.9	Activated carbon sorbent injection
10	5282.4	179.6	101.5	11.52	-39	255.8	-62.2	Test again without sorbent
11	5248.2	183.2	102.2	11.41	-39	255.8	-62.2	Duplicate of previous test number
12	5273.0	182.1	101.7	10.86	-35	183.9	-61.8	Precharger voltage reduced to -35kV
13	5313.9	187.0	100.9	11.30	-36	197.2	-55.0	Test with “Sorbent 2” and “Sorbent 3”
14	5191.7	185.0	103.3	14.81	-34	127.9	-52.7	No sorbent and 15% bleed flow ratio
15	5224.1	183.9	102.6	15.66	-34	143.9	-52.9	Repeat of test number 15

Table 2: Advanced ElectroCore Field Prototype Particle Separation Efficiency Test Results

Test No.	*EPA Method 5 Inlet Loading at Test Plane B [grains/scf]*	*EPA Method 5 Outlet Loading at Test Plane D_2 [grains/scf]*	*P5A Outlet Loading at Test Plane D_2 [grains/scf]*	*EPA Method 5 Concentration Efficiency [percent]*	*Bleed Flow Ratio [percent]*	*EPA Method 5 Mass Efficiency [percent]*	*P5A Mass Efficiency [percent]*
1	0.0440	0.0141	0.0113	67.94	9.42	70.96	76.78
2	0.0243	0.0065	0.0067	73.37	8.22	75.56	74.68
3	Impactor	Run					
4	0.7798	0.1182	0.1167	84.85	9.08	86.22	86.40
5	0.1172	0.0156	0.0202	86.67	11.20	88.16	84.71
6	0.1390	0.0186	0.0236	86.58	10.83	88.03	84.86
7	0.3542	0.0597	0.0247	83.16	10.42	84.91	93.76
8	0.0933	0.0521	0.0044	44.21	29.31	60.56	96.65
9	0.1899	0.0250	0.0092	86.83	11.19	88.30	95.68
10	0.3094	0.0581	0.0150	81.22	11.52	83.38	95.71
11	0.6252	0.0747	0.0387	88.05	11.41	89.42	94.52
12	0.3419	0.0953	0.0208	72.13	10.86	75.16	94.57
13	0.1275	0.0596	0.0275	53.28	11.30	58.56	80.85
14	0.1947	0.0240	0.0064	87.65	14.81	89.48	97.18
15	0.1628	0.0296	0.0080	81.85	15.66	84.69	95.85

