**Pilot Demonstration of Technology for the Production of High Value Materials from the
Ultra-Fine (PM_{2.5}) Fraction of Coal Combustion Ash**

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Abstract

Dry fly ash samples were collected from 6 of the 7 largest power plants operated by Louisville Gas and Electric Company (LG&E). Samples were taken from individual ESP hoppers in a continuous flow through stages of particulate collection. A total of 41 samples were taken from 16 operating units. The samples were thoroughly characterized for pertinent physical and chemical composition. The fly ash samples contained 10 to 50% -10 μ m material, with higher concentrations of finer particles located in the latter stages of particulate collection.

Flotation evaluation was conducted on a continuous flow through a single unit at each power station to assess the viability of using froth flotation to reduce the LOI in the fly ash to very low levels (i.e. 0.5% LOI) in order to enable eventual use as fillers. Ash from all of the units tested responded favorably with the exception of the ash from Henderson Station, which is attributed to a significant proportion of un-combusted or partially-combusted petroleum coke in the ash at this station,

Bulk samples of dry ash and pond ash were also collected from Mill Creek, Trimble County, E.W. Brown and Coleman power plants and evaluated for carbon removal by froth flotation. Release analyses showed that flotation could effectively reduce carbon to acceptable levels for most of the substrates tested. The exception was the Mill Creek ashes. The cause of this exception will be further investigated.

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Executive Summary

Dry fly ash samples were obtained from 6 of the 7 largest power plants operated by Louisville Gas and Electric Company (LG&E). Samples were taken from individual hoppers located below electrostatic precipitators. Every effort was made to obtain samples from a continuous sample flow through the various stages of particulate collection. A total of 41 samples were taken from 16 operating units. All samples were analyzed for particle size distribution, LOI, C, H, N, S, O, major oxides and trace elements. It is envisioned that the ashes with higher proportions of fine material would be most suitable as substrates for processing to produce filler. In general, the fly ash samples contained 10 to 50% $-10\mu\text{m}$ material, with higher concentrations of finer particles in the latter stages of particulate collection.

Flotation evaluation was conducted on ash samples collected at various stages of a continuous flow through a single unit at each power station. This was done to assess the viability of using froth flotation to reduce the LOI in the fly ash to very low levels (i.e. $<0.5\%$ LOI) in order to enable eventual use as fillers. Most ash samples responded favorably with the exception of samples retrieved from Henderson Station. The poor floatability of this sample is attributed to a significant proportion of un-combusted or partially-combusted petroleum coke, which is used in significant quantities at this particular plant. Bulk samples of dry ash and pond ash were also collected from each station and evaluated for carbon removal by froth flotation.

Bulk samples of dry and pond ash were collected from Mill Creek, Trimble County, E.W. Brown and Coleman power plants. Dry ash samples (500 to 1000 lbs from each plant) were collected from ash silos where available. If the power station did not have an ash silo available, the bulk composite sample was retrieved by taking samples from the individual hoppers. Pond ash samples were also collected from each site (1000 lbs each) from the area of the pond where fine ash particles settled (i.e. as far from the feed end of the pond as feasible). Release analyses of the bulk dry and pond ash samples showed that flotation could effectively reduce carbon to acceptable levels for most of the substrates tested. The exception is the Mill Creek ashes that did not respond to flotation. The cause of this exception will be further investigated.

Results and Discussion

The results and discussion of progress made during this reporting period are summarized in this section, which is organized by Task. For clarity, major accomplishments of each Task are highlighted and a narrative description of specific activities follows.

Task 1 – Feedstock Evaluation

The objectives of this task are to obtain the necessary data to finalize equipment selection for the PDU design and the reagent requirements to produce high quality filler and superpozzolan from both dry ESP ash and pond ash.

Subtask 1.1 Sample Procurement

Status: Completed

Samples of fly ash were obtained from the power plants operated by LG&E, KU and WKE. The sampling procedure was to obtain approximately 1 kg of ash from each of the individual hoppers located under each of the electrostatic precipitators. Pictures of the sampling are shown in Figure 1. In particularly large plants, the duct is typically split into multiple parallel flow streams. In these cases, rather than sample each individual hopper, samples were taken from hoppers along a continuous flow of duct from the first ESP field to the last. By doing so, the number of samples taken was significantly reduced while still obtaining a representative flow of the ash within each particulate recovery system for each operating boiler unit. A total of 41 fly ash samples were obtained from the 6 of the 7 largest plants operated by LG&E Energy and its subsidiaries. Table 1 summarizes the plants that were sampled. The Seebree complex consists of two separate plants, Henderson and Green. The notation used for samples from these sites is the notation used at Seebree, G1 refers to Green unit 1 while H1 and H2 refers to Henderson units 1 and 2.

Figure 1. Photographs of Sampling Individual Hoppers at LG&E Power Plants.

<i>Table 1. Summary of Plants and Fly Ash Samples Obtained</i>				
Utility	Plant	Units Sampled	No. of Rows Sampled	No. of Bins Sampled
LG&E	Mill Creek	2	2	2
		3A	2	2
		4A	4	4
LG&E	Trimble	1	4	4
LG&E	Cane Run	4	1	1
		5	1	4
		6	2	3
WKE	Seebree	G1	4	4
		H1	2	2
		H2	2	2
KU	EW Brown	1	1	1
		2	1	1
		3	3	3
WKE	Coleman	1	2	2
		2	2	2
		3	2	4

Subtask 1.2 Sample Characterization

Status: Individual Sample Characterization completed
Bulk Sample Characterization in progress.

