1 of 1

SEP 09 1993

August 26, 1993

Mr. Otis Mills, Jr.
PM-30, 922 H
U.S. Department of Energy
Pittsburgh Energy Technology Center
P.O. Box 10940
Pittsburgh, PA 15236

RE: DOE-PETC Grant No. DE-FG22-91PC91280
"Coal-Sand Attrition System and It's Importance in Fine Coal Cleaning

Dear Otis:

Enclosed herewith is our quarterly technical progress report on the subject grant for the period 6/1/93 - 8/31/93. As per DOE reporting requirements, a copy of this report has been mailed to appropriate addressees.

Should you have any questions regarding this report, I would be pleased to respond.

Sincerely,

Rajendra K. Mehta
205-348-1584

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Coal-Sand attrition system and it's importance in fine coal cleaning

The research efforts during this quarter (June through August) were divided into four categories:

1. Continuous grinding tests using steel media
2. Fracture tests on coal samples compacted at different pressure
3. SEM- Image analysis of feed and ground product coal samples
4. Zeta potential measurements of coal samples ground by different media
5. Flotation tests of coal samples ground by different media

Continuous Grinding Tests:

As indicated in the seventh quarterly report, continuous grinding tests using silica sand as grinding media had been carried out under selected conditions. Continuous grinding tests using steel shots were made during this quarter. The tests were carried out in the same grinding circuit, under similar test conditions in order to compare the tests results.

In the steel media continuous grinding tests, 173 grams coal and 713.9 grams steel shots were employed in each test to match the volume of the sand media used in the former tests. We decided to use only minus 100 mesh of the coal feed in these continuous tests because coarser feeds might have caused problems as pointed out in last quarterly report. 25% starting pulp density was used during these tests. The weight of steel shots was measured before and after grinding tests to calculate to the consumption of the grinding media. For all of the four coals, four passes were carried out to produce fine grinding products and the results were compared with those of sand media continuous grinding tests.

The results of steel media continuous tests are given in Tables 1-4. The media wear measured in the tests for Black Creek, Illinois #6, Pittsburgh #8 coals were 0.24%, 0.24%, and 0.20% respectively.

If we compare the data of Tables 1-4 with the data of sand media continuous grinding tests (Tables 1-4 of the seventh quarterly report), we can see that the size distributions of the ground products using different grinding media for same coal are quite similar. The amount of coarser particles (>16 micron) for steel media ground products is smaller, while the ultra-fine part (< 2 micron for example,) were almost the same. That means that the sand media grinding produced relatively more finer particles compared with steel media grinding. This phenomenon might due to the different grinding mechanisms involved in these two systems.

MASTER

Fracture Mechanics Tests

In the seventh quarterly report, the conditions of fracture mechanics tests were described in detail. The tests carried out in those tests were for coal samples prepared at constant pressure of about 12,700 psi applied for a duration of one hour. In order to understand the effect of initial compaction pressure on the fracture mechanism and to compare the results of different conditions, more tests were carried out for Illinois #6 coal and Pocahontas #3 coal at different conditions. We used 19,100 psi and 25,500 psi pressure for a duration of 10 minutes in these tests. The other conditions were the same.

The results of the fracture mechanics tests are given in terms of stress, strain, and Poisson ratio, which are shown in Tables 5-10.

As mentioned in the seventh quarterly report, the cakes made with the softest coal (Pocahontas #3) tend to exhibit greater resistance to stress. This feature could presumably be attributed to the presence of a significant amount of clay or other mineral matter in the coal. This is also true for the coarser coal (50X60 mesh) cylinders made at higher pressure. If we compare Tables 5, 6 and Tables 8, 9, we can see that the pressure that caused the coal cores to crackdown for Pocahontas #3 coal is greater than those for Illinois #6 coal. The vertical strains for the former are greater as well. For finer coals, however, this is not true (table 7, table 10). The reason needs to be studied further. If we compare the Tables 5-10 with table 5, table 15 and table 23 of the last quarterly report, we find that the higher the pressure applied on the coal in making coal cylinders, the higher the stresses needed to break the cylinders.

