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

By

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WORK DESCRIPTION

Work continued during the past quarter to improve the performance of the POC-scale unit. For the charging system, a more robust "turbocharger" has been fabricated and installed. All of the internal components of the charger have been constructed from the same material (i.e., Plexiglas) to prevent particles from contacting surfaces with different work functions. For the electrode system, a new set of vinyl-coated electrodes have been constructed and tested. The coated electrodes (i) allow higher field strengths to be tested without of risk of arcing and (ii) minimize the likelihood of charge reversal caused by particles colliding with the conducting surfaces of the uncoated electrodes. Tests are underway to evaluate these modifications.

Several different coal samples were collected for testing during this reporting period. These samples included (i) a "reject" material that was collected from the pyrite trap of a pulverizer at a coal-fired power plant, (ii) an "intermediate" product that was selectively withdrawn from the grinding chamber of a pulverizer at a power plant, and (iii) a run-of-mine feed coal from an operating coal preparation plant. Tests were conducted with these samples to investigate the effects of several key parameters (e.g., particle size, charger type, sample history, electrode coatings, etc.) on the performance of the bench-scale separator.

PROJECT TASKS

Task 2 - Sample Acquisition

Raymond Mill Samples

Most of the tests completed during the past year were conducted using "reject" material collected from the pyrite traps of Raymond mills at the Glen Lyn (American Electric Power) and Possum Point (Virginia Power) coal-fired power plants. Unfortunately, these reject samples proved to be unsatisfactory for several reasons. One major problem was that the reject streams were very high in ash and contained so little combustible matter that the treatment of these streams may not be commercially viable. In addition, extensive crushing was required to reduce the top size of the reject stream to the optimum treatment size (i.e., below 35 mesh) for the TES process. This stream was also found to contain unwanted extraneous material (e.g., metal scrap, rusted fragments, tramp iron, etc.) that could seriously damage the crushing, handling and separation equipment.

Because of the aforementioned problems, an "intermediate" product was collected from within the grinding chamber of a typical roller-race mill (see Figure 1) for use in the test program. The intermediate product was collected from sampling ports installed at various locations along the height of the grinding chamber. As will be discussed later, samples collected near the bottom of the grinding chamber tend to possess a higher ash content than those collected near the top of the chamber. The segregation within the grinding chamber can be attributed to the selective fluidization of the crushed coal particles created by the upward stream of hot gas that sweeps up in an annulus around the table or grinding bowl. The hot gas carries the coal upwards toward the classifier section of the mill. Heavy particles (larger low-density coal or smaller high-density mineral matter) fall back into the grinding chamber and are subjected to further crushing. Lighter particles are carried on to the classifier, pass through the entry vanes, and are split into a fine product (minus 200 mesh) that leaves the classifier and a coarse product that falls back to mix with fresh feed in the center of the grinding chamber. Harder material (such as pyrite, rock or tramp metal) falls through an annulus to produce a reject stream leaving the mill base. The segregation within the mill makes it possible to extract a high ash stream from the wall of the pulverizer. This stream can be fed to the TES separator, upgraded to reject ash and pyrite, and the clean coal product returned back into the pulverizer.