Samples obtained in Subtask 1.1 were given identification numbers for internal tracking purposes at CAER and apparent color differences were noted. Each samples was analyzed for particle size distribution by laser diffraction. In addition, wet screen analysis was conducted at 100 mesh, where sufficient amount of coarse material was present, in order to determine the chemistry of the coarse and fine size fractions. The LOI was determined for each sample and if sufficient quantity of sample was present, the LOI of the >100 mesh fraction was also determined. A summary of the results obtained are shown in Table 2.

The color of each ash ranged from light gray to black. Color may be an important consideration, particularly if the ultra-fine particles are to be considered for use as polymer filler. Technical input from polymer compounders has revealed that, in general, lighter colors are more desirable. This is primarily a cosmetic criteria rather than a technical consideration. Some color variations may be rectified by using other additives, but again, lighter colored ashes will require minimal amounts of additives.

The amount of -5 micron material present varied from 10.38% to 56.31% while the amount of material finer than 10 microns ranged from 9.28% to 71.20%. With some exception, the general trend in size distribution was that samples collected further from the boiler were finer. For example, EW Brown Unit 3 utilizes a 4-field ESP collection system. Since the duct work in this system is split into numerous parallel flows, samples were obtained along one continuous flow pattern. i.e. rows 1,3 and 4. At the time of sampling, ash had already been removed from all of the hoppers in the 2nd row. The ash in row 1 contained 26.39% - 10 μ m while the ash in rows 3 and 4 were progressively finer (47.32% and 61.62% -10 μ m, respectively). With some variation, a similar trend was apparent for most of the units sampled.

The LOI, or Loss on Ignition, varied from 0.9% to 17.4%. In many cases, ash collected earlier in particulate recovery system was lower in LOI than ash collected later in the system. For example, Mill Creek unit 4A, using 4 rows of ash collection (rows A, B, C and D) showed an increase in LOI in each of the successive rows (3.9%, 4.7%, 6.5%, and 7.5% LOI). While this tendency did not occur in every single unit sampled, it did occur in most of the units sampled.

Another interesting observation was the amount of coarse (+150 μ m or + 100 mesh) material present. While some samples contained essentially nothing in this size range, some contained as much as 19.2% coarse material. In most cases, the + 150 μ m was predominantly carbon, with grades as high as 78% LOI.

To summarize, the ash samples collected varied considerably with respect to color, size distribution and LOI. Despite these variations, some general trends were observed. Ash color varied from light gray to black and color variations were essentially consistent within each unit. The amount of LOI present also varied considerably, but the general trend was for LOI to increase the further away from the boiler the ash was collected. In other words, the first row of

ESP hoppers contained lower LOI than the second, third or fourth rows if present. Similarly, the amount of ultra-fine particles ($< 5 \mu\text{m}$ or $< 10 \mu\text{m}$) increased the further away from the boiler the ash was collected. In other words, coarse particles are collected in the first stages of particulate collection and finer particles are collected in subsequent stages. Lastly, when coarse particles are present (i.e. > 100 mesh or $150 \mu\text{m}$), the coarse particles are generally enriched in carbon.

Proximate and ultimate analyses of the ash samples were also conducted as part of the sample characterization. As shown in Table 3, the samples contained from 1 to 3% volatile matter, $<0.3\%$ H and very little N. The sulfur content varied from 0.04% to 1.16% S while the oxygen content ranged from 0.11 to 2.30%. Interestingly, the anomalously higher S and O concentrations occurred from the same samples collected at Mill Creek, a utility burning high sulfur coal. Results of the carbon analyses are consistent with the LOI results showing that most of the LOI is attributed to unburned carbon, a result consistent with widely reported observations pertaining to Class F ashes derived from combustion of bituminous rank coals.

Major oxides and trace elements were determined by XRD analysis and are summarized in Tables 4 and 5. It is important to note that the trace element results are for the total trace element concentrations present in the ash samples. Leaching studies are in progress on candidate samples to determine the leaching potential of the trace elements. As a general observation, ash chemistry, with respect to major oxides, is consistent within a given utility unit. The same general trend holds true for trace elements as well, however, some trace element concentrations are higher in the later stages of particulate collection. It is interesting to note that the fly ash generated at Seebree contained as much as 5200 ppm vanadium, which is attributed to the high proportion of petroleum coke used as a fuel source at this station. These concentrations of vanadium in the ash do not warrant elimination of Seebree as a potential substrate.

The results shown in Tables 2-5 were used to select the individual units at each station which had the greatest potential to produce a mineral-grade filler. The criteria used for unit selection were high proportion of ultrafine particles (i.e. $<10 \mu\text{m}$), low LOI and, to a lesser extent, light color.

Additional larger samples were obtained from the selected units at each power plant (Figure 2). Dry ash samples (500 to 1000 lbs) were obtained from each plant as well as a composite pond ash sample (1000 to 2000 lbs). No pond ash sample was retrieved from Cane Run since they co-mingle scrubber sludge with fly ash at this site to produce poz-o-tek which is not suitable for further processing.

