ADVANCED HYBRID PARTICULATE COLLECTOR

Quarterly Technical Progress Report
for the period July 1, 1999, through September 30, 1999

Prepared for:

AAD Document Control
U.S. Department of Energy
Federal Energy Technology Center
PO Box 10940, MS921-143
Pittsburgh, PA 15236-0940

DOE Contract No. DE-AC22-95PC95258--12
Performance Monitor: Thomas Feeley

Prepared by:

Stanley Miller

Energy & Environmental Research Center
University of North Dakota
PO Box 9018
Grand Forks, ND 58202-9018

Rich Gebert

W.L. Gore & Associate, Inc.
101 Lewisville Road
PO Box 1100
Elkton, MD 21922-1100

William Swanson

Otter Tail Power Company
PO Box 218
Big Stone City, SD 57216

November 1999

ACKNOWLEDGMENT

This report was prepared with the support of the U.S. Department of Energy (DOE) Federal Energy Technology Center Contract No. DE-AC22-95PC85258. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the views of DOE.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ADVANCED HYBRID PARTICULATE COLLECTOR

ABSTRACT

A new concept in particulate control, called an advanced hybrid particulate collector (AHPC), is being developed under funding from the U.S. Department of Energy. The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in a manner that has not been done before. The AHPC concept consists of a combination of fabric filtration and electrostatic precipitation in the same housing, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper. The AHPC provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emission with conventional ESPs, and it solves the problem of reentrainment and collection of dust in conventional baghouses. The AHPC is currently being tested at the 2.7-MW scale at the Big Stone power station.

ADVANCED HYBRID PARTICULATE COLLECTOR

EXECUTIVE SUMMARY

A new concept in particulate control, called an advanced hybrid particulate collector (AHPC), is being developed at the Energy & Environmental Research Center (EERC) with U.S. Department of Energy (DOE) funding. In addition to DOE and the EERC, the project team includes W.L. Gore & Associates, Inc., Allied Environmental Technologies, Inc., and the Big Stone power station. The AHPC combines the best features of electrostatic precipitators (ESPs) and baghouses in a unique approach to develop a compact but highly efficient system. Filtration and electrostatics are employed in the same housing, providing major synergism between the two collection methods, both in the particulate collection step and in the transfer of dust to the hopper. The AHPC provides ultrahigh collection efficiency, overcoming the problem of excessive fine-particle emissions with conventional ESPs, and solves the problem of reentrainment and re-collection of dust in conventional baghouses.

The objective of the project is to develop a highly reliable AHPC that can provide >99.99% particulate collection efficiency for particle sizes from 0.01 to 50 µm, is applicable for use with all U.S. coals, and is cost-competitive with existing technologies.

Phase I of the development effort consisted of design, construction, and testing of a 200-acfm (5.7-m^3/min) working AHPC model. Results from both 8- and 100-hr tests showed that the concept worked well, achieving greater than 99.99% collection efficiency for fine particles at high filtration velocities.

Phase I started at Maturity Level I, an idea with no supportive experimental data, and progressed smoothly from the design and construction of the 200-acfm (5.7-m^3/min) model through 100-hr proof-of-concept tests at the subscale level. Since all of the developmental goals of Phase I were met, the approach is being scaled up in Phase II. Additional 200-acfm (5.7-m^3/min) tests were conducted as part of the Phase II effort to help optimize the scaled-up design. For Phase II, a size of 9000 acfm (255 m^3/min) was selected as the best combination of being large enough to allow meaningful tests with full-scale components, but yet small enough to be transportable and cost-effective. A scaleup in size by a factor of 45 is a large developmental step that presents some risk, but the Phase I results looked highly promising, so the risk appeared to be warranted to facilitate rapid maturing of the technology, leading to near-term commercialization.

During the last quarter (July–September 1999), the main project activity was start-up in late July and operation of the 9000-acfm (255-m^3/min) AHPC at the Big Stone power station. The AHPC was operated for approximately 6 weeks until September 8 when it was shut down for an annual plant outage. After minor modifications, the AHPC was started again September 29 and has been operating continuously since then. Plans are to operate the field AHPC through mid-December, which will complete the planned Phase II testing. Results during the first 6 weeks have been highly successful in terms of trouble-free operability and ultrahigh collection efficiency.

ADVANCED HYBRID PARTICULATE COLLECTOR

1.0 PHASE II PLANNED WORK

1.1 Phase II Objectives

The overall project objective remains the same as for Phase I: to develop a highly reliable advanced hybrid particulate collector (AHPC) that can provide >99.99% particulate collection efficiency for all particle sizes from 0.01 to 50 µm, is applicable for use with all U.S. coals, and is cost-competitive with existing technologies. The developmental objective for Phase II is to take the concept from Maturity Level II, which was achieved in Phase I, through Maturity Level III, engineering development scale. This is being achieved by increasing the scale of the AHPC size and the test duration by a factor of 45 to 50 and by utilizing full-scale components.

1.2 Phase II Statement of Work

1.2.1 Task 1 – Project Management and Reporting

The purpose of Task 1 is to separate the management aspects of the project from the design, construction, and experimental work. Since the project team includes W.L. Gore & Associates, Inc., Allied Environmental Technologies, Inc., the Energy & Environmental Research Center (EERC), and the Big Stone power station, coordination of work among the four members and with the U.S. Department of Energy (DOE) will require dedicated project management for the life of the project. Task 1 includes all project management activities associated with the project such as planning, coordination, communication, and reporting. An economic analysis of the AHPC based on the field results will be conducted under Task 1 and included with the final report.

1.2.2 Task 2a – Additional 200-acfm (5.7-m^3/min) Tests

Additional 200-acfm (5.7-m^3/min) tests were planned to help design the scaled-up unit with the appropriate geometric configuration. Approximately 2 weeks of additional testing was planned to determine if the AHPC could be designed in a more compact configuration than tested in Phase I without compromising performance. These tests were completed, and results were reported in previous quarterly reports.

1.2.3 Task 2b – Design of 9000-acfm (255-m^3/min) Field Demonstration AHPC

The goal for the scaleup tests is to evaluate the AHPC under the most realistic conditions achievable, including the use of full-scale components where possible. The 9000-acfm (255-m^3/min) size represents a large, pilot-scale (2.4-MW electrical equivalent) unit but appears to provide the best combination of being large enough to allow meaningful tests with full-scale components, but yet small enough to be transportable and cost-effective.

1.2.4 Task 2c – Construction and Installation of 9000-acfm (255-m^3/min) Unit

The AHPC vessel was constructed at the EERC. The selection of the Phase II field site was made during the early design phase of the 9000-acfm (255-m^3/min) AHPC unit. The AHPC unit was then installed on a slipstream of a full-scale, coal-fired utility boiler.

1.2.5 Task 3 – Field Testing of 9000-acfm (255-m^3/min) Unit

The primary purpose of Phase II is to provide long-term operating data that can be used to scale up the AHPC for application to full-scale boilers rather than to test a number of variables. Approximately 6 months of testing was originally planned. However, because of a delay in the construction and installation, the current plan is to test for approximately 4.5 months and complete the field testing by mid-December 1999. One of the most important objectives is to demonstrate that longer-term bag life can be achieved when operating at an air-to-cloth (A:C) ratio of 12 ft/min (3.7 m/min), using commercially available bags that were provided by W.L. Gore & Associates. A second important objective is to demonstrate ultrahigh particulate collection over an extended time period. After initial shakedown, the main parameter that may change is the A:C ratio. If operation at 12 ft/min (3.7 m/min) is highly successful after 3.5 months of operation, the plan is to increase the A:C ratio to 16 ft/min (4.9 m/min) for the last month of testing. Extensive particulate monitoring to establish the fine-particle collection efficiency was originally planned three times during the testing: near the beginning, at the middle, and near the end of the tests. However, for the shortened field testing, particulate monitoring is now planned only during the first and last months of operation. If extended testing was unlikely at the end of Phase II, the plan was to disassemble the field AHPC unit and either return it to the EERC for storage or field-salvage the components. However, the EERC was recently selected by DOE for Phase III testing of the AHPC, and further testing of the AHPC at the Big Stone plant is now planned for next year under a separate project.