The particle size distributions resulting from the application of load used to compress the coal samples are given on the basis of the initial particle sizes in Tables 11-13. Compare the results listed in these tables with table 25 and table 29 of the last quarterly report, some conclusions can be made. For the coarser coals (50X60 mesh), the higher the pressure applied in making the coal cylinders, the finer the particle size distributions of the coal cakes. This is also a reasonable result and easy to understand. For the finer coals (200X270 mesh), on the other hand, in spite of applying pressure even as high as two times on the coal samples, the size distributions are almost the same for the same coal. This might be because of the high surface energy of the fine particles.

SEM- Image Analysis of Coal

Twelve (12) samples consisting of four 200X270 mesh raw feed coal samples and eight 200X270 mesh ground product samples were thoroughly screened to remove -270 mesh fines. Following the wet screening, the 200X270 mesh material was mounted in briquettes consisting of melted Carnauba wax and polyethylene (1:1 weight ratio). These briquettes were then sectioned

and the sections remounted to eliminate gravitational and orientation effects. Finally, the briquettes were sputter-coated with gold and analyzed using a Cambridge Stereoscan 150 SEM in conjunction with a Kontron SEM-IPS image analysis system.

Three phases, consisting of mineral matter, pyrite and carbonaceous material, were identified from the back scattered electron image, and the images were analyzed to determine the area fraction of each phase present in a given particle. Weight % for each phase were obtained by assuming area fraction was equivalent to volume fraction and by using specific gravities for carbonaceous material, mineral matter and pyrite of 1.3, 2.65, 5.0 to convert the volume fraction to mass fraction data. At the same time, the circular shape factor was given by:

$$(4 \pi \text{ area}) / (\text{perimeter}^2)$$

was determined for each particle. In general, approximately 1500 particles were analyzed for each sample.

The liberation spectra (i.e., weight percent of particles in class vs. composition class) obtained from the SEM-Image analysis work are shown in Figures 1-12 and the shape factor distributions are shown in Figures 13-16. In terms of liberation, one would normally expect that the amount of free carbonaceous material in the 200X270 mesh size class would increase after grinding since the more brittle mineral matter would tend to break into finer size classes. This is clearly the case for the Illinois and BC coals; however, the opposite is true for the Pocahontas coal, while the Pittsburgh coal yields inconclusive results. Of course, the liberation spectrum for a given size class is also influenced by the larger size classes and the overall liberation spectrum of the feed material. Thus, it is difficult to draw any general conclusions about the shape of the spectrum for a given size class without knowing the entire liberation spectrum of the feed. In general, however, it appears that there is no significant difference in the liberation spectra obtained using either sand or steel media. For three out of four of the coal samples, the liberation spectra for the two media types are almost identical. Only in the case of the Pittsburgh coal, do the data indicate that liberation of carbonaceous material is improved with steel media. Thus, it is probably not fair to draw any conclusion concerning preferential liberation with changes in media type.

In terms of shape, Figures 13- 16 clearly show a shift in the shape factor distribution to more circular shapes (i.e. the distribution shifts closer to 1) after grinding, with the shift being more pronounced for the sand media. This shift may be more easily compared by looking at the mass mean shape factors listed in the symbol key for each figure. Thus, it appears that the sand grinding media produces a more spherical product shape.

Zeta Potential Measurements

Zeta-potential is defined as the potential difference between the bulk solution and a hypothetical plane, close to the interface, at which shearing of the fluid is considered to begin. Measurements of zeta-potential is helpful to the further study the flotation behavior of ground coal products, dispersion and flocculation behavior. Zeta - potential measurements were carried out using Lazer Zee Meter Model 501. The results of the measurements are given in Fig. 17 - 20. It was interesting to note that for all coals the sand ground coal product acquired smaller potential than the steel media ground coal product at all pH values. The reason for this behavior needs to be studied further.

Flotation Tests

Froth flotation utilizes the differences in physio-chemical surface properties of particles of various minerals. Because of chemical, electrical, or physical attraction between the polar portions and surface sites, the collectors adsorb on the particles with their non-polar ends orientated towards the bulk solution, thereby imparting hydrophobicity to the particles. Since flotation is one of the most popular method employed in ultra-fine coal cleaning, flotation tests were carried out to see the influence of sand and steel grinding media on the flotation behavior of the coals. The size distribution of flotation feeds is shown in Figure 21.

