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INTRODUCTION

This project is divided into four tasks. The Management Plan was developed in Task 1. Task 2, Evaluation of Mechanisms in FGD Sorbent and Ash Interactions, focuses on the characteristics of binary mixtures of these distinct powders. Task 3, Evaluation of Mechanisms in Conditioning Agents and Ash, is designed to examine the effects of various conditioning agents on fine ash particles to determine the mechanisms by which these agents alter the physical properties of the ash. Tasks 2 and 3 began with an extensive literature search and the assembly of existing theories. This phase of the project is now complete. During the past quarter samples were assembled and initial experiments were planned. Laboratory analyses have begun and will continue through the next several quarters. Pilot-scale evaluations will follow these laboratory investigations. The results of the laboratory and pilot-scale work performed under tasks 2 and 3 will be included in a Flue Gas Conditioning Model that will be issued under task 4. The Final Report for the project will also be prepared under task 4.

Summary of Experiments and Planned Analyses

Each of the two tasks (Task 2 and Task 3) active during this period includes several groups of experiments. Each group of experiments has been given a title and a corresponding number. For example, E 2.1 represents the first group of experiments to be performed under Task 2. The literature reviews reported in Topical Reports 1 and 2 emphasized the roles adsorbed water can have in controlling the bulk properties of powders. The series of experiments which we are currently performing are directed at defining the extent to which water affects key properties of sorbent and ash particles. The following table specifies the tests that are being performed under each set of laboratory experiments.

Table 1
Initial Experiments

#	EXPERIMENT TITLE
E 2.1	Standard Characterization of Mixtures of Sorbents and Ashes
E 2.2	Characterization of Water Adsorption by Mixtures of Sorbents and Ashes
E 2.3	Characterization of Water-Conditioned Sorbent and Ash Mixtures
E 3.1	Standard Characterization of Powders and Ash Samples
E 3.2	Characterization of Water Adsorption by Powders and Fly Ashes
E 3.3	Characterization of Water-Conditioned Powders
E 3.4	Solvent Leaching Studies of Fly Ashes

Table 2 presents a summary of the variety of analyses that are being performed under each of the experiments listed in Table 1.

Table 2
Summary of Planned Analyses

ANALYTICAL METHOD	EXPERIMENT #						
	2.1	2.2	2.3	3.1	3.2	3.3	3.4
volumetric size distribution (Coulter Counter)				X			
aerodynamic size distribution (Shimadzu)	X			X			
compacted bulk porosity	X			X			X
uncompacted bulk porosity	X		X	X		X	X
specific surface area (BET analyzer)	X			X			X
tensile strength (electrostatic tensiometer)	X		X	X		X	X
scanning electron micrographs	X			X			X
drag-equivalent diameter			X	X		X	X
relative gas flow resistance			X	X		X	X
thermogravimetric analysis		X			X		
water content (Karl Fischer titrator)		X			X		X
water adsorption isotherms (25°C)		X			X		X
solvent leaching / chemical analyses of leachates							X
mineral analyses, soluble surface equilibrium pH				X			X
electrical resistivity	X		X	X		X	X
true particle density (pycnometer)	X			X			

Selection and Acquisition of Mixtures of Sorbents and Ashes for Analysis

The samples selected for analyses under Task 2 were chosen because of their characteristics and unusual operating histories. We have identified those sorbents that should represent the extremes of important physical characteristics (size and surface area) and sorbent injection applications that are widely used or have a high potential for wide application. Among the samples from low-temperature sorbent injection applications, the primary characteristics that we expect will determine the ease of final particle collection are particle size, degree of agglomeration, amount and distribution of surface area, and special chemical additives. We have obtained samples from three types of tests performed at the DOE Duct Injection Test Facility (DITF) at the Muskingum Plant of Ohio Edison in Beverly, OH. Sorbent and ash mixtures from $\text{Ca}(\text{OH})_2$ slurry injection tests, injection tests of dry $\text{Ca}(\text{OH})_2$ (coplanar with water spray), and $\text{Ca}(\text{OH})_2$ slurry injection tests performed with CaCl_2 additive were obtained from the stockpile of samples generated under Contract DE-AC22-88PC88851. These samples from the DITF have well documented operating histories. According to data obtained at the DITF, the slurry injection samples should be highly agglomerated in comparison to the dry injection samples. As would be expected with the addition of a deliquescent salt, addition of

CaCl_2 to the slurry injected at the DITF apparently caused a high potential for water adsorption. Gas phase utilization of the sorbent increased as increasing amounts of CaCl_2 were added to the slurry. (Similar results have been observed in other tests of CaCl_2 addition.) We believe the CaCl_2 increases the partial pressure of water around the sorbent particle, thereby promoting SO_2 capture. In addition to these three types of sorbent and ash mixtures, we obtained and are analyzing a sample of base line fly ash collected from the ESP hoppers at the Muskingum Plant.