Figure 2a.

Figure 2b.

Figure 2c.

Figure 2d.

Figure 2e.

Figure 2. Photographs of Bulk Sampling at LG&E Power Plants. A-Using long-arm track hoe to sample wet pond. B- Pond ash sample recovered with track hoe. C- Sampling decanted pond by shoveling. D- Sampling dry fly ash from silo. E-Truck located below dry ash silo.

Table 2. Summary of Fly Ash Sample Location, Identification, Size and LOI.

utility	plant	unit	row	bin	sample	MA#	%	%	%	%	Color	LOI %	LOI %	LOI
							-10 Micron	-5 Micron	<100M	>100M			<100 Mesh	>100 Mesh
LG&E	Mill Creek	2	1	10	92827	50440	35.14	20.53	97.94	2.06	Dk Brown	1.8%	1.48%	14.56%
	Mill Creek	2	2	8	92831	50444	32.45	17.31	98.32	1.68	Dk Brown	2.4%	1.83%	30.95%
	Mill Creek	3A	2	1	92832	50445	26.03	12.33	97.5	2.5	Black	3.4%	3.23%	18.61%
	Mill Creek	3A	3	1	92835	50448	38.26	23.87	94.1	5.9	Black	6.3%	5.79%	20.04%
	Mill Creek	4A	A	3	92844	50457	27.76	14.70	96.70	3.30	Black	3.9%	2.29%	49.70%
	Mill Creek	4A	B	3	92846	50459	37.27	23.96	98.0	2.0	Black	4.7%	4.28%	19.87%
	Mill Creek	4A	C	3	92847	50460	56.15	32.09	98.3	1.70	Dk Brown	6.5%	5.74%	32.13%
	Mill Creek	4A	D	3	92849	50462	25.97	14.77	98.6	1.4	Dk Brown	7.5%	7.03%	21.06%
LG&E	Trimble	1	1	A21	92855	50481	27.15	14.29	97.34	2.66	Dk Brown	1.1%	0.72%	12.68%
	Trimble	1	2		92856	50482	17.88	10.38	97.72	2.28	Dk Brown	1.9%	1.43%	21.49%
	Trimble	1	3		92857	50483	49.60	32.58	93.66	6.34	Brown	2.9%	2.40%	8.36%
	Trimble	1	4		92858	50484	47.93	33.92	85.65	14.35	Brown	4.4%	4.08%	2.09%
LG&E	Cane Run	4A	2	A5	92913	50601	9.35	16.71	97.37	2.63	Grey	6.7%	5.76%	35.74%
	Cane Run	5	2	5	92922	50602	17.59	31.93	96.98	3.02	Grey	5.5%	4.14%	46.60%
	Cane Run	5	2	6	92923	50617	25.92	14.32	86.98	13.02	Grey	4.6%	4.13%	43.26%
	Cane Run	5	2	7	92924	50618	23.78	16.89	84.72	15.28	Dk Grey	11.8%	9.87%	41.16%
	Cane Run	5	2	8	92925	50619	24.03	15.38	90.31	9.69	Dk Grey	16.0%	12.46%	56.12%
	Cane Run	6	1	9	92929	50621	24.89	41.45	98.76	1.27	Lt Grey	2.5%	2.19%	22.65%
	Cane Run	6	1	11	92930	50622	25.42	40.82	98.02	1.98	Lt Grey	3.5%	3.12%	36.15%
	Cane Run	6	2	3	92931	50603	15.29	21.55	95.87	4.13	Lt Grey	7.8%	6.33%	34.62%
WKE	Seebree	G1	1	BB3	93081	52143	25.33	13.30	89.19	10.81	Grey	23.3%	20.68%	45.2%
	Seebree	G1	2	BB2	93082	52144	16.25	10.80	97.16	2.84	Grey	33.2%	32.81%	51.6%
	Seebree	G1	3	AB3	93083	52145	57.0	47.88	99.04	0.96	Grey	35.15%	34.58%	56.24%
	Seebree	G1	4	AB1	93084	52146	30.81	20.46	96.20	3.80	Grey	24.7%	24.03%	41.1%
	Seebree	H1	1	H1-1	93087	52122	12.4	7.64	90.12	9.88	Grey	53.69%	51.07%	32.68%
	Seebree	H1	1	H1-11	93088	52148	13.6	8.31	89.98	10.02	Grey	55.37%	53.79	60.7
	Seebree	H2	2	H2-6	93089	52149	20.67	9.9	92.94	7.06	Grey	28.0	24.32	76.6
	Seebree	H2	2	H2-10	93090	52150	9.73	6.43	76.97	22.03	Grey	61.0	54.29	61.2
KU	Brown	1	2	1-1	92893	50519	20.39	12.96	96.93	3.07	Lt Black	12.0%	11.81%	6.19%
	Brown	2	2	2-11	92899	50523	47.91	31.75	96.17	3.83	Lt Tan	2.7%	2.57%	3.66%
	Brown	3	1	A25	92902	50524	26.39	14.13	97.42	2.58	Lt Brown	2.9%	2.18%	25.97%
	Brown	3	3	A13	92906	50528	47.32	32.69	80.75	19.25	Lt Tan	5.6%	4.89%	3.84%
	Brown	3	4	B10	92908	50530	61.62	43.13	78.8	21.2	Lt Tan	3.5%	3.21%	24.56%
WKE	Coleman	1	2	15	92939	50681	22.14	35.29	95.3	4.7	Lt Grey	9.1%	7.26%	38.72%
	Coleman	1	2	17	92940	50682	19.41	33.72	90.5	9.5	Lt Grey	4.7%	4.21%	38.98%
	Coleman	2	2	15	93029	51319	32.35	20.55	89.64	10.36	Dk Grey	15.7%	10.12%	53.96%
	Coleman	2	2	16	93030	51320	26.89	16.38	82.28	7.72	Dk Grey	17.4%	13.44%	36.56%
	Coleman	3	1	6	92943	50690	9.28	16.98	89.08	10.92	Lt Grey	6.7%	3.70%	27.47%
	Coleman	3	1	8	92944	50691	19.03	10.42	98.13	1.87	Lt Grey	4.3%	4.04%	41.12%
	Coleman	3	2	10	92945	50683	23.8	36.2	96.23	3.77	Lt Grey	6.0%	4.60%	36.07%
	Coleman	3	2	12	92946	50692	26.99	40.04	95.40	4.60	Lt Grey	7.3%	5.69%	421.18%

