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**POC-SCALE TESTING OF A DRY TRIBOELECTROSTATIC
SEPARATOR FOR FINE COAL CLEANING**

By

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TABLE OF CONTENTS

DISCLAIMER.....	1
TABLE OF CONTENTS	2
WORK DESCRIPTION.....	3
INTRODUCTION.....	3
SAMPLE ACQUISITION.....	3
BENCH-SCALE TESTING	3
PROCESS DESIGN.....	7
PROCUREMENT AND FABRICATION.....	7
INSTALLATION	7
SHAKEDOWN TESTING	7
DETAILED TESTING	10
SAMPLE ANALYSIS/CHARACTERIZATION.....	17
SUMMARY AND CONCLUSION	17

WORK DESCRIPTION

Introduction

During the past quarter, the installation, testing and shakedown phases of commissioning the TES unit were completed (Tasks 4, 5.1 and 5.2). A representative from Carpco Inc. was on site to provide training in the operation of the test unit and assist with the initial test runs. Problems have been encountered with the recycle conveyor generating dust that neutralizes the particle charge. Testing has continued by batch feeding the unit while the recycle conveying problem is being solved. Good separations have been achieved while operating in this mode. Comparison tests have also been carried out using a bench-scale triboelectrostatic separator in parallel with the POC Carpco unit.

Sample Acquisition

During the past quarter, samples of pulverizer reject from the Glen Lyn power plant were delivered on a regular basis by American Electric Power to the POC test facility located on the Virginia Tech campus. Sufficient sample is presently on hand for the current test program and further supplies of feed material will be obtained as required.

Bench-Scale Testing

Several series of bench-scale tests were conducted during the past quarter to further quantify the effects of several important operating variables on separation performance. All of these experiments were conducted using the Glen Lyn sample (feed ash $\approx$ 42-45%).

Effect of Electrode Position: Figure 1 shows the results of tests performed to determine the influence of electrode position on combustible recovery and product ash content. In these

tests, the position the negative electrode was moved between five different positions (0, 1.5, 3.0, 4.5 and 6.0 cm), while the position of the positive electrode was held fixed at three different values (i.e., 0, 3.0 and 6.0 cm). The first experiment was performed with the positive electrode held in the closest position (0-cm) to the feed inlet. Under this condition, the combustible recovery increased from 58% to 68% as the negative electrode was moved outward by a distance of 6 cm. The increased recovery was obtained with very little increase in product ash content. Similar results were also obtained for the other two positive electrode positions of 3 and 6 cm. However, the increase in recovery was somewhat less pronounced (i.e., 57% to 62%) at the larger electrode spacing.

Figure 1. Effects of electrode position on the separation performance of the bench-scale TES unit.

Effect of Humidity: Figure 2 shows the effect of relative humidity on combustible recovery and clean coal ash content. As shown, the combustible recovery and ash contents remain relatively constant at approximately 66-68% and 15-16%, respectively, when the relative humidity is held below about 50%. On the other hand, the combustible recovery begins to drop from 68% to 62% as the relative humidity increased to 60%. A further increase in relative humidity to 70% causes a sharp decrease in recovery to 54% with little change in the ash content of the clean coal product. These results suggest that humidity is an important parameter in the particle charging process and will need to be monitored to ensure that good recoveries are maintained.

Figure 2. Effects of relative humidity on the separation performance of the bench-scale TES unit.

Effect of Particle Size: Figure 3 shows the separation curves (combustible recovery versus ash content) obtained for coal pulverized to three different topsizes (i.e., 20, 30 and 65 mesh). As shown, the coarsest grind size (20 mesh x 0) produced the worst recovery-ash curve, while the finer grind sizes (minus 30 and 65 mesh) were upgraded more efficiently. It is unknown whether the poorer results were due to incomplete liberation, inadequate charging or inefficient collection. In any case, the results suggest that the optimum toplevel for upgrading this particular coal is approximately 30 mesh.

Figure 3. Effects of particle size on the separation performance of the bench-scale TES unit.

Process Design

Details related to the design and operation of both the TES separation chamber and the various turbo-charging designs have been provided in previous technical progress reports together with the relevant schematic and engineering drawings. Several minor equipment modifications are currently underway to further improve the design. These improvements are addressed in the *Shakedown Testing* section of this report.