For each of the four samples, a composite sample was mixed from samples taken from the hoppers on the inlet, middle and outlet fields of the ESP using the following ratio: 100 parts inlet, 10 parts middle, and 1 part outlet. These composite samples were then combined with all available recycle ash obtained concurrently. (Recycle ash is already a composite ESP hopper ash since it is taken from the ash disposal system fed by all the ESP hoppers.) The samples combined to form the sorbent and ash mixture from the tests of dry $\text{Ca}(\text{OH})_2$ injection were obtained at the DITF between June 18 and June 21, 1991. The samples combined to form the sorbent and ash mixture from the tests of $\text{Ca}(\text{OH})_2$ slurry injection were obtained at the DITF between November 7 and November 15, 1991. During this period of operation the Ca/S ratio was approximately 2.6:1. Tests run at the DITF between February 19 and February 26, 1992 were used as the sources of samples from $\text{Ca}(\text{OH})_2$ slurry injection tests performed with CaCl_2 additive. Between 2.6 and 3.6 wt % CaCl_2 was added during these tests. The base line ash was mixed from ESP hopper ash samples obtained during February 1990 and March 1992.

We also will include the particulate product of a conventional spray dryer application in E 2.1. The EPRI High Sulfur Test Center (HSTC) at Plant Kintigh in Somerset, NY is the source for this sample, which should have a larger median particle size than the dry duct injection sample from the DITF. A sample of base line ash will also be obtained from Plant Kintigh for comparison with this spray dryer ash. A sample of ash and sorbent mixture from the application of ADVACATE (an advanced sorbent material prepared by reacting lime with fly ash) has also been selected for analysis under E 2.1. Because of the relatively high surface area of ADVACATE sorbent material, samples from this process may be significantly compromised over time. Therefore we feel it will be best to obtain relatively fresh samples from the ADVACATE process from an upcoming project at TVA's Shawnee Plant. As with the other sorbent and ash mixtures, a base line ash will also be obtained from Shawnee.

In high-temperature sorbent injection applications the problems encountered with particle collection in ESP's result primarily from increased resistivity and mass loading (especially in the finer particle sizes). The increased surface areas and mass loadings from this process would be expected to increase filtering pressure drop in fabric filters. The furnace injection of hydrated lime has generated higher SO_2 removal levels than the injection of limestone. We have recently obtained a sample of ash from tests of furnace injection of $\text{Ca}(\text{OH})_2$ performed

at Ohio Edison's Edgewater facility. Lignosulfonate-modified sorbent has also shown promise due to its ability to generate small sorbent particles with high surface areas. We are also trying to locate a sufficiently large sample of ash collected from tests of lignosulfonate-modified sorbent injection, although a source of this ash has not yet been found.

Selection and Acquisition of Fly Ash Samples for Analysis

We have selected for analysis under Task 3 dust cake ashes from Texas Utilities' Monticello Station, Gulf Power Company's Plant Scholz, Southwestern Public Services Company's Harrington Station, and the 20 MW Atmospheric Fluidized-Bed Combustion (AFBC) pilot facility that was located at TVA's Shawnee Generating Station. The first three pulverized-coal ash samples represent a variety of coal types, particle morphologies, and ash chemistries. The dust cake ash from Harrington may provide some interesting results because, being ash from a Powder River Basin coal, it has a very high calcium content (29% by weight). Ashes from Powder River Basin coals have the highest calcium contents and the highest relative gas flow resistances of a / pulverized coal ashes with which we are familiar. The AFBC ash differs quite a bit from the other three dust cake ashes because of the method of combustion and its high calcium content.

In addition to the four dust cake ashes mentioned above, a variety of powders will also be used in Task 3 analyses. These powders and their characteristics will be discussed in a later quarterly report. Table 3 presents a summary of all the samples we have obtained or plan to obtain for analysis.