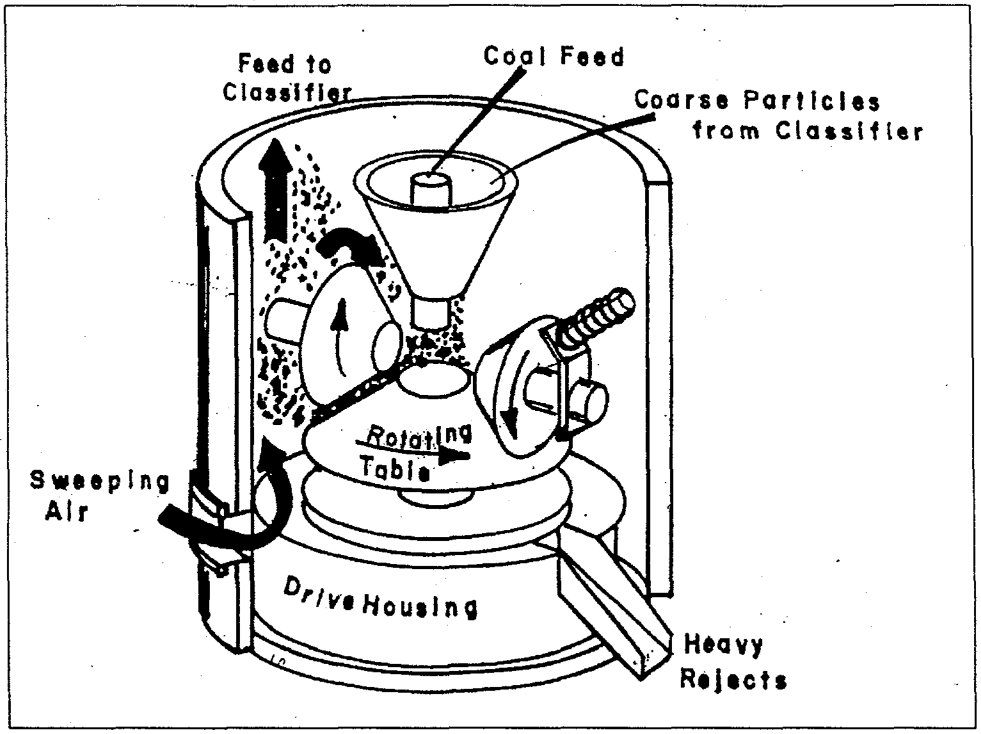

Figure 1. Simplified schematic of a generic roll-race mill.

The dry cleaning of an intermediate product, which was originally suggested by Dr. Robin Oder, is considerably more attractive due to the lower ash content (35-45%) and smaller topsize (minus 1 mm) of this stream. To investigate this approach, Dr. Robin Oder supplied approximately 50 lb of intermediate product for TES testing from a 633 Raymond mill at the Shawville (Reliant Energy) power plant, Pennsylvania. Personnel from CCMP also collected a "fresh" sample of intermediate product from the Shawville plant during this quarter to ensure that sufficient sample was on hand to complete the proposed test programs.

Run-of-Mine Sample

A run-of-mine sample from the Pittston Coal Company's Moss No. 3 preparation plant was also tested during this reporting period using both bench-scale and POC-scale units. The

Moss No. 3 coal sample consisted of a three-part blend of Kennedy, Tiller and Greasy Creek seams in approximately equal proportions. The float-sink data for the composite sample are provided in Table 1. The float-sink data indicate that nearly half (49.32% by weight) of the feed coal has an ash content of less than 4.24%. Likewise, more than 40% (40.88% by weight) of the feed coal is comprised of particles with an ash content above 86%. Thus, the middlings fraction in this particular feed coal represents less than 10% (9.80% by weight) of the feed coal weight. These results suggest that the Moss No. 3 feed coal is well liberated and, if properly charged, should provide a good feed sample for the TES process.

Table 1. Washability data for the run-of-mine blend from the Moss No. 3 preparation plant.

Coal Fraction	Sink SG	Float SG	Individual			Cumulative		
			Weight (%)	Ash (%)	Sulfur (%)	Weight (%)	Ash (%)	Sulfur (%)
Clean	---	1.35	49.32	4.24	0.79	49.32	4.24	0.79
Middlings	1.35	1.60	9.80	19.22	1.07	59.12	6.72	7.37
Reject	1.60	---	40.88	86.43	0.31	100.00	39.31	1.58

Task 3.2 - Bench-Scale Separator Tests

Experimental

During the past quarter, bench-scale tests were carried out using samples of Moss No. 3 coal, Glen Lyn and Possum Point mill rejects, and Shawville intermediate mill products. As standard practice, bench-scale tests are conducted to evaluate the cleaning potential of all test samples prior to conducting POC-scale tests. Most of the bench-scale tests were conducted by charging the feed particles using a pneumatic tube charger in series with a two stage horizontal rotary charger.

Testing of Moss No. 3 Coal

Bench-scale TES tests were carried out to compare the results obtained when treating "natural" fines to those obtained when treating "freshly pulverized" fines. In these tests, the sample of natural fines was prepared by screening a run-of-mine coal sample from the Moss No. 3 preparation plant to obtain a 35 mesh x 0 fraction. The sample of freshly pulverized fines was prepared by crushing coarse lumps of coal from the Moss No. 3 preparation plant down to a topsize of 35 mesh. Each of the two 35 mesh x 0 samples were passed separately through the bench-scale separator and the resultant products collected and analyzed. Each test was run in duplicate so that the experimental repeatability could be determined.

The results of the bench-scale comparison tests are summarized in Table 2. The data indicate that the separation efficiencies obtained with the naturally occurring fines were slightly superior to those obtained with the freshly pulverized fines by approximately five percentage points (45.2-46.8% versus 40.1-40.9%). In this case, the separation efficiency was defined as the

Table 2. Comparison of test data obtained using "natural" and "freshly pulverized" fines from the Moss No. 3 preparation plant.

Coal Source	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
Natural (-35 mesh)	33.97	14.19	56.30	53.03	68.91	46.76
	33.78	13.56	54.05	50.06	65.35	45.19
Fresh (-35 Mesh)	29.84	15.24	50.83	58.98	71.25	40.87
	29.87	15.38	49.81	57.91	69.88	40.09

recovery of combustible matter minus the recovery of ash in the same product. Although the freshly pulverized sample gave slightly higher recoveries (69.9-71.3% versus 65.4-68.9%), this improvement was more than offset by the higher ash content of the clean coal products obtained when treating the freshly pulverized sample (14.2-13.6% versus 15.2-15.4%).

