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ADVANCED HYBRID PARTICULATE COLLECTOR

Quarterly Technical Progress Report

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TABLE OF CONTENTS

LIST OF FIGURES	ii
LIST OF TABLES	ii
1.0 INTRODUCTION AND SUMMARY	1
2.0 OBJECTIVE	1
3.0 MODIFICATIONS TO THE 200-acfm AHPC MODEL	1
4.0 SHAKEDOWN AND COLD-FLOW TESTING RESULTS	2
4.1 Planned Tests	2
4.2 Baffle Design	2
4.3 Voltage Adjustment	4
4.4 Pulse Pressure and Duration	4
4.5 Multiple Cleaning Cycle Tests	5
4.6 Decision Point for Combustion Tests	5

LIST OF FIGURES

1	Pressure drop as a function of time for the AHPC full-baffle configuration with 50-kV applied voltage	7
2	Pressure drop as a function of time for the AHPC full-baffle configuration with the voltage off	7
3	Pressure drop as a function of time for the AHPC minimum-baffle configuration with 50-kV applied voltage	8
4	Pressure drop as a function of time for the AHPC minimum-baffle configuration with the voltage off	8
5	Pressure drop as a function of time for the AHPC full-baffle configuration with 50-kV applied voltage using conductive graphite/Teflon bags	9
6	Project logic and decision points	10

LIST OF TABLES

1	Test Matrix for Subtask 3.1 – Cold-Flow Shakedown Testing	3
2	Multiple Cleaning Cycle Test Parameters	6

ADVANCED HYBRID PARTICULATE COLLECTOR

1.0 INTRODUCTION AND SUMMARY

This is the third quarterly report for the project and covers the period of April through June 1996. Discussion of the project review meeting held at the Energy & Environmental Research Center (EERC) April 18 was included in the last quarterly report and will not be repeated here.

The main technical progress for the previous quarter was the design and construction of the 200-acfm working model of the advanced hybrid particulate collector (AHPC). Some additional modifications to the 200-acfm AHPC were made during April through June, and extensive shakedown and cold-flow testing were completed. The initial modeling results by ALENTEC (presented in the last quarterly report) indicated that the flow baffling as constructed should be sufficient to direct most of the flow into the electrostatic precipitator (ESP) zone of the AHPC before it reaches the bags. Cold-flow tests now confirm that the baffle configuration is sufficient for proper AHPC performance. Cold-flow multiple cleaning cycle tests show that there is a huge benefit to having the electric field on compared to having the field off. These tests also show that the AHPC functions properly and that pressure drop can be easily controlled.

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 the shakedown and cold-flow testing of the 200-acfm AHPC model.

3.0 MODIFICATIONS TO THE 200-acfm AHPC MODEL

Two modifications were made to the AHPC design that reflect a change from the original design. The first is a modification to allow cleaning the bags one at a time instead of cleaning the whole row (four bags in the AHPC model). The original design had a single blowpipe with nozzles to direct the cleaning pulse to each bag. The nozzles are simply holes in the pipe over each bag, similar to full-scale designs, and one pulse of compressed air directed into the blowpipe simultaneously cleans all of the bags in a row. Shakedown tests showed that the bags could be cleaned on-line by this method, but the cloud of dust remaining was not effectively directed into the ESP zone without increasing the pulse time. However, this would require reversing the entire flow pattern in the AHPC vessel, which would interrupt the flow of the entire process. In other words, there is no place for the excess cleaning air to go. Further cleaning tests showed that the bags could be effectively cleaned off-line, which is somewhat similar to cleaning one row of bags at a time in a full-scale baghouse. Off-line cleaning would not be as severe of a test of the ability of the AHPC to operate properly, so it was decided to modify the pulsing system to allow cleaning a single bag at a time on-line. The modification consisted of installing separate pulse nozzles, each

with its own pulse valve and control timer, over each bag. Cleaning one bag at a time on-line is a more severe test of the AHPC than cleaning a whole row at a time in a multiple-row compartment, because some of the reverse pulse gas is directed to adjacent bags instead of toward the wires and plates. When a whole row is cleaned at one time, the simultaneous pulses of adjacent bags complement each other to facilitate moving the dust cloud into the ESP zone. Nevertheless, we decided to try the on-line, one-bag-at-a-time cleaning method to prove that the AHPC can operate with true on-line cleaning, even though it is not likely to function as well as cleaning a whole row at a time. The testing of this modification confirmed that the AHPC may be cleaned one bag at a time on-line without adversely affecting the ESP or the other bags.

