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ADVANCED HYBRID PARTICULATE COLLECTOR

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ADVANCED HYBRID PARTICULATE COLLECTOR

1.0 INTRODUCTION AND SUMMARY

This is the fourth quarterly report for the project and covers the period July through September 1996.

The main technical progress for the previous quarter were the completion of the cold-flow testing. According to the management plan, the cold-flow test data were reviewed by the U.S. Department of Energy (DOE), ALENTEC, W.L. Gore & Associates, and the Energy & Environmental Research Center (EERC). It was decided that enough information had been obtained through the cold-flow testing program to bring advanced hybrid particulate collector (AHPC) research to the next step in its development. The objective for this quarter was to test the AHPC in real flue gas conditions. The initial tests were performed on the particulate test combustor (PTC) firing Absoloka subbituminous using two types of bags: PTFE and graphite-impregnated PTFE. Both bag types were evaluated in the on-line and off-line cleaning modes. Findings showed only a small difference in performance between the PTFE and graphite-impregnated PTFE. In the on-line cleaning mode, both the PTFE and graphite-impregnated PTFE bags maintained pressure drop across the bags of between 8.0 and 6.0 in. W.C. In the off-line mode, the pressure drop across both bag types ranged from 8.0 to 5.5 in. W.C. Dust-loading efficiencies averaged 99.986% over all the tests.

2.0 OBJECTIVE

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 cost-competitive with existing technologies.

The specific work objective for this quarter was to test the AHPC in real flue gas conditions.

3.0 HOT-FLOW TESTS RESULTS FIRING COAL

3.1 Test Parameters

Tests on the AHPC were conducted in the month of September, 1996, using the PTC firing Absoloka subbituminous coal. During the 4 days of testing, two types of GORE-TEX® bags were evaluated. The designations for these bag types were "PTFE-only bags" and "graphite-impregnated PTFE bags." Both bag types were evaluated using off-line and on-line cleaning. "Off-line" refers to the condition whereby the flue gas flow will be diverted or bypassed around the AHPC. A bag-cleaning cycle for these tests involves each bag being pulsed one at a time and only one pulse per bag per cleaning cycle. Table 1 presents the test matrix used for these experiments. The duration of each test was about 8 hr. The air-to-cloth (A/C) ratio of 12 ft/min, pulse pressure of 60 psig, pulse duration of 1.00 s, and an electrostatic precipitator (ESP) voltage of 50 kV remained unchanged during the 4 days of testing. Particulate sampling was done by aerodynamic particle sizing-scanning mobility particle sizing (APS-SMPS), Environmental Protection Agency (EPA) Method 5, and multicyclone. Table 1 also shows the sampling requirements for this test series.

TABLE 1

Test Matrix for Subtask 3.1 - AHPC Testing Matrix Firing Absoloka Subbituminous

Date	Test Matrix	PTC Run No.	Type of Bag	No. of Bags in Use	No. of Bags per Pulse	Pulse Pressure, psig	Pulse Duration, s	Pulsing Initiated, in. of W.C.	Pulsing Cycle, min	Coal/Ash Type	Flue Gas Conditioning	Sampling Requirements, baghouse inlet	Sampling Requirements, baghouse outlet
9/17/96	2	568	PTFE	Four	One	60	1.00	8	NA ¹	ABS ²	No		APS
9/18/96	3	569	PTFE	Four	One	60	1.00	8	NA	ABS	No	EPA Meth. 5	EPA Meth. 5/APS
9/19/96	4	570	Graphite/ PTFE	Four	One	60	1.00	8	NA	ABS	No	Multicyclone	EPA Meth. 5/APS
9/20/96	5	571	Graphite/ PTFE	Four	One	60	1.00	8	NA	ABS	No	EPA Meth. 5	EPA Meth. 5/APS

¹ Not applicable.² Absoloka.