2.0 PROJECT STATUS

2.1 Field Test Site

The main selection criteria for the field site demonstration were:

- An interest in the AHPC technology and a willingness to host the demonstration.
- Burning a coal that is representative of coals widely used in the United States.
- A reasonable distance from the EERC.
- The long-term potential for a retrofit of the AHPC, if results look promising.
- Production of ash that is reasonably challenging for the AHPC.

As stated in the October–December 1998 quarterly report, the Big Stone plant, located near Milbank, South Dakota, and operated by Otter Tail Power Company, is the field site for the demonstration.

Big Stone power plant was commissioned for service in 1975. The unit is jointly owned by three partners: Northwestern, Montana–Dakota Utilities, and Otter Tail Power Company. The unit is a 450-MW-rated, Babcock and Wilcox cyclone-fired boiler. The primary fuel for the first 20 years of operation was North Dakota lignite. In the early 1990s, a supplemental fuel program using alternative fuels such as chipped tires and refuse-derived fuel (RDF) pellets was begun. Today, the alternative fuel program supplies approximately 5% of the overall fuel. The RDF pellets were dropped, but the chipped tire program continues, and the program has been expanded to include waste seed, petroleum coke, copier toner, waste wood, etc. The loading of the plant has substantially increased in the last few years, and new generation records have been set each year.

After 20 years of burning lignite, the primary fuel was switched to Powder River Basin subbituminous coal. This fuel has approximately one-half of the moisture and one-third more heat than North Dakota lignite. Almost all of the effects of this new fuel have been positive. However, one challenge that has occurred is the decreased efficiency of the electrostatic precipitator (ESP). The overall increase in resistivity of the fly ash has dictated an upgrade to the existing pollution control equipment. The controls on the precipitator were all upgraded. A humidification system was installed to reduce the flue gas temperature as well as increase moisture. Even with the upgrade, control of the opacity with this equipment is marginal. In 1998, testing of chemical additives to the humidification system to modify the resistivity of the fly ash was started. These chemicals are used periodically as the composition of the supplied fuel changes. With the upgrades, emission limits are met under almost all circumstances without dropping load. However, the aging ESP and the new flue gas-conditioning system are marginal in overall control and do not allow much freedom in fuel supply.

2.2 Design, Construction, and Installation of 9000-acfm (255-m^3/min) AHPC

As reported in the January–March 1999 quarterly report, the 9000-acfm (255-m^3/min) field AHPC was constructed and assembled in the EERC high-bay facility prior to shipping the unit to the Big Stone plant. Installation and shakedown testing were completed from May–July, as reported in the April–July quarterly report.

Figure 1 (figures follow text) is a top view of the geometric arrangement of the AHPC showing how the rows of bags are centered between parallel collecting plates with rows of discharge electrodes on opposite sides of the bags between the bags and plates. Figures 2 and 3, which were taken during construction without bags and before installation of the tube sheet, show the arrangement of discharge electrodes and collecting plates. AHPC specifications are given in Table 1, and the bag pulsing specifications are shown in Table 2. Photos of the AHPC as installed at the ESP inlet duct at Big Stone plant are shown in Figures 4 and 5. Note the small, compact, high-voltage (HV) power supply at the top of the unit (Figure 5). This small housing, which contains the entire transformer rectifier (TR) set and controls, is mounted directly over one of the support insulators for the discharge electrodes. Figure 6 shows one of the Goyen pulse valves along with one of the sight ports. Figure 7, taken from the opposite side at the top of the AHPC, shows one of the pneumatic plate rappers along with another sight port. Figure 8 is a photo taken through the sight port during actual operation showing the first bag centered between the directional discharge electrodes and plates.

TABLE 1

AHPC Specifications

Flow Rate	8646 acfm at 12 ft/min (245 m^3/min at 2.7 m/min) 11,520 acfm at 16 ft/min (326 m^3/min at 4.9 m/min)
Bags	32 (4 rows × 8 bags/row) 5.75 in. d. × 15 ft long (14.6 cm d. × 4.6 m long)
Bag Type	GORE-TEX® all ePTFE No-Stat®
Collection Plates	18 gauge, 29-in. (73.7-cm) spacing 14 ft 4 in. × 7 ft 3 in. (4.4 m × 2.2 m)
Discharge Electrodes	Rigid mast type with directional spikes toward plates
Discharge electrode spikes to plate distance	5 in. (12.7 cm)
Discharge Electrode Spike to Bag Distance	6.5 in. (16.5 cm)
Rappers	Pneumatic vibrator type for both plates and discharge electrodes
HV Power	ABB switched integrated rectifier (SIR)

TABLE 2

Pulsing System

Header Volume	7 ft^3 (0.2 m^3)
Pulse Valves	Goyen 3 in. (7.6 cm)
Blow Tubes	3-in. (7.6-cm) diameter
Nozzle Size	1-in. (2.54-cm) diameter
Pulse Header Pressure	70–90 psig (483–621 kPa)
Pulse Time	200–400 ms
Pulse Initiation Set Point	8 in. W.C. (2 kPa)

2.3 AHPC Field Testing Start-Up and Initial Operation

After completing the shakedown testing and replacing the HV power supply (described in the previous quarterly report), the field AHPC unit was started on July 29, 1999. Based on shakedown testing, the initial secondary current was set at 50 mA and the bag cleaning trigger point was set at 8 in. W.C. (2 kPa), to initiate pulsing all four rows of bags in sequence. The flow rate was set to a nominal 12 ft/min (3.7 m/min) based on pitot readings. However, since the fan speed was not automatically controlled by the flow rate, there was always an increase in flow rate after pulsing. This fluctuation was most significant during the first few days of testing when there was a greater change in pressure drop from pulsing. Initially, the flow rate increased by about 30% after pulsing corresponding to an A:C ratio after pulsing of at least 15 ft/min (4.6 m/min). However, after a month of operation, the fluctuation was only about 15%, as a result of some seasoning of the bags. The fan speed was set so that before the pulse the A:C ratio was in the range of 11.5 to 12 ft/min (3.5 to 3.7 m/min). With the increase in flow after pulsing, the integrated average flow rate throughout the pulsing cycles was typically in the range from 12 to 13 ft/min (3.7 to 4 m/min) during the first 6 weeks (July 29–September 8).

2.4 Pressure Drop

The AHPC tube sheet pressure drop data for the first 4 days of operation are shown in Figure 9. These initial data were recorded manually prior to the data logging working properly. Initially, the bags cleaned down to 4 in. W.C. (1 kPa), but after 4 days of operation, they cleaned down to 5.3 in. W.C. (1.3 kPa). This decrease was expected, with some seasoning of the bags.

Over the course of the first 6 weeks (July 29–September 8), there were a number interruptions to the operation. During this time, there were six unplanned outages to the plant ranging from a few hours up to 24 hours. In each case, the outage caused the induced-draft (ID) fan to shut down automatically, and the AHPC was then brought on-line manually when the plant was up to stable operating conditions. There were also two occurrences where significant rainfall led to water leaking into the AHPC around an insulator, which resulted in arcing and automatic shutdown of the SIR. In these, cases the AHPC remained on-line, but the pulse interval increased significantly without ESP power.

