

# TECHNICAL PROGRESS REPORT

For the Seventeenth Quarter  
(October 1, 1999 to December 31, 1999)

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

By

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## **WORK DESCRIPTION**

### Introduction

During the past quarter, several modifications were made to the TES unit and the materials handling system. The cylindrical electrodes were replaced by a set of screen electrodes to provide a more uniform electrostatic field. The problem with the recycle conveyor neutralizing the particle charge was also corrected by replacing it with a bucket elevator. In addition, problems with the turbocharger were corrected by increasing the number of charging stages from one to two. These modifications have significantly improved the separation performance and have permitted the POC-scale unit to achieve results in line with those obtained by the bench-scale separator.

## **PROJECT TASKS**

### Task 2 - Sample Acquisition

During the past quarter, samples of pulverized reject from Glen Lyn power plant continued to be used as the test material. A further delivery of this material will be made in the next quarter.

### Task 3.2 - Bench-Scale Separator Tests

Experiments associated with the bench-scale test program were successfully completed as outlined in the project Statement of Work. The results of these tests were reported in previous Technical Progress Reports. However, several additional bench-scale tests may still be conducted for the purpose of evaluating the performance of the POC test unit. These data will be reported in the next Technical Progress Report as they become available.

## Task 5.2 - POC Shakedown Testing

Several additional shakedown tests were conducted during the past quarter to resolve minor problems associated with dust control, materials handling, inert gas flushing, particle charging, electrostatic field generation and instrumentation/control. All of the shakedown tests were conducted using pulverized samples of mill rejects from the Glen Lyn power plant. Specific details related to the various shakedown tests are described in the following sections.

### *Dust Control System*

The POC test circuit was designed to operate as a closed system so that inert gas and dust could be contained within the test unit. However, due to the nature of test work, a significant amount of dust is still generated during the preparation of the test samples. In particular, airborne dust is produced during sample pulverization, sizing, loading and discharging. To minimize the adverse impacts of the dust, the POC test area was partitioned from the rest of the test facility using plastic curtains (see Figure 1). A negative pressure is maintained within the enclosed area by means of fans that discharge to the outside of the building. All activities that have the potential to generate dust are now kept within this area. As a result, the impacts of the airborne dust have been significantly reduced.

### *Material Handling System*

The original design of the TES test circuit called for the installation of a vertical screw conveyor to carry raw feed and middlings to the top of the TES charging system (see Figure 2). Unfortunately, after installing and testing the vertical screw, it was discovered that this means of particle transport created a large amount of ultrafine dust via attrition of

the coal and mineral particles. The ultrafine mixture of dust adhered nonselectively to the surfaces of larger particles and had an adverse impact on the charging characteristics of the coal and mineral particles.

Several alternative methods for particle transport were evaluated in an attempt to overcome the dust generation problem. The most attractive candidates involved the replacement of the single vertical screw with (i) two longer inclined screws or (ii) an enclosed bucket elevator. The bucket elevator was eventually selected due to the lower capital cost, lower space requirement and preferred particle handling characteristics. The manufacturer of the bucket elevator was also able to provide an “off-the-shelf” unit that could be completely sealed from the outside air so that the inert atmosphere could be maintained within the test circuit. Therefore, the vertical screw conveyor was decommissioned and replaced with a vertical bucket elevator (see Figures 3 and 4). To accommodate sampling, the manifold that combines the raw feed with the recycled product was constructed with sampling ports so that the feed and recycle streams could be easily sampled during operation (see Figure 4b). Data obtained from subsequent shakedown tests indicated that the bucket elevator virtually eliminated the particle attrition problem and greatly improved the charging/separation performance.

### *Particle Charging System*

As indicated in the last Technical Progress Report, a rotary turbocharger equipped with high-speed rotating vanes proved to be the most effective method for selective charging. Advantages of this system include design simplicity, low operating cost, minimal wear, high capacity and plug-free operation. However, the preliminary data indicated that the single-stage design was not be capable of handling the desired throughput capacity of

200-250 kg/hr. To overcome this shortcoming, a two-stage unit was constructed and installed (see Figure 5). All of the test data included in this report were obtained using the two-stage charger. In addition, a three-stage charger has been constructed and is currently being tested to determine whether the additional stage of charging further improves the separation performance. These data should be available during the next month and will be included in the next Technical Progress Report.