Table 3. Summary of Fly Ash Sample Proximate and Ultimate Analyses.

utility	plant	unit	row	bin	%VM	%FC	%C	%H	%N	%S	%O
LG&E	Mill Creek	2	1	10	1.81	<0.01	1.19	<0.01	<0.01	0.20	0.46
	Mill Creek	2	2	8	1.82	0.44	1.60	0.05	<0.01	0.20	0.61
	Mill Creek	3A	2	1	2.51	0.36	2.13	0.08	<0.01	0.22	0.82
	Mill Creek	3A	3	1	2.74	2.97	3.86	0.10	<0.01	0.39	1.76
	Mill Creek	4A	A	3			3.40	0.02	<0.01	0.25	0.45
	Mill Creek	4A	B	3			3.39	0.04	<0.01	0.27	0.48
	Mill Creek	4A	C	3			1.48	0.33	<0.01	1.16	2.12
	Mill Creek	4A	D	3			2.30	0.33	<0.01	1.10	2.30
LG&E	Trimble	1	1	A21			0.83	<0.01	<0.01	0.14	0.11
	Trimble	1	2		1.11	0.56	1.46	<0.01	<0.01	0.14	0.23
	Trimble	1	3				0.71	0.09	<0.01	0.56	1.51
	Trimble	1	4				1.07	0.16	<0.01	0.88	1.58
LG&E	Cane Run	4A	2	A5			5.60	0.02	0.05	0.44	2.42
	Cane Run	5	2	5			4.60	<0.01	0.06	0.47	0.82
	Cane Run	5	2	6	2.47	2.50	3.67	0.10	<0.01	0.34	1.42
	Cane Run	5	2	7	2.84	8.98	10.00	0.11	0.08	0.49	1.85
	Cane Run	5	2	8	3.92	11.92	14.34	0.15	0.14	0.53	1.49
	Cane Run	6	1	9	2.10	0.87	1.89	0.02	<0.01	0.29	1.15
	Cane Run	6	1	11	1.60	2.23	2.87	0.04	<0.01	0.22	1.01
	Cane Run	6	2	3			6.01	<0.01	0.04	0.62	1.29
WKE	Seebree	G1	1	BB3			22.85	0.13	0.19	0.39	0.86
	Seebree	G1	2	BB2			31.15	0.03	0.32	0.54	1.59
	Seebree	G1	3	AB3			13.19	0.14	0.14	1.66	4.57
	Seebree	G1	4	AB1			12.78	0.82	0.09	2.61	7.42
	Seebree	H1	1	H1-1	3.18	41.04	42.72	0.16	0.47	1.95	2.12
	Seebree	H1	1	H1-11			52.81	0.28	0.61	2.37	0.28
	Seebree	H2	2	H2-6			25.52	0.12	0.25	1.22	<0.01
	Seebree	H2	2	H2-10			57.09	0.10	0.56	2.52	0.42
KU	Brown	1	2	1-1			10.35	0.13	0.08	0.36	1.40
	Brown	2	2	2-11			1.60	0.05	<0.01	0.18	0.91
	Brown	3	1	A25			2.20	<0.01	<0.01	0.09	0.67
	Brown	3	3	A13			2.51	0.02	<0.01	0.71	1.98
	Brown	3	4	B10			2.38	0.05	<0.01	0.17	0.99
WKE	Coleman	1	2	15	2.16	6.55	7.46	0.01	0.05	0.08	1.59
	Coleman	1	2	17	1.81	2.53	3.65	0.03	0.01	0.12	0.86
	Coleman	2	2	15			14.23	0.08	0.14	0.22	1.02
	Coleman	2	2	16			16.19	0.13	0.12	0.24	0.72
	Coleman	3	1	6	1.53	4.96	6.05	0.04	0.05	0.08	0.59
	Coleman	3	1	8	1.57	2.78	3.76	0.02	<0.01	0.14	0.75
	Coleman	3	2	10	1.80	3.91	4.85	0.04	0.02	0.11	1.08
	Coleman	3	2	12	2.11	4.72	5.84	0.05	0.04	0.25	1.12