Operation of the AHPC was steady, with a pulse interval in the range from 25–40 minutes for the first week. The first unplanned plant outage occurred August 6. Figure 10 shows the AHPC pressure drop coming back on-line following the outage. Note that the pulse interval was greater during the first several hours while the unit was heating up but appeared to steady out after about 6 hours. The data shown in Figure 10 (and subsequent pressure drop graphs) are the data as logged every 15 seconds with the automated data collection system. In addition to the automatically logged data, manual pressure drop data were also recorded during the times an operator was present. Comparing the pulse intervals and bag cleanability before and after the outage indicates no obvious effect of the shutdown on AHPC performance.

From August 6–12, three more unplanned outages occurred which resulted in AHPC shutdown, but in each case, the AHPC came back on-line without any noticeable difficulties. However, early on August 12, the SIR shut down because of water-induced arcing, and the unit went into continuous pulsing (see Figure 11). Even without the SIR power, the AHPC should not have been continuously pulsing, but, as shown in Figure 11, the pressure drop varied between 6.4 and 7 in. W.C. (1.6 and 1.7 kPa). This was caused by bounce in the photohelic switch, which caused the pulse trigger to reset. The time delay between pulsing each row of bags was previously programmed at 10 seconds so this limited the continuous pulsing of all of the bags to every 40 seconds. The continuous pulsing occurred for approximately 5 hours, until the operator arrived in the morning, and the AHPC was taken off-line. A significant amount of water apparently leaked into the AHPC compartment which not only caused the arcing that shut down the SIR, but water was noticed dripping out of the hopper bottom, in spite of the compartment temperature remaining above 250EF (121EC). After purging the compartment with dry air, several attempts were made to bring the AHPC back on-line, but significant arcing continued. Finally, the decision was made to bring the AHPC on-line without the SIR power, with the expectation that any wetted surfaces where arcing occurred would dry. The AHPC was operated as such for about 4 hours until sufficient drying occurred to allow the SIR to operate again without arcing. Details of the effect on pressure drop during this time are provided in Figures 12 and 13. Note that the pulse interval was about 5 min from 10:00 a.m. until 2:00 p.m., and immediately started increasing after 2:00 p.m. when it was possible to start applying power to the SIR. While the pulse interval eventually increased to the range from 15 to 30 min, it appeared that the bags did not clean as well after the moisture problem. Before the event, the bags cleaned down to 5.7 in. W.C. (1.4 kPa), but after, they only cleaned to about 6.2 in. W.C. (1.5 kPa). Whether the difference was the result of multiple pulsing or moisture on the bags is not known. However, the AHPC continued to operate satisfactorily. Three days later, the pulse interval was about 25 min and the bags cleaned down to about 6.2 in. W.C. (1.5 kPa) (Figure 14).

Three weeks after initial start-up, operation continued to be steady, with a pulse interval from 15 to 25 min and the bags cleaning down to about 6.4 in. W.C. (1.6 kPa) (Figure 15). Following two more plant outages on August 21 and 22, the AHPC operation appeared to improve somewhat, achieving a pulse interval of 30 min and bags cleaning down to 6.1 in. W.C. (1.5 kPa) (Figure 16). This good operability continued through September 2 (Figure 17). On September 3, the second water leak around an insulator occurred, leading to moisture in the AHPC, arcing, and SIR shutdown (Figure 18). In this case, the problem was noticed early, and the unit was taken off-line for about an hour. Again, coming back on-line proved to be difficult because of excessive sparking and arcing. However, by significantly reducing the secondary current limit and temporarily increasing the pulse set point to 8.3 in. W.C. (2.1 kPa), it was possible to operate with a pulse interval of about 10 min until 9:00 a.m. the next day, when the secondary current was restored to the previous normal operating range. In this case, the moisture problem did not appear to cause any permanent deleterious effect on AHPC performance. Following the moisture problem, good AHPC operability was seen until the AHPC was shut down and taken off-line September 8 (Figure 19) for the annual Big Stone plant outage.

While the multiple unplanned outages added difficulty to the AHPC operation during this time, they also provided a severe test of the ruggedness of the AHPC during multiple start-ups, SIR power outages, and moisture in the compartment. In spite of all of these interruptions, the AHPC continued to operate very well and functioned within expectations.

2.5 Particulate Emissions

Two inlet and two outlet U.S. Environmental Protection Agency (EPA) Method 17 dust loadings were completed after 3 weeks of operation (see Table 3). Based on these measurements, the collection efficiency was at least 99.99%. However, the measured efficiency was somewhat limited by the weighing accuracy of the filters before and after sampling. The sampling time for

TABLE 3

AHPC2 Dust Loadings Taken 8/18/99

Inlet		Sample	
Grains/scf	% H_2O	Time	
1.17	12.84	25 min	
1.36	12.84	15 min	
Outlet		**Sample**	**Removal**
Grains/scf	% H_2O	Time	Efficiency %
0.0000913	12.2	4 hr	99.993
0.0000398	11.8	17 hr	99.997

the second outlet dust loading was extended to 17 hours to lower the detection limit, but weighing accuracy was still a limiting factor. The ultrahigh collection efficiency was confirmed by the perfectly clean outlet filter, even after sampling for 17 hours. The flue gas moisture values of 12% along with leak checks of the sampling trains before and after sampling provide quality control checks that the indicated flue gas volume was the actual volume sampled. Another indication of ultrahigh collection is that inspection of the clean plenum area of the AHPC following 6 weeks of operation showed the tube sheet to be completely clean.

2.6 Electrical Conditions

Since the dust is known to cause operational difficulties for the Big Stone ESP because of high resistivity, it was expected that resistivity problems might also be an issue with the AHPC. The first evidence of high resistivity was the significant amount of sparking that was present from the first days of operation. Since the sparking was worse at higher temperatures, the indication is that this was caused by an increase in resistivity. The HV power supply was set to a spark rate limit of 30 sparks per minute and an initial current limit of 50 mA. With these settings, under minimal sparking conditions, the power supply operated in a current limit mode. However, when significant sparking occurred, the sparking control reduced the current to stay within the sparking limit. In some cases, this resulted in current reductions to 25 mA or even lower. Visual inspection through the sight ports during periods of severe sparking showed that sparking always was between the discharge electrodes and plates rather than between the electrodes and bags. In spite of a total of 150,000 sparks during the 6 weeks and some arcing when water leaked into the compartment, sparks were never observed going to the bags. In addition, after pulling bags and inspecting, there was no evidence of sparking damage (see next section).

High-resistivity dust also limits ESP performance when back corona is present. From visual inspection through the site ports, back corona could be observed along the support ribs of the plates and various other sharper points on the plate suspension system. The presence of back corona confirms that the dust resistivity is sufficiently high to limit ESP performance. In spite of the back corona, the

AHPC appeared to function very well. However, the implication is that AHPC performance could be improved in cases where the resistivity does not limit ESP performance.

2.7 Filter Bag Evaluation

GORE-TEX® Membrane/GORE-TEX® Felt with GORE-NO STAT® Fiber Filter Bags were installed and precoated with fly ash dust prior to start-up of the AHPC on July 29, 1999. During the 6 weeks of operation, the bags encountered several system upset conditions, including low ESP performance in which the power levels were reduced by 50%–100%. During this time, the bags were required to operate at an A:C ratio of 12 ft/min (3.7 m/min) for 6–12 hours while cleaning on-line. In addition, there were several unscheduled Big Stone boiler shutdowns where the AHPC and filter bags had immediate loss of airflow and power. During these periods, including the subsequent restarts, the changes in temperature in the AHPC chamber may have exposed the bags to flue gas dew point excursions. The condensation of vapors on the bags can cause a moist cake to form on the media surface. The bags have recovered very well through these upset conditions and have seasoned to an operating condition filter drag of 0.5 in. W.C./ft/min (0.12 kPa/m/min), which is considered typical for a coal-fired boiler application.