Table 3
Overall List of Samples

ID #	DESCRIPTION/SOURCE	in hand?
2870	Muskingum baseline ESP hopper ash; 2 pints	yes
2871	dry injection of $\text{Ca}(\text{OH})_2$ coplanar with water spray; (DITF; 7 pints)	yes
2872	injection of $\text{Ca}(\text{OH})_2$ slurry; (DITF; .5 pints);	yes
2873	injection of $\text{Ca}(\text{OH})_2$ slurry with CaCl_2 additive; (DITF; 3 pints);	yes
	Kintigh base line ESP hopper ash	on way
	conventional spray dryer; (High Sulfur Test Center)	on way
	Shawnee Unit 9 base line ESP hopper ash	
	ADVACATE, (upcoming project at TVA's Shawnee Plant)	
	Edgewater base line ESP hopper ash	
2883	furnace injection of $\text{Ca}(\text{OH})_2$; (Edgewater; 10 gal)	yes
	furnace injection of lignosulfonate-modified $\text{Ca}(\text{OH})_2$; (Edgewater)	
2029	Monticello dust cake ash; 1 pint	yes

Table 3 (continued)

ID #	DESCRIPTION/SOURCE	in hand?
2101	Scholz dust cake ash; 3 gal	yes
1994	TVA 20 MW AFBC dust cake ash; 3 pints	yes
2515	Harrington dust cake ash; 3 pints	yes
2029-W	leached Monticello dust cake ash; 50 g	yes
2101-W	leached Scholz dust cake ash; 50 g	yes
1994-W	leached TVA 20 MW AFBC dust cake ash; 50 g	yes
2515-W	leached Harrington dust cake ash; 50 g	yes
1856	glass beads; 1 gal	yes
3063	silicon dioxide (Cabosil L-90), 2 qt	yes
3064	silicon dioxide (Cabosil M-5), 2 qt	yes
3065	silicon dioxide (Cabosil EH-5), 15 gal	yes
3238	aluminosilicate (Neutralite), 15 gal	yes
2769	silicon dioxide (Kenite 900), 1 gal	yes
2874	alumina powder, 45 μ m median diameter; 1000 g	yes

ANALYSES OF MIXTURES OF SORBENTS AND ASHES

SEM pictures of the three mixtures of sorbent and ash from the DITF and the base line ESP hopper ash from Muskingum are shown in Figures 1 through 4. The effects of sorbent addition on particle morphology are evident in Figures 2 through 4 by the presence of irregularly shaped particles and deposits on the surfaces of the spherical fly ash particles. In contrast, the base line ash particles (Figure 1) have the characteristic relatively smooth, spherical morphology normally associated with pulverized-coal (PC) fly ashes.

Resistivity determinations made on these four ashes in ascending and descending temperature modes. These data are shown in Figures 5 and 6. Sorbent injection processes performed at the DITF lowered the duct temperature to around 165° F from about 350° F for base line operation. Consequently, during collection in the ESP, the particulate matter from the sorbent injection processes had a significantly lower resistivity (approximately $4 \times 10^7 \Omega \cdot \text{cm}$) than the base line ash (approximately $3 \times 10^{11} \Omega \cdot \text{cm}$ at 350° F).

Specific surface areas and true particle densities have been measured for the four samples obtained from the DOE/PETC Duct Injection Test Facility. These data are summarized in Table 4. The primary difference indicated by these initial analyses of these four samples is the significant increase in specific surface area due to sorbent addition. The specific surface areas of the three sorbent and ash mixtures from the DITF are quite similar.

a

b

c

d

Figure 1. SEM photographs of Muskingum ESP hopper ash taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

a

b

c

d

Figure 2. SEM photographs of a mixture of sorbent and ash from tests of dry sorbent injection at the DITF taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

a

b

c

d

Figure 3. SEM photographs of a mixture of sorbent and ash from tests of slurry/recycle injection at the DITF taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X

a

b

c

d

Figure 4. SEM photographs of a mixture of sorbent and ash from tests of slurry/recycle injection with CaCl_2 addition at the DITF taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

Figure 5. Data obtained from ascending temperature resistivity determinations of the Muskingum ESP hopper ash (2870), a mixture of sorbent and ash from tests of dry sorbent injection at the DITF (2871), a mixture of sorbent and ash from tests of slurry/recycle injection at the DITF (2872), and a mixture of sorbent and ash from tests of slurry/recycle injection with CaCl₂ addition at the DITF (2873).