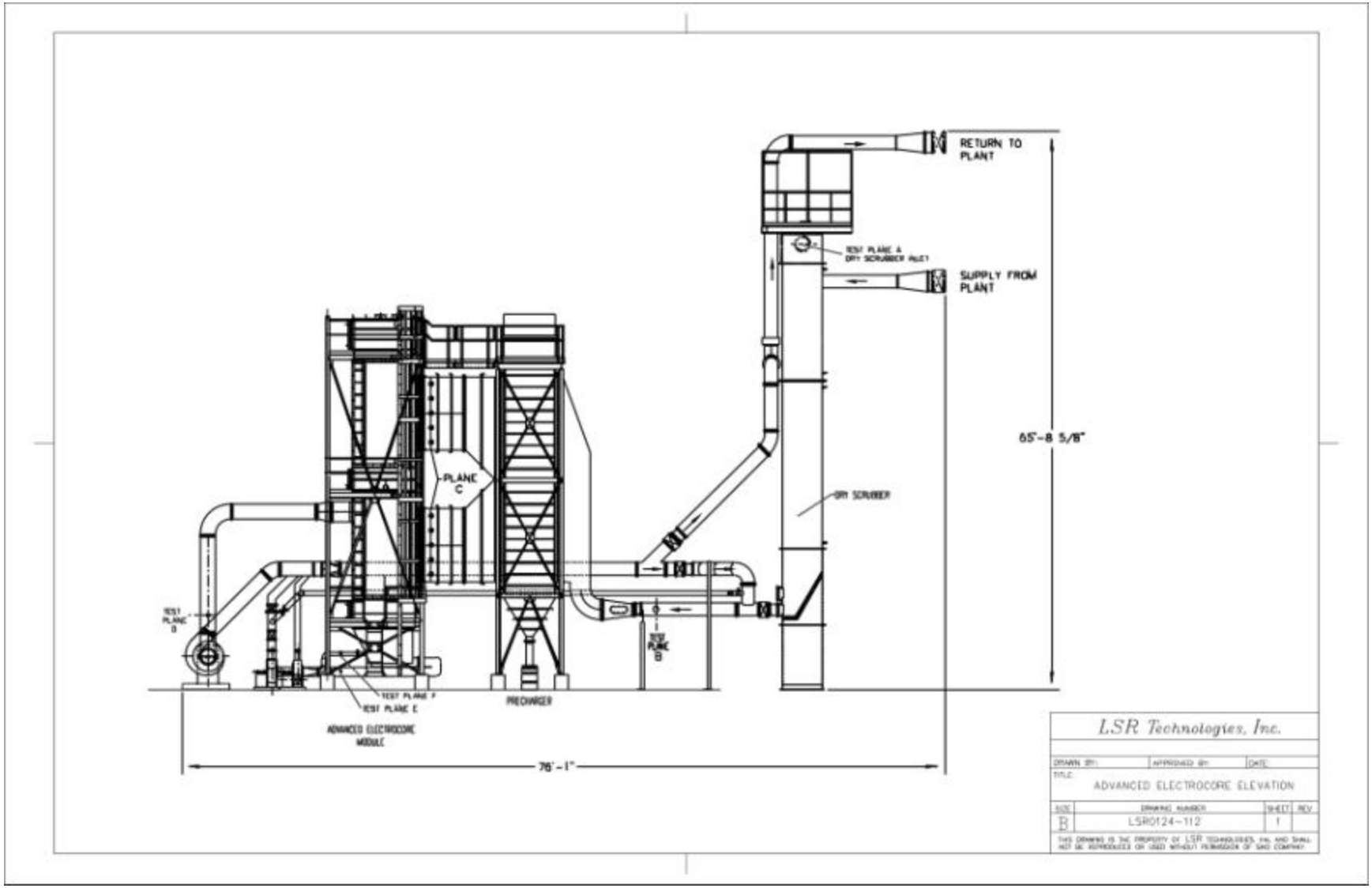


Figure 1: Elevation View of Advanced ElectroCore Field Prototype

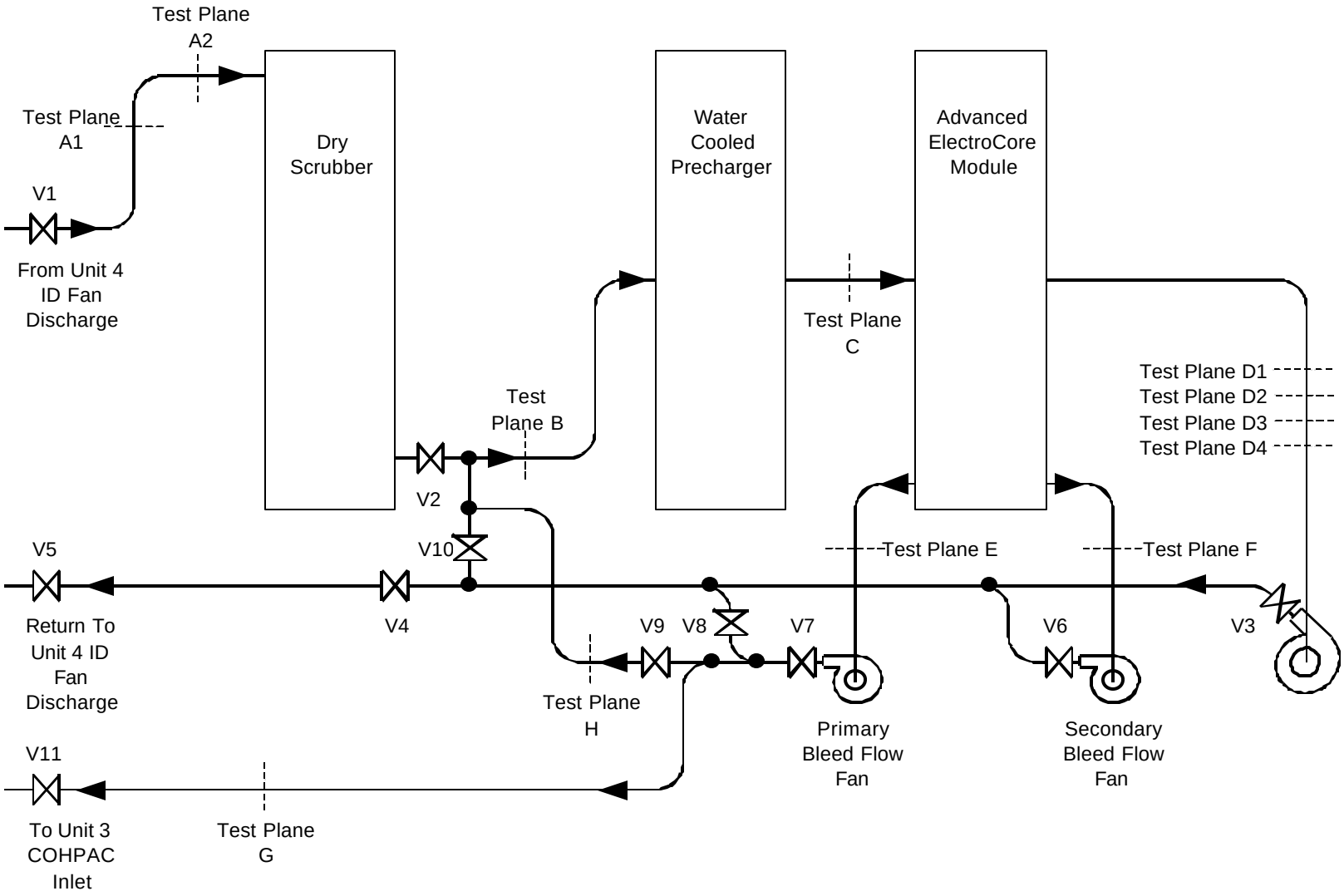


Figure 2: Schematic of Advanced ElectroCore Field Prototype Layout

Results

The test conditions for particle measurements are summarized in Table 1, and the raw data for those tests taken by Method 5 and with P5A are shown in Table 2. In order to interpret these data points, a number of observations were made which affect data quality and accuracy. The most significant of these observations were:

(1) The conditions of the boiler flue gas were such that there were many operational upsets during test runs. These upsets may have been caused by soot blowing of the boiler backpass, rapping of the ESPs last field, or irregular boiler control. As evidence of the variations in stack opacity, the particulate carryover from the boiler showed wide variations.

(2) The P5A calibration depends on particle size and composition, which changed frequently with test conditions. For example, in addition to boiler upsets, some tests were performed with and without sorbents, and with and without recycle return.

(3) Like other collection devices, the Advanced ElectroCore system has a tendency for solids to buildup, accumulate, and then release cyclically. Hence, due to the dynamic changes in the system and shifting of solids, it was difficult to find steady-state run conditions during the tests.

(4) During the Method 5 tests, several of the filters at the ElectroCore outlet (Test Plane D) were very white and clean (usually signifying very low outlet emissions) except for a small buildup of loose granules. The loose material could have been dislodged from wall surfaces. It also represented the major fraction of the filter weight in these tests, which was only 40-50 mg. Thus, the loose material may not be representative of normal Advanced ElectroCore conditions and may in effect be a source of error in the data.

(5) It was also observed that when the Method 5 probe at the precharger inlet (Test Plane B) was repositioned, there was an immediate response on the P5A showing heavy solids carryover. These spikes undoubtedly affected the Method 5 outlet result as well. Each of the phenomena described above contributed to the difficulty of data analysis and interpreting data.

The performance obtained during the initial testing shows that the ElectroCore is capable of bringing an underperforming ESP into compliance with the most stringent regulations. In addition, these tests do not represent the best performance that the Advanced ElectroCore is capable of achieving. All operating regimes need to be evaluated to find what operating conditions give the best performance. Effects such as the residence time in the precharger and changes in the specific separating area need to be investigated before being sure the unit is operating up to its full potential.

Conclusions

The Advanced ElectroCore is a modular Pilot Unit designed to be used as a mobile test unit. It can be transported readily by truck for installation and testing of power boilers burning difficult fuels, plants with opacity problems, or in plants anticipating higher dust loads. The following conclusions can be made from its initial operation:

(1) The ElectroCore effectively removed flyash and sorbent particles from boiler flue gas. As a polishing device, it showed the ability to bring an underperforming ESP into compliance with new and proposed regulations. It can also eliminate the intermittent "spikes" in opacity that accompany ESP rapping.