Procurement and Fabrication

This task has been successfully completed.

Installation

This task has been successfully completed.

Shakedown Testing

Several series of shakedown tests were successfully completed using samples of pulverizer mill rejects from the Glen Lyn power plant. These tests were conducted to determine whether the fundamental design of the TES circuit was adequate. Components evaluated in the shakedown tests included systems for materials handling, gas inerting, particle charging, electrostatic field generation and instrumentation/control.

Materials Handling - The inclined screw conveyors were found to be very effective for introducing feed solids into the TES and for discharging the clean/reject products from the TES. These conveyors also provided an effective and inexpensive means for sealing the unit from outside air so that the inert atmosphere could be maintained within the separation chamber. The initial problem with the under capacity of the recycle conveyor screw that

carries solids to the top of the TES unit was rectified via design modifications by the manufacturer (AFC). Unfortunately, it now appears that the vertical recycle screw creates a large amount of dust via attrition of the coal and mineral particles. The mixture of coal and mineral dust appears to adhere nonselectively to the surfaces of larger particles and adversely impacts their charging characteristics. Several alternative methods for particle transport that avoid this problem are currently under evaluation. These options include the replacement of the vertical screw with two longer inclined screws or an enclosed bucket elevator.

Particle Charging System – The shakedown test data indicate the static charger equipped with fixed copper rods cannot provide the level of charging necessary to obtain good separations. On the other hand, the two-stage rotary turbocharger equipped with high-speed rotating vanes proved to be effective for selectively charging the feed particles. The current two-stage design appears to be capable of handling the desired throughput capacity of 200-250 kg/hr without plugging. However, a three-stage unit is currently being designed and will be installed to determine whether an additional stage of charging further improves the separation performance.

Electrode System - No major problems were noted regarding the design of the interchangeable electrode systems. To date, there has been no arcing observed between the electrodes except when the adjustable power supplies are set to extreme potentials. The only shortcoming of the current design appears to be the amount of time and effort required to switch between the rotating cylindrical electrodes to the screen electrodes. To minimize this turn-around time, a special set of flat screen electrodes were fabricated. The new design

allowed the screens to be mounted over the cylindrical electrodes without requiring their removal. Tests are currently underway to evaluate the effectiveness of this electrode configuration.

Inerting System – The nitrogen flushing system used to maintain an inert atmosphere within the TES unit is working as designed. The inert gas eliminates the possibility of coal dust explosions and has the added benefit of reducing the relative humidity within the separation chamber. The only disadvantage of the current design is that the expanded gas from the liquid nitrogen tank significantly reduces the temperature within the TES unit. Since electrostatic separations are generally more effective at higher temperatures, a heat exchanger is currently being designed and will be installed to preheat the nitrogen gas before it enters the separation chamber.

Instrumentation – The current design of the instrumentation package has proven to be very effective in providing on-line information for controlling and monitoring the performance of the TES unit. All of the system interlocks have been thoroughly tested and found to work in accordance with all safety protocols. In particular, the twin oxygen sensors have been found to effectively provide redundant data that ensure that the unit is not operated under a condition that may be unsafe. The humidity sensor also appears to be adequately robust to withstand the dusty conditions within the separation chamber. The only modification that may be made to the instrumentation package is the installation of a local thermostat for controlling temperature within the separation chamber.

Detailed Testing

After completing the preliminary shakedown tests, several series of detailed tests were initiated to evaluate the separation capabilities of the current design. The detailed tests were carried out using pulverizer reject material from the Glen Lyn power plant. Upon receipt, the mill rejects were crushed to below 2 mm and then dry screened to produce different feeds for the TES unit. To date, tests were carried out using feeds of two different size classes, i.e., 28 x 70 mesh and minus 28 mesh.