### *Electrode System*

Most of the initial shakedown tests were conducted using the cylindrical electrodes developed by Carpco. More recently, the cylindrical electrodes and associated cleaning brushes were removed and placed in storage racks (see Figure 6a). These electrodes were replaced with the flow-through screen-type electrodes (see Figure 6b). The screen electrodes provide a more uniform electrostatic field that appears to enhance the separation performance. Although the replacement has been successfully completed, several minor problems were encountered during the replacement procedure. For example, the turnbuckles used to support the cylindrical electrodes were found to be too short to allow a full range of incline angles to be tested for the screen electrodes. This was resolved by installing an extension to the threaded turnbuckle rods. The power supply cords were also found to be slightly short and were replaced with longer ones supplied by Carpco. Finally, the flow pattern within the separator suggests that there is some short-circuiting of particles through the open areas on each side of the screen electrodes. Tests are currently being conducted to determine the impact that the short-circuiting may have on separator performance. If deemed appropriate in light of the test data, a system of baffles constructed

of thin plastic sheeting will be installed to block the flow of particles around the screen electrodes.

### *Inerting System*

The nitrogen flushing system used to maintain an inert atmosphere within the TES unit continues to work effectively. The relatively short (<5 ft) inclined screw conveyors used to feed the unit and to remove the clean coal and refuse products work very well in preventing the escape of nitrogen gas. As a result, minimal gas is consumed in each test run. 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 higher temperatures are often preferred for electrostatic separations, a heat exchanger is currently being designed to preheat the nitrogen gas before it enters the separation chamber. In addition, a safety evaluation is currently underway to determine whether the separation can be achieved without the use of an inert gas. Information collected to date now indicates that the arcing between electrodes can be entirely eliminated through the selection of a proper combination of electrode spacing and applied potential. As such, the risk of explosion within the closed-loop separation system now appears to be minimal.

### *Instrumentation System*

The TES instrumentation package continues to work effectively. In particular, the sensors (i.e., twin oxygen monitors, electronic humidity gauge and temperature controller) continue to operate effectively. This suggests that the sensors are robust enough to withstand the dusty conditions within the separation chamber. Photographs of these sensors and TES control panel are shown in Figure 7.



## Task 6 - Detailed Testing

### *Background*

In the last quarterly report, two sets of test results were reported, i.e., bench-scale continuous tests and pilot-scale continuous tests. The test work was conducted on a sample obtained from the pulverizer reject stream at the Glen Lyn Power plant, Glen Lyn, Virginia. The sample was pulverized to minus 28 mesh and subjected to separation tests.

It was found that the pilot-scale tests gave results substantially inferior to the bench-scale test results. There reasons for the discrepancy may be given as follows:

1. The bench-scale test unit was equipped with screen electrodes, while the pilot-scale test unit was made of drum-type electrodes equipped with self-cleaning brushes. The latter is Carpco's patented design and the former is the invention made as part of the current project.
2. The pilot-scale unit was equipped with a recycle loop, which was made of a screw conveyer. It was possible that the screw conveyer was causing particles to break considerably during transportation. Also, the screw was made of stainless steel, while the casing (tubing) was made of PVC. It was thought that the steel was causing one type of particles positively charged, while the PVC tubing was causing them negatively charged.
3. The particle size of the feed may have been too large for the pilot-scale tests. Owing to its size, large particles may fall too fast to be captured by the electrodes. Furthermore, the potential gradient in the pilot-scale unit is lower than that in the laboratory unit due to the large separation distances between the electrodes.

4. In the pilot-scale unit, it was difficult to change the electrode positions. This was particularly the case with the cylindrical electrodes of Carpcó's design, which are bulky.
5. In the bench-scale unit, particles were charged while they were being fed and recycled through a PVC tubing pneumatically (i.e., by blowing a stream of compressed air). In the pilot-scale unit, particles were charged by means of a turbocharger shown previously in Figure 5. In the latter, the particles present in the feed and recycle streams were agitated by means of Plexiglas blades. The particles were thrown against the inner wall (Plexiglas cylinder) of the charger by the impeller and then swirl downward. The particles acquired surface charge while being in contact with the Plexiglas wall. An advantage of using the dynamic mixer was that it was not necessary to use a large volume of gas to move the particles through the recycle loop.

During the last reporting period, much of the problems were corrected, as listed below:

1. The Carpcó's cylindrical electrodes were replaced by a set of screen electrodes. Two engineers from Carpcó spent one week in Blacksburg to assist in the replacement procedure.
2. The screw conveyor was replaced by a bucket elevator.
3. The particles size of the feed was reduced to -35 mesh from -28 mesh.
4. The turbo-charger was modified to install blades in two layers (see Figure 5).

These modifications were discussed in detail in the previous section of this report entitled POC Shakedown Testing.

### *Effects of Electrode/Splitter Position*

The first series of detailed tests were conducted by changing the configuration of the electrodes relative to the feed point and the splitter locations at the bottom. Figure 8 is a schematic representation of the configuration. The data given in Figure 9 and Table 1 show the test results obtained using the minus 35 mesh Glen Lyn mill reject samples. Also shown for comparison are the results obtained on the minus 28 mesh fraction. The results are given in Figure 9 and were obtained with the following configuration:  $D_{cf}=8$  inches,  $D_{af}=7$  inches, and  $D_{as}=3.15$  inches, while  $D_{cs}$  was varied in the range of 0 to 2.37 inches.