Testing of Raymond Mill Reject

Several bench-scale tests were conducted using "reject" material from the Virginia Power Possum Point power plant located in Manassas, Virginia. The mill reject, which was collected from the pyrite trap of the Raymond mill pulverizer, was screened to remove 35 mesh oversize material prior to being fed to the bench-scale separator. Unfortunately, the ash content of the minus 35 mesh feed was found to be very high (i.e., >60% ash). Therefore, a second series of tests were carried out using artificially prepared feeds with a lower ash content. The artificial feeds were created by blending a small amount of low-ash mill feed coal that had been crushed to minus 35 mesh with the high-ash minus 35-mesh mill reject. Two artificial feed samples, i.e., 46% ash and a 38% ash, were prepared in this manner.

Table 3 summarizes the results of the tests conducted using the minus 35 mesh reject material and the two artificial feed samples. The original high-ash reject material showed little reduction in ash content. In this particular case, the ash content was reduced from 61.5-61.3% down to 51.1-44.4%. The separation efficiencies for these tests ranged from 22.1-27.2%. In contrast, the best separation results were obtained with the artificial feed mixture that had an ash content of approximately 38%. In this case, the feed was cleaned down to 18.1-18.9% ash at a recovery of 60.5-62.8%. The separation efficiency for this series of tests was 38.8%. As expected, the results obtained using the artificial mixture with the 46% ash content was between those obtained with the high-ash (61%) reject material and low-ash (38%) artificial mixture.

Table 3. Summary of test results obtained using mill "reject" from the Possum Point Power Plant.

Coal Source	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
Natural (-35 mesh)	61.50	51.11	72.05	50.38	63.98	22.11
	61.26	44.37	71.73	38.27	54.95	27.23
Artificial* (-35 mesh)	45.65	28.77	59.75	45.51	59.65	30.96
	45.98	27.43	59.84	42.76	57.45	31.94
Artificial* (-35 Mesh)	37.83	18.86	55.41	48.10	62.77	38.80
	38.01	18.05	54.85	45.76	60.50	38.76

* Obtained by mixing the high-ash mill reject with low-ash feed coal.

Testing of Raymond Mill Intermediate Products

The use of mill reject material as feed for the TES process was determined to be inappropriate due to the high ash content of this stream. Therefore, samples of "intermediate" products were taken from within the grinding chamber of the Raymond mill at the Shawville power plant. Figure 2 shows the general layout of the mill and the specific locations of the four sampling ports installed along the height of the grinding chamber. Samples were collected from each of the sampling points and were subjected size and ash analyses.

Figure 3 shows the ash content of the intermediate products collected from each of the four sampling ports. Because of the inherent segregation of particles within the mill classifier, the sample taken near the bottom of the mill (Sample #1) possessed a much higher ash content than the sample taken near the top of the mill (Sample #4). However, the ash content of each of the four intermediate products was significantly lower than that of the reject material collected