(2) Although this unit has not been optimized, its performance located downstream of an ESP was quite respectable, ranging from 85-97% depending on measurement method.

(3) The cooled pipe precharger has a tendency to disengage about 20-25% of the incoming particulate matter. A rapping or pulse-type cleaning system needs to be used once per day to maintain precharger performance.

(4) Additional testing is needed to characterize performance as a function of bleed flow, SSA, and electrical input. The unit should also be tested continuously over a long operating period to assure that performance is not degraded over time.

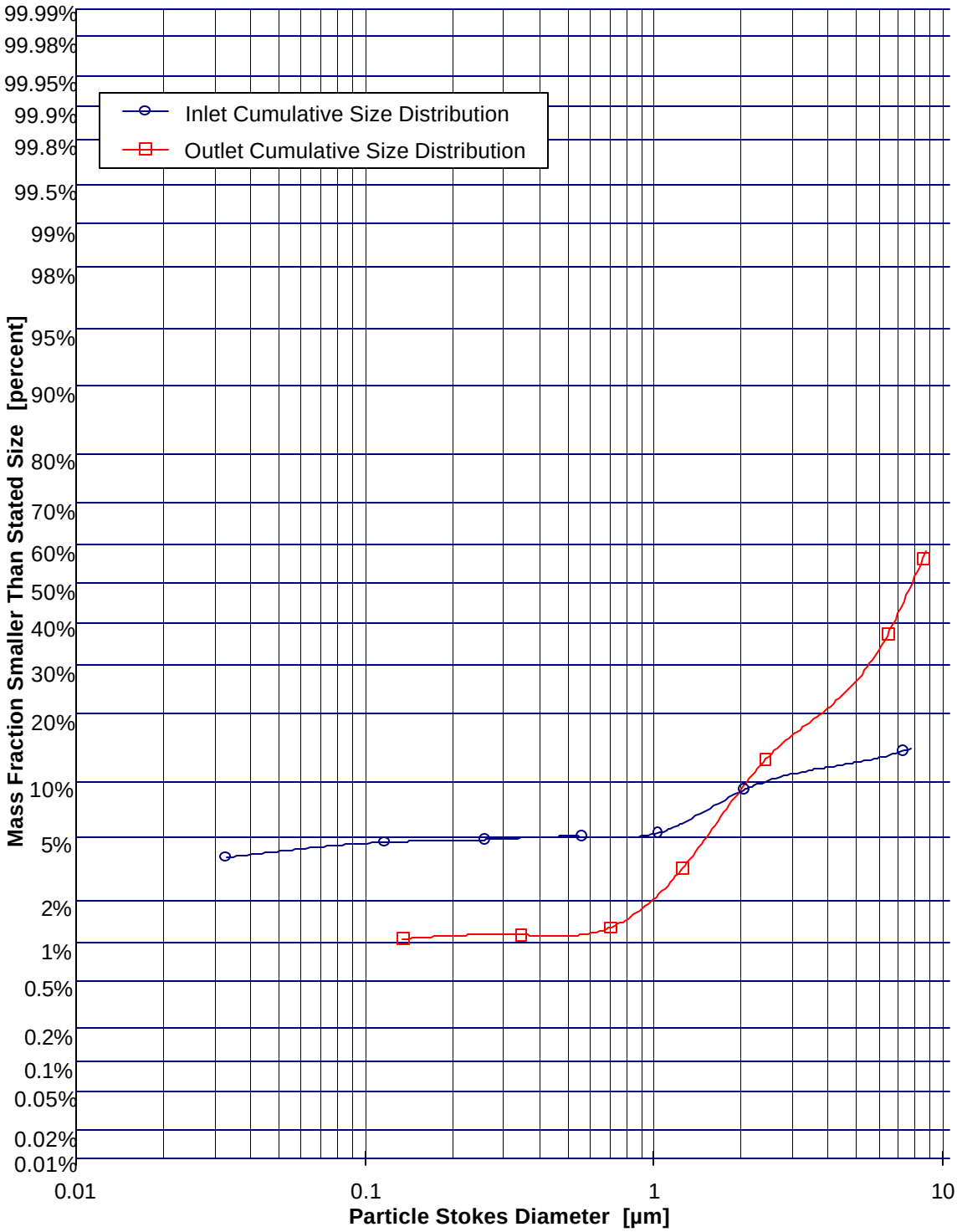


Figure 3: Inlet and Outlet Cumulative Particle Size Distribution

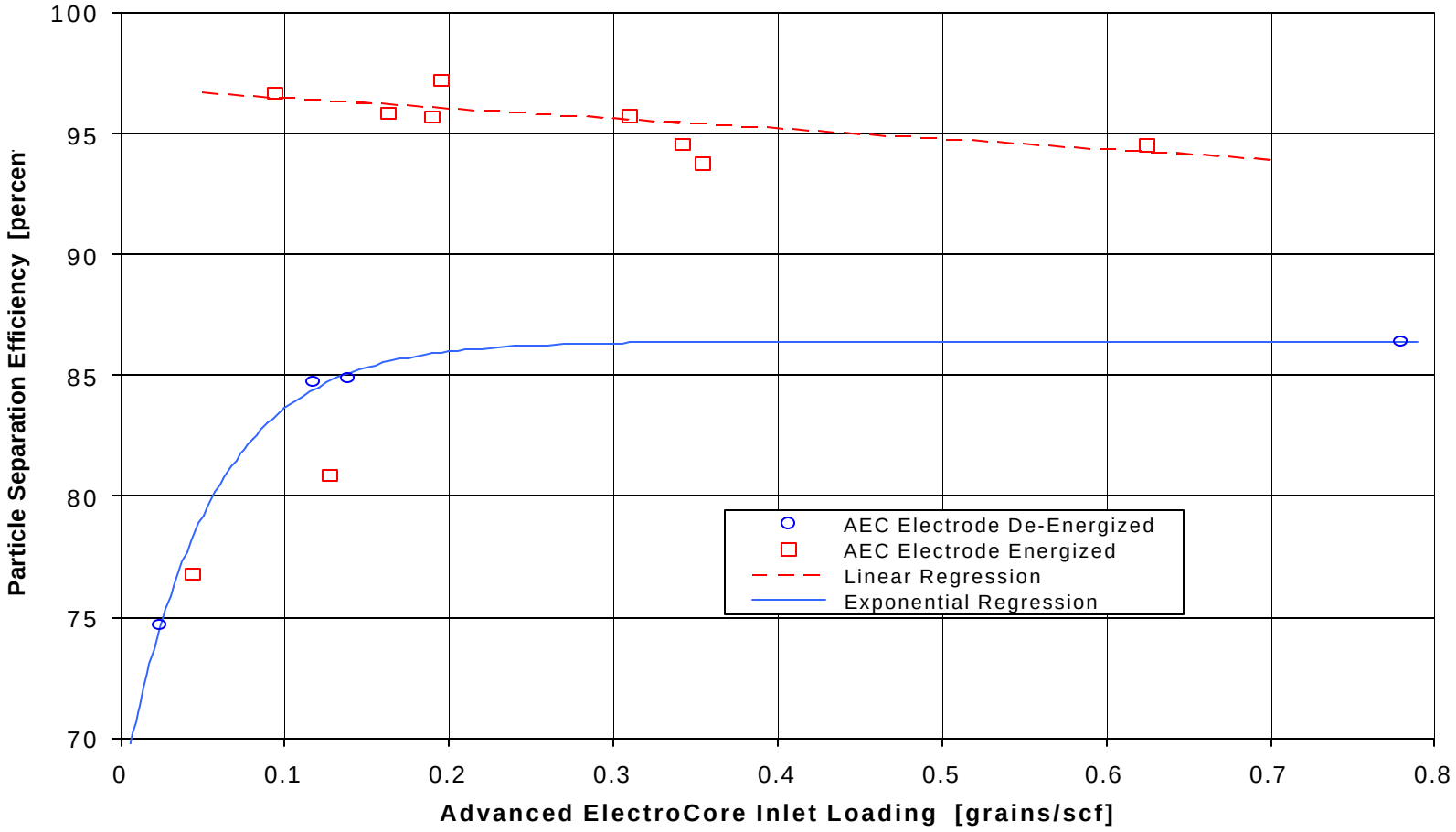


Figure 4: Efficiency of Advanced ElectroCore Field Prototype From P5A Analysis