The results (ash content and combustible recovery) have been plotted versus the distance between the cathode and the splitter ( $D_{cs}$ ) at the bottom. Ash-forming minerals move toward the cathode, while clean coal particles move toward the anode, which is consistent with the results of the bench-scale test work reported earlier. Because of the feed composition, the amount of the ash-forming minerals reporting to the cathode was considerably larger than the amount of coal reporting to the anode. Therefore, controlling the amount of the ash-forming minerals (tailings) reporting to the product stream controlled the amount of the middlings recycled. For this reason, the tests were conducted by varying the distance ( $D_{cs}$ ) between the cathode and the splitter. As  $D_{cs}$  was increased, the amount of the middlings recycled was reduced. The results show that as the amount of the recycled material decreased, the ash content was decreased, as some of the middlings reported to the clean coal product. However, the changes in recovery due to recycling are minimal.

The results given in Figure 9 and Table 1 suggest that there is no need to recycle the middlings stream for the sample tested in this series. This finding may indicate that the separation is as good as it can be in the first pass. The results show also that the minus 35 mesh particles gave a higher recovery than the minus 28 mesh particles. Surprisingly, even the ash contents were slightly lower with the finer feed. A possible explanation may be that the coarse particles may fall too fast to be attracted by the electrodes.

#### *Effects of Applied Potential*

Figure 10 and Table 2 show the results obtained on the minus 35 mesh sample with the following electrode configurations:  $D_{cf}=8$  inches,  $D_{af}=7$  inches,  $D_{as}=3.15$  inches, and  $D_{cs}=2.36$  inches. At this configuration, the amount of the middlings recycled was minimal. The potential difference between the two electrodes was varied in the range of 20 to 100 kV. The results showed that coal recovery decreased with increasing electrode potential difference, which may seem surprising. A possible explanation may be that the charge of the coal particles is substantially higher than that of the ash-forming minerals, as has been found in Task 3.1 (Charger Tests). At low potentials, highly charged coal particles were recovered in preference to the weakly charged ash-forming minerals, resulting in high recoveries. As the potential difference was increased, weakly charged ash particles and some of the middlings were pulled toward the cathode, causing a decrease in recovery. Decreasing ash content observed with decreasing recovery can be attributed to the loss of middlings to the cathode.

### *Effects of Charger Speed*

Figure 11 and Table 3 show the results obtained using the minus 35 mesh feed by changing the rotation speed of the impeller in the turbocharger. The electrode and splitter were configured as follows:  $D_{cf}=8$  inches,  $D_{af}=7$  inches,  $D_{cs}=2.36$  inches, and  $D_{as}=3.15$  inches. These dimensions are the same as the case with the results given in Figure 9. All of the tests were conducted at 60 kV of potential difference between the electrodes. As shown, combustible recovery increased with increasing impeller speed, which suggests that the coal recovery increased with increasing charge of the coal particles. As shown in Task 3.1 (Charger Tests), the charge of the coal particles increased with increasing impeller speed of the turbo charger. The combustible recovery increased from 50 to 59%, with little changes in ash contents. These results suggest that proper design of the charger is important for improving the recovery. The results shown in Figure 11 and Table 3 were obtained using two impellers in the turbocharger. In the future work, a third layer of impellers will be installed to see if the recovery can be further increased without deteriorating the product quality.

### Task 7 - 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 was continued at a rapid pace during this quarter. The test work showed that the modifications to the TES unit and the reduction in feed size from 28 mesh to 35 mesh resulted in significant overall improvement in yield and combustible recovery compared to the data reported in the last quarter. At that time, there was a significant discrepancy between the bench-scale and the pilot-scale results. The pilot-scale test work is now approaching the bench scale test results. However, further pilot-scale test work is required to further improve the results and duplicate the bench-scale test work.



Figure 1. Plastic safety curtains used to restrict airborne dust in the testing facility.



(a)



(b)

Figure 2. Photographs of vertical screw conveyor used in the original design of the TES circuit showing views from (a) the bottom and (b) the top floors.