3.2 Test Results Using GORE-TEX® PTFE Bags

The purpose of Run PTC-AB-568 was to evaluate the PTFE bags in the on-line cleaning mode. The test began on the morning of September 17, 1996. Natural gas was fired to heat up the PTC, the AHPC, and adjacent piping. The PTC was then switched to Absoloka subbituminous fuel and flue gas was directed into the AHPC containing four newly installed PTFE bags. Flue gas composition remained fairly consistent throughout the 4-day test period. Table 2 shows the average values of flue gas components. ESP voltage was set at 50-kV, with an average current output of about 0.25 milli-amperes. Figure 1 shows the differential pressure (dP) over the time of the run. A photomagnehelix pressure sensor was used to trigger the cleaning sequence when the dP on the bags reached 8 in. W.C.

TABLE 2

Average Flue Gas Analysis for Tests PTC-AB-568 – PTC-AB-571 (on a dry basis)				
Oxygen, % by vol.	Carbon Dioxide, % by vol.	Moisture, % by vol.	Sulfur Dioxide, ppm	Nitrogen Acid Gases, ppm
4.0-4.5	16-17	9.5-10.0	720	700

Approximately 2 hr of operation were required before the bags achieved a steady-state equilibrium in performance. The cleaning cycle dropped the dP from 8.0 to around 6.0 in. on the average. The pulse interval started at about 40 min with clean bags and decreased in time to about 18 min at steady-state conditions. A graph of pulse interval versus run time is given in Figure 2.

Figure 1. Pressure drop as a function of time for the AHPC with on-line cleaning using PTFE bags and 50-kV applied voltage.

The purpose of Run PTC-AB-569 was to evaluate the PTFE bags using off-line cleaning. This test was conducted on September 18, 1996. After the successful completion of Run PTC-AB-568, the now-dirty PTFE bags were pulsed several times with the AHPC off-line. The dust-laden flue gas was again directed into the AHPC. ESP voltage was 50 kV, with an average current output during the test of 0.33 milliamperes. Figure 3 presents the dP measurements versus run time for Run PTC-AB-569. Once the dP reached 8 in. W.C., the operator would bypass the flue gas flow from the AHPC and initiate a bag-cleaning cycle. During the cleaning cycle, the dP read zero, since no flow was going through the AHPC. The ESP was left on during the off-line cleaning cycle. Because the bags were already conditioned, the pulse intervals quickly reached steady-state conditions. The average pulse interval for Run PTC-AB-569 was about 35 min. The pulse interval plotted against run time is found on the graph in Figure 4.

Particulate sampling data for this run are presented in Table 3. Dust loadings from the inlet and outlet of the AHPC are 2.9020 and 0.00010 grains/scf, respectively. This gives a dust collection efficiency of 99.996%. The weights of the outlet dust loading samples were small, so in order to establish measurement precision of the method, these outlet filters were reweighed multiple times.

Figure 2. Pulse interval as a function of time for the AHPC with on-line cleaning using PTFE bags and 50-kV applied voltage.

Figure 3. Pressure drop as a function of time for the AHPC with off-line cleaning using PTFE bags and 50-kV applied voltage.

Figure 4. Pulse interval as a function of time for the AHPC with off-line cleaning using PTFE bags and 50-kV applied voltage.

TABLE 3

AHPC Dust-Loading Data

Run	Date	Location	Dust Loading, grains/scf	Collection, Efficiency %	Outlet Filter Weighing Precision, RSD,* %
PTC-AB-569	9/18/96	Baghouse inlet	2.9020		
PTC-AB-569	9/18/96	Baghouse outlet	0.00010	99.996	2.89
PTC-AB-570	9/19/96	Baghouse inlet	2.4225		
PTC-AB-570	9/19/96	Baghouse outlet	0.00070	99.971	6.26
PTC-AB-571	9/20/96	Baghouse inlet	2.8999		
PTC-AB-571	9/20/96	Baghouse outlet	0.00026	99.991	1.86

* Relative standard deviation.