The operation of the AHPC was stopped on September 8, 1999, two days prior to the scheduled Big Stone annual maintenance shutdown. The shutdown procedure included cleaning bags on-line and off-line to remove most of the dust cake from the bag surface. On September 13, the filter bags were removed from the AHPC unit, visually inspected, and stored in plastic bags until reinstallation. Three bags were returned to W.L. Gore & Associates, Inc., for lab analysis.

There was a thin layer of dust present on the surface, typical of most coal-fired boiler applications. The primary dust cake was easily brushed off and revealed a membrane that looked white and like new. Discoloration would suggest particles adhering to the surface. A photo taken of the bag after brushing clearly shows a clean surface and the part number stamped on the bag during production is visible (Figure 20).

Additional samples were analyzed using a microscope to determine if the high A:C ratio caused dust penetration into the membrane. Under magnification of 10–50x, the media surface was clear of particulate matter after brushing, which indicates no dust penetration into the membrane.

All bags were visually evaluated for spark damage. No evidence of sparking to the bags or across the media was observed. While at Big Stone, two additional bags were cleaned by lightly brushing the membrane surface in order to investigate the presence of any spark damage. There was no visual indication that the bags encountered sparking to or across the media. The media is designed to dissipate the electric charge that potentially may build up on the media from charged dust depositing on the surface and charged air particles passing through the media.

The air permeability analysis of the AHPC filter bag media was performed in the lab using a Frazierometer. This device measures the amount of air that flows through a flat sample of media 3.5 in.

(8.9 cm) in diameter and correlates it to a Frazier number. The Frazier number describes the volume of air (ft^3/min [m^3/min]) passing through 1 ft^2 (0.09 m^2) of media at a differential pressure of 0.5 in. W.C. (0.12 kPa). A Frazier number of 1.0 indicated 1 $ft^3/min/ft^2$ (0.3 $m^3/min/m^2$ at 0.5 in. W.C. (0.12 kPa). Canceling units of ft^2 (m^2) , the Frazier number units are expressed as ft/min (m/min) at 0.5 in. W.C. (0.12 kPa).

Samples of the AHPC filter bag media were cut from the top, middle, and bottom bag locations. Sample size was 5 in. (12.7 cm) in a vertical direction on the bag and the entire circumference of the bag. The sample was tested for permeability in the condition it was received from the field application. Three tests were done per sample. Therefore, the test produces a total of nine data points for each filter bag. These are then averaged to create a bag permeability number. Upon observation, the as-received media appeared to retain much of the dust cake that was present during bag removal. The average Frazier numbers for the three bags were 1.9, 1.8, and 2.4 ft/min (0.6, 0.5, and 0.7 m/min) at 0.5 in. W.C. (0.12 kPa). Next, the sample was carefully brushed to remove the primary dust layer from the membrane surface. The samples were retested in the exact locations to measure the permeability change after brushing. The average bag permeabilities were 3.0, 3.0, and 4.6 ft/min (0.9, 0.9, and 1.4 m/min) at 0.5 in. W.C. (0.12 kPa). These media permeability values are typical of filter bags from coal-fired boiler applications. As a baseline, the new media Frazier number is generally within the range of 3.5–6.0 ft/min (1.1–1.8 m/min) at 0.5 in. W.C. (0.12 kPa).

In summary, after 6 weeks of operation, the bags seasoned to an online cleaned condition filter drag of 0.5 in. W.C./ft/min (0.12 kPa/m/min), which is considered typical for a coal-fired boiler application, and there was no evidence of sparking to or across the media. The bags have met Phase II experimental objectives of operation including A:C ratio of 12 ft/min (3.7 m/min), dissipation of charge and spark potential, particulate release upon pulse jet cleaning, low particulate matter emissions, and recoverability from AHPC system upsets.

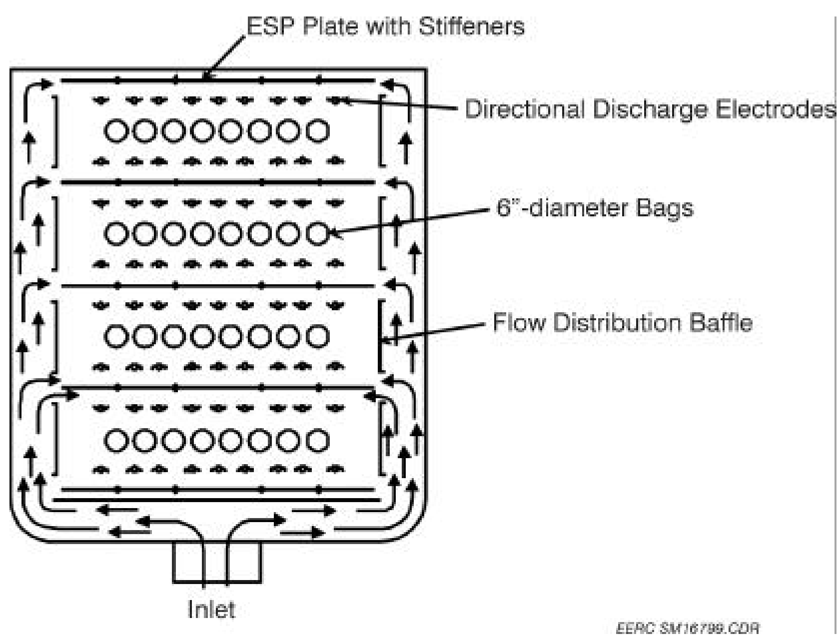

Figure 1. Top view of the 9000-acfm AHPC.

EERC SM16803.CDR

Figure 2. Internal arrangement of directional electrodes and plates shown without bags and tube sheet.

EERC SM16800.CDR

Figure 3. View from top of the AHPC with tube sheet and bags removed showing two rows of nine discharge electrodes.

Figure 4. AHPC installed at the ESP inlet at the Big Stone plant.

Figure 5. AHPC showing access platform and HV power supply.

Figure 6. Goyen pulse valve and sight port at top of AHPC.

Figure 7. Pneumatic plate rapper and sight port at top of AHPC.

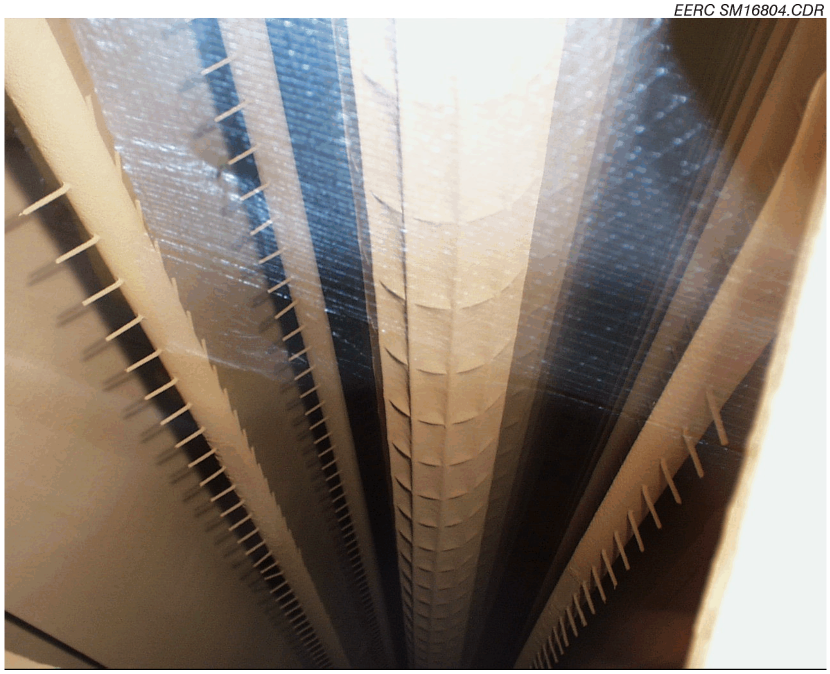

Figure 8. View through sight port taken during actual operation.