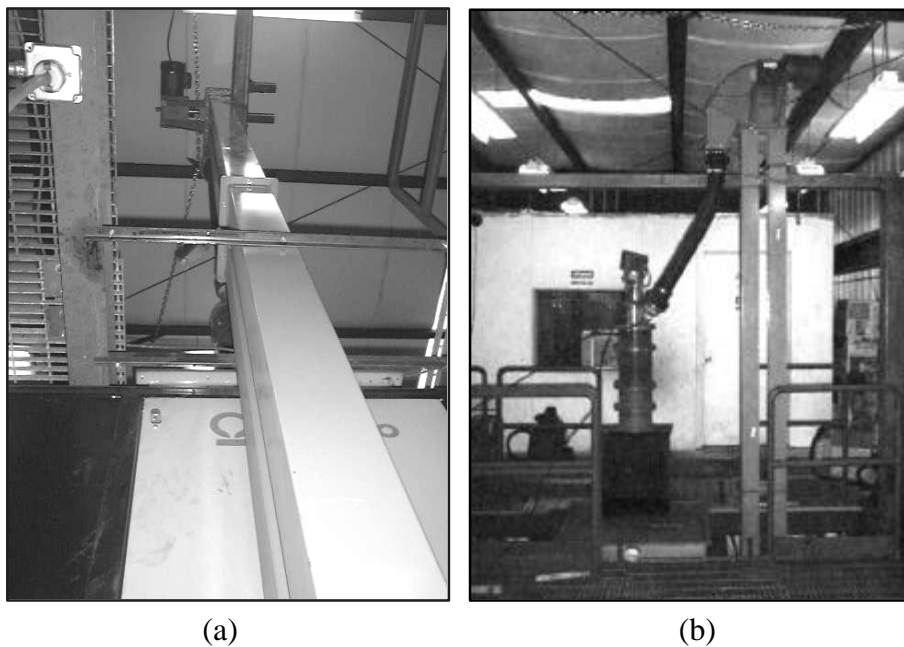


Figure 3. Photographs of enclosed bucket elevator used in the modified TES circuit showing views from (a) the bottom and (b) top floors.

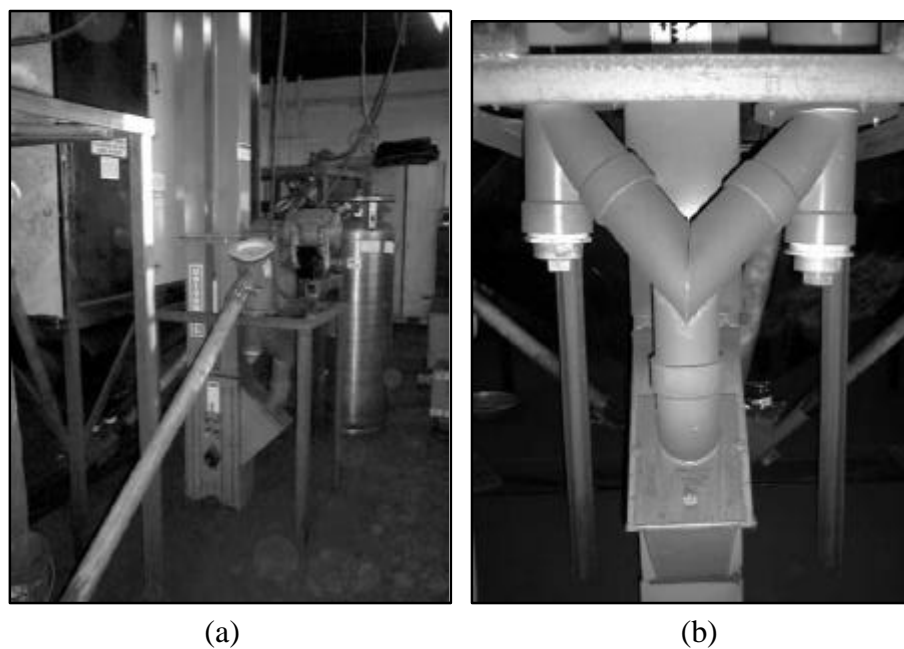


Figure 4. Photographs of (a) the feed inlet to the bucket elevator and (b) sampling ports for the feed and recycle streams.