Black Creek Coal

This coal was the hardest coal among the four coals in terms of its grindability. Only frother (MIBC) was added to float this coal. Fig. 22 - 25 give the flotation results of this coal. Ash content of the flotation concentrate and the flotation recovery based on fixed carbon were used as two main criteria to evaluate the experimental results. From the results, we can see that the floatabilities of the Black Creek coal at different PH are different and the variation for the sand ground coal is greater. At lower pH values, say lower than 6, the ash content in the concentrate obtained for steel ground coal is lower compared with those of sand ground coal. When pH values are higher than 6, however, the flotation concentrates are cleaner for the sand ground coal. Obviously, concentrate of sand ground coal is cleaner at natural PH value. This is favorable to sand grinding of coal. With the increase of the MIBC dosage, the recoveries of the coal become higher for both ground products and the recoveries for steel ground products are higher than those of sand ground products. The maximum recoveries for the both products are the same. This means

that the sand ground Black Creek coal consumes a little more MIBC than that of steel ground coal during flotation.

Illinois #6 Coal

This coal was more difficult to float compared with other coals tested. To float the coal, both frother (MIBC) and collector (kerosene) need to be added, as frother and collector, respectively. The flotation results of Illinois #6 coal are shown in Fig. 26 to Fig. 29. For steel ground Illinois #6 coal, the recoveries of flotation change slightly with the change of pH values and the recoveries are higher than 95% at any pH values. For sand ground Illinois #6 coal, however, the recoveries are much lower at high pH values. On the other hand, the ash content of the concentrates for sand ground coal is lower than those of steel ground coal at any given pH value. At lower kerosene dosage, the recoveries for steel ground coal are higher. But when we reach the highest recoveries for both grinding products, the consumption of collector is the same. The dosage of kerosene had little effect on the ash content of the concentrates.

Pittsburgh #8 Coal

Pittsburgh #8 coal was similar to Black Creek coal in the flotation behavior, with MIBC function as both frother and collector, the dosage of MIBC for both coals was almost the same. Fig. 30 to Fig. 33 show the results of flotation tests of the Pittsburgh #8 coal. The difference in flotation phenomena between the two coals was that the ash contents of flotation concentrates for sand ground Pittsburgh #8 coal was lower compared with the those of steel ground Pittsburgh #8 coal, while this was true at higher pH values for Black Creek coal, and sand ground Pittsburgh #8 coal might have had higher flotation recoveries at some pH values, around PH=7, for example. Also, at high pH values, sand ground products had poor floatabilities. Therefore, for this coal, we could get higher flotation recovery with lower ash content in the concentrate using sand as grinding medium at natural PH value.

Pocahontas #3 Coal

This coal exhibited superior floatability. Without adding any flotation reagent, higher than 90% recovery was obtained with ash content of the concentrate lower than 2%. For this coal, the flotation results for sand ground and steel ground products are almost the same. The results are reasonable. Sand ground feed had cleaner flotation concentrate than steel ground feed, with a little lower recovery. Fig. 34 and Fig. 35 show the flotation results for this coal.

From the flotation test results we can convincingly argue that the sand ground coals' flotation concentrates were cleaner i.e. contained less ash than the steel ground coals. This might be partly due to the finer grinding products (see Fig. 21) and / or to the good dispersion properties in the flotation pulp of sand ground coals. We can draw a conclusion that using sand as grinding medium, ground coal had no adverse effects on the flotation results.

Table 1. The product size distributions of minus 100 mesh Pocahontas #3 coal ground in a continuous mode at 2500 rpm, 25% solids and a flow rate of 43 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing			
	1st pass	2nd pass	3rd pass	4th pass
192	100.0	100.0	100.0	100.0
128	100.0	100.0	100.0	100.0
96	99.9	100.0	100.0	100.0
64	96.0	99.8	100.0	100.0
48	94.5	99.8	100.0	100.0
32	88.3	99.8	100.0	100.0
24	82.9	99.7	100.0	100.0
16	69.6	97.2	96.9	97.6
12	55.8	93.3	93.2	96.9
8	38.8	80.3	80.2	85.7
6	28.0	67.2	68.2	75.9
4	17.5	44.9	46.7	52.8
3	12.0	31.8	33.8	38.8
2	7.7	19.3	20.4	22.8
1.5	4.9	12.5	13.1	14.7
1	3.9	9.7	10.1	11.2