Table 4. Summary of Fly Ash Sample Major Oxide Analyses

utility	plant	unit	row	bin	%SiO2	%Al2O3	%Fe2O3	%CaO	%MgO	%Na2O	%K2O	%P2O5	%TiO2	%SO3
LG&E	Mill Creek	2	1	10	48.10	18.09	19.13	3.54	0.97	0.52	2.69	0.26	1.09	0.47
	Mill Creek	2	2	8	46.82	19.19	17.54	3.96	0.88	0.43	2.51	0.25	1.08	0.60
	Mill Creek	3A	2	1	48.59	19.94	18.03	3.79	0.96	0.63	2.64	0.30	1.09	0.67
	Mill Creek	3A	3	1	47.45	19.96	17.05	4.15	0.96	0.56	2.79	0.32	1.10	1.08
	Mill Creek	4A	A	3	46.10	18.60	19.29	3.33	0.91	0.53	2.63	0.23	1.04	0.36
	Mill Creek	4A	B	3	48.64	20.03	19.13	3.37	1.02	0.58	2.75	0.26	1.08	0.43
	Mill Creek	4A	C	3	46.92	20.28	18.06	3.52	1.03	0.68	3.00	0.42	1.14	1.73
	Mill Creek	4A	D	3	47.22	20.38	21.02	3.77	1.34	1.44	2.71	0.41	1.05	1.68
LG&E	Trimble	1	1	A21	46.57	19.27	23.09	2.69	0.69	0.52	2.11	0.38	1.14	0.29
	Trimble	1	2		47.10	20.73	22.68	3.25	0.74	0.46	2.07	0.29	1.11	0.28
	Trimble	1	3		49.40	22.57	17.94	3.09	0.82	0.60	2.43	0.54	1.19	0.86
	Trimble	1	4		43.39	19.39	21.17	3.30	0.84	0.62	2.40	0.56	1.15	1.17
LG&E	Cane Run	4A	2	A5	47.50	19.33	17.97	3.21	0.91	0.40	2.80	0.14	1.02	1.97
	Cane Run	5	2	5	48.17	20.30	17.97	2.70	0.96	0.40	2.91	0.12	1.01	1.00
	Cane Run	5	2	6	47.59	20.17	18.71	2.88	0.95	0.39	2.90	0.13	1.00	0.78
	Cane Run	5	2	7	48.25	20.48	18.95	3.11	0.99	0.41	2.94	0.13	1.02	0.92
	Cane Run	5	2	8	47.55	20.08	18.95	2.90	0.94	0.38	2.87	0.13	1.00	0.90
	Cane Run	6	1	9	49.19	20.20	16.25	3.10	0.98	0.46	3.01	0.15	1.05	0.48
	Cane Run	6	1	11	48.88	19.89	17.47	3.54	0.95	0.42	2.96	0.15	1.03	0.47
	Cane Run	6	2	3	47.49	19.06	18.87	3.81	0.90	0.37	2.71	0.15	0.96	0.94
WKE	Seebree	G1	1	BB3	49.17	19.97	17.17	2.75	0.95	0.45	2.67	0.16	1.18	1.24
	Seebree	G1	2	BB2	49.77	21.33	15.22	2.75	0.98	0.42	2.70	0.17	1.18	1.69
	Seebree	G1	3	AB3	46.99	22.38	13.66	2.64	1.12	0.50	2.94	0.28	1.26	1.44
	Seebree	G1	4	AB1	44.68	20.09	17.21	3.43	1.18	0.62	2.97	0.35	1.12	2.46
	Seebree	H1	1	H1-1	44.19	18.59	16.47	5.42	0.96	0.80	2.34	0.14	1.01	4.83
	Seebree	H1	1	H1-11	42.92	19.15	16.91	5.55	1.19	0.81	2.39	0.24	1.09	4.29
	Seebree	H2	2	H2-6	45.77	19.42	16.84	4.89	1.05	0.85	2.37	0.15	1.09	2.65
	Seebree	H2	2	H2-10	39.82	17.22	18.76	7.71	1.20	0.63	2.17	0.23	0.88	4.96
KU	Brown	1	2	1-1	51.88	24.21	13.07	1.17	0.93	0.18	2.57	0.20	1.59	0.12
	Brown	2	2	2-11	52.62	27.24	8.60	1.48	1.10	0.23	2.97	0.34	1.79	0.05
	Brown	3	1	A25	55.50	25.36	8.11	1.11	0.93	0.16	2.56	0.18	1.98	<0.01

