ADVANCED HYBRID PARTICULATE COLLECTOR – PHASE III

Quarterly Technical Progress Report
for the period January 1, 2000, through March 31, 2000

Prepared for:

AAD Document Control
U.S. Department of Energy
National Energy Technology Laboratory
PO Box 10940, MS 921-143
Pittsburgh, PA 15236-0940

DOE Contract No. DE-FC26-99FT40719--02
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May 2000

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ACKNOWLEDGMENT

This report was prepared with the support of the U.S. Department of Energy (DOE) National Energy Technology Laboratory Contract No. DE-FC26-99FT40719. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the views of DOE.

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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 unique configuration. 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 re-collection of dust in conventional baghouses. In Phase II, a 2.5-MW-scale AHPC was designed, constructed, installed, and tested at the Big Stone power station. For Phase III, further testing of an improved version of the 2.5-MW-scale AHPC at the Big Stone power station is planned to facilitate commercialization of the AHPC technology.

ADVANCED HYBRID PARTICULATE COLLECTOR – PHASE III

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 less costly than 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 was scaled up in Phase II to a size of 9000 acfm (255 m^3/min equivalent in size to 2.5 MW) and was installed on a slipstream at the Big Stone power station.

For Phase II, the AHPC at Big Stone power station was operated continuously from late July 1999 until mid-December 1999, except for a 3-week down period in September corresponding to an annual plant outage. The Phase II results were highly successful in that ultrahigh particle collection efficiency was achieved, pressure drop was well controlled, and system operability was excellent.

For Phase III, the overall project objective remains the same as for Phases I and II: to develop a highly reliable 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 less costly than existing technologies. The developmental objective for Phase III is to obtain the necessary engineering data to facilitate scaleup of the AHPC to the full-scale demonstration size for near-term commercialization of this technology.

The approach to meet the Phase III objectives is continued testing of the 9000-acfm (255-m^3/min) field demonstration AHPC at the Big Stone power station. Seven 1-month tests are planned: six will each address a specific primary variable, and one will serve as a contingency test either to further test one of the six main variables or to evaluate a new variable. In addition to the testing at the Big Stone plant, some supporting laboratory tests and approximately 2 weeks of further testing with the 200-acfm (5.7-m^3/min) AHPC at the EERC will be conducted.

During the last quarter (January–March 2000), the main project activity has focused on completing improvements to the field AHPC unit that were planned within the scope of work for Phase III. These improvements include a new data acquisition and control system, installation of additional heaters, a modified ash collection and discharge system, and changes to the roof to facilitate access and to prevent water leakage. In addition to those improvements, significant modifications were made to the field AHPC unit that were outside of the planned scope of work. These modifications were made at the request of the commercialization partners specifically to address issues of interest to commercial design. The primary modifications include:

- Installation of a side inlet transition section.
- Design, construction, and installation of different discharge electrodes and collecting plates.
- A more compact plate- and bag-spacing arrangement.
- A modified pulsing system.

These system changes along with the planned improvements that were part of the original Phase III scope of work were completed in early April.

After a week of shakedown testing, the field AHPC was successfully started up on April 18, 2000, to begin Test 1 and has been running continuously up to the current time (early May). Plans are to complete the first test by May 18 to accommodate a planned spring plant outage scheduled from May 19–26, 2000.

ADVANCED HYBRID PARTICULATE COLLECTOR – PHASE III

1.0 INTRODUCTION

This project was awarded under the U.S. Department of Energy (DOE) Program Solicitation DE-PA26-99FT40251 and specifically addresses Technical Topical Area 3 – Primary PM Emissions Control. Phase III is a logical continuation of the development toward full-scale commercialization of the advanced hybrid particulate collector (AHPC).

In 1994, The University of North Dakota (UND) Energy & Environmental Research Center (EERC) responded to DOE Program Research and Development Announcement (PRDA) No. DE-RA22-94PC92291, Advanced Environmental Control Technologies for Coal-Based Power Systems Phases I and II, under Topic 7: Advanced Concepts for Control of Fine Particles and Vapor-Phase Toxic Emissions. The EERC proposal was subsequently selected for DOE funding, and the EERC was awarded Contract DE-AC22-95PC95258. Phase I work consisted of initial development of the AHPC starting as a completely new concept without any supporting experimental data. The project team included the EERC as the main contractor, Allied Environmental Technologies Company (ALENTEC) as a subcontractor, and W.L. Gore & Associates, Inc. (Gore), as a technical and financial partner. Following highly successful results from the Phase I work, the EERC submitted a Phase II downselection proposal to DOE in June 1997 to continue development of the AHPC. The 2-year Phase II contract was awarded in March 1998 and included additional 200-acfm (5.7-m^3/min) testing, similar to the tests completed in Phase I, as well as the design, construction, installation at a full-scale power plant, and testing of a 9000-acfm (255-m^3/min [2.5-MW equivalent]) version of the AHPC. The Phase II testing was completed in December 1999. Following completion of several modifications and improvements to the Phase II AHPC, the Phase III testing began in mid-April 2000.