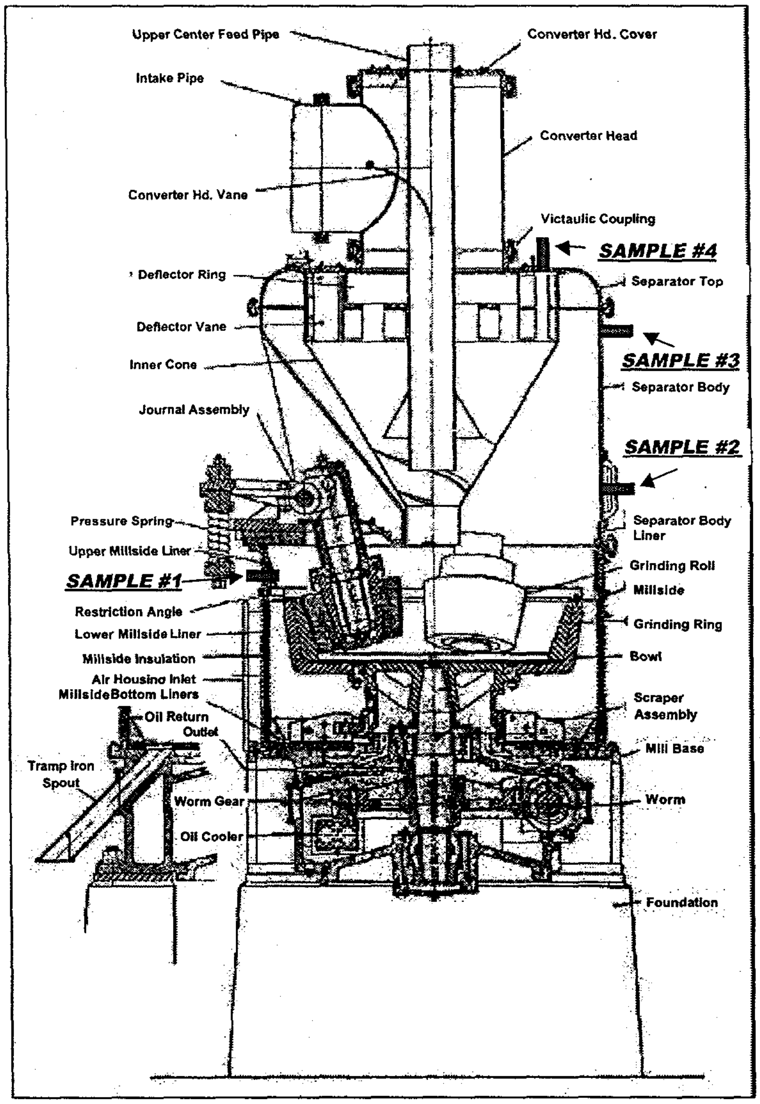

Figure 2. Detailed schematic of the Raymond mill showing the location of sampling ports for the collection of intermediate products.

from the pyrite trap. The lower ash content and finer size distribution make the intermediate products a more attractive source of feed coal for the TES process.

Three sets of bench-scale tests were conducted to evaluate the cleanability of the intermediate products collected as a function of mill height. In each set of tests, the samples were dry screened into several different size fractions before being tested. For the first sample

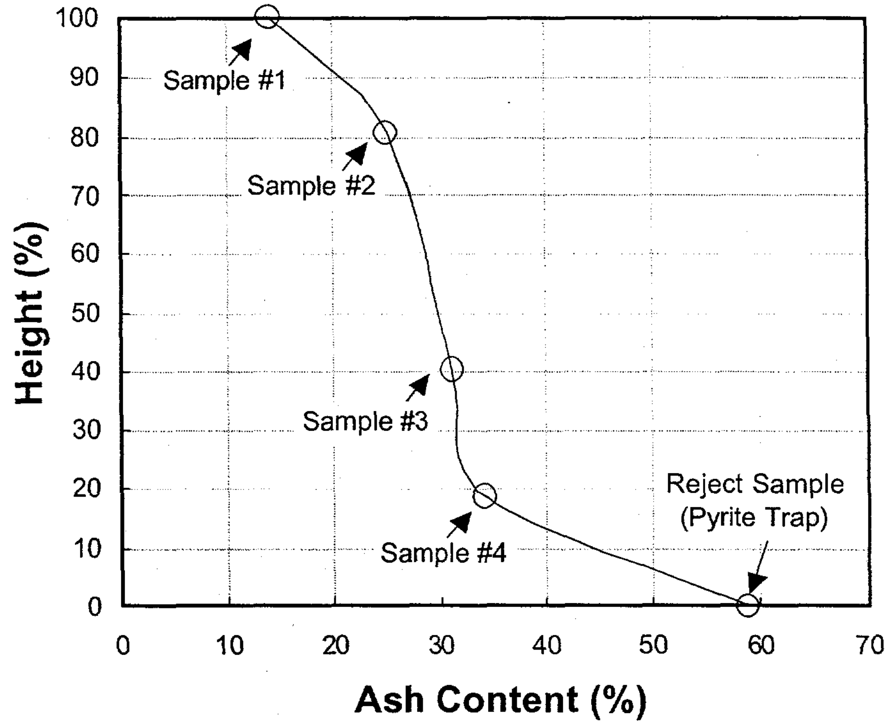

Figure 3. Effect of sample port position (measured in terms of percentage of grinding chamber height) on the ash content of the intermediate product.

(Sample #1), the size fractions included 35 x 48 mesh, 14 x 100 mesh, 100 x 200 mesh, and 48 mesh x 0. The next two samples (Samples #2 and #3) were screened into 35 x 100 mesh and 28 mesh x 0 fractions. The final sample (Sample #4), which was obtained from the top of the mill, was not tested because of its very low ash content (i.e., 14.1% ash).

The results of these tests conducted with the first intermediate product (Sample #1) is summarized in Table 4. In general, the test data do not follow any discernable trend, perhaps because of the large variability in the ash contents of the different size fractions in the feed. However, the data do suggest that the "by-zero" material (i.e., 48 mesh x 0) provided a higher recovery (60-64%), lower clean coal ash (14-16%), and higher separation efficiency (31-33%) than the screened fractions in which the finest material had been removed. This finding is

Table 4. Results of bench-scale tests conducted on an intermediate product (Sample #1) from the Shawville power plant.