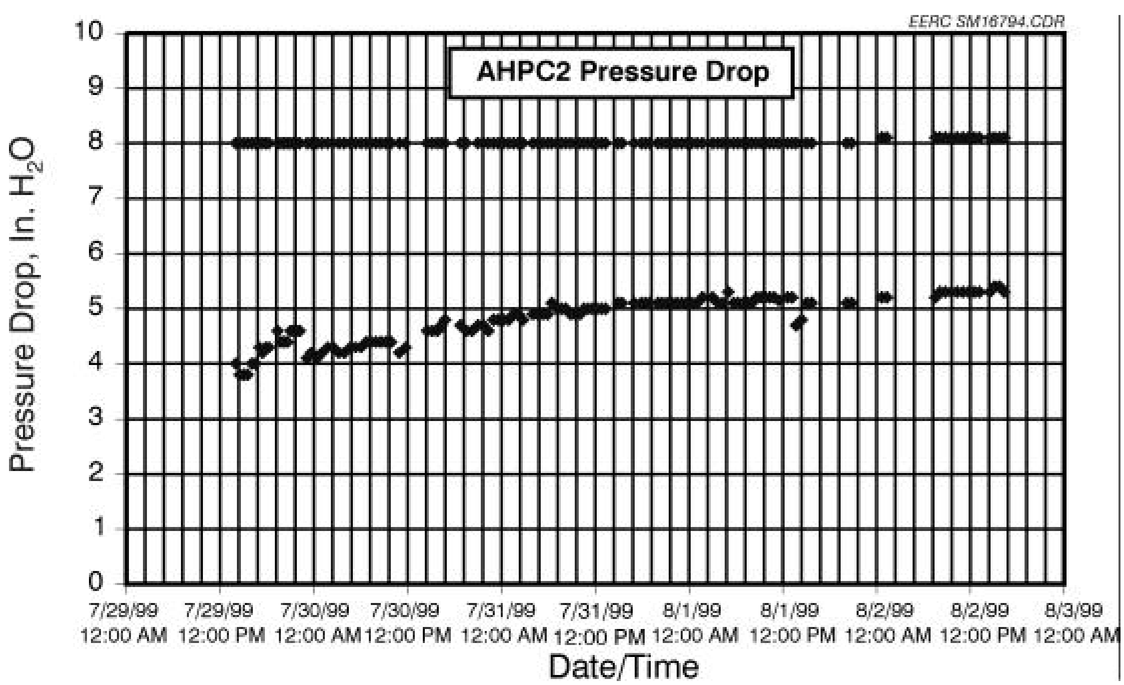

Figure 9. AHPC2 pressure drop before and after bag cleaning during the first three days of operation.

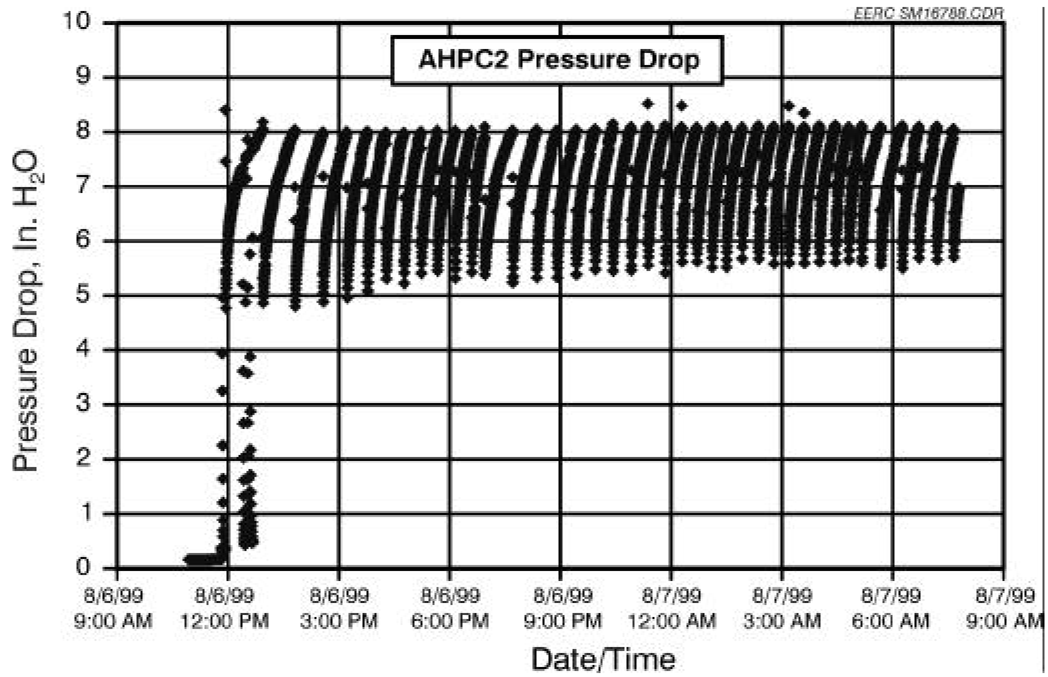

Figure 10. AHPC2 pressure drop during start-up after plant outage.

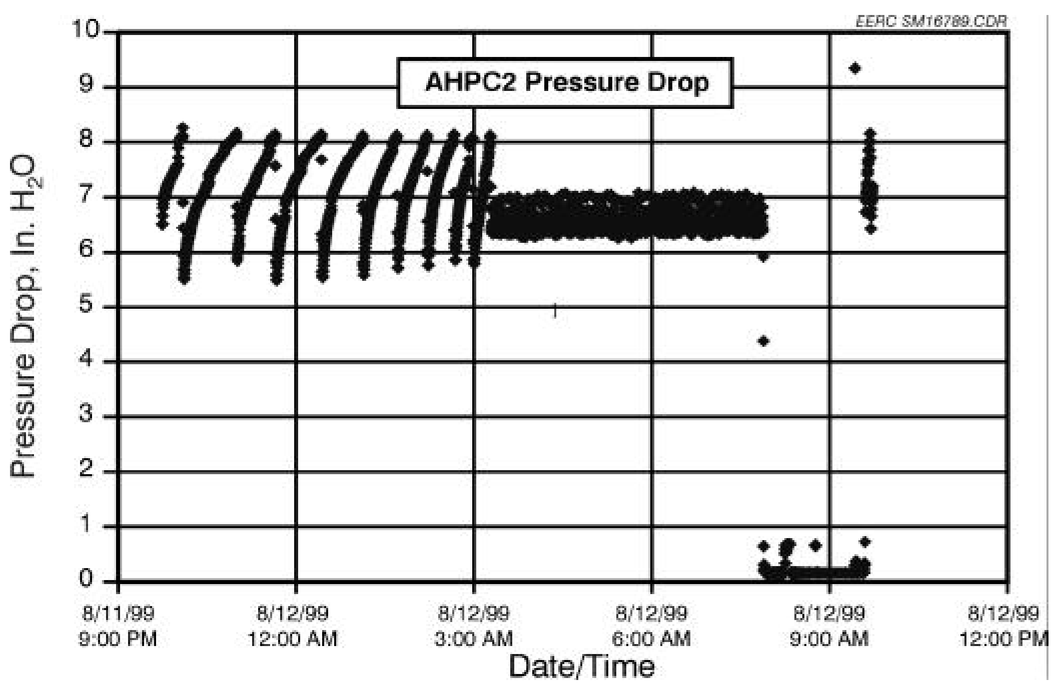

Figure 11. AHPC2 pressure drop showing continuous pulsing following arcing problems.