WKE	Brown	3	3	A13	50.67	26.96	10.88	1.38	0.99	0.22	2.70	0.40	1.62	0.52
	Brown	3	4	B10	5.60	2.55	76.57	1.45	0.09	0.05	0.45	0.08	0.24	1.37
	Coleman	1	2	15	52.26	26.81	9.38	1.25	0.92	0.23	2.68	0.14	1.64	0.10
	Coleman	1	2	17	52.79	26.32	9.89	1.21	0.89	0.21	2.65	0.13	1.63	0.21
	Coleman	2	2	15	47.95	26.18	14.15	1.73	0.81	0.19	2.28	0.24	1.51	0.31
	Coleman	2	2	16	48.02	25.82	15.09	1.93	0.79	0.19	2.21	0.23	1.48	0.39
	Coleman	3	1	6	53.65	25.83	9.15	1.34	0.78	0.18	2.42	0.11	1.67	0.27
	Coleman	3	1	8	54.61	25.84	9.10	1.19	0.78	0.18	2.40	0.10	1.67	0.34
	Coleman	3	2	10	52.18	26.44	9.56	1.35	0.92	0.23	2.60	0.13	1.56	0.24
	Coleman	3	2	12	52.06	26.23	9.99	1.46	0.90	0.23	2.66	0.14	1.58	0.39
Average					49.68	23.18	15.45	2.39	0.90	0.48	2.58	0.24	1.35	0.54

Table 5. Summary of Fly Ash Sample Trace Element Analyses

utility	plant	unit	row	bin	V	Cr	Mn	Co	Ni	Cu	Zn	As	Rb	Sr	Zr	Mo	Cd	Sb	Ba	Pb
LG&E	Mill Creek	2	1	10	330	96	368	51	87	74	372	91	81	278	167	37	20	10	797	55
	Mill Creek	2	2	8	222	96	387	50	90	75	225	153	104	243	174	18	30	10	667	68
	Mill Creek	3A	2	1	306	81	301	50	44	70	280	64	142	243	170	30	20	10	706	51
	Mill Creek	3A	3	1	385	95	384	47	86	94	409	153	40	303	179	62	10	10	764	67
	Mill Creek	4A	A	3	369	80	291	50	59	68	278	76	14	280	165	39	30	10	891	55
	Mill Creek	4A	B	3	386	80	298	51	40	69	351	103	64	270	161	49	20	10	908	57
	Mill Creek	4A	C	3	500	95	411	51	103	115	633	227	<10	254	174	92	10	10	1354	80
	Mill Creek	4A	D	3	364	61	318	55	16	88	555	142	4	308	147	57	20	10	1035	67
LG&E	Trimble	1	1	A21	135	78	266	58	14	60	90	56	<10	667	181	<10	20	10	687	53
	Trimble	1	2		140	58	230	563	<10	51	77	34	<10	546	183	<10	20	10	624	48
	Trimble	1	3		185	73	288	47	20	86	162	259	<10	729	212	23	10	10	733	81
	Trimble	1	4		239	62	347	55	<10	102	197	285	<10	615	186	37	20	10	717	87
LG&E	Cane Run	4A	2	A5	255	77	283	50	91	166	301	58	<10	217	148	34	20	10	529	51
	Cane Run	5	2	5	245	61	198	49	37	168	285	66	<10	223	144	33	10	10	496	50
	Cane Run	5	2	6	242	79	257	50	80	159	276	59	<10	221	142	35	20	10	499!	52
	Cane Run	5	2	7	248	62	220	52	38	167	287	65	<10	223	141	35	20	10	502	53
	Cane Run	5	2	8	254	79	256	52	95	164	270	59	<10	220	141	37	20	10	487	53
	Cane Run	6	1	9	265	61	230	45	32	155	360	76	<10	229	164	47	10	10	547	52
	Cane Run	6	1	11	263	77	294	48	72	143	311	63	<10	235	167	50	10	10	548	51
	Cane Run	6	2	3	235	77	314	50	60	119	233	29	20	202	139	24	20	10	528	47
WKE	Seebree	G1	1	BB3	4710	78	285	50	591	80	207	66	<10	376	195	97	10	10	1267	51
	Seebree	G1	2	BB2	5071	70	263	46	655	85	205	81	17	356	187	95	20	<10	1321	52
	Seebree	G1	3	AB3	5200	79	312	47	686	132	402	292	<10	449	196	166	<10	<10	2024	84
	Seebree	G1	4	AB1	4479	71	391	50	557	98	508	262	25	267	154	144	20	10	1803	83
	Seebree	H1	1	H1-1	2403	65	335	49	403	64	182	28	<10	193	191	58	20	10	850	45
	Seebree	H1	1	H1-11	3129	70	419	53	561	80	242	56	45	289	177	66	20	10	1175	50
	Seebree	H2	2	H2-6	2324	79	378	51	417	66	185	25	62	226	190	50	20	10	904	44
	Seebree	H2	2	H2-10	2947	71	506	55	488	64	148	19	29	245	147	47	30	10	1107	47
KU	Brown	1	2	1-1	212	60	139	46	24	152	75	115	<10	805	279	20	<10	<10	1555	52
	Brown	2	2	2-11	264	59	137	42	49	252	159	280	<10	1131	329	38	10	10	1445	78
	Brown	3	1	A25	205	76	161	32	61	159	67	68	<10	956	367	22	<10	<10	1401	38
	Brown	3	3	A13	297	78	209	50	91	237	176	421	<10	1122	295	46	<10	<10	1514	101
	Brown	3	4	B10	<10	86	344	166	14	25	45	336	<10	41	<10	<10	8	3	99	116
WKE	Coleman	1	2	15	236	61	140	47	80	181	148	240	20	566	278	33	<10	<10	995	67
	Coleman	1	2	17	236	77	191	46	96	174	128	203	<10	548	286	29	<10	<10	956	64
	Coleman	2	2	15	239	80	185	54	85	151	113	194	33	802	236	14	10	10	1469	66
	Coleman	2	2	16	226	62	133	55	34	141	106	177	<10	814	239	13	10	<10	1473	66
	Coleman	3	1	6	194	80	175	37	69	136	75	91	47	578	307	17	<10	<10	971	41
	Coleman	3	1	8	175	60	114	37	34	122	74	79	33	532	309	16	<10	<10	921	40
	Coleman	3	2	10	218	65	173	44	55	160	124	133	125	491	253	18	10	<10	901	51
	Coleman	3	2	12	226	81	223	47	95	172	132	159	10	551	267	27	<10	<10	1011	57
Average					940	74	272	64	151	120	231	133	22	435	199	43	13	7	943	60