2.0 PHASE III PLANNED WORK

2.1 Phase III Objectives

The objective of the project is to develop a highly reliable 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 less costly than existing technologies. This goal has remained unchanged since the concept was originally proposed in 1994. The approach objective with the AHPC is to utilize filtration and electrostatic mechanisms in a unique manner that is superior to conventional fabric filters and electrostatic precipitators (ESPs). The developmental objective for Phase III is to obtain the necessary engineering data to facilitate scaleup of the AHPC to the full-scale demonstration size for near-term commercialization of this technology.

2.2 Phase III Planned Tests

Seven 1-month tests are proposed: six will each address a specific primary variable, and one will serve as a contingency test either to further test one of the six main variables or to evaluate a new variable. Four of the tests will include a single level of the variable tested for the entire month for direct comparison among the main tests. In two of the tests, the variable will be evaluated at several levels during the 1-month test. Particulate emissions testing including both Environmental Protection Agency (EPA) Method 5 dust loading and real-time laser particle sizer sampling will be conducted over several days for three of the tests to confirm the ultrahigh fine particle collection. In addition to the testing at the Big Stone plant, some supporting laboratory tests and approximately 2 weeks of further testing with the 200-acfm (5.7-m^3/min) AHPC at the EERC will also be conducted.

The original planned tests along with specific test objectives are listed below. The tests may be conducted in a different order than listed here:

- Test 1 – A/C (air/cloth) Ratio Tests
  Test Objective: Determine the effect of variable SCA (specific collection area) at constant A/C ratio.

- Test 2 – Single-Side Inlet
  Test Objective: Determine the significance of the distance from the entrance baffle to the last bag on flow distribution and AHPC performance.

- Test 3 – Bag Type
  Test Objective: Determine if the 9000-acfm (255-m^3/min) AHPC can function properly with nonconductive bags (or an alternative fabric material).

- Test 4 – Bag-to-Electrode Spacing
  Test Objective: Determine if the bag-to-electrode spacing can be reduced without causing bag damage.

- Test 5 – Pulse Optimization
  Test Objective: Optimize the bag-pulsing system to facilitate full-scale engineering design.

- Test 6 – Temperature
  Test Objective: Evaluate AHPC performance at a temperature that is near the peak resistivity of the fly ash.

- Test 7 – Contingency
  Test Objective: After reviewing results from the first six tests, an additional test will be conducted if necessary to further evaluate any of the main variables tested or to test a new variable.

- Supporting Laboratory and 200-acfm (5.7-m^3/min) Tests

In support of Tests 3 and 4, additional 200-acfm (5.7-m^3/min) tests are expected to answer critical questions that have not previously been addressed. The 200-acfm (5.7-m^3/min) tests are expected to show whether major bag-sparking problems would be anticipated in the 9000-acfm (255-m^3/min) unit if nonconductive bags are used or if the bag-to-electrode spacing is reduced.

In support of Test 5, a new modified pulsing system will first be tested in the laboratory using full-length pulse blow tubes of the same diameter and with identical valves and nozzles as would be employed at a larger scale. After verification in the laboratory that sufficient pulse pressure and volume can be achieved for all of the bags in a full-scale row, this modified pulsing system will be installed on the 9000-acfm (255-m^3/min) AHPC.

3.0 AHPC MODIFICATIONS

3.1 Intellectual Property and Licensing Agreement

U.S. Patent No. 5,938,818, entitled Advanced Hybrid Particulate Collector and Method of Operation, was issued August 17, 1999. The patent is assigned to the EERC Foundation, which has entered into an exclusive licensing agreement with Gore, to commercialize the technology. Recently Gore entered into an agreement with ELEX, a Swiss company, to sell the AHPC into selected industrial and power markets. The addition of a commercial vendor to the team has provided valuable input to the test program to help understand what factors are critical to successful commercialization of the AHPC and has led to the modifications detailed in the following section.