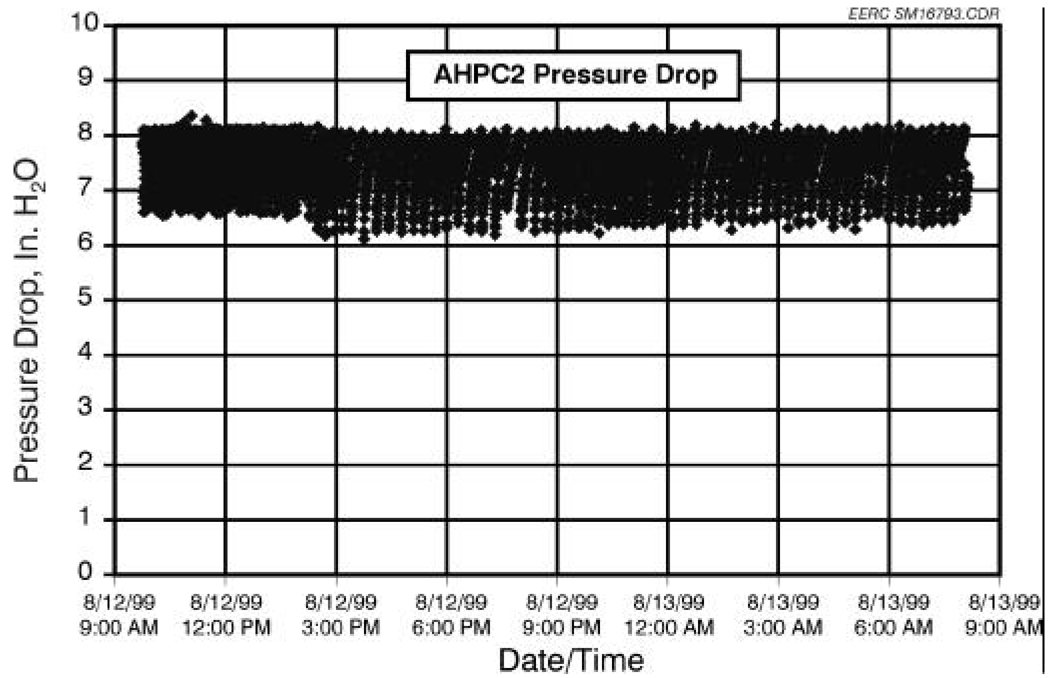

Figure 12. AHPC2 pressure drop showing start-up after arcing problems.

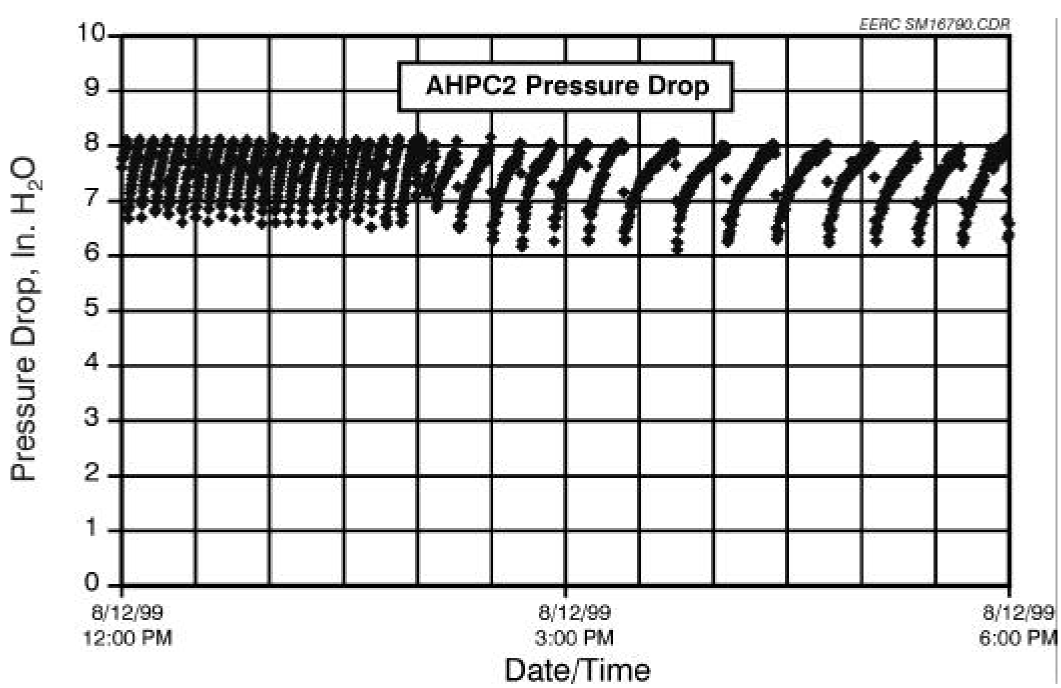

Figure 13. Expanded view of AHPC2 pressure drop showing effect of restored HV power.

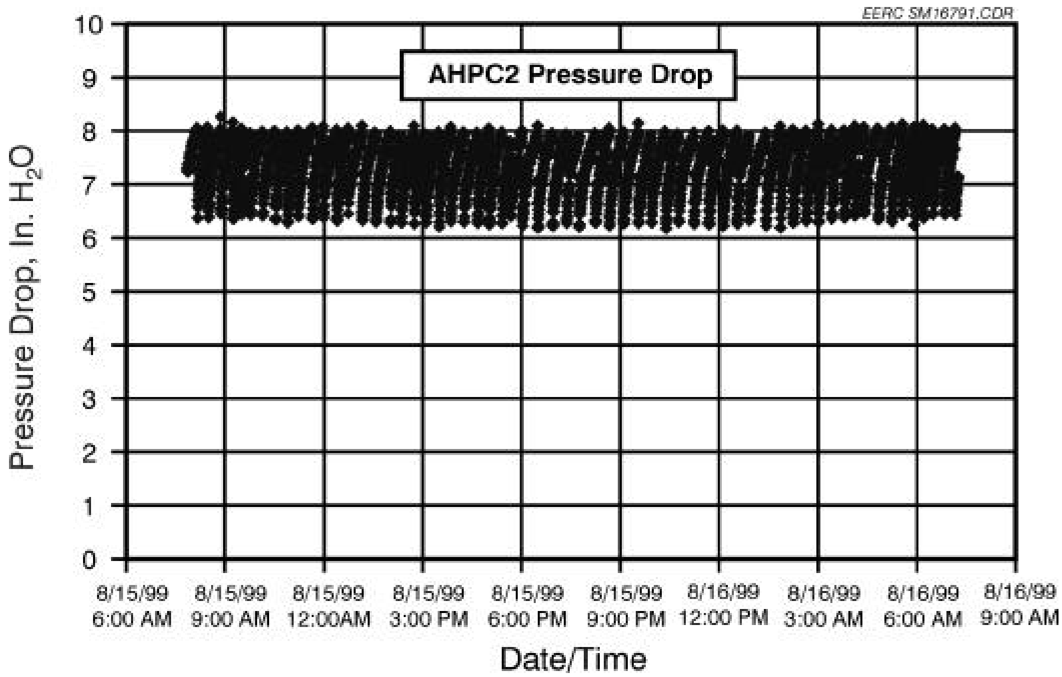

Figure 14. AHPC2 pressure drop showing steady operations 2½ weeks after initial start-up.