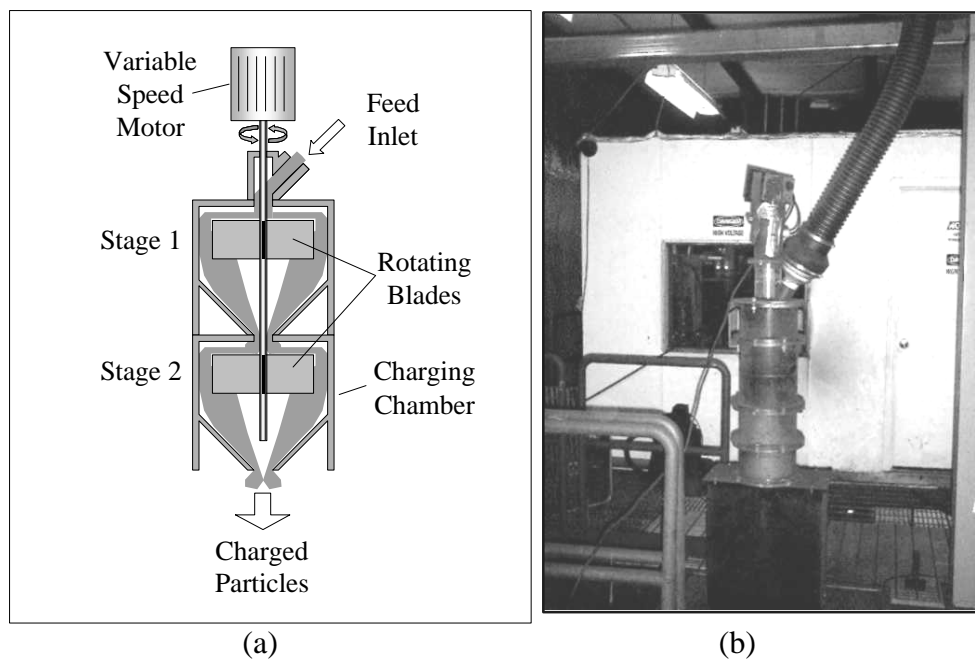


Figure 5. Schematic (a) and photograph (b) of the three-stage rotary turbocharger mounted atop the TESunit.

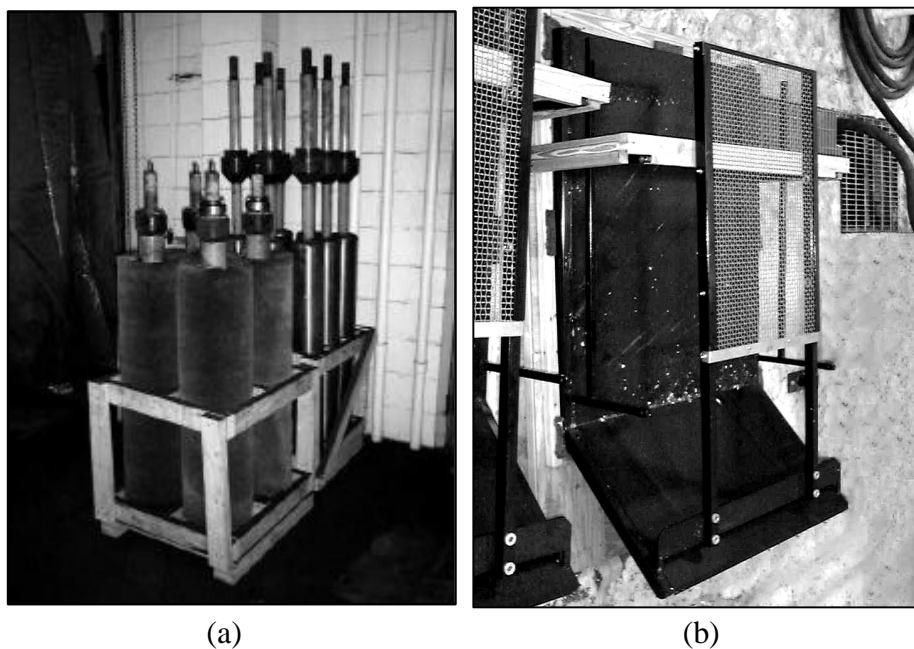


Figure 6. Photographs of (a) the cylindrical electrodes and brushes removed from the TES unit and (b) the screen electrodes just prior to installation.

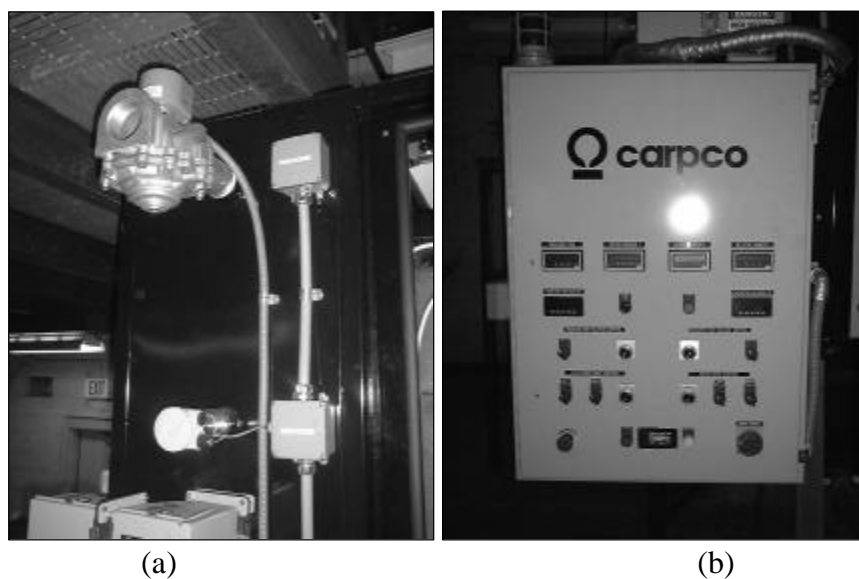


Figure 7. Photographs of (a) the sensors for oxygen, humidity and pressure and (b) the TES control and display panel.