As outlined in the project statement of work, a variety of different operating and design variables will be investigated in the detailed test work. Work carried out to date has focused on (i) feed size distribution, (ii) electrode design and (iii) electrode configuration. Initial test results showed that better separations could be made with the bench-scale unit than with the POC-scale unit. By a process of elimination, it was concluded that the vertical recycle conveyor was grinding the feed material via attrition. This resulted in dust coatings on both the coal and refuse particles that would not accept a differential charge at the turbocharger. Until this problem can be corrected, it was decided to run the unit as a batch process whereby the feed is fed directly into the turbocharger without passing through the recycle screw.

Figure 4 provides a comparison of the test results obtained from the tests conducted with and without the recycle screw. In the first three experiments, the feed coal was passed through the vertical recycle screw as would be necessary during routine operation. The discharge from the recycle was then either (i) fed directly into the TES without passing through the turbocharger, (ii) fed across a grounded metal plate to remove any residual

Figure 4. Effects of different feed handling procedures on separation performance.

charge before passing into the TES, or (iii) fed to the turbocharger before passing into the TES. As shown, poor separation results were obtained in all three cases.

In the next series of tests, the feed coal was manually carried to the top of the unit and fed directly by hand into the turbocharger before passing into the TES. As shown in Figure 4, much improved separation results were obtained by bypassing the recycle screw. The numerical data corresponding to these tests are provided in Table 1.

Table 1. Comparison tests illustrating the separation problems created by the recycle screw conveyor.

Test Procedure	Product Yield (%)	Reject Yield (%)	Product Ash (%)	Reject Ash (%)	Feed Ash (%)	Ash Rejection (%)	Comb. Recovery (%)
Screw Feed > TES	57.4	42.6	43.6	48.3	45.6	45.1	59.6
Screw Feed > Metal Plate > TES	50.5	49.5	39.0	44.0	41.5	52.5	52.6
Screw Feed > Charger > TES	51.3	48.7	43.7	47.6	45.6	50.9	53.1
Manual Feed > Charger > TES	49.2	50.8	31.4	59.4	45.6	66.1	62.1

In light of the encouraging results obtained by manual feeding, two series of tests were conducted to evaluate the effectiveness of the proposed electrode systems for upgrading the minus 28 mesh sample from the Glen Lyn plant. In the first series of experiments, the rotating cylindrical electrodes were evaluated (see Figure 5a). The second series of tests were conducted using screen electrodes mounted directly over the cylindrical electrodes (see Figure 5b). In both series of experiments, the coal product from the initial separation step (i.e., rougher stage) was subjected to two additional stages of upgrading (i.e., cleaner stage and recleaner stage) to produce higher quality products. Likewise, the reject sample from the rougher stage was reprocessed (scavenger stage) in an attempt to recover additional organic matter. For reference, diagrams illustrating the different stages of upgrading are provided in Figure 6 and Figure 7 for the cylindrical electrodes and screen electrodes, respectively. The corresponding numerical test data are provided in Table 2 and Table 3.

Figure 5. Photographs of the cylindrical (a) and screen electrode (b) configurations evaluated in the TES test program.

The separation results obtained from the comparison tests conducted using the different electrode systems are summarized in Figure 8 (yield-ash curve) and Figure 9 (recovery-rejection curve). Although the results are preliminary in nature, the test data suggest that the two electrode systems are very similar in terms of performance. Both configurations reduced the feed ash by more than half (48% to 20%) after just two stages of cleaning. In fact, somewhat poorer yields were obtained using the screen electrode system. However, a careful review of the laboratory test conditions indicated that the tests conducted using the screen electrodes were carried out at a much higher relative humidity (50% versus 32%) and lower temperature (48°F versus 72°F) than those performed using the cylindrical

Figure 6. Multi-stage flowsheet used for the evaluation of the cylindrical electrode system.

Figure 7. Multi-stage flowsheet used for the evaluation of the screen electrode system .

Table 2. Test data obtained from the multi-stage tests conducted with the screen electrode system.