Size (mesh)	Ash Content (%) Feed	Clean	Reject	Yield (%)	Recovery (%)	Efficiency (%)
14 x 100	32.23	24.4	37.62	40.77	45.48	14.62
100 x 200	42.35	25.46	51.97	36.29	46.92	25.10
35 x 48	24.61	17.03	32.23	50.13	55.17	20.48
48 x 0	27.37	14.73	40.94	51.77	60.78	32.92
48 x 0	27.25	15.66	41.11	54.46	63.14	31.84

important since it suggests that the intermediate feed material need not be "dedusted" prior to being fed to the TES process.

The bench-scale data for tests conducted using Samples #2 and #3 are summarized in Tables 5 and 6. The data obtained with these samples also indicated that higher recoveries could be obtained using the "by-zero" samples (28 mesh x 0). In addition, the recovery values were generally consistent with those obtained using Sample #1. However, the ash contents of the products obtained for the by-zero fractions of Samples #2 and #3 were slightly higher than those obtained using the 35 x 100 mesh fraction.

Table 5. Results of bench-scale tests conducted on an intermediate product (Sample #2) from the Shawville power plant.

Size (mesh)	Ash Content (%) Feed	Clean	Reject	Yield (%)	Recovery (%)	Efficiency (%)
35 x 100	35.59	23.03	44.10	40.39	48.27	22.13
28 x 0	34.15	23.37	44.94	50.02	58.21	23.98

Table 6. Results of bench-scale tests conducted on an intermediate product (Sample #3) from the Shawville power plant.

Size (mesh)	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
35 x 100	26.7	10.1	40.04	44.56	54.65	37.79
28 x 0	25.2	13.3	38.3	52.40	60.74	33.08

Comparison of Charging Systems

Two additional series of bench-scale tests were carried out to compare the effectiveness of the pneumatic charging and the turbo-charging systems. In order to compare the two chargers, tests were carried out using Sample #1 from the Shawville Raymond mill. Four different circuit configurations were evaluated in the test program, i.e.:

1. The TES unit fed directly with no charger.
2. The feed passing through the pneumatic charger only.
3. The feed passing through the rotary charger only.
4. The feed passing through both the pneumatic charger and rotary charger.

Figure 4 shows simplified schematics of the four different charger configuration evaluated in this study. The dashed lines in the figure represent streams that were transferred manually (by hand) during each test run.