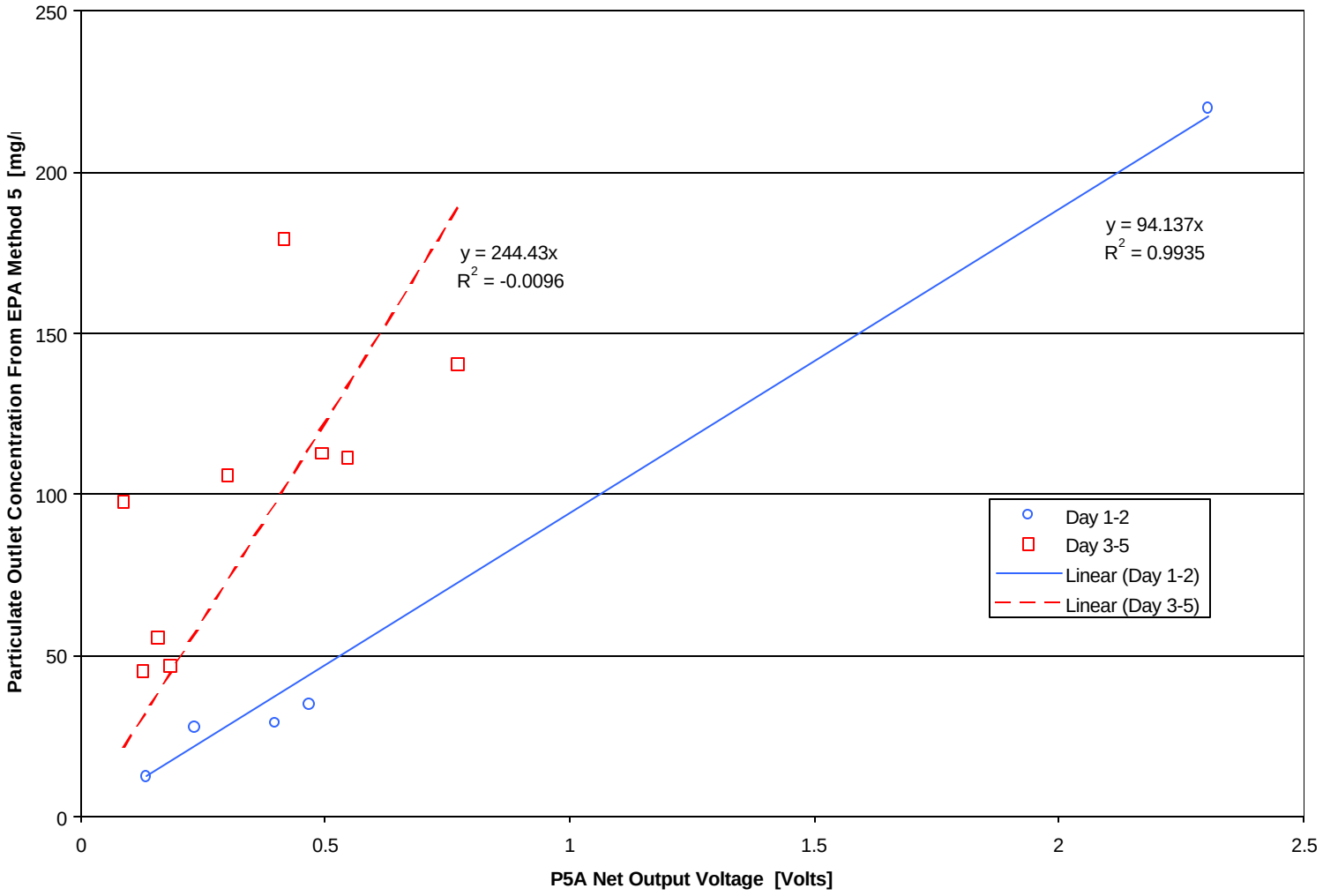


Figure 5: Correlation of P5A Output to EPA Method 5 Data

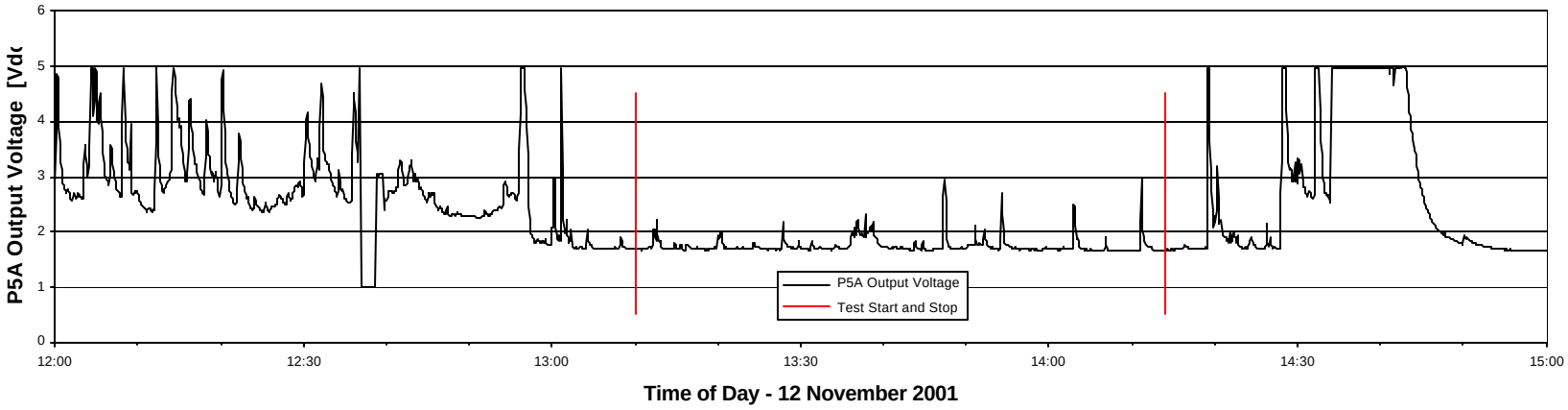


Figure 6: P5A Output Voltage For Test Number 2

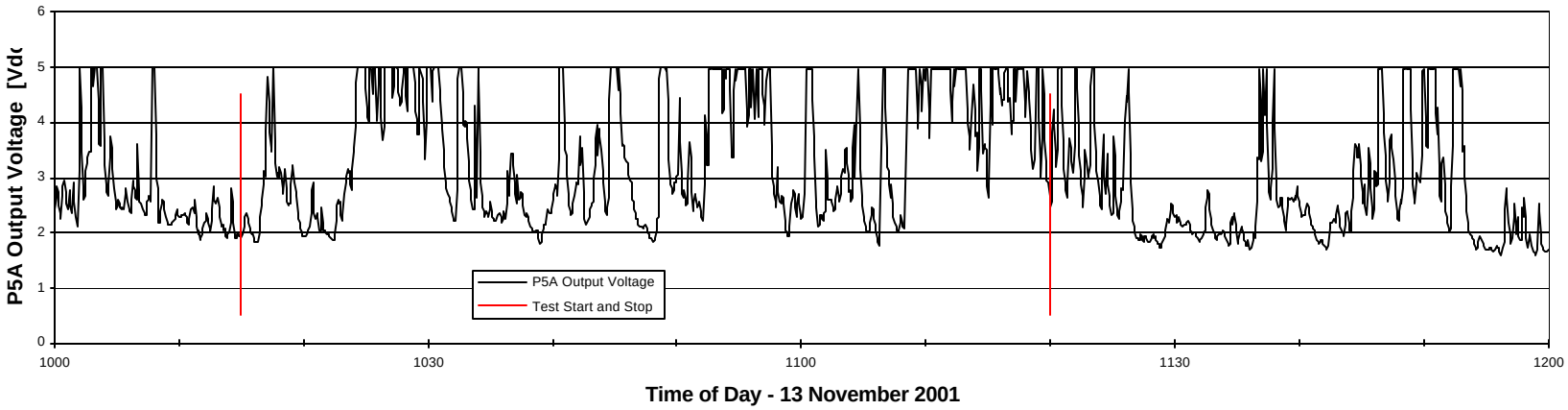


Figure 7: P5A Output Voltage For Test Number 4