ADVANCED HYBRID PARTICULATE COLLECTOR

Quarterly Technical Progress Report

for the period January 1, 1999, through March 31, 1999

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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 transfer of the 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.

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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., and Allied Environmental Technologies, Inc. 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 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 recollection 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 5.7-m^3/min (200-acfm) 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 5.7-m^3/min (200-acfm) 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 5.7-m^3/min (200-acfm) tests were conducted as part of the Phase II effort to help optimize the scaled-up design. For Phase II, a size of 255 m^3/min (9000 acfm) 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 (January–March 1999), the main project activity was continuing construction on the 255-m^3/min (9000-acfm) AHPC and planning for the field installation at the Big Stone power station. The main vessel construction is now complete and has been erected in one of the high-bay areas at the EERC. Construction of the collection electrodes, the discharge electrodes, and the top of the unit is complete. The unit is expected to be ready for field installation by mid-May, and plans are to proceed with installation of the unit at Big Stone during the last half of May 1999.

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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 will be 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., and the Energy & Environmental Research Center (EERC), coordination of work among the three members and with the U.S. Department of Energy (DOE) will require dedicated project management for the life of the project. In addition to the project management responsibilities of Phase I, a further activity for Phase II is the selection of an appropriate site for the tests and coordination of the installation and testing with the host personnel. 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 5.7-m^3/min (200-acfm) Tests

Additional 5.7-m^3/min (200-acfm) tests were planned to help design the scaled-up unit with the appropriate geometric configuration. Approximately 2 weeks of additional testing were planned to determine if the AHPC could be designed in a more compact configuration than tested in Phase I without compromising performance. During the first week, Configuration 1 was to be evaluated for 8 hr. If this resulted in satisfactory performance equivalent to the Phase I results, Configuration 2 was to be evaluated for 8 hr. If the second configuration worked well, the test was to be extended to approximately 50 hr.

Configuration 3 was to be tested during a second week and again tested up to 50 hr if results looked promising. The results from these additional 5.7-m^3/min (200-acfm) tests were intended to serve as a basis to help design the 255-m^3/min (9000-acfm) unit.

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

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

1.2.5 Task 3 – Field Testing of 255-m^3/min (9000-acfm) 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 were originally planned. However, because of a delay in the construction and installation, the plan is now to test approximately 4.5 months and still complete the field testing by the end of October 1999, according to the original schedule. 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 3.7 m/min (12 ft/min), using commercially available bags that are being 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 only parameter that may change is the A:C ratio. If operation at 3.7 m/min (12 ft/min) is highly successful after 3.5 months of operation, the A:C ratio will likely be increased to 4.9 m/min (16 ft/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. Field data will be recorded with a data logger and transmitted to the EERC via modem. At the end of the Phase II testing, if there is no need for further testing at the field site, the AHPC field unit will be disassembled and either returned to the EERC for storage or field-salvaged. If results from the field tests indicate commercial viability and there is interest in continued tests at the field site location, the EERC will seek additional commercial funding to continue the tests.

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 previous quarterly report (October–December 1998), the Big Stone plant, located near Milbank, South Dakota, and operated by Otter Tail Power Company, will be the field site for the demonstration. The plant is a single, 420-MW, cyclone-fired unit that burns a Powder River Basin subbituminous coal and has an electrostatic precipitator (ESP) for particulate control. The inlet and outlet duct tie-ins to connect the AHPC to the main ESP duct have already been installed, as reported in the previous quarterly report. During the past quarter (January–March), the electrical service to the AHPC location has been completed by Otter Tail personnel at the plant site. The foundation design for the AHPC main vessel as well as the slab for the induced-draft (ID) fan were also completed. One of the causes for delaying the field installation is the delayed completion of the foundation. The plan was to complete the foundation in early April. However, because of delays due to weather, the foundation installation is expected to be completed the last week of April. Figures 1–3 (following text of report) show the layout of how the AHPC will be installed at this location.