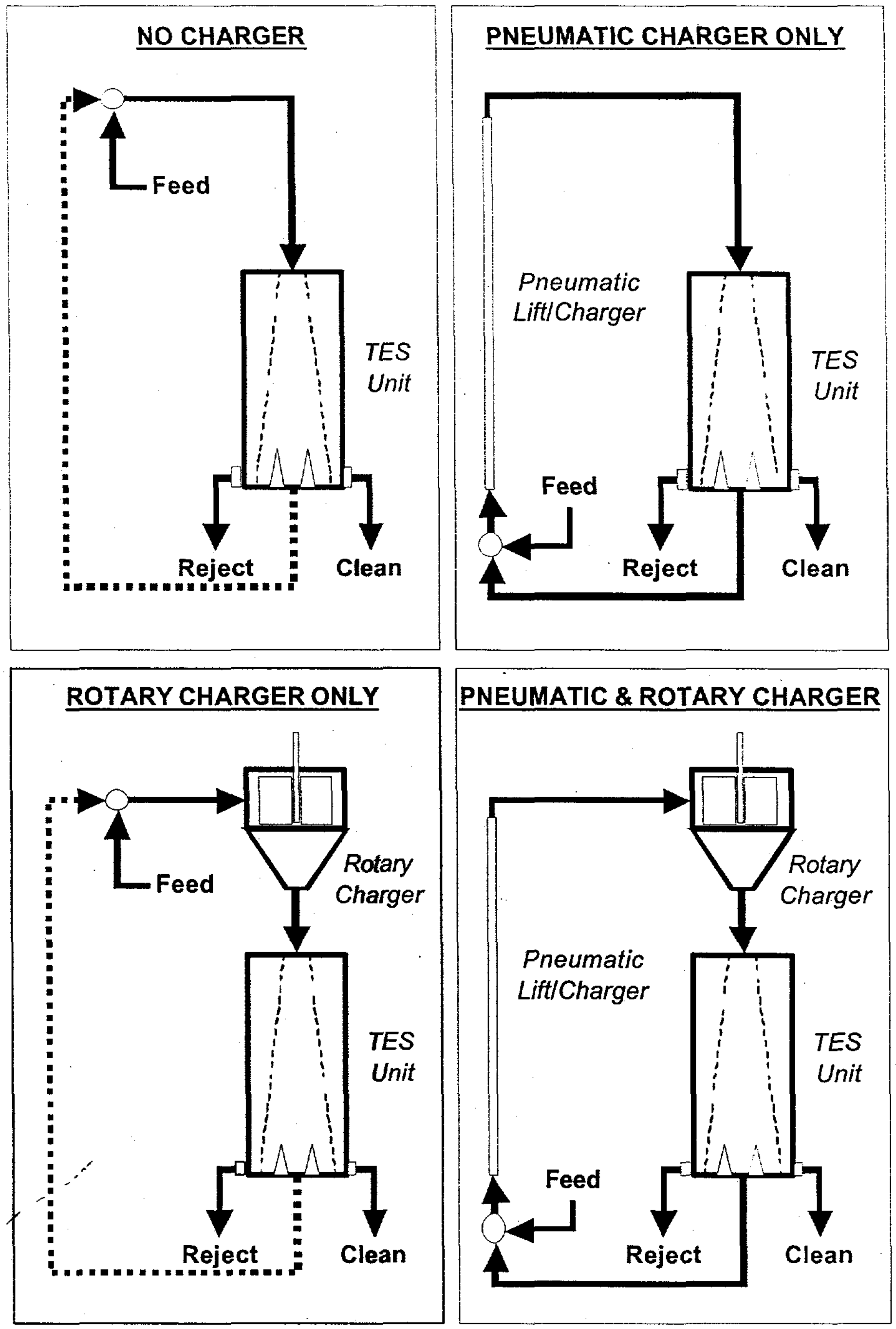

Figure 4. Charger configurations evaluated in the bench-scale test program.

The results of the charger comparison tests are summarized in Table 7. The data indicate that there is virtually no separation when no charger was employed. The average separation efficiency obtained with the pneumatic charger was slightly higher than that obtained with the rotary charger (20.1% versus 14.8%). It is also worth noting that the pneumatic charger provided a high recovery (65%) and poor clean coal ash (25.4%), while the rotary charger provided a low

Table 7. Effect of charger configuration on the performance of the bench-scale separator (Sample #1, 28 mesh x 0).

No Charger

Test Run	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
1	31.23	16.92	31.72	3.3	4.0	2.2
2	31.11	16.76	30.60	---	---	---
Mean	31.17	16.84	31.16	---	---	---

Pneumatic Charger Only

Test Run	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
1	33.05	25.49	43.38	57.7	64.3	19.7
2	33.02	25.20	43.87	58.1	64.9	20.5
Mean	33.04	25.35	43.63	57.9	64.6	20.1

Rotary Charger Only

Test Run	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
1	30.90	13.65	35.00	19.2	24.0	15.5
2	30.90	13.79	34.52	17.5	21.8	14.0
Mean	30.90	13.72	34.76	18.3	22.9	14.8

Both Pneumatic & Rotary Charger

Test Run	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
1	33.02	17.83	42.83	39.2	48.1	27.0
2	33.02	18.55	43.21	41.3	50.2	27.0
Mean	33.02	18.19	43.02	40.3	49.2	27.0

recovery (23%) and good clean coal ash (13.7%). Although the best separation efficiency (27%) was obtained by combining both the pneumatic and rotary chargers in series, this two-stage configuration produced too low of a recovery (49%) and reject ash (43%) to be commercially viable. In light of these results, modifications are currently being made to the POC-scale unit to improve the charging system so that good recoveries can be maintained.

Effect of Electrode Shielding

The strength of the electrostatic field is constrained by the onset of arcing between the surfaces of the oppositely charged electrodes. To prevent this problem, a series of bench-scale tests were carried out using screen electrodes that were "shielded" by covering the screen wires with a plastic spray-on coating. Two series of tests were carried out, the first using the rotary charger only and the second using both the pneumatic and rotary chargers in series.

Table 8 shows the results obtained with the shielded and unshielded electrodes. In all cases, the shielded electrodes provided a superior level of performance when compared to the unshielded electrodes. For the tests conducted with the rotary charger only, the shielded electrodes increased the average recovery from 22.9% to 34.3% with essentially no change in the clean coal ash content (13.7% versus 13.6%). Likewise, the shielded electrodes improved the average recovery for the tests conducted with the two chargers in series from 49.2% to 62.7%. In fact, the shielded electrode test increased the reject ash content by approximately 3%, clean coal yield by 9-12%, recovery by 11-13%, and separation efficiency by 5-8%. Since the electrode potential was held constant in all tests, the improved level of performance obtained with the coated electrodes is believed to be due to prevention of accidental charge reversal. The charge reversal occurs when selectively charged particles collide with uncoated electrodes fabricated from copper or steel wires. The plastic shielding insulates the electrodes and prevents the particles from making contact with the conducting surfaces, thereby preventing charge reversal. Therefore, the coated electrodes (i) allow higher field strengths to be tested without of risk of arcing and (ii) minimize the likelihood of charge reversal caused by particles colliding with the uncoated electrode conductors. Additional testing is underway to further evaluate the benefits of the electrode shielding.