One other minor modification was made to the AHPC. The number of vertical electrode wires installed on both banks of the ESP section was increased from 4 to 7. The original spacing between electrode wires was 8 inches. With the addition of three more vertical wires per bank, the electrode spacing decreased from 8 to 4 inches. The purpose of the increase was to facilitate more rapid charging of the particles and to make the electric field more uniform. At this time, it is unclear whether this modification improved the overall AHPC performance.

4.0 SHAKEDOWN AND COLD-FLOW TESTING RESULTS

4.1 Planned Tests

The primary purpose of the cold-flow testing with air was to properly adjust the pulse-cleaning parameters and flow baffling to achieve the best interaction between the ESP and filtration zones. Reentrained dust (fly ash) was injected into the carrier air upstream of the AHPC, operating at an air-to-cloth (A/C) ratio of 12 ft/min. The original suggested test matrix for the cold-flow tests is shown in Table 1. The planned independent variables to be adjusted for these tests included pulse pressure, pulse volume or duration, applied voltage, baffling, and dust type (dust cohesive strength and resistivity). All of the variables were adjusted during the cold-flow testing except dust type. After discussions with the project team, we decided that the cohesive characteristics and dust resistivity under cold-flow conditions would not adequately simulate the effects of these variables under combustion conditions, so no dust-type tests were completed. We decided that if a dust could be found that allowed for adequate testing of the function of the ESP and filtration zones, no dust-type cold-flow tests would be conducted. Since the first test dust chosen, the Absaloka fly ash, worked well, all tests were completed with this dust. The primary dependent variables were pressure drop before and after cleaning and a visual subjective evaluation of the cleaning dynamics. Limited outlet particulate emission measurements were originally planned to verify high collection efficiency. While formal outlet particulate measurements were not conducted, visual inspection of the outlet plenum and clean side of the bags indicated near 100% efficiency. Again, extensive particulate emission testing for the cold-flow runs would not be indicative of real flue gas, since the carrier gas would have a much lower submicron particle concentration than real flue gas.

4.2 Baffle Design

The main purpose of the baffle is simply to direct the flow into the ESP zone to facilitate collection of most of the dust before it reaches the bags. The primary method of evaluating the effectiveness of the baffle was visual observation of the dust flow patterns. The multiple sight ports

TABLE 1

Test Matrix for Subtask 3.1 – Cold-Flow Shakedown Testing

Test	Pulse Pressure	Pulse Duration	Baffling	Voltage	Dust Cohesive Strength	Dust Resistivity
1	High	long	Min.	50	High	Low
2	Med.	long	Min.	50	High	Low
3	Low	long	Min.	50	High	Low
4	High	Med.	Min.	50	High	Low
5	Med.	Med.	Min.	50	High	Low
6	Low	Med.	Min.	50	High	Low
7	High	Short	Min.	50	High	Low
8	Med.	Short	Min.	50	High	Low
9	Low	Short	Min.	50	High	Low
10	High	long	Max.	50	High	Low
11	Med.	long	Max.	50	High	Low
12	Low	long	Max.	50	High	Low
13	High	Med.	Max.	50	High	Low
14	Med.	Med.	Max.	50	High	Low
15	Low	Med.	Max.	50	High	Low
16	High	Short	Max.	50	High	Low
17	Med.	Short	Max.	50	High	Low
18	Low	Short	Max.	50	High	Low
19	Med.	Med.	Max.	0	High	Low
20	Med.	Med.	Min.	30	High	Low
21	Med.	Med.	Min.	0	High	Low
22	Med.	Med.	Min.	30	High	Low
23	Med.	Med.	Max.	50	Low	Low
24	Med.	Med.	Max.	50	Low	Low
25	High	High	Max.	50	Low	Low
26	High	Low	Max.	50	Low	Low
27	Low	High	Max.	50	Low	Low
28	Low	Low	Max.	50	Low	Low
29	Med.	Med.	Max.	50	Low	High
30	Med.	Med.	Max.	30	Low	High
30-50	Repeat select tests and/or change variable.					

