ADVANCED HYBRID PARTICULATE COLLECTOR

Quarterly Technical Progress Report

for the period April 1, 1999, through June 30, 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-m³/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-m³/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-m³/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 m³/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 (April–June 1999), the main project activity was installation of the 255-m³/min (9000-acfm) AHPC at the Big Stone power station. The unit was shipped to the Big Stone plant in May, and as of mid-July, the installation was complete. During shakedown testing, a problem was discovered with the high-voltage power supply that required replacement of the entire supply. As of late July, a new supply was being shipped which should allow start-up of the AHPC immediately after installation.

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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-m³/min (200-acfm) Tests

Additional 5.7-m³/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-m³/min (200-acfm) tests were intended to serve as a basis to help design the 255-m³/min (9000-acfm) unit.

1.2.3 Task 2b – Design of 255-m³/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-m³/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-m³/min (9000-acfm) Unit

The AHPC vessel and ducting was to 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-m³/min (9000-acfm) AHPC unit. The AHPC unit was to be installed on a slipstream of a full-scale, coal-fired utility boiler.

1.2.5 Task 3 – Field Testing of 255-m³/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 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 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 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. 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.

2.2 Design, Construction, and Installation of 255-m³/min (9000-acfm) AHPC

As reported in the last quarterly report (January–March 1999), the 255-m³/min (9000-acfm) field AHPC was constructed and assembled in the EERC high-bay facility prior to shipping the unit to the Big Stone plant. For shipping, the AHPC was disassembled and loaded onto three flatbed trucks as shown in Figures 1–4.

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 μ s, 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	$3\phi \times 480 \text{ V AC}$
Output	80 kV/250 mA
Efficiency	>90%
Power Factor	$\cos \phi_1 = 1$
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 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" H₂O @ 400°F and is 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.

2.2.6 *Field Installation at Big Stone Plant*

The 255-m³/min (9000-acfm) field AHPC was installed at the ESP inlet duct location (described in the January–March 1999 quarterly report). The installation required the use of a large crane to lift the AHPC into place and to install the 24-in.-diameter inlet and outlet ducting.

After assembling the internal components of the AHPC, the entire unit was insulated and covered with steel siding. Figures 5–10 show the AHPC as installed at the Big Stone plant. The power panels for the entire unit along with pressure transducers, heater controls, and a data logger are installed at the base of the hopper enclosure area, which is accessible through an overhead door. In addition, an 8 × 30-ft trailer, located next to the AHPC, will serve as a remote office. The signal from the data logger is fed to a computer in the trailer that is accessible from the EERC by modem.

2.2.7 Field Shakedown Testing

All system components, including the ID fan, inlet and outlet flow control dampers, pulsing system, rappers, hopper heaters, pressure transducers, thermocouples, data logger, computer, and high-voltage power supply, were tested under cold-flow conditions. Except for minor corrections, all system components but the high-voltage power supply passed shakedown tests. After problems were encountered with the power supply and consultation with the vendor, ABB, it was determined that the supply installed was designed for European plant conditions (50 Hz 3 ϕ 400 V) rather than U.S. plant conditions (60 Hz 3 ϕ 480 V). As of late July, the supply was being replaced with another ABB supply designed for U.S. power systems. Since the rest of the components have passed shakedown testing, start-up is planned immediately after successful installation of the replacement power supply.

Figure 1. Removal of AHPC vessel from the high-bay construction area.

Figure 2. Loading the AHPC vessel onto a flatbed trailer.

Figure 3. Securing the AHPC on the trailer.

Figure 4. The AHPC on the trailer for shipping to the Big Stone plant.

Figure 5. The AHPC during final stages of installation at the Big Stone power station.

Figure 6. The AHPC installed below the ESP inlet duct at the Big Stone plant.

Figure 7. Top access to the AHPC via enclosed ladder to deck area.

Figure 8. Inlet and outlet piping run to the AHPC.

Figure 9. AHPC variable-speed ID fan.

Figure 10. Adjustable speed controller for the ID fan.