From those data, the relative standard deviation (RSD) for the outlet weight was calculated to be 2.89%. The APS data for PTC-AB-569 are shown in Figure 5. Respirable mass values of less than 0.1 mg/m^3 would demonstrate removal efficiencies in this particle size range of $>99.99\%$. The graph shows the respirable mass to be less than 0.1 mg/m^3 . This confirms the AHPC dust-cleaning efficiency of 99.996 % given by the dust-loading data. The spikes seen on the graph show respirable mass emission during the bag-cleaning sequences.

The PTFE bags performed well in both the on-line and the off-line cleaning modes.

Figure 5. APS data for PTC-AB-569.

3.3 Test Results Using GORE-TEX® Graphite-Impregnated PTFE Bags

The purpose of Run PTC-AB-570 was to evaluate the graphite-impregnated PTFE bags in the on-line cleaning mode. The test began on the morning of September 19, 1996. Four new graphite-impregnated PTFE bags were installed in the AHPC. ESP voltage was set at 50 kV with an average current output of about 0.40 milliamperes. Figure 6 shows the dP over the time of the run. The last two cleaning cycles, shown in Figure 6, reveal the dP falling from 8.0 to 5.0 in. W.C. and the pulse interval increasing from an average of 16 to about 20 min. The reason is that for those two cleaning cycles, the bags were each pulsed twice instead of just once.

Approximately 2 hr of operation was required before the bags achieved a steady-state equilibrium in performance. The cleaning cycle dropped the dP from 8.0 to around 6.0 in. on the average. The pulse interval started at about 40 min with clean bags and decreased in time to about 16 min at steady-state conditions. A graph showing pulse interval versus run time is found in Figure 7.

Particulate sampling data for Run PTC-AB-570 are also presented in Table 3. Dust loadings from the inlet and outlet of the AHPC were 2.4225 and 0.00070 grains/scf, respectively. This gives a dust collection efficiency of 99.971%. The filters of the outlet dust-loading samples were again reweighed to establish measurement precision. The outlet filter % RSD of 0.0626%. APS data for PTC-AB-570 is shown in the graph in Figure 8. The respirable mass integrated average, as shown on the graph, was 0.55 mg/m³. This emission rate is higher than the emission rate recorded for PTC-AB-569 and corresponds to a lower AHPC dust collection efficiency of 99.971%. The higher respirable mass emission data may be due to several nicks in the bag's PTFE membrane which were discovered after the tests. The nicks were caused by the use of a faulty brush in cleaning the bags after a test. The brush has been discarded, and the cleaning procedure has been changed to correct for this problem.

Figure 6. Pressure drop as a function of time for the AHPC with on-line cleaning using graphite-impregnated PTFE bags and 50-kV applied voltage.

Figure 7. Pulse interval as a function of time for the AHPC with on-line cleaning using graphite-impregnated PTFE bags and 50-kV applied voltage.

Figure 8. APS data for PTC-AB -570.

The purpose of Run PTC-AB-571 was to evaluate the graphite-impregnated PTFE bags in the off-line cleaning mode. Test parameters remained the same for this run as for those above. The results of this run are found in Figure 9. The graphite-impregnated PTFE bags were cleaned before the start of Run PTC-AB-571 by multiple-pulse cycles in the off-line mode. At steady-state conditions, the dP dropped from 8.0 to an average value of 5.0 in. W.C., and the pulse interval averaged 26 min. The pulse interval data are presented in Figure 10.

PTC-AB-571 particulate sampling data are also presented in Table 3. Dust loadings from the inlet and outlet of the AHPC were 2.8999 grains/scf and 0.00026 grains/scf, respectively. This gives a dust collection efficiency of 99.991%. The outlet dust loading filter was again reweighed in order to establish measurement precision. The outlet filter precision was 1.86% RSD. APS data for PTC-AB-571 are shown on the graph in Figure 11. The respirable mass integrated average, as shown on the graph, was 0.20 and 0.24 mg/m³. This corresponds to an AHPC dust collection efficiency of +99.99%. Even though they were slightly damaged, the GORE-TEX® bags seemed to be able to recover over the duration of the test.