Table 8. Effect of electrode shielding (plastic coating) on the performance of the bench-scale separator (Sample #1, 28 mesh x 0).

Rotary Charger – No Shielding

Test	Ash Content (%)			Yield	Recovery	Efficiency
Run	Feed	Clean	Reject	(%)	(%)	(%)
1	30.90	13.65	35.00	19.2	24.0	15.5
2	30.90	13.79	34.52	17.5	21.8	14.0
Mean	30.90	13.72	34.76	18.3	22.9	14.8

Rotary Charger – With Shielding

Test	Ash Content (%)			Yield	Recovery	Efficiency
Run	Feed	Clean	Reject	(%)	(%)	(%)
1	31.05	13.85	37.83	28.3	35.3	22.7
2	31.30	13.38	37.71	26.3	33.2	22.0
Mean	31.18	13.62	37.77	27.3	34.3	22.3

Pneumatic & Rotary Charger – No Shielding

Test	Ash Content (%)			Yield	Recovery	Efficiency
Run	Feed	Clean	Reject	(%)	(%)	(%)
1	33.02	17.83	42.83	39.2	48.1	27.0
2	33.02	18.55	43.21	41.3	50.2	27.0
Mean	33.02	18.19	43.02	40.3	49.2	27.0

Pneumatic & Rotary Charger – With Shielding

Test	Ash Content (%)			Yield	Recovery	Efficiency
Run	Feed	Clean	Reject	(%)	(%)	(%)
1	31.23	18.00	45.73	52.3	62.3	32.2
2	31.57	18.09	46.57	52.7	63.0	32.9
Mean	31.40	18.05	46.15	52.5	62.7	32.5

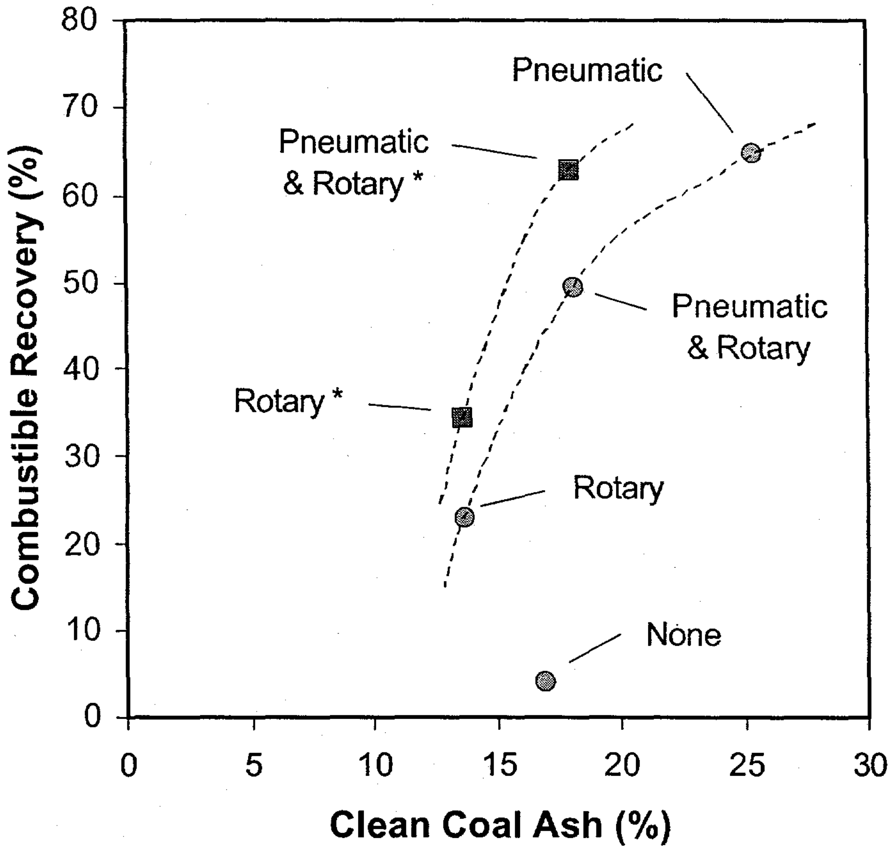

Figure 5. Summary of test results obtained using different charging systems (pneumatic and rotary) and electrode configurations (shielded and unshielded). An asterisk is used to designate tests with the shielded electrodes.

Figure 5 provides a graphical summary of the test results obtained with the different charging and electrode systems. As shown, the shielded electrodes (designated by an asterisk) gave a superior recovery-ash curve to that obtained using the uncoated electrodes. It is also obvious from this plot that the pneumatic charger gives a high recovery/low ash product, while the rotary charger gives a low recovery/high ash product. The data point obtained by combining the two chargers in series represents a compromise between these two operating extremes.