Table 2. The product size distributions of minus 100 mesh Pittsburgh #8 coal ground in a continuous mode at 2500 rpm, 26% solids and a flow rate of 62 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing			
	1st pass	2nd pass	3rd pass	4th pass
192	100.0	100.0	100.0	100.0
128	99.9	100.0	100.0	100.0
96	99.7	100.0	100.0	100.0
64	94.6	99.3	99.9	99.8
48	92.1	98.7	99.8	99.7
32	82.8	97.4	99.8	99.7
24	68.1	96.8	99.8	99.7
16	56.7	88.1	93.6	97.8
12	41.5	75.6	84.5	89.7
8	26.1	53.3	62.5	71.5
6	18.1	38.1	46.3	54.0
4	11.8	22.7	27.1	32.5
3	8.5	15.9	18.9	22.0
2	6.1	10.8	12.5	14.6
1.5	3.9	7.1	8.3	9.5
1	3.2	5.7	6.6	7.6

Table 3. The product size distributions of minus 100 mesh Illinois #6 coal ground in a continuous mode at 2500 rpm, 24% solids and a flow rate of 56 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing			
	1st pass	2nd pass	3rd pass	4th pass
192	100.0	100.0	100.0	100.0
128	100.0	100.0	100.0	100.0
96	100.0	100.0	100.0	100.0
64	97.9	99.6	99.9	100.0
48	97.3	99.3	99.8	100.0
32	92.8	98.9	99.6	100.0
24	86.8	97.3	99.3	100.0
16	70.1	88.3	92.3	96.1
12	53.1	73.8	80.1	86.5
8	33.2	50.8	57.6	66.1
6	22.8	35.8	41.6	49.3
4	14.7	22.3	25.4	30.4
3	10.8	16.2	18.3	21.5
2	7.5	10.8	12.3	13.6
1.5	4.5	6.2	7.2	7.6
1	3.5	4.7	5.5	5.6

Table 4. The product size distributions of minus 100 mesh Black Creek coal ground in a continuous mode at 2500 rpm, 26% solids and a flow rate of 62 ml/min.

Particle Sizes (μm)	Cumulative Weight Percent Passing			
	1st pass	2nd pass	3rd pass	4th pass
192	100.0	100.0	100.0	100.0
128	98.9	100.0	100.0	100.0
96	95.9	100.0	100.0	100.0
64	88.1	98.8	99.4	99.9
48	84.9	98.4	98.9	99.8
32	74.1	96.3	97.7	99.7
24	65.4	93.9	96.9	99.5
16	49.7	83.8	88.6	93.8
12	36.1	69.4	76.2	83.7
8	22.3	46.4	53.3	61.9
6	14.9	31.6	37.3	44.5
4	9.2	17.9	20.8	25.0
3	6.3	12.2	14.1	16.7
2	4.2	8.3	9.3	10.8
1.5	2.5	5.3	5.9	6.9
1	2.1	4.2	4.7	5.4

Table 5. The stress, strain and Poisson ratio of a compressed cake made from a 50 x 60 mesh size Pocahontas #3 coal (19100 psi)

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	5101.20		
31.83	7441.20	20.24	2.71×10^{-3}
47.75	10455.12	40.48	3.87×10^{-3}
63.66	13478.40	75.90	5.63×10^{-3}
79.58	16211.52	101.20	6.24×10^{-3}
95.49	18401.76	131.56	7.15×10^{-3}
111.41	20124.00	151.80	7.54×10^{-3}
127.32	21930.48	177.10	8.08×10^{-3}
143.24	23446.80	212.52	9.06×10^{-3}
159.15	24935.04	247.94	9.94×10^{-3}
175.07	26479.44	283.36	10.70×10^{-3}
190.99	27883.44	323.84	11.60×10^{-3}
206.90	29427.84	364.32	12.38×10^{-3}
222.82	30878.64	414.92	13.44×10^{-3}
238.73	32348.16	465.52	14.39×10^{-3}
254.65	34004.88	516.12	15.15×10^{-3}
270.56	36279.36	581.90	16.04×10^{-3}

Table 6. The stress, strain and Poisson ratio of a compressed cake made from a 50X60 mesh size Pocahontas #3 coal (25,500 psi)