3.2 AHPC Improvements Outside of the Phase III Scope of Work

3.2.1 Side Transition Inlet

To facilitate transport and test flexibility, the Phase II 9000-acfm AHPC was designed with an inlet that entered a manifold which then distributed the flow to opposite sides of the vessel. To reach the entrance slots for each row of bags required that the flow make four 90 degree turns. Early in the Phase II field testing, it was discovered that there was severe flow maldistribution among the different bag rows. Subsequently, additional baffling was installed which did improve flow distribution from row to row. However, there was significant turbulence imparted to the flow, it was not uniform from top to bottom, and it did not uniformly move into each row of bags. On the advice of the commercialization team, the decision was made to install a gradual transition-type inlet similar to the inlet transition configuration used in commercial ESPs. The inlet was installed on only one side of the vessel so it no longer has the flexibility of two opposite-side inlets. However, this modification has greatly improved the flow maldistribution problem. The inlet transition installation required cutting out almost one whole side of the vessel, installing the transition, and a significant change to the inlet piping (see Figure 1).

Figure 1. AHPC unit installed at Big Stone with new inlet ducting and side transition inlet configuration.

The inlet transition has turning vanes to help minimize turbulence through the 90 degree bend at the entrance to the transition, and then two rows of baffle distributer plates (see Figure 2) within the transition to help equalize the flow at the entrance to the main AHPC collector.

3.2.2 Discharge Electrodes and Plates

The discharge electrodes used in Phase II were custom-built by a different commercial ESP vendor, and they functioned well for the tests. However, the commercialization team decided to install ELEX discharge electrodes for Phase III. The collecting plates for Phase II were custom-designed and fabricated at the EERC. These plates had stiffeners that had a sharp edge. Subsequently, during the Phase II testing, significant back corona was observed emitting from the stiffener edges. To minimize the back corona, the decision was made to construct new plates that are closer to commercial design, without sharp-edged stiffeners. The rapping cleaning of the plates was also marginal in Phase II, so improvements to the plate suspension to facilitate better rapping were implemented.

3.2.3 Plate Spacing

The plate-to-plate spacing for Phase II was 29 inches. Since new plates were being installed, the decision was made to decrease the plate spacing to 23.6 inches, or 600 mm. This decision was based on the fact that no sparking to the bags was observed in Phase II, which implies that the spacing could be reduced without compromising AHPC performance. A more

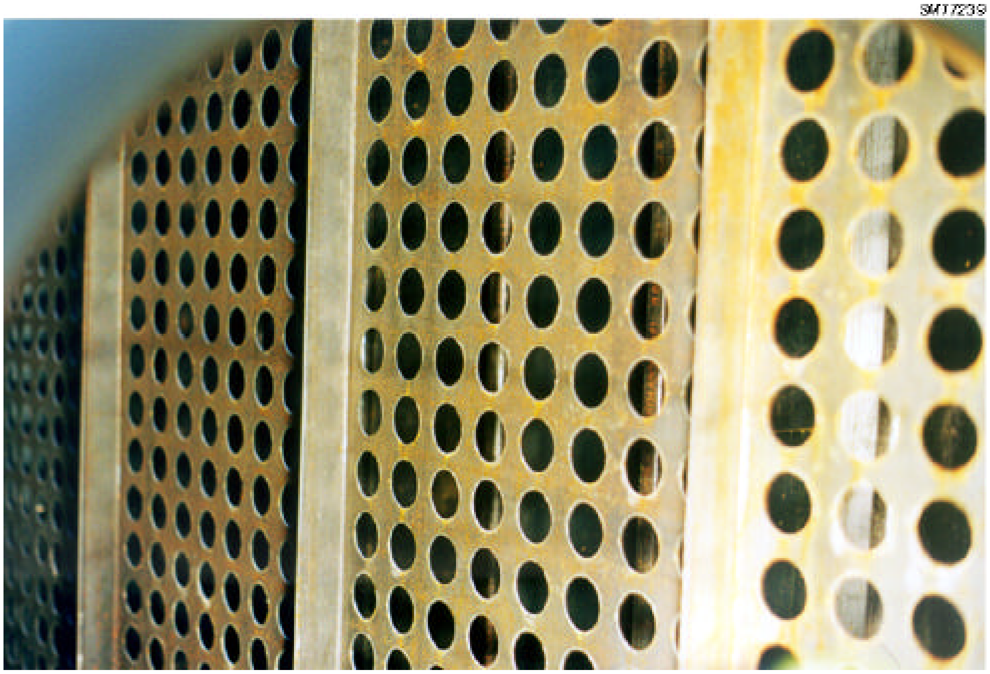

Figure 2. Inlet transition baffle distributer plates at the entrance to the AHPC.

compact geometric arrangement is desirable because it makes for a smaller device, leading to cost savings. The 600-mm spacing has also been employed on commercial ESP units.