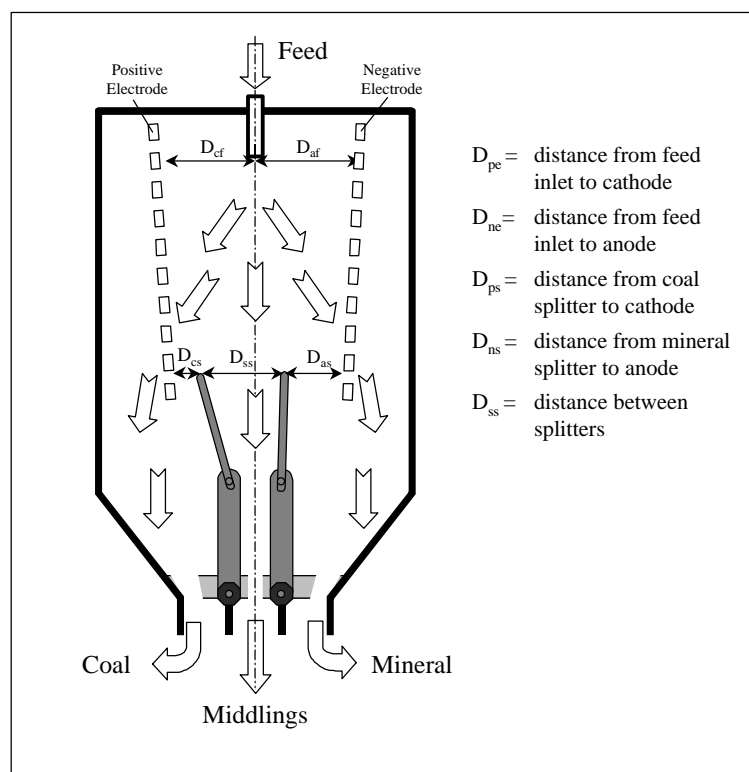


Figure 8. Schematic showing the dimensions used to specify the positions of the TES electrodes and splitters.

Table 1. Results of the POC-scale triboelectrostatic separation tests conducted on the mill reject from Glen Lyn Plower Plant, Virginia, by changing splitter position ( $D_{cs}$ ).

Particle Size (mesh)	Splitter Position (Dcs in inches)	Product				Combustible Recovery (%)
		Yield		Ash		
		Clean Coal	Reject	Clean Coal	Reject	
35 x 0	0	37.6	62.4	18.7	63.5	57.3
	0.97	36.7	63.3	16.2	64.3	57.7
	1.57	36.8	63.2	16.0	64.6	58.0
	2.36	36.9	63.1	15.5	64.9	58.4
28 x 0	0	32.4	67.6	18.1	61.6	50.5
	0.97	32.2	67.8	18.1	61.5	50.2
	1.57	31.8	68.2	17.4	61.6	50.1
	2.36	31.2	68.8	16.3	61.7	49.8

Table 2. Results of the POC-scale triboelectrostatic separation tests conducted on the mill reject (35 mesh x 0) from Glen Lyn plower plant, Virginia, by changing the potential difference between the cathode and anode at a potential difference of 60 kV.

Potential Difference (kV)	Product				Combustible Recovery (%)
	Yield (% wt)		Ash (% wt)		
	Clean Coal	Reject	Clean Coal	Reject	
20	48.0	52.1	25.5	66.2	67.1
40	40.7	59.3	19.7	65.2	61.3
60	36.9	63.1	15.5	64.9	58.4
80	33.6	66.4	15.3	62.5	53.3

Table 3. Results of the POC-scale triboelectrostatic separation tests conducted on the mill reject (35 mesh x 0) from Glen Lyn plower plant, Virginia, by changing the impeller speed of the turbocharger.

Charger Speed Reading	Product				Combustible Recovery (%)
	Yield (%wt)		Ash (%wt)		
	Clean Coal	Reject	Clean Coal	Reject	
20	31.3	68.7	14.8	62.1	50.2
40	35.9	64.1	15.5	64.1	56.9
60	36.9	63.1	15.5	64.9	58.4
80	37.3	67.8	15.7	65.1	58.9