Unit	Stream	Individual Data				Cumulative Data			
		Mass Yield (%)	Ash Content (%)	Distribution		Mass Yield (%)	Ash Content (%)	Distribution	
				Combust. (%)	Ash (%)			Combust. (%)	Ash (%)
Rougher	Product	40.67	31.37	53.68	26.58	40.67	31.37	53.68	26.58
	Reject	59.33	59.40	46.32	73.42	59.33	59.40	46.32	73.42
	Feed	100.00	48.00	100.00	100.00	100.00	48.00	100.00	100.00
Scavenger	Product	2.14	40.61	3.12	1.46	41.94	31.65	55.12	27.65
	Reject	97.86	59.81	96.88	98.54	58.06	59.81	44.88	72.35
	Feed	100.00	59.40	100.00	100.00	100.00	48.00	100.00	100.00
Cleaner	Product	52.26	19.24	61.50	32.05	21.26	19.24	33.01	8.52
	Reject	47.74	44.65	38.50	67.95	78.74	55.76	66.99	91.48
	Feed	100.00	31.37	100.00	100.00	100.00	48.00	100.00	100.00
Recleaner	Product	59.68	11.05	65.73	34.27	12.68	11.05	21.70	2.92
	Reject	40.32	31.36	34.27	65.73	87.32	53.37	78.30	97.08
	Feed	100.00	19.24	100.00	100.00	100.00	48.00	100.00	100.00

Table 3. Test data obtained from the multi-stage tests conducted with the screen electrode system.

Unit	Stream	Individual Data				Cumulative Data			
		Mass Yield (%)	Ash Content (%)	Distribution		Mass Yield (%)	Ash Content (%)	Distribution	
				Combust. (%)	Ash (%)			Combust. (%)	Ash (%)
Rougher	Product	36.98	34.33	46.70	26.45	36.98	34.33	46.70	26.45
	Reject	63.02	56.02	53.30	73.55	63.02	56.02	53.30	73.55
	Feed	100.00	48.00	100.00	100.00	100.00	48.00	100.00	100.00
Scavenger	Product	22.78	42.02	30.03	17.09	51.33	36.48	62.70	39.01
	Reject	77.22	60.15	69.97	82.91	48.67	60.15	37.30	60.99
	Feed	100.00	56.02	100.00	100.00	100.00	48.00	100.00	100.00
Cleaner	Product	46.39	19.02	57.21	25.70	17.15	19.02	26.71	6.80
	Reject	53.61	47.58	42.79	74.30	82.85	54.00	73.29	93.20
	Feed	100.00	34.33	100.00	100.00	100.00	48.00	100.00	100.00
Recleaner	Product	69.71	15.07	73.11	55.23	11.96	15.07	19.53	3.75
	Reject	30.29	28.11	26.89	44.77	88.04	52.47	80.47	96.25
	Feed	100.00	19.02	100.00	100.00	100.00	48.00	100.00	100.00

Figure 8. Yield-ash data obtained from the comparison tests conducted using the cylindrical electrode and screen electrode systems.

Figure 9. Recovery-rejection data obtained from the comparison tests conducted using the cylindrical electrode and screen electrode systems

electrodes. As shown previously, conditions of higher humidity and lower temperature are detrimental to the electrostatic separation process. Therefore, additional tests will need to be conducted under the same conditions of humidity and temperature before a conclusion can be reached regarding the effectiveness of the two electrode systems.

It should also be noted that the separation results obtained to date were achieved without the use of a recycled middlings product. Previous test work indicates that the middlings recycle stream can further improve the separation performance by optimizing recovery and clean coal quality. However, an alternative to the vertical recycle screw (which grinds the sample) will need to be identified and installed before these tests can be performed. The two most attractive alternatives for resolving this problem are the installation of either (i) a twin set of inclined screw conveyors or (ii) an enclosed bucket elevator.

Sample Analysis/Characterization

Analysis and characterization of samples continued throughout the quarter as outlined in the project work plan.

SUMMARY AND CONCLUSION

The testing phase of the project commenced during this quarter. Initial test work showed that the vertical recycle conveyor is grinding the feed material, resulting in dust coating both the coal and refuse particles which are consequently not accepting a differential charge at the turbo-charger. As a temporary measure, the unit is being run as a batch operation without a recycle circuit. The beneficiated product is being reprocessed in several stages and an acceptable clean coal ash and yield is being obtained. It is anticipated that

when the recycling problem is resolved further improvements in yield and combustible recovery will be achieved. An alternative recycle conveying system is being investigated and cost quotations being obtained.