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

During the last quarter (January–March 1999), the main project activity was construction work on the 255-m^3/min (9000-acfm) field AHPC. The unit is now about 90% complete and has been erected and partially assembled in the EERC high-bay facility for system component shakedown prior to shipping the unit to the Big Stone plant. Figures 4–5 show the unit in its current configuration for shakedown testing at the EERC. This approach should greatly expedite the installation and shakedown of the unit in the field.

One of the goals of the scaled up AHPC for Phase II was to employ full-scale components where possible. Specific system components of the AHPC are described briefly below.

2.2.1 Power Supply

The power supply chosen for the AHPC, manufactured by ABB Environmental Systems, is a state-of-the art switched integrated rectifier (SIR) that is available commercially. It has a number of features that make it ideal for the 9000-acfm field AHPC, including very compact size and rapid control response. It combines the T/R set and control cabinet into one unit that will be mounted directly on top of the AHPC. SIR makes use of the latest high-frequency switching technology available. The high frequency makes it possible to reduce all energy-storing components in size, as a much smaller amount of energy is converted in each cycle. The HV transformer in SIR has thus been reduced to only 15% in size, compared with a conventional T/R operating at mains frequency. Also the inductors and capacitors inside SIR can be made drastically smaller.

The high-frequency power is produced by IGBT transistors that chop the rectified main supply voltage. The result is up to 50 kHz AC, which is converted into high voltage by a very small transformer (143 lb, including the insulation oil, compared to around 1760 lb for a conventional T/R working at mains frequency – 50/60 Hz). After full-wave rectification, the HV DC from SIR is then supplied directly to the ESP field. The high switching frequency results in an ESP DC voltage which is almost ripple-free. The SIR can be controlled within 20 µs, compared to a conventional T/R which only can be controlled within one half-period of the mains ~8.33 ms. Thus SIR can be controlled ~400 times faster than a conventional T/R. Table 1 summarizes the main supply specifications.

TABLE 1

SIR Specifications

Model	SIR 80/250
Input	$3\phi \times 480$ V AC
Output	80 kV/250 mA
Efficiency	>90%
Power Factor	$\cos \varphi_1 = 1$
Weight	<180 kg

2.2.2 Discharge Electrodes

The high-voltage electrodes were custom-manufactured by a major electrostatic precipitator vendor, Environmental Elements Corporation, and are consistent with their full-scale electrode designs.

2.2.3 Insulators and Rappers

Insulators for suspending the discharge electrodes and rappers for both the discharge and collecting electrodes were supplied by BHA, which is a major supplier of precipitator components. These are off-the-shelf items that are commonly used in full-scale systems.

2.2.4 Bags and Cages

Bags and cages were supplied by W.L. Gore and are identical to those commonly used in full-scale baghouses.

2.2.5 Induced-Draft Fan

The ID fan was supplied by Winger Associates, Inc., and has already been shipped directly to the Big Stone site. The fan is oversized to accommodate higher A:C ratios. The Phase II plans are to test primarily at 12 ft/min or 9000 acfm. However, some testing at 16 ft/min is planned, which will require operating at a flow rate of 12,000 acfm. The ID fan should readily accommodate operation at 16 ft/min and is sized to operate at even higher flow rates, should that be necessary for future testing. The Twin City Fan Model 929 RBA industrial exhauster is capable of 16,000 cfm @ 30" H_2O @ 400°F and will be powered by a 460-volt, 125-hp TEFC premium efficiency, inverter duty motor. The variable-speed motor will facilitate draft control and operation at various flow rates.

Figure 1. Inlet and outlet ports from the underside of the main ESP inlet duct.