Task 6-POC Detailed Testing

Experimental Testing

The data collected throughout the course of this project suggest that the bench-scale unit produces a superior results when compared to POC-scale unit. In order to further verify this conclusion, an additional series of bench-scale and POC-scale tests were conducted during the past quarter using a run-of-mine coal sample from the Moss No. 3 preparation plant. The test data, which are summarized in Table 9, show that the bench-scale unit did indeed attain a higher combustible recovery (69-71% versus 50-57%), lower clean coal ash (15.2-15.4% versus 18.1-19.0%), and higher separation efficiency (40.1-41.1% versus 23.4-27.7%) than the POC-scale unit. Several modifications are currently underway to improve the separation performance of the POC-scale unit. These modifications are described in the following section of this report.

Table 9. Comparison of bench-scale and POC-scale tests conducted using the run-of-mine sample from the Moss No. 3 preparation plant.

Test Unit	Ash Content (%)			Yield (%)	Recovery (%)	Efficiency (%)
	Feed	Clean	Reject			
Bench	29.84	15.24	50.83	58.98	71.25	41.13
	29.87	15.38	49.81	57.91	69.88	40.06
POC	30.08	18.24	41.53	49.16	57.49	27.68
	29.72	18.97	38.66	45.40	52.35	23.37
	29.72	18.10	38.72	43.65	50.86	24.28

POC-Scale Modifications

In light of the superior performance of the bench-scale unit, several modifications are being made to the POC-scale separator. These modifications include:

- A new turbocharger is being constructed which should greatly improve the charging efficiency. The new charger has been installed and is currently being evaluated using intermediate products from the Shawville power plant.
- The tribocharger used to date has been constructed of several different materials (i.e., Plexiglas shell and housing, copper plate in the conical part of the chute, and glass in the vertical feed distributor). Since these materials have different work functions, the surface charge created by contact with one type of material may be cancelled when the particle contacts another type of material. The charger and feed chute are now being built entirely of Plexiglas to avoid this problem.
- At present, the discharge from the turbocharger falls by gravity to the electric field below. The bench-scale unit utilizes a pneumatic system to transport material and to disperse particles before they enter the separator's electric field. A nitrogen injection system that will help disperse the charged particles has been installed on the POC unit.

Task 7 - Sample Analysis/Characterization

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

SUMMARY AND CONCLUSION

1. Various coal samples were collected during the past quarter for use in the TES test program. These samples included Raymond mill "reject" material from the Glen Lyn and Possum Point power plants, Raymond mill "intermediate" products from the Shawville power plant, and a blend of run-of-mine coals from the Moss No. 3 preparation plant.

2. In order to evaluate the effects of sample history on separator performance, a series of bench-scale tests conducted with "naturally occurring" and "freshly pulverized" fines of run-of-mine coal from the Moss No. 3 preparation plant. The test results indicate that freshly pulverized fines do not separate as effectively as the naturally occurring material.

3. A variety of tests were conducted using "reject" material collected from the pyrite trap of a Raymond mill. The test data collected to date suggest that the material in this stream is too high in ash and too variable to be a suitable feed for the TES process. In addition, this stream often contains extraneous material (e.g., metal scrap, rusted fragments, tramp iron, etc.) that has the potential to seriously damage the crushing, handling and separation equipment.

4. Because of problems associated with the testing of Raymond mill "reject" material, several "intermediate" products were collected from sampling ports located along the height of the grinding chamber. Although the testing of these samples is still preliminary in nature, the test work completed to date indicates that good recoveries can be maintained for a wide range of size fractions. Testing of these samples will continue during the next quarter.

5. Bench-scale separation tests were performed to compare the performance of two different particle charging systems, i.e., pneumatic and rotary. These tests again verified that no charging occurred and that no separation was possible without the charging step. In addition, the test data suggest that the pneumatic charger provided a high recovery and poor clean coal ash, while the rotary charger provided a low recovery and good clean coal ash.

6. The effects of electrode shielding were evaluated by conducting tests with and without plastic coatings on the electrode surfaces. The results show that shielding increases recovery and

improves clean coal quality. The improvement has been attributed to elimination of charge reversal that can occur when selectively charged particles collide with the conducting surfaces of the uncoated electrodes. Furthermore, the shielding prevents arcing between the electrodes even when high field strengths are utilized, thereby reducing the risks of an accidental coal dust explosion.

7. Work continued during the past quarter to improve the performance of the charging and electrode systems for the POC-scale unit. For the charging system, a more robust "turbocharger" has been designed, fabricated and installed. All of the internal components of the charger have been constructed from the same material (i.e., Plexiglas) to prevent particles from contacting surfaces with different work functions. A system has also been installed to improve the dispersion of particles prior to their injection into the separator chamber.