Figure 6. Data obtained from descending temperature resistivity determinations of the Muskingum ESP hopper ash (2870), a mixture of sorbent and ash from tests of dry sorbent injection at the DITF (2871), a mixture of sorbent and ash from tests of slurry/recycle injection at the DITF (2872), and a mixture of sorbent and ash from tests of slurry/recycle injection with CaCl₂ addition at the DITF (2873).

Table 4
Measured Physical Characteristics of DITF Samples

sample	true particle density, g/cm ³	specific surface area, m ² /g
base line fly ash	2.56	0.62
sorbent/ash mixture from tests of dry sorbent injection	2.47	5.2
sorbent/ash mixture from tests of slurry/recycle injection	2.52	7.5
sorbent/ash mixture from tests of slurry/recycle injection with CaCl ₂ addition	2.51	6.0

ANALYSES OF DUST CAKE ASHES

Chemical Characteristics

Table 5 presents the results of chemical analyses of the four dust cake ashes selected for Task 3 studies.

Table 5
Chemical Characteristics of Dust Cake Ashes, % wt.*

Source	Scholz	Monticello	Harrington	AFBC
Sample ID	2101	2029	2515	1994
Li ₂ O	0.02	0.02	0.02	0.02
Na ₂ O	0.82	0.45	1.3	0.35
K ₂ O	3.3	0.98	0.34	1.4
MgO	0.99	2.3	6.2	0.81
CaO	3.4	10.2	29.3	29.7
Fe ₂ O ₃	19.9	3.5	5.5	14.4
Al ₂ O ₃	19.2	20.3	18.8	11.0
SiO ₂	50.1	60.4	31.7	23.6
TiO ₂	1.0	1.6	1.3	0.54
P ₂ O ₅	0.21	0.08	1.4	0.14
SO ₃	1.00	0.53	2.5	17.4
Loss on ignition (LOI)	11.8	0.37	0.24	12.7
soluble SO ₄ ⁼	3.8	0.50	3.3	18.4
Equilibrium pH	4.8	9.9	11.2	11.5

* Equilibrium pH is a dimensionless quantity

Each of these ashes has a distinct chemical composition. The key differences are highlighted in Table 6. The Scholz dust cake ash, generated from the combustion of high-sulfur coal, has a high LOI value due primarily to the presence of a relatively large proportion of unburned char particles. The SO_3 and $\text{SO}_4^{=}$ also contribute to the high LOI of the Scholz ash. The Harrington dust cake ash is more alkaline than the Monticello ash, with even higher concentrations of calcium. Like the Monticello ash, the LOI of the Harrington ash is very low. Although Powder River Basin coal contains relatively low levels of sulfur, the dust cake ash from Harrington contains more soluble $\text{SO}_4^{=}$ than the Monticello ash and almost as much as the Scholz ash. This is due to the ability of the high concentration of alkali in the Harrington ash to react with essentially all the available SO_2 in the flue gas. The high alkalinity and the high calcium content of the AFBC ash are due to the addition of limestone to the furnace prior to combustion. The high LOI of this ash is due to the large amount of SO_2 that has reacted with the sorbent during combustion. The high sulfur content of this ash is also evident in its high levels of SO_3 and soluble $\text{SO}_4^{=}$.

Table 6
Chemical Differences Between the Dust Cake Ashes

Dust Cake Ash	acid/alkali	Ca concentration	SO_3 , soluble $\text{SO}_4^{=}$	LOI
Scholz	acid	low	medium	high
Monticello	alkali	high	low	low
Harrington	alkali	high	medium	low
AFBC	alkali	high	high	high

Physical Characteristics

Table 7 presents the results of physical analyses describing the four dust cake ashes. In addition to these data, Figures 7 through 10 show SEM photographs of these dust cake ash particles. Figures 11 through 13 present the aerodynamic size distributions measured for three of these ashes.

a

b

c

d

Figure 7. SEM photographs of Scholz dust cake ash taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

a

b

c

d

Figure 8. SEM photographs of Monticello dust cake ash taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

a

b

c

d

Figure 9. SEM photographs of Harrington dust cake ash taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

a

b

c

d

Figure 10. SEM photographs of AFBC dust cake ash taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

Figure 11. Aerodynamic size distribution of the Scholz dust cake ash.