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	2227.68		
31.83	5073.12	15.18	2.99×10^{-3}
47.75	7890.48	30.36	3.85×10^{-3}
63.66	10258.56	40.48	3.95×10^{-3}
79.58	12392.64	55.66	4.49×10^{-3}
95.49	14526.72	70.84	4.88×10^{-3}
111.41	16267.68	96.14	5.91×10^{-3}
127.32	18167.76	121.44	6.68×10^{-3}
143.24	19674.72	141.68	7.20×10^{-3}
159.15	21350.16	172.04	8.06×10^{-3}
175.07	22782.24	192.28	8.44×10^{-3}
190.99	23961.60	217.58	9.08×10^{-3}
206.90	25328.16	253.00	9.99×10^{-3}
222.82	26676.00	283.36	10.62×10^{-3}
238.73	28154.88	313.72	11.14×10^{-3}
254.65	29437.20	354.20	12.03×10^{-3}
270.56	30990.96	394.68	12.73×10^{-3}
286.49	33190.56	435.16	13.11×10^{-3}

Table 7. The stress, strain and Poisson ratio of a compressed cake made from a 200X270 mesh size Pocahontas #3 coal (25,500 psi)

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	2246.40		
31.83	3341.52		
47.75	4305.60		
63.66	5269.68		
79.58	6233.76	10.12	1.62×10^{-3}
95.49	7048.08	20.24	2.87×10^{-3}
111.41	8105.76	25.30	3.12×10^{-3}
127.32	9565.92	30.36	3.17×10^{-3}
143.24	10717.20	50.60	4.72×10^{-3}
159.15	11334.96	151.80	13.39×10^{-3}

Table 8. The stress, strain and Poisson ratio of a compressed cake made from a 50X60 mesh size Illinois #6 coal (19,100 psi)

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	10642.32	25.30	2.38×10^{-3}
31.83	15912.00	125.60	7.89×10^{-3}
47.75	17952.48	273.24	15.22×10^{-3}
63.66	18195.84	430.10	23.64×10^{-3}
79.58	20526.48	632.50	30.81×10^{-3}

Table 9. The stress, strain and Poisson ratio of a compressed cake made from a 50X60 mesh size Illinois #6 coal (25,500 psi)

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	11353.68	25.30	2.23×10^{-3}
31.83	19843.20	111.32	5.61×10^{-3}
47.75	27246.96	263.12	9.66×10^{-3}
63.66	32179.68	419.98	13.05×10^{-3}
79.58	35259.12	607.20	17.22×10^{-3}
95.49	32469.84	779.24	24.00×10^{-3}

Table 10. The stress, strain and Poisson ratio of a compressed cake made from a 200X270 mesh size Illinois #6 coal (25,500 psi)

Stress (psi)	Strain		Poisson Ratio
	Vertical	Horizontal	
15.92	1778.40		
31.83	3397.68		
47.75	4960.80	15.18	3.06×10^{-3}
63.66	6458.40	25.30	3.92×10^{-3}
79.58	8395.92	30.36	3.62×10^{-3}
95.49	10286.64	45.54	4.43×10^{-3}
111.41	12317.76	60.72	4.93×10^{-3}
127.32	14208.48	75.90	5.34×10^{-3}
143.24	16361.28	101.20	6.19×10^{-3}
159.15	18252.00	126.50	6.93×10^{-3}
175.07	20460.96	161.92	7.91×10^{-3}
190.99	23184.72	212.52	9.17×10^{-3}
206.90	25412.40	273.24	10.75×10^{-3}
222.82	25740.00	779.24	30.27×10^{-3}

Table 11. The particle size distributions resulting from the compression of 50 x 60 mesh coal at 19,100 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes

Size	Cumulative Weight Percent Passing	
(mesh)	Illinois #6	Pocahontas #3
50	100.00	100.00
60	84.76	96.93
100	38.94	67.17
150	27.28	54.31
200	17.49	42.08
270	11.79	18.83
Max σ (psi)	79.58	270.56
Max ϵ_v	20526.48	36279.36
Poisson Ratio	30.81×10^{-3}	16.04×10^{-3}

Table 12. The particle size distributions resulting from the compression of 50X60 mesh coal at 25,500 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes

Size	Cumulative Weight Percent Passing	
(mesh)	Illinois #6	Pocahontas #3
50	100.00	100.00
60	85.63	98.24
100	39.23	68.98
150	27.20	56.00
200	17.41	43.16
270	12.37	19.31
Max σ (psi)	95.49	286.48
Max ϵ_v	32469.84	33190.56
Poisson Ratio	24.00×10^{-3}	13.11×10^{-3}