greatly enhanced flow visualization and, along with video, provided a good indication of local velocities and dust distribution. After several iterations, visual results indicated that a 2-inch-wide opening on each side of a "V"-shaped baffle was very effective at directing the flow between the

wires and plates. One further baffle modification was to block off the top 6 inches of the openings on each side to minimize flow through the space between the top of the electrodes and top of the main AHPC compartment. Short-term tests to date indicate that this baffle configuration works reasonably well and should allow for proper functioning of the AHPC. An attempt was made to compare this V configuration with a minimum baffle configuration, consisting of a 6-inch, circular deflection plate placed 5 inches in front of the 4-inch-diameter inlet. The purpose of the deflection plate was to protect the bags from direct impaction of high-velocity, ash-laden gas, but without further flow direction. Essentially, the deflection plate was an attempt at a "minimum baffle" configuration. Results are presented later in this report.

4.3 Voltage Adjustment

During the shakedown tests, the voltage was varied over a wide range to first make sure that there were no problems with the electrical insulation and that effective corona power could be generated without sparking. After correcting one minor insulation problem, results showed that corona could be easily generated (observed on the wires through the sight ports). At a voltage of approximately 70 kV, some back corona was noticed on the bags. It was not clear whether this was caused only by the high-resistivity fabric or by some traces of fine silica dust that was earlier tested as a flow tracer (fly ash worked just as well as a flow tracer, so the silica dust was not subsequently used). Further inspection of the bags revealed blackened spots and damage to the bags where the back corona was observed. This indicates that under severe back corona conditions, fabric damage might occur. However, 70 kV is a much higher voltage than would typically be used. At the much lower operating voltage of 50 kV chosen for subsequent tests, no back corona was observed. Should back corona be a problem, one of the ways to prevent it is to employ conductive GORE-TEX® graphite-impregnated bags. A set of these was tested to 75 kV with no corona observed on the bags. Full-scale ESPs operate with automatic voltage controls to maximize corona power (and subsequently collection efficiency) and minimize sparking. The actual operating voltage will be highly dependent on the electrode spacing, electrode alignment, dust resistivity, rapping efficiency, etc. Similarly, the operating voltage of the AHPC will be dependent on the same parameters. However, the cold-flow tests do not indicate a voltage limit problem that would impair performance.

4.4 Pulse Pressure and Duration

Pulse pressure and duration are the primary operational variables that can be adjusted to provide the best bag cleaning. The goal is not only to remove most of the dust from the bags, but also to prevent recollection on the bags of the fine-particle dust cloud formed from reentrained dust. For proper operation, this dust cloud should be propelled into the ESP zone where most of it will be trapped. Fortunately, the whole AHPC compartment can be observed visually through the sight ports, because the ESP zone traps most of the incoming dust. This allows immediate evaluation of the effects of changing pulse pressure or duration on bag-cleaning efficiency. Following multiple iterations, it was found that a lower-pressure, longer-duration pulse was more effective while cleaning one bag at a time on-line. When the pulse is initiated, larger agglomerates quickly fall to the hopper, but a cloud of reentrained dust always remains. Pushing this remaining cloud into the ESP zone appears to require a longer-duration pulse. With a longer-duration pulse, the dust is effectively transferred into the ESP zone, even though the cleaning is nonideal. Because adjacent bags are still in the forward filtration mode, a concern is that the dust would simply transfer to the next bag. However, the cleaning velocity appears to be sufficient to overcome the

suction of the other bags so that the cloud moves back into the ESP zone, providing excellent bag cleaning.

4.5 Multiple Cleaning Cycle Tests

After we successfully completed the short-term tests and achieved effective interaction between the ESP and filtration zones, we completed several multiple cleaning cycle tests to clearly demonstrate the performance of the AHPC. The purpose of these tests was to evaluate the effect of the electric field (on or off), baffling (maximum or minimum), and the use of conductive or all PTFE (polytetrafluoroethylene) bags on AHPC performance. A new set of all PTFE bags was installed for these tests. Absaloka fly ash was injected into the duct upstream of the AHPC at a rate of 4 lb/hr, which corresponds to a dust loading of 2.3 grains/acf. The air flow was maintained at 200 acfm at ambient temperature, which corresponds to an A/C ratio of 12 ft/min. When the ESP was on, the ESP voltage was 50 kV. Each bag was cleaned individually in rapid succession on-line when the differential pressure reached 8 inches WC. Test duration ranged from 2 to 7 hours, the shorter tests for the tests without the electric field. Test parameters are shown in Table 2, and the results are shown in Figures 1-5. The effect of the electric field is dramatic, as shown in Figures 1 and 2. With 50 kV applied to the high-voltage electrode, the bags effectively cleaned from 8 to 4 inches and only required cleaning about every 50 minutes. Without the electric field, the cleaning cycle interval was 7 minutes at the start of the test, but was less than 4 minutes at the end of the test. Furthermore, the bags were cleaned only down to 6 inches. From these results, the electric field clearly offers an enormous benefit.