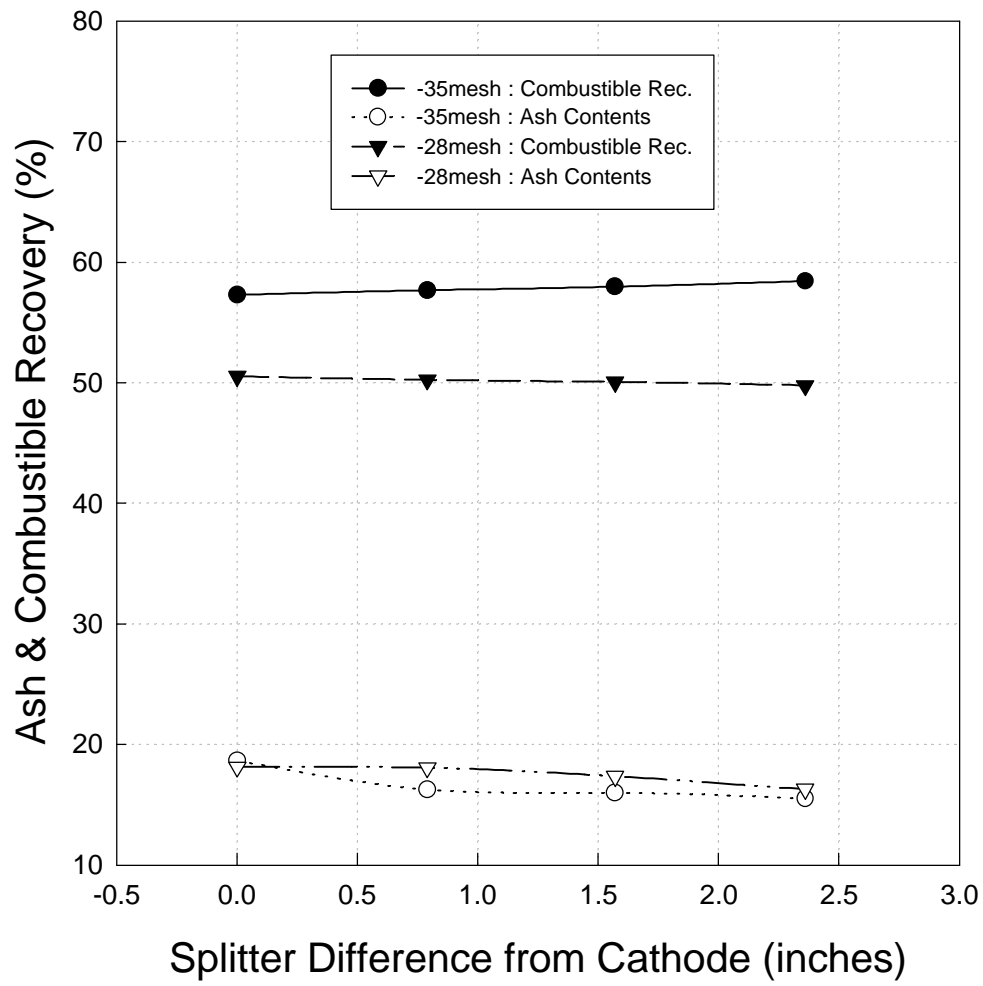


Figure 9. The results of the POC-scale triboelectrostatic separation tests conducted on the mill reject sample from Glen Lyn power plant, Virginia. The sample was pulverized to 28 mesh x 0 and 35 mesh x 0 prior to the pilot-scale tests. The results are plotted as a function of the distance ( $D_{cs}$ ) between the cathode and splitter, which controls the amount of middlings recycled.