3.4 Fly Ash Mass Balance

As a check of the validity of the inlet dust-loading data, the fly ash collected in the hopper was weighed and from this weight a dust loading could be calculated. Table 4 presents the inlet

Figure 9. Pressure drop as a function of time for the AHPC with off-line cleaning using graphite-impregnated PTFE bags and 50-kV applied voltage.

Figure 10. Pulse interval as a function of time for the AHPC with on-line cleaning using graphite-impregnated PTFE bags and 50-kV applied voltage.

Figure 11. APS data for PTC-AB-571.

TABLE 4

Mass Balance for Tests PTC-AB-568 – PTC-AB-571

Date	Run	Location	Method 5/ Multiclone Dust Loading, grains/scf	Dust Loading from AHPC Hopper Ash, grains/scf	Difference, %
9/18/96	PTC-AB-569	Baghouse inlet	2.9020	2.01	31
9/19/96	PTC-AB-570	Baghouse inlet	2.4225	2.25	7
9/20/96	PTC-AB-571	Baghouse inlet	2.8999	1.89	35
Average			2.74	2.05	24
With Weigh-Back			2.74	2.63	4

dust-loading data provided by EPA Method 5 and multicyclone sampling for Runs PTC-AB-569, PTC-AB-570 and PTC-AB-571. Dust-loading data using the hopper ash was calculated and presented in Table 4. Comparison of the gas sampling dust loadings and the hopper ash dust loadings showed the hopper ash dust loading to be low by an average of 24% throughout the test period. On cleaning the baghouse interior, inlet plenum, and inlet piping, 22.76 lb of fly ash were recovered. The inlet plenum contained the most ash at 14.48 lbs collected. When the recovered ash was added back to the hopper ash total, the dust loading calculated from the hopper ash was 2.63 grains/scf. This compared well with the 2.74 grains/scf average derived from the inlet particulate sampling data. The percent difference between the gas sampling dust loadings and the hopper ash dust loadings decreased from 24% to 4% when the recovered ash was added back in to the mass balance.

Because the accumulation of large amounts of ash in the inlet plenum, we plan to redesign the plenum to minimize this problem.

4.0 MODIFICATIONS TO THE 200-acfm AHPC MODEL AND TEST PLAN

4.1 Design Modifications

From the coal-fired test series, several modifications to the AHPC were deemed necessary. Because of the drop-out of fly ash in the inlet plenum, design changes were made to minimize drop-out zones within the inlet plenum. Modifications were also made to the bag-cleaning system. Piping delivering pulse air to the bags, was replaced by larger-diameter pipe in order to increase the quantity of air available to clean the bags. Pressure taps were installed inside one of the bag cages to provide static pressure measurement during a bag pulse. The ESP grid was modified to increase the current density between the grid and the plate.

4.2 Suggested Changes to the Test Plan

Because of the need for more optimization studies, further testing will be conducted at an A/C ratio of 12 before tests are conducted at higher ratios. To obtain this optimization data, more 8-hr tests firing coal will be performed before proceeding with the 100-hr tests.

To help evaluate the performance of the ESP and the interaction between the electrostatic and filtration zones, it is desirable to know how much dust the ESP collects and how much dust the bags collect. Since this cannot be determined directly, an approach to determine the ESP performance is to run some tests without bags. Similarly, the benefit of the ESP to bag cleaning cannot be measured directly, but can be evaluated by testing the bags alone without the electric field on. Therefore, additional tests are planned with the ESP alone and with the bags alone. Tests are also planned without the bags or electric field to determine how much dust is collected in the AHPC as a knockout chamber.