Figure 12. Aerodynamic size distribution of the Monticello dust cake ash.

Figure 13. Aerodynamic size distribution of the AFBC dust cake ash.

Table 7
Physical Characteristics of Dust Cake Ashes

Source	Scholz	Monticello	Harrington	AFBC
Sample ID	2101	2029	2515	1994
aerodynamic MMD, μm (Bahco Classifier)	9.4	7.5	10.0	3.2
aerodynamic MMD, μm (Shimadzu)	8.9	4.6	--	2.7
volumetric MMD, μm (Coulter Counter)	7.5	5.8	6.6	4.3
specific surface area, m^2/g	3.00	0.9	1.5	20.9
morphology factor	9.3	2.5	4.1	44
uncompacted bulk porosity, % (7% RH)	76.6	64.2	74.3	89.8
compacted bulk porosity, %	55.4	38.5	39.1	69.2
drag-equivalent diameter, μm	2.56	3.54	2.34	0.69
relative gas flow resistance, in. $\text{H}_2\text{O} \cdot \text{min} \cdot \text{ft}/\text{lb}$	3.5	7.9	14	13
true particle density, g/cm^3	2.44	2.47	2.66	2.65
effective angle of internal friction, deg.	44.5	39.5	45.0	47.5
tensile strength, Nt/m^2 (35% RH)	3.6	13	--	> 9.0

These four ashes differ in size, morphology, and cohesivity. Because of the recycle cyclone that was part of the process stream at the 20 MW AFBC, the AFBC ash has the finest size distribution of the four ashes. The relatively low combustion temperatures of the AFBC account for the irregular shapes and the high surface area of the AFBC ash particles.

Particle shape is a primary determinant of ash cohesivity. One way to characterize the shape of particles is by their specific surface area. High specific surface area indicates some combination of very small particle size, rough particle surfaces, or irregular (non-spherical) particle shapes. We have also observed many ashes with the SEM to obtain a qualitative idea of the shapes of the ash particles. Ash cohesivity is reflected in the value of the effective angle of internal friction (measured by the ring shear device), tensile strength (measured with the electrostatic tensiometer), and the uncompacted and compacted bulk porosity values. In prior studies we have noted a positive correlation between irregular particle shape and increasing ash cohesivity. This correlation can be seen for the four dust cake ashes by comparing the measured specific surface areas and appearances of the ash particles in Figures 7 through 10 with the bulk porosity values. Increased ash cohesivity is associated with irregular particle shapes and relatively high bulk porosity values.

Adsorption Isotherms

During the past quarter water adsorption isotherms have been measured for the Harrington and AFBC dust cake ashes. These data are shown in Figures 14 and 15. The most striking

Figure 14. Water adsorption isotherm measured for the Harrington dust cake ash.

Figure 15. Water adsorption isotherm measured for the AFBC dust cake ash.

difference in these two sets of data is the very large difference (about two orders of magnitude) in the amount of water adsorbed at a given partial pressure of water. We believe that differences in specific surface area and ash chemistry combine to cause the different adsorption properties of these ashes. In addition to its higher specific surface area (more sites for adsorption), the AFBC ash particles may also absorb water once it has been deposited on the particle surface. The likely explanations for differences in adsorption should become clearer as more isotherms are measured. Adsorption isotherms will be performed soon on the three mixtures of sorbent and ash from the DOE/PETC Duct Injection Test Facility.

UNCOMPACTED BULK POROSITY OF WATER-CONDITIONED ASHES

Table 8 summarizes the results of uncompact bulk porosity measurements at various relative humidity levels for the four dust cake ashes selected for Task 3 studies. These data are also shown in Figure 16. We plan to run one more set of uncompact bulk porosity measurements on these samples at 75% relative humidity.

Table 8
Uncompact Bulk Porosity of Dust Cake Ashes as a Function of Relative Humidity

Dust Cake Ash Source	7% Relative Humidity	26% Relative Humidity	53% Relative Humidity	92% Relative Humidity
Scholz HSFP	76.6	76.1	78.4	87.1
Monticello	64.2	67.1	68.0	79.6
Harrington	74.3	75.5	74.6	77.9
AFBC	89.8	87.8	89.9	91.0

The uncompact bulk porosities of the Scholz and Monticello ashes increase more rapidly than the corresponding values measured for the Harrington and AFBC dust cake ashes. This difference may be due to the extremely high calcium content of these latter two ashes. Particle morphology and concentrations of soluble compounds on the surfaces of the particles may also affect this data. Further analyses of these ashes are planned to understand this behavior.