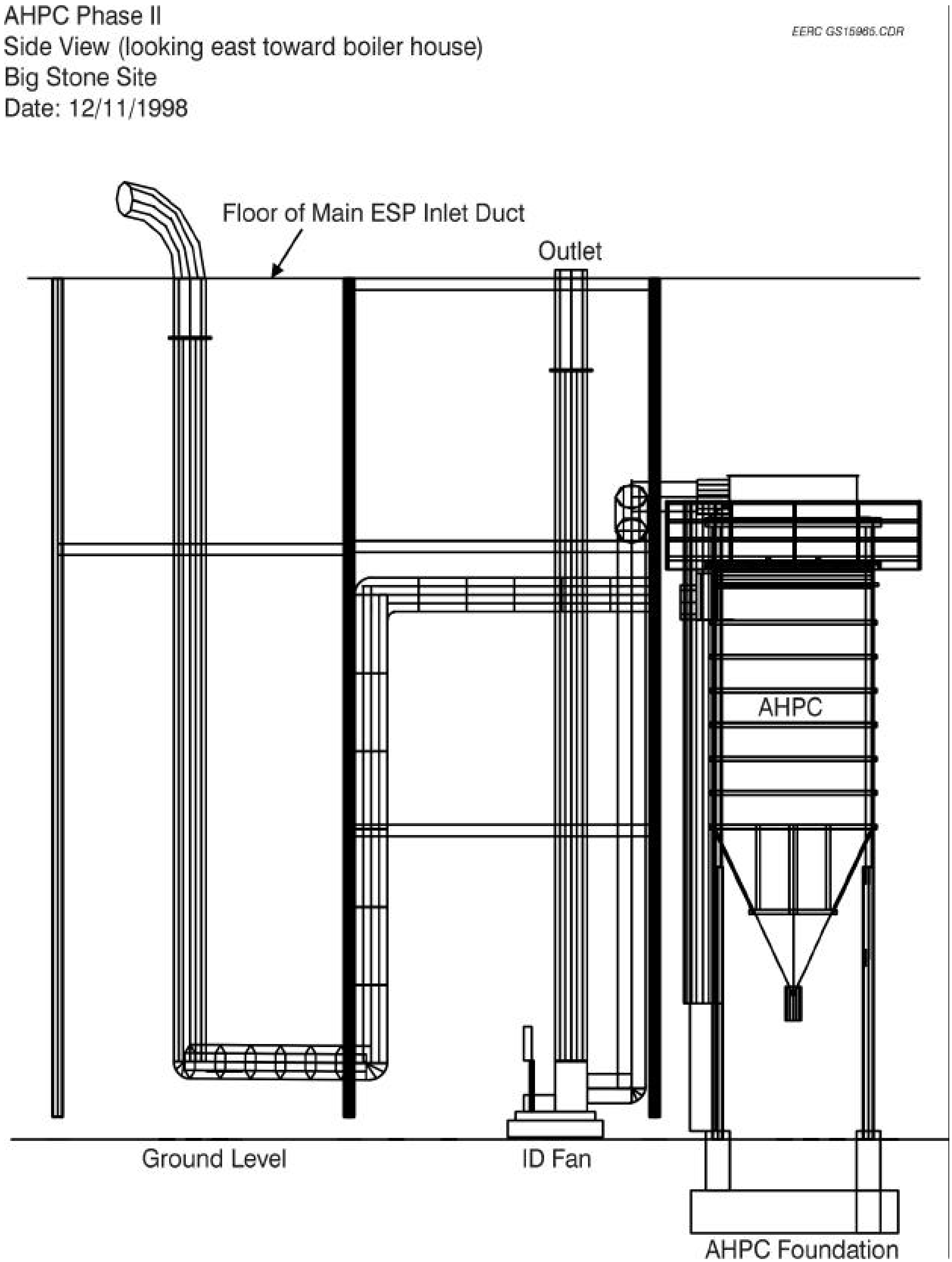

Figure 2. Side view layout of how the AHPC will be installed at this location.