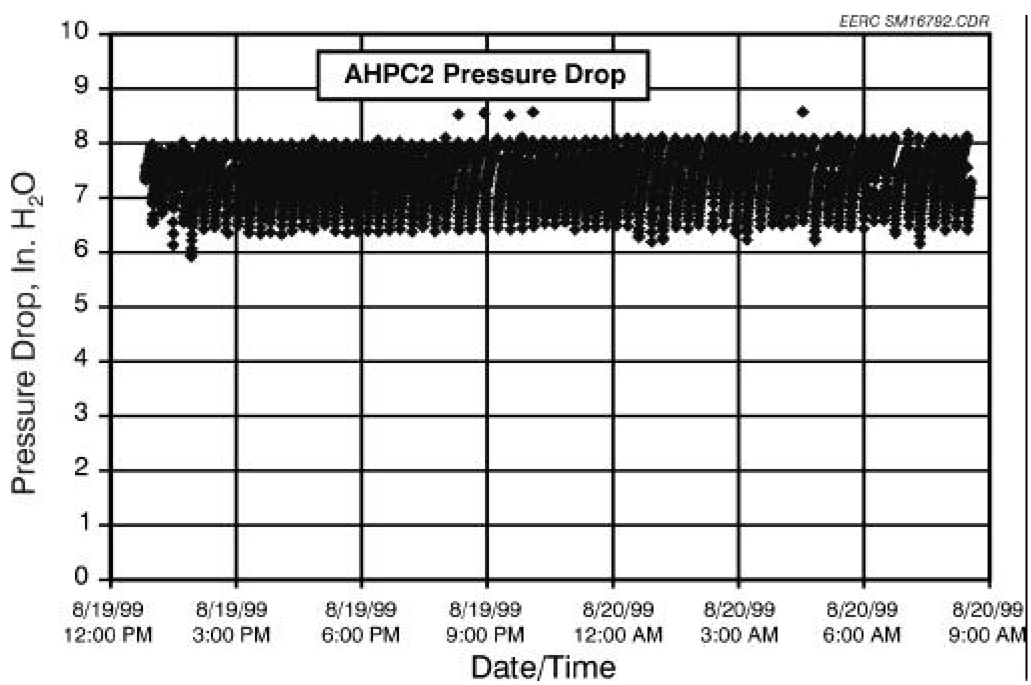

Figure 15. AHPC2 pressure drop 3 weeks after start-up.

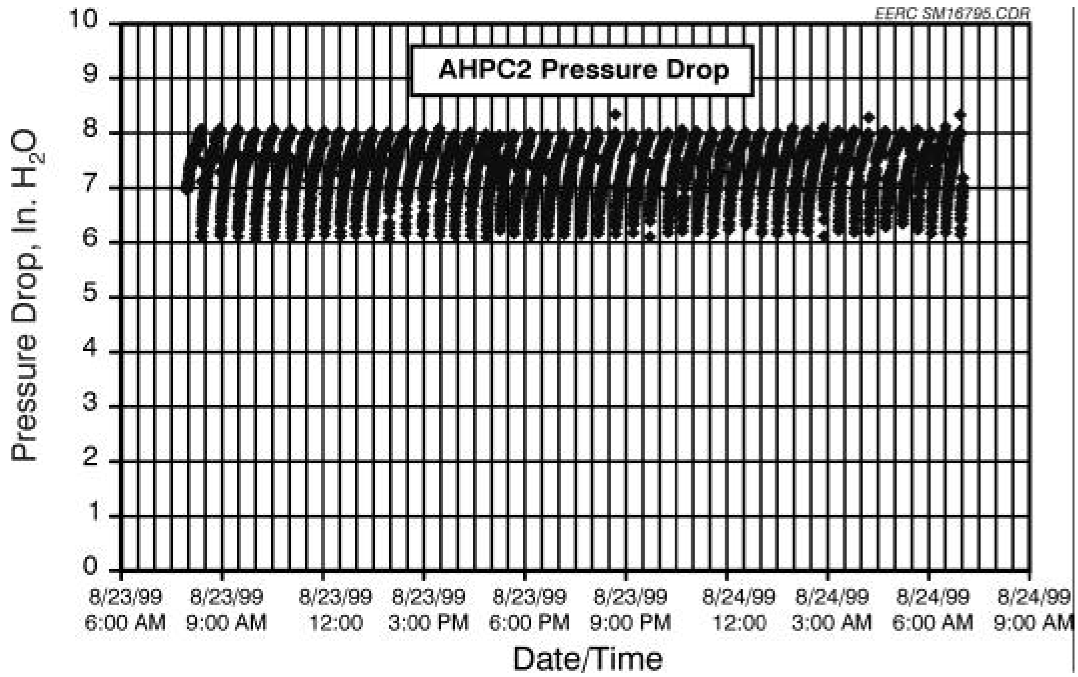

Figure 16. AHPC2 pressure drop after additional plant outages.

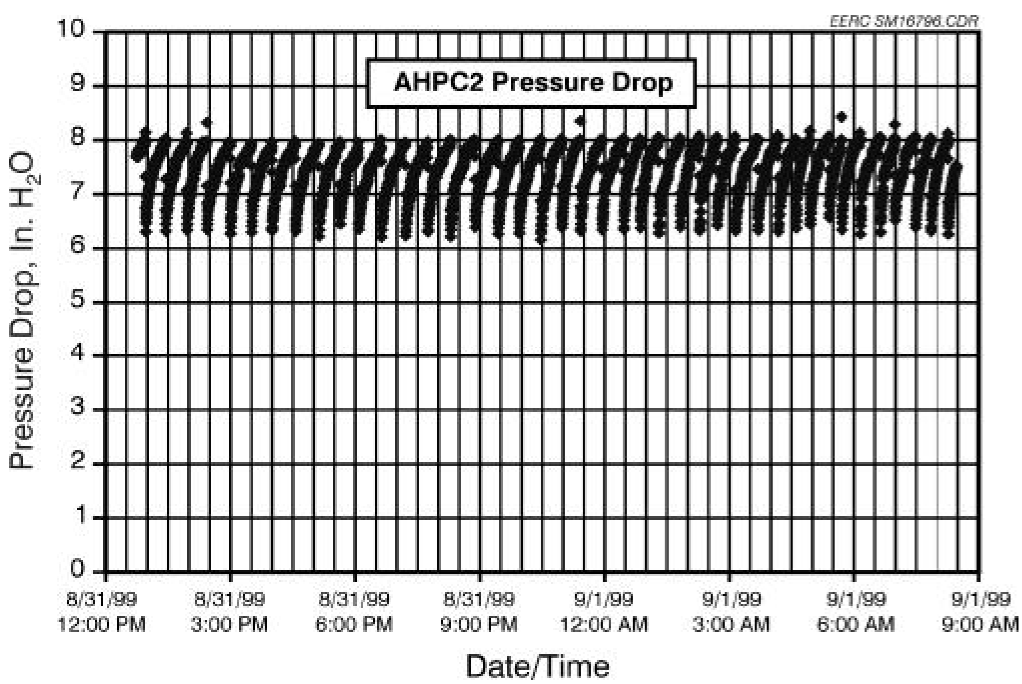

Figure 17. AHPC2 pressure drop 4 weeks after start-up.