SOLVENT LEACHING STUDIES OF DUST CAKE ASHES

Solvent leaching tests have been run on the four dust cake ashes. Leachate samples were produced by sequentially passing 10 ml samples of distilled, deionized water through a 5 gram sample bed of dust cake ash. A slight vacuum (17 to 20 in H₂O) was used to pull the water and dissolved solids through a fritted glass filter (4-8 μ m pore size) for collection. Additional distilled, deionized water was used to wash the walls of the collection vessel. The total collected leachate and wall washings were then diluted up to 25 ml total volume and submitted for analysis.

Figure 16. Uncompacted bulk porosity of the four dust cake ashes as a function of the relative humidity used to condition the ashes.

Chemical Characteristics of Leachates

The results of the chemical analyses of the leachate samples are presented in Tables 9 through 12. These results indicate that relatively large amounts of soluble compounds are present on the dust cake ashes.

Table 9
Chemical Constituents of Leachates from Solvent Leaching Test of Scholz Ash

wash #	ppm in wash*							$\mu\text{eq/ml}$		Eq. pH
	Na ⁺	Mg ⁺⁺	K ⁺	Fe ⁺⁺⁺	Ca ⁺⁺	H ⁺	SO ₄ ⁼	$\Sigma(\text{cations})$	SO ₄ ⁼	
1	250	**	128	5.2	460	0.63	4289	37.4	89.4	3.2
3	18	**	9	0.1	344	0.04	900	18.2	18.8	4.4
5	1.8	**	1.7	< 0.1	126	-	302	6.4	6.3	7.0
7	1.4	**	1.4	< 0.1	69	-	158	3.5	3.3	7.5
9	1.5	**	0.9	< 0.1	43	-	98.3	2.2	2.0	7.1

Table 10
Chemical Constituents of Leachates from Solvent Leaching Test of Monticello Ash

wash #	ppm in wash*							$\mu\text{eq/ml}$		Eq. pH
	Na ⁺	Mg ⁺⁺	K ⁺	Fe ⁺⁺⁺	Ca ⁺⁺	H ⁺	SO ₄ ⁼	$\Sigma(\text{cations})$	SO ₄ ⁼	
1	9.3	0.37	2.1	< 0.1	114	-	269.6	6.2	5.6	7.7
3	2.4	0.12	0.6	< 0.1	72	-	102.0	3.7	2.1	10.3
5	1.4	0.14	0.3	< 0.1	52	-	49.0	2.7	1.0	10.1
7	0.8	0.16	0.1	< 0.1	30	-	22.9	1.5	0.48	9.3
9	1.0	0.08	0.2	< 0.1	37	-	24.6	1.9	0.51	9.9

Table 11
Chemical Constituents of Leachates from Solvent Leaching Test of Harrington Ash

wash #	ppm in wash*							$\mu\text{eq/ml}$		Eq. pH
	Na ⁺	Mg ⁺⁺	K ⁺	Fe ⁺⁺⁺	Ca ⁺⁺	H ⁺	SO ₄ ⁼	$\Sigma(\text{cations})$	SO ₄ ⁼	
1	55	< 0.03	5.7	< 0.1	126	-	253.6	6.3	5.3	10.7
3	14	< 0.03	2.4	< 0.1	134	-	16.4	7.4	0.34	11.4
5	3.7	< 0.03	0.6	< 0.1	82	-	15.9	4.3	0.33	11.0
7	1.9	< 0.03	0.3	< 0.1	72	-	14.7	3.7	0.31	11.0
9	1.5	< 0.03	0.2	< 0.1	60	-	14.1	3.1	0.29	10.9

Table 12
Chemical Constituents of Leachates from Solvent Leaching Test of AFBC Ash

wash #	ppm in wash*							$\mu\text{eq/ml}$		Eq. pH
	Na ⁺	Mg ⁺⁺	K ⁺	Fe ⁺⁺⁺	Ca ⁺⁺	H ⁺	SO ₄ ⁼	$\Sigma(\text{cations})$	SO ₄ ⁼	
1	9.2	< 0.03	10.5	< 0.1	870	-	1000.0	44.1	20.8	11.6
3	3.6	< 0.03	3.2	< 0.1	700	-	871.7	35.2	18.1	11.7
5	3.2	< 0.03	3.8	< 0.1	560	-	783.7	28.2	16.3	11.6
7	2.4	< 0.03	2.6	< 0.1	475	-	805.0	23.9	16.8	11.4
9	2.0	0.04	2.1	< 0.1	395	-	746.3	19.9	15.5	11.1