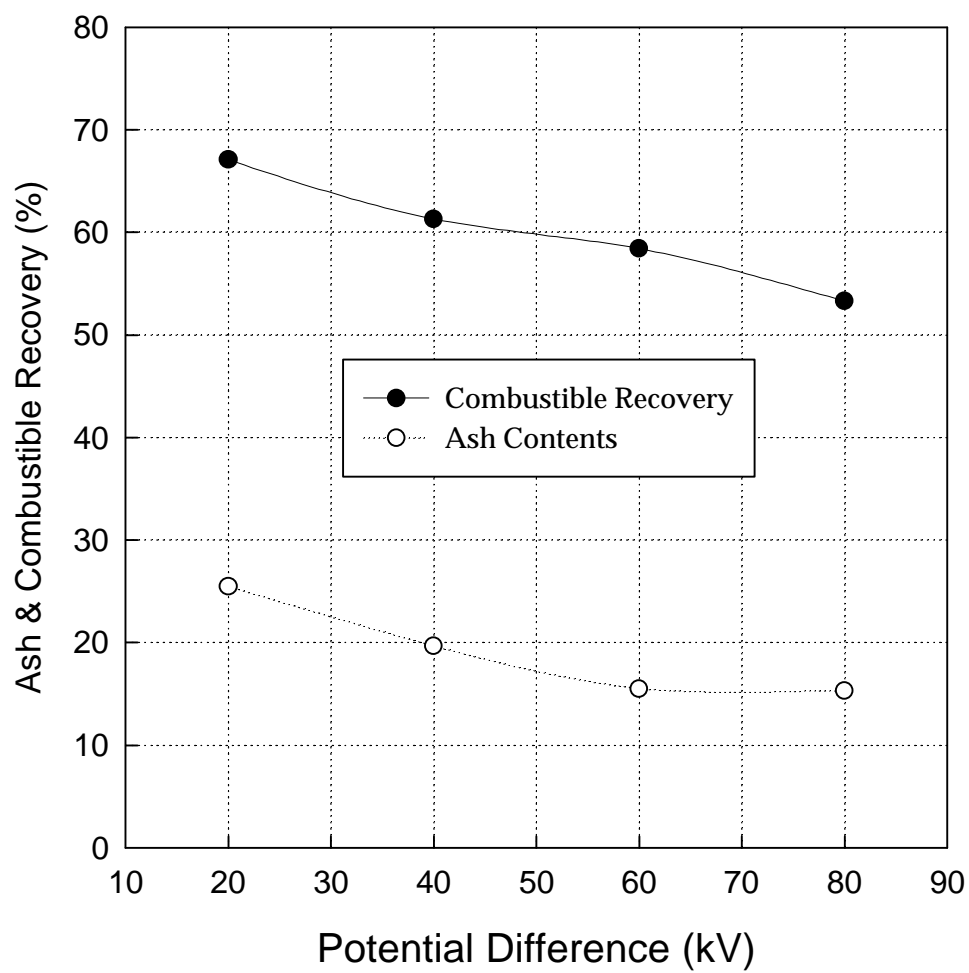


Figure 10. The results of the pilot-scale triboelectrostatic separation tests conducted on the mill reject sample (35 mesh x 0) from Glen Lyn power plant, Virginia. The tests were conducted by changing the potential difference between the cathode and anode.

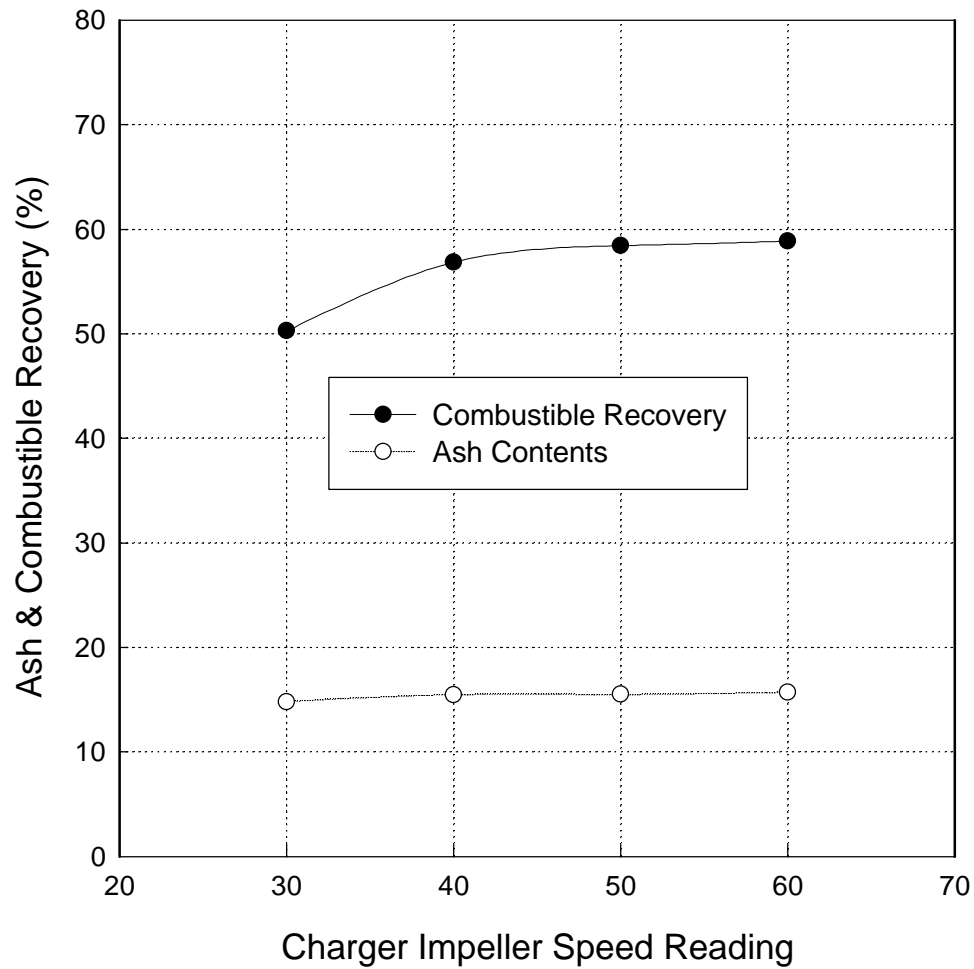


Figure 11. The results of the pilot-scale triboelectrostatic separation tests conducted on the mill reject sample (35 mesh x 0) from Glen Lyn power plant, Virginia. The sample was pulverized to 28 mesh x 0 and 35 mesh x 0 prior to the pilot-scale tests. The tests were conducted by changing the impeller speed of the Turbocharger.