Subtask 1.3 Evaluation of Dispersion Parameters

Status: Evaluation of Flotation Parameters essentially completed.
Evaluation of Dispersion Parameters in progress.

The objective of this subtask is to assess the amenability of candidate substrates to carbon removal by froth flotation. Once carbon is reduced to desirable levels, dispersion parameters will be evaluated in order to recover a high proportion of ultra-fine particles.

Froth flotation evaluation was determined using a Denver Model D5 Batch Flotation Machine. A 10% wt. solids slurry was prepared by mixing ash and tap water in a 2 liter rectangular flotation cell, which was mounted on the flotation machine and agitated at 1200 rpm in the absence of air. The collector used (SPP) was a mixture of #2 fuel oil and an oil-soluble petroleum sulfonate while the frother was a glycol-based commercial product. The appropriate dosages of each reagent were added to the flotation cell, air was introduced and the resulting froth product was recovered by hand scraping until the froth was exhausted. Additional reagents were added and an additional froth product was recovered. This was repeated until no additional carbon was recovered from the slurry. All of the flotation products were separately filtered, dried, weighed and analyzed for LOI using ASTM procedures. Results were calculated to determine the grade and yield of the non-floated fraction after each flotation stage and presented as cumulative tailings grade as shown in Figure 3.

The results for Trimble Unit 1, row 1 indicate that the feed contained only 1% LOI. After the first flotation stage, the grade was reduced to 0.33% LOI with a yield of 91%. The second flotation stage lowered the LOI to 0.11% LOI with a yield of 81% and after the final flotation stage, the grade of the non-floated fraction was 0.03% LOI with a yield of 71%. For the row 2 sample, the feed grade was 4.5% LOI which was reduced to 0.06% LOI after 3 stages of flotation with a yield of 73%. The LOI was not reduced to these low levels with the samples from rows 3 and 4. These results are considered excellent with respect to carbon reduction as well as yield, particularly when considering that approximately 96% of the ash recovered in Unit 1 is contained in rows 1 and 2. While these results were obtained by employing several stages of flotation and starvation reagent dosages, the pilot plant will utilize a single flotation stage and proper reagent utilization should provide similar results.

Results for ash from other generating stations are shown in Figures 4 to 8. For the Cane Run samples, the LOI for the ash samples obtained from the first row of ESP hoppers was reduced to 1% LOI, however the yield was only 28%. Ash from the second row was only reduced to 2% LOI. For the samples obtained from EW Brown, flotation reduced the LOI to below 1% for ash from the first and fourth row while ash from the second row was only reduced from 4% to 3.5% LOI. The samples from Coleman, despite having a relatively high LOI of 6 to 9%, were reduced to less than 1% LOI for samples from both Units 1 and 2. The yields for results with these samples ranged from 20 to 65%. Mill Creek Unit 2 ash sample from row 2 was reduced to below 1% LOI with a yield of 62% while ash from row 1 was only reduced to below 2% LOI. The poorest flotation results were obtained with ash from Henderson Unit 2. Ash from rows 1 and 2 contained 29% and 60% LOI, respectively. These very high LOI concentrations are due to the presence of uncombusted or partially combusted petroleum coke, which is used as part of the

fuel mix at this station. The high surface area of petroleum coke adsorbs significant amounts of flotation reagents and can make flotation separations expensive and inefficient, or both. In this case, the LOI of the ash was only reduced to 6% LOI with yields of only 25%.

In summary, flotation was effective for reducing the LOI of some ash samples to very low levels (<0.5% LOI) with very high yields (>70%). The level of carbon reduction achieved by flotation varied with each unit sampled, as well as within the rows of each unit. The best results, in terms of LOI reduction and yield) were obtained with samples from Trimble, EW Brown and Coleman and Mill Creek. Flotation was not as effective for the Cane Run sample while results obtained with the Henderson sample were very poor, which is attributed to a high proportion of petroleum coke in the fly ash.

Figure 3. Results of Flotation Evaluation for Trimble Unit 1 Ash.

Figure 4. Results of Flotation Evaluation for Cane Run Unit 6 Ash.

Figure 5. Results of Flotation Evaluation for E.W. Brown Unit 3 Ash.

Figure 6. Results of Flotation Evaluation for Coleman Units 1 and 2 Ash.

Figure 7. Results of Flotation Evaluation for Mill Creek Unit 2 Ash.

Figure 8. Results of Flotation Evaluation for Henderson Unit 2 Ash.