Table 13. The particle size distributions resulting from the compression of 200 x 270 mesh coal at 25,500 psi and the maximum stress, strain and Poisson ratio exhibited by the respective dry cakes

Size (μm)	Cumulative Weight Percent Passing	
	Illinois #6	Pocahontas #3
192	100.00	100.00
128	100.00	100.00
96	100.00	100.00
64	85.50	97.80
48	74.40	95.20
32	48.20	81.50
24	34.40	68.90
16	22.80	50.80
12	15.50	37.50
8	10.50	25.30
6	7.40	18.00
4	5.30	11.20
3	3.70	7.40
2	2.50	4.60
1.5	1.30	3.00
1	1.00	2.50
Max σ (psi)	222.82	159.15
Max ϵ_v	25740.00	11334.96
Poisson Ratio	30.27×10^{-3}	13.39×10^{-3}

Figure 1. Liberation spectra (based on carbonaceous material) for Illinois coal sample.

Figure 2. Liberation spectra (based on pyrite) for Illinois coal sample.

Figure 3. Liberation spectra (based on mineral matter) for Illinois coal sample.

Figure 4. Liberation spectra (based on carbonaceous material) for Pittsburgh coal sample.

Figure 5. Liberation spectra (based on pyrite) for Pittsburgh coal sample.

Figure 6. Liberation spectra (based on mineral matter) for Pittsburgh coal sample.

Figure 7. Liberation spectra (based on carbonaceous material) for Pocahontas coal sample.

Figure 8. Liberation spectra (based on pyrite) for Pocahontas coal sample.

Figure 9. Liberation spectra (based on mineral matter) for Pocahontas coal sample.

Figure 10. Liberation spectra (based on carbonaceous material) for BC coal sample.

Figure 11. Liberation spectra (based on pyrite) for BC coal sample.

Figure 12. Liberation spectra (based on mineral matter) for BC coal sample.

Figure 13. Circular shape factor distribution for Illinois coal sample.
(Mass mean shape factor in parentheses.)

Figure 14. Circular shape factor distribution for Pittsburgh coal sample.
(Mass mean shape factor in parentheses.)

Figure 15. Circular shape factor distribution for Pocahontas coal sample.
(Mass mean shape factor in parentheses.)

Figure 16. Circular shape factor distribution for BC coal sample.
(Mass mean shape factor in parentheses.)

Fig. 17 Zeta-potential versus PH for Black Creek Coal

Fig. 18 Zeta-potential versus PH for Illinois #6 coal

Fig. 19 Zeta-potential versus PH for Pittsburgh #8 coal

Fig. 20 Zeta-potential versus PH for Pocahontas #3 coal

Fig. 21   Size Distribution of Flotation Feed

Fig. 22   **Ash Content of Concentration as Function of PH Values of Black Creek Coal**

Fig. 23 Recovery of Coal as Function of PH of Black Creek Coal

Fig. 24   **Ash Content of the Concentration as
Function of MIBC Dosage of Black Creek Coal**

Fig. 25   **Recovery of Coal as Function
of MIBC Dosage of Black Greek Coal**

Fig. 26   **Ash Content of Concentration as**
Function of PH Values of ILlinois #6 Coal

**Fig. 27   Recovery of Coal as Function
of PH Values of Illinois #6 Coal**

Fig. 28   **Ash Content of the Concentration as
Function of Kerosene Dosage of Illinois #6 Coal**

**Fig. 29   Flotation Recovery as Function
of Kerosene Dosage of Illinois #6 Coal**

Fig. 30 Ash Content of Concentration of Pittsburgh #8 Coal as Function of PH Values

Fig. 31

Flotation Recovery of Pittsburgh #8 Coal as Function of PH Values

Fig. 32 Ash content of Concentration as Function of MIBC Dosage of Pittsburgh #8 Coal

Fig. 33

**Recovery of Coal as Function
of MIBC Dosage of Pittsburgh #8 Coal**

Fig. 34

Ash Content of Concentration as
Function of PH of Pocahontas #3 Coal

Fig. 35 Flotation Recovery of Coal as Function of PH Value of Pocahontas #3 Coal

**DATE
FILMED**

2 / 7 / 94

END