* 10 ml of leachate diluted with 15 ml of distilled, deionized water

** analysis not run

There is good numerical agreement between the measured concentration of soluble SO₄⁼ and the total soluble cations present in leachate samples #3, #5, #7 and #9 for the Scholz ash. The excess of SO₄⁼ in leachate sample #1 indicates that this leachate was highly acidic. (Although the acidic nature of this leachate should be evident in the concentration of H⁺ ions, the equilibrium pH measurement is not a reliable indicator of H⁺ concentration.) These results demonstrate that the relatively large amount of soluble SO₄⁼ leached from the surfaces of the Scholz ash probably existed on the particles as free sulfuric acid, and as salts of Ca, Na, K, and Fe.

The analyses of the Monticello leachates indicate that CaSO₄ is initially leached from the particles, followed by an excess of calcium, resulting in alkaline leachates. The concentrations of the sulfate ions and the cations both decrease gradually with repeated leachings. Leaching of the Harrington ash rapidly removed the SO₄⁼, leaving highly alkaline leachates as early as the third leaching. The soluble cations in the Harrington ash (primarily calcium) leached out more slowly, causing the leachates to become gradually less alkaline.

In contrast to the concentrations of soluble SO₄⁼ measured for the PC ashes, the concentrations of SO₄⁼ in the AFBC leachates dropped initially and then leveled off at a relatively high value (about 780 ppm). The total concentration of cations (dominated by calcium) continued to drop gradually with repeated leachings. We believe this behavior is indicative of two trends. During combustion, the calcium and sulfur have reacted to form calcium sulfite and calcium sulfate throughout the ash particles. Therefore the leaching process can affect the entire ash particle, not just its surface. In addition, there seems to be an excess of unreacted calcium in the ash.

Physical Characteristics of Leached Dust Cake Ashes

50 g samples of each of the four dust cake ashes have been leached in preparation for further testing under Experiment 3.4. (The leaching technique used for these 50 g samples used the

same procedure and the same ratio of ash to distilled, deionized water as the solvent leaching tests described above.) Specific surface areas have been measured for these leached ashes. Uncompacted bulk porosity measurements have also been made on these ashes at 6 % and 53 % RH. These data are summarized in Table 13. The largest differences in the uncompacted bulk porosity measurements of the leached and the unleached dust cake ashes measured so far are reductions in the porosity of the leached PC ashes as humidity increases. Further uncompacted bulk porosity measurements, at other RH values, will be performed to more precisely assess these trends.

SEM photographs of leached Scholz and Harrington ashes are shown in Figures 17 and 18. We cannot positively identify any significant differences between the leached and unleached ashes based on these photographs. Resistivity determinations, chemical analyses, adsorption isotherms and/or Karl Fischer titration will also be performed on the leached dust cake ashes.

Table 13
Physical Characteristics of Leached Dust Cake Ashes

Dust Cake Ash Source	specific surface area, m ² /g	uncompacted bulk porosity, % (6 % RH)	uncompacted bulk porosity, % (53 % RH)
Scholz HSFP	8.3	73.2	71.7
Monticello	1.6	65.2	64.5
Harrington	7.1	77.4	75.6
AFBC	18.4	90.2	90.6

PLANS FOR THE UPCOMING QUARTER

Laboratory experiments will be continuing on the four source dust cake ashes and the four leached ashes. In addition, we expect to receive the rest of the mixtures of sorbents and ashes (with the exception of the two samples from Shawnee). A variety of analyses will be performed on the ashes and the mixtures of ashes and sorbents with emphasis on adsorption isotherms, Karl Fischer titration, tensile strength measurements, resistivity measurements, and further uncompacted bulk porosity determinations.

a

b

c

d

Figure 17. SEM photographs of leached Scholz dust cake ash taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

a

b

c

d

Figure 18. SEM photographs of leached Harrington dust cake ash taken at magnifications of a) 100X, b) 500X, c) 1000X, and d) 5000X.

FUNDAMENTAL MECHANISMS IN FLUE GAS CONDITIONING

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