Figures 3 and 4 are similar tests, except with the minimum-baffle configuration. Comparing these two tests, again, the effect of having the electric field on is highly beneficial. However, when comparing Figure 3 with Figure 1 and Figure 4 with Figure 2, the effect of the baffling is much less significant than the effect of the electric field. There is a benefit to the maximum baffling configuration, but it is totally dwarfed by the much larger field effect. In actuality, the circular disk deflector was fairly effective at diverting the flow to the sides of the vessel and into the ESP zone, so the comparison is not the same as if there were no baffling. However, these results are encouraging because they indicate that the AHPC performance is not highly sensitive to an exact baffling configuration.

Figure 5 shows that the conductive graphite/PTFE bags provided similar results to the all-PTFE bags. This is not surprising because there were no sparking or back corona problems observed for either of these tests. This result is also encouraging because it indicates that the performance of the AHPC is not highly susceptible to charge buildup on the bags. The bags appeared to clean as well for the all-PTFE bags where charge buildup might be expected to occur.

4.6 Decision Point for Combustion Tests

According to the management plan, following the cold-flow tests, the data are to be reviewed by the U.S. Department of Energy (DOE), ALENTEC, W.L. Gore & Associates, and the EERC. If it is determined that fundamental flaws exist in the design and function of the AHPC and if no obvious modifications can be made to improve operations, the project may be terminated by the DOE Project Manager. Figure 6 illustrates the decision point. Since the objectives of the cold-flow testing have been met, and the results clearly demonstrate that the AHPC can clean adequately to control pressure drop, the EERC believes the planned 8-hour combustion tests should proceed. Tests can begin in late August or early September.

TABLE 2

Multiple Cleaning Cycle Test Parameters

Test	Ash Type	Air/Cloth, ft/min	Flow Rate, scfm	Fly Ash Feed Rate, lb/hr	Rapping Pressure, psig	Rapping Duration, sec	Rapping Cycle, min	Baffling	Voyage	Type of Bag	No. of Bags per Pulse	Pulse Pressure, psig	Pulse Duration, sec
1	AB*	12.0	200	4	20	0.1	As needed	Baffle	50	Teflon	1	30	1.00
2	AB	12.0	200	4	20	0.1	As needed	Baffle	Off	Teflon	1	30	1.00
3	AB	12.0	200	4	20	0.1	As needed	Deflection plate	50	Telfon	1	30	1.00
4	AB	12.0	200	4	20	0.1	As needed	Deflection plate	Off	Teflon	1	30	1.00
5	AB	12.0	200	4	20	0.1	As needed	Baffle	50	Teflon	1	30	1.00

* Absaloka.

Figure 1. Pressure drop as a function of time for the AHPC full-baffle configuration with 50-kV applied voltage. Upper peak values represent pressure drop before cleaning, and lower peak values represent pressure drop immediately after cleaning.

Figure 2. Pressure drop as a function of time for the AHPC full-baffle configuration with the voltage off. Upper peak values represent pressure drop before cleaning, and lower peak values represent pressure drop immediately after cleaning.

Figure 3. Pressure drop as a function of time for the AHPC minimum-baffle configuration with 50-kV applied voltage. Upper peak values represent pressure drop before cleaning, and lower peak values represent pressure drop immediately after cleaning.

Figure 4. Pressure drop as a function of time for the AHPC minimum-baffle configuration with the voltage off. Upper peak values represent pressure drop before cleaning, and lower peak values represent pressure drop immediately after cleaning.

Figure 5. Pressure drop as a function of time for the AHPC full-baffle configuration with 50-kV applied voltage using conductive graphite/Teflon bags. Upper peak values represent pressure drop before cleaning, and lower peak values represent pressure drop immediately after cleaning.

Figure 6. Project logic and decision points.