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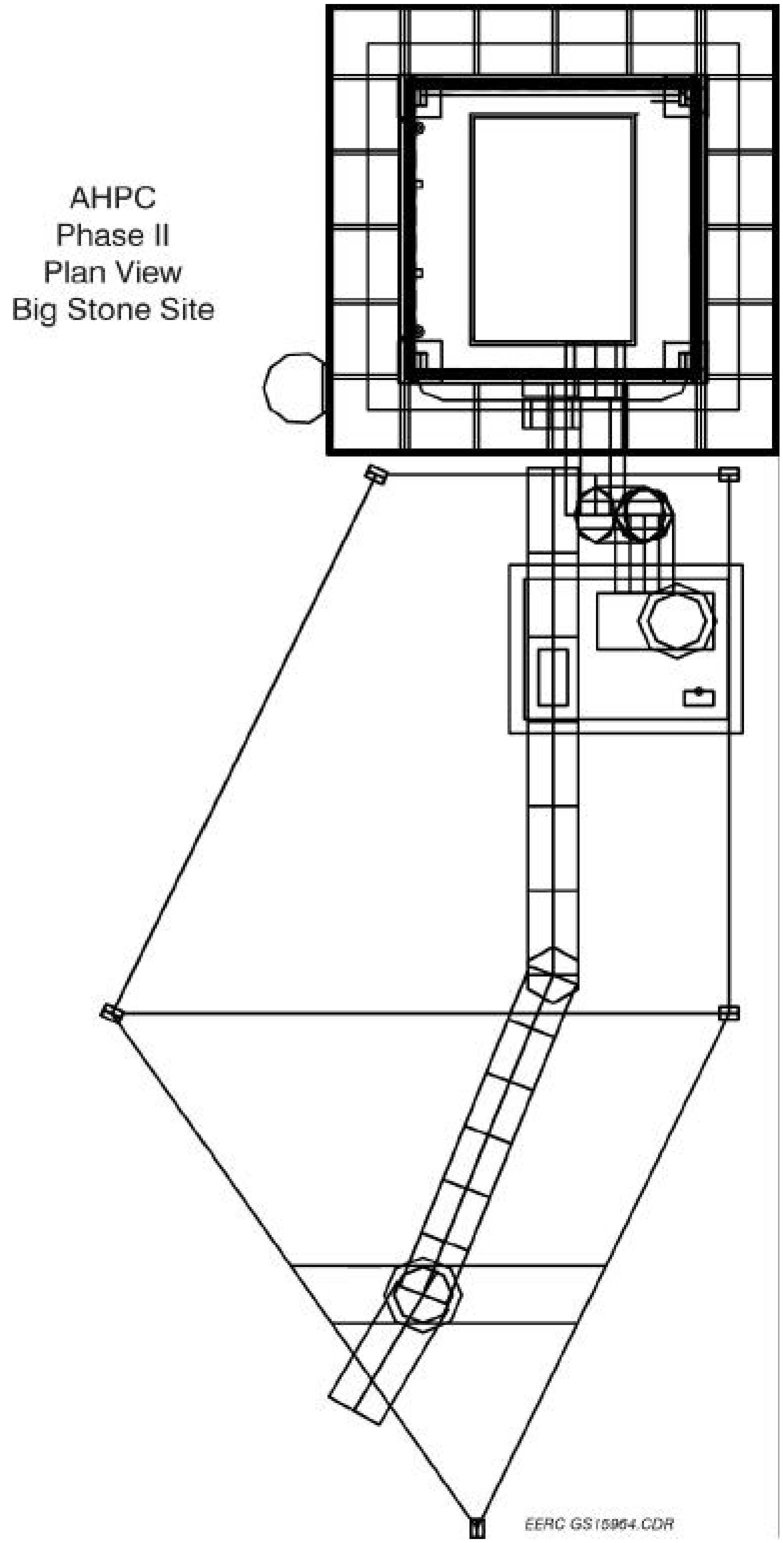


Figure 3. Top view layout of how the AHPC will be installed at this location.
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EERC SM16053.TIF

Figure 4. AHPC erected in the EERC high-bay pilot plant. Note that the top of the AHPC will have a walkway around all sides as shown here.

EERC SM16054.TIF

Figure 5. Erected AHPC vessel on support stand at the EERC.