Bulk samples of dry ash as well as pond ash were also obtained from each power station. The purpose of this sampling effort was to obtain sufficient sample to conduct dispersion testing and determine differences in dispersion behavior between dry ash and ash that had been stored in a pond. Dry ash samples (500 to 1000 lbs from each plant) were collected from ash silos where available. If the power station did not have an ash silo available, the bulk composite sample was retrieved by taking samples from the individual hoppers. Pond ash samples were also collected from each site. The pond ash samples (1000 lbs each) were collected from the portion of each pond enriched in fine ash by examining the flow regime of the slurry through the pond. In general, fine ash accumulates distal to the point where the slurry enters the pond. Pond ash samples were collected as far from the feed end of the slurry as feasible.

A representative portion of each dry and pond ash slurry was subjected to a flotation release analysis (as described previously), in order to assess the effectiveness of using froth flotation to reduce carbon to as low a level as feasible. Prior to conducting the release analysis, each sample was screened to remove the +100mesh (150 μ m) material was removed in order to simulate the hydraulic classification that will be utilized in the process flowsheet.

The results obtained with the samples from the Trimble County station are shown in Figure 9. The dry ash contained 0.65% LOI, which was reduced to 0.22% LOI with a yield of 98%. Additional flotation stages reduced the LOI to 0.1%, at a lower yield of 84%. The pond ash sample contained 1.7% LOI which was reduced to 0.8% LOI with a yield of 80%.

Figure 9. Flotation Release Analyses of Trimble County Dry and Pond Ash Samples.

Results for E.W. Brown are shown in Figure 10. Both the dry ash and pond ash responded similarly to flotation. The dry ash contained 1.75% LOI, which was reduced to 0.9% LOI with a yield of 90%. No further LOI reduction was achieved with additional flotation stages. The pond ash contained 3.5% LOI which was reduced to 0.5% LOI with a yield of 83% and further reduced to 0.2% LOI with a yield of 70%.

Figure 10. Flotation Release Analyses of E.W. Brown Dry and Pond Ash Samples.

As with the E.W. Brown ash, Coleman dry and pond ash responded similarly to flotation (Figure 11). The dry ash contained 2.2% LOI which was reduced to 0.2% LOI with a yield of 80%. The pond ash, despite having a higher feed grade of 6.5% LOI was reduced to the same LOI (0.2%) with the same yield (80%). Results with Mill Creek ash were quite different (Figure 12). The dry ash contained only 1.8% LOI, which was only reduced marginally by as many as 5 stages of flotation. The Mill Creek pond ash contained 7.9 % LOI, which was reduced to only 6.1% LOI with a yield of 55%. It is noteworthy that both the Mill Creek dry and pond ashes behaved similarly despite the differences in feed grade and flotation has little effect on LOI reduction. No explanation is offered for this behavior at the present time, but it will be addressed in the next report.

A bulk sample of the Cane Run ash will be collected and evaluated with froth flotation in the next quarter. At Cane Run, fly ash is combined with scrubber sludge to produce poz-o-tech rather than using pond disposal. Hence, no pond ash is available for sampling since poz-o-tech is a chemical reaction between the two components that cannot be separated by flotation.

Figure 11. Flotation Release Analyses of Coleman Dry and Pond Ash Samples.

Figure 12. Flotation Release Analyses of Mill Creek Dry and Pond Ash Samples.

Task 2 - Filler and Superpozzolan Testing

No activity

Task 3 - Finalization of Flowsheet Design

No Activity

Task 4 - Construction of PDU Facility

While no specific activity pertaining to the construction of the PDU facility was carried out during this reporting period, the area of the CAER facility that will eventually house the PDU facility was renovated. All equipment contained on the existing support structure was removed along with all electrical and instrumentation wiring in order to prepare for construction of the PDU. The entire area was thoroughly cleaned and painted and new lighting was installed.

Task 5 - Operation of PDU-No Activity

Conclusion

Characterization of the fly ash samples collected at the 6 power stations confirms that there is a substantial amount of ultrafine particles present to warrant concentration for eventual use as fillers or superpozzolan. In general, the concentration of ultrafines increases in the latter stages of particulate collection. Chemical characterization of the ashes indicated no unusual compositions with respect to major oxides or trace elements. The one exception was the fly ash at Seebree, which contained 2000 to 5200 ppm vanadium, attributed to the large quantities of petroleum coke used at this power station.

Froth flotation has been demonstrated to be effective for reducing the un-burned carbon to acceptably low levels (i.e. <0.5% LOI) for most, but not all of the substrates tested. The flotation results from Cane Run samples showed that flotation could only reduce carbon to as low as 1.0 to 2.0% LOI. The samples from Seebree contained prohibitively high levels of petroleum coke and it is not feasible to use flotation to remove carbon. Flotation results from bulk samples that were evaluated were consistent with the smaller sampling of rows within the individual units. No bulk samples were obtained from Seebree because of the high petroleum coke concentration and bulk samples from Cane Run will be collected and discussed in the next report.

Dispersion testing on candidate substrates is in progress and results will be included in the next status report. A reproducible, batch-scale dispersion test has been developed and is in use to determine adsorption and dispersion properties of ultra-fine ash particles while a pilot-scale continuous classifier has been designed, constructed and is also being tested. Evaluations of process modeling software are also in progress.