3.2.4 Bag Spacing, Tube Sheet, and Pulse Tube Changes

Using narrower plate spacing necessitated several other changes. Since the bags are centered between two adjacent plates, a change in plate spacing required a change in bag spacing. The change in bag spacing was accomplished by modifying the tube sheet to accommodate the narrower bag spacing, which also required that the pulse tube spacing be changed to the new bag-spacing dimensions.

3.3 Impact of AHPC Modifications on Phase III Schedule

The milestone schedule as approved is shown in Table 1. Because of the delay in implementing the improvements, start-up of the first test occurred on April 18, 2000; therefore, the schedule for completing Test 1 will be delayed by about two months. However, looking at the milestone schedule, there is a total of 20 weeks (from 2 to 5 weeks between any two tests) scheduled to make changes to the system between tests. In many cases, this time will be necessary, but in some cases only a few days between tests may be required, so this will provide an opportunity to make up the 2 months by the end of the test program. Furthermore, the contract completion date is September 29, 2001, so there is some time available for extending the test schedule beyond January 31, 2000, should it be necessary.

TABLE 1

Original Schedule

Description	Original Planned Completion Date
Field Testing	
Test 1 – Single-Side Inlet	March 15, 2000
Test 2 – A/C Ratio and SCA Tests	May 10, 2000
Test 3 – Bag Type	June 30, 2000
Test 4 – Bag-to-Electrode Spacing	August 25, 2000
Test 5 – Pulse Optimization	October 31, 2000
Test 6 – Temperature	December 15, 2000
Test 7 – Contingency	January 31, 2001
Removal of Field AHPC from Big Stone Site	June 1, 2001
Supporting Pilot and Laboratory Tests	
200-acfm Testing	May 28, 2000
Pulsing System Design, Construction, and Testing	August 31, 2000

Completion of the 200-acfm testing will also be delayed, but since the timing for these tests is somewhat dependent on the decision on the order in which the field tests are conducted, the 200-acfm testing has not been scheduled yet.

3.4 Impact of Improvements on Planned Tests

The seven planned AHPC field tests, as detailed in the original statement of work, were listed in Section 2.2. The first test currently being conducted is Test 2, single-side inlet. Based on our current understanding of the Phase III objectives, we do not plan to change any of these tests as a result of the modifications other than the order in which they are completed. The most obvious question is whether there will still be a need to complete Test 4, bag-to-electrode spacing, since the bag-to-electrode spacing will already have been reduced. In effect, the first test, single-side inlet, will be a test of both the single-side inlet and a closer electrode spacing. However, the electrode spacing will also be tested in the 200-acfm AHPC. If these tests indicate that there is a good basis for an even closer spacing, there would be reason to test the closer spacing in the larger AHPC, as originally planned. At this point, no other changes to the statement of work are anticipated. Should changes be necessary as a consequence of the results from the first tests, they would be addressed later in the Phase III test program.

4.0 SHAKEDOWN TESTING AND PHASE III START-UP

In the previous quarterly report (October–December 1999) a description of the new data acquisition and control system was provided. The system is based on a National Instruments FieldPoint modular input/output system with a serial communication network. It includes the capability for both remote access and control as well as local control. Shakedown of the system showed the control and data monitoring to be significantly improved over the Phase II system. Two weeks after start-up, the control system has performed flawlessly in terms of automatic control over the pulsing system, rapping system, high-voltage power, fan control for system flow, and ash handling.

The AHPC operation 2 weeks after start-up has been highly successful. Since start-up operation has been continuous, with no failures of any system components. Bag cleaning has been on-line from the start and with a pressure drop of less than 7.5 inches WC, even though a smaller pulse nozzle size is being used compared to Phase II. In addition, there has been no sparking to date either to the plates or to the bags. These early results suggest that good AHPC performance can be achieved even with the more compact plate and bag arrangement being tested. More detailed results of the first tests will be presented in the next quarterly report.