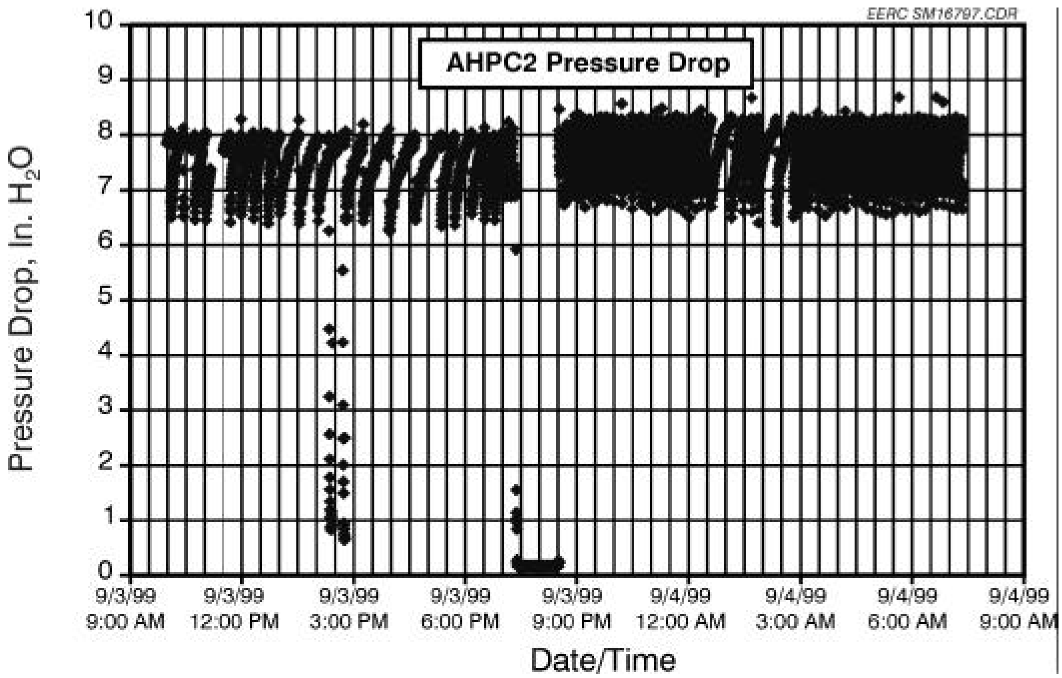

Figure 18. AHPC2 pressure drop during second arcing event.

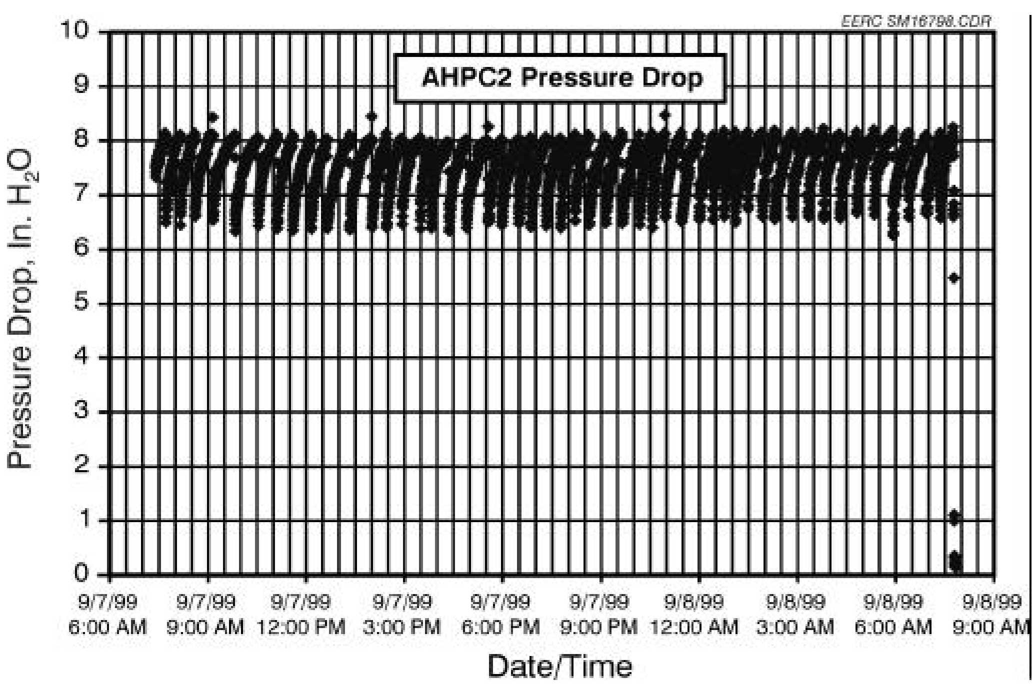

Figure 19. AHPC2 pressure drop prior to shutdown for plant outage.

EERC SM16801.CDR

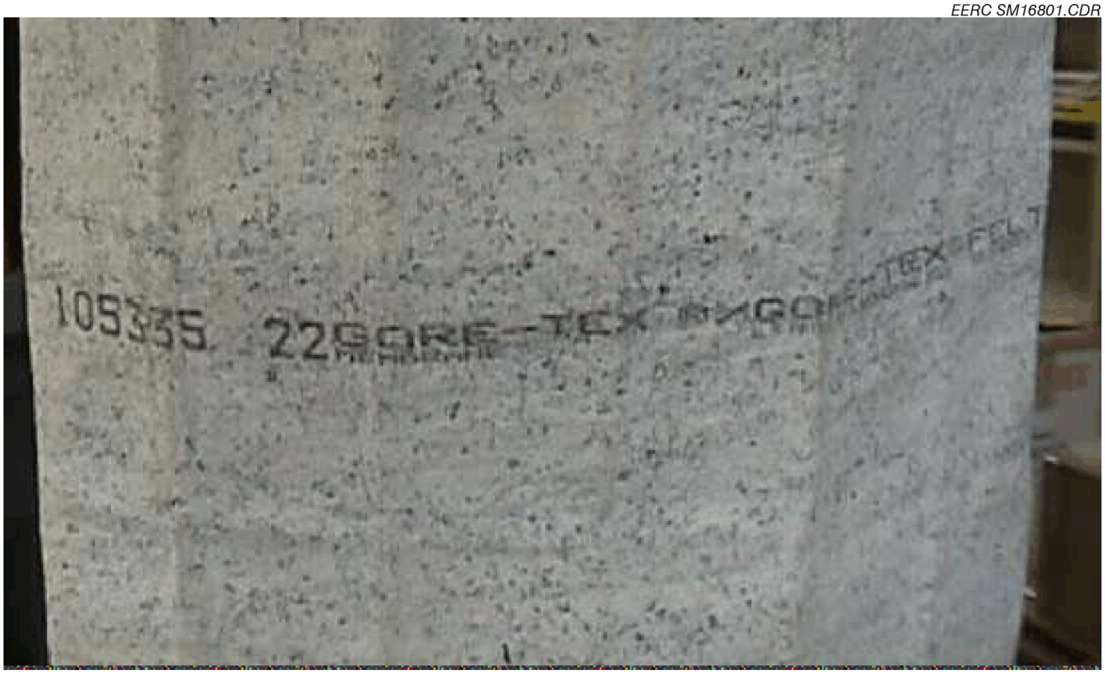

Figure 20. Filter bag name stamp exposed after brushing off primary dust cake showing clean fabric.