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FUNDAMENTAL MECHANISMS IN FLUE GAS CONDITIONING

**QUARTERLY REPORT
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INTRODUCTION

This project is divided into four tasks. We developed our Management Plan in Task 1. Task 2, Evaluation of Mechanisms in FGD Sorbent and Ash Interactions, focuses on characteristics of binary mixtures of these distinct powders. Task 3, Evaluation of Mechanisms in Conditioning Agents and Ash, is designed to examine effects of various conditioning agents on fine ash particles to determine mechanisms by which these agents alter physical properties of ash. We began Tasks 2 and 3 with an extensive literature search and assembly of existing theories. We completed this phase of the project with publication of two special Topical Reports. During the past several quarters we continued our analyses of the samples in our database. We will be continuing these laboratory analyses during the next quarter. Pilot-scale evaluations will follow these laboratory investigations. We will include the results of laboratory and pilot-scale work performed under Tasks 2 and 3 in a Flue Gas Conditioning Model that we will issue under Task 4. The Final Report for the project will also be prepared under Task 4.

Task 2 and Task 3 each include several groups of experiments. Each experiment has a title and a corresponding number. We described all of these experiments and tests that are included under each experiment (except Experiment 3.5, which is discussed in this report) in our fourth Quarterly Report (April - June 1992). In our literature reviews reported in Topical Reports 1 and 2, we emphasized the roles adsorbed water can have in controlling bulk properties of powders. The experiments we have been performing are primarily designed to define the extent to which water affects key properties of ashes, powders, and mixtures of sorbents and ashes. We have included selected data from prior quarterly reports in this report for the sake of completeness, and for comparisons with newly-acquired data. In several places in this report samples are referred to by their identification (SID) numbers. Table 1 provides a brief description of all the samples we have used in this project along with their SID numbers.

SUMMARY

As suggested by our literature review, our data indicate that water adsorption depends on particle morphology and surface chemistry. Our recent laboratory efforts were primarily directed toward the determination of the effects of adsorbed water on the tensile and cohesive strengths of powders, the development of apparatus for SO₃ and organosiloxane conditioning, and the conditioning of powders and ashes with organosiloxane. Details of these conditioning methods are discussed under section 3.5.

Table 1
Identification of Samples

	SID	Description of Sample
SORBENTS	2870	Muskingum base line ESP hopper ash
	2871	DITF dry $\text{Ca}(\text{OH})_2$ injection
	2872	DITF $\text{Ca}(\text{OH})_2$ slurry injection
	2873	DITF $\text{Ca}(\text{OH})_2$ slurry injection with CaCl_2 addition
AND	2884	Kintigh base line ESP hopper ash
BASE LINE	2885	spray dryer ash (High Sulfur Test Center)
	2883	Edgewater furnace $\text{Ca}(\text{OH})_2$ injection
ASHES	2890	ADVACATE injection
	2907	Yorktown furnace injection of lignosulfonate-modified lime
DUST CAKE	2101	Scholz dust cake ash
ASHES	2029	Monticello dust cake ash
	2515	Harrington dust cake ash
	1994	AFBC dust cake ash
LEACHED	2101-W	leached Scholz dust cake ash (first set)
	2029-W	leached Monticello dust cake ash (first set)
	2515-W	leached Harrington dust cake ash (first set)
DUST CAKE	1994-W	leached AFBC dust cake ash (first set)
ASHES	2101-L	leached Scholz dust cake ash (second set)
	2029-L	leached Monticello dust cake ash (second set)
	2515-L	leached Harrington dust cake ash (second set)
	1994-L	leached AFBC dust cake ash (second set)
POWDERS	1856	glass beads
	3063	silicon dioxide (Cabosil L-90)
	3064	silicon dioxide (Cabosil M-5)
	3065	silicon dioxide (Cabosil EH-5)
	3238	aluminosilicate (Neutralite)
	2769	silicon dioxide (Kenite 900)
	2874	alumina powder

Outside of the laboratory, we presented a paper entitled "How Particulate Properties Affect the Collection of Fine Particles" while attending the Air and Waste Management Association's 86th Annual Meeting and Exhibition which was held in Denver on June 13-18, 1993.

TASK 2: ANALYSES OF MIXTURES OF SORBENTS AND ASHES

E 2.1 Standard Characterization of Mixtures of Sorbents and Ashes

During the past quarter, we obtained and performed selected analyses on a sample of ash generated from the furnace injection of lignosulfonate-modified lime at the Yorktown plant (SID 2907). This sample was collected from the Unit #2 inlet field ESP hopper on April 10, 1993. Analyses of this ash performed so far include determinations of water content, uncompacted bulk porosity determinations, and measurements of tensile strength as functions of relative humidity. These data are included in sections 2.2 and 2.3. Other data describing this ash that should be available soon include chemical analyses and specific surface area.

E 2.2 Characterization of Water Adsorption by Mixtures of Sorbents and Ashes

We performed measurements of water content on a variety of samples under Experiment 2.2. Table 2 presents a summary of the results of these Karl Fischer determinations of water content made under Task 2. The ADVACATE ash (SID 2890) has very high water contents. This probably provides some of the explanation for the high LOI of this ash (as noted in our last quarterly report). The high surface area of this ash provides more sites for adsorption of water. The water contents measured for the lignosulfonate-modified lime injection sample (SID 2907) are relatively similar to those measured earlier for the other mixtures of sorbents and ashes. Other water contents measured this quarter confirm the tendency for CaCl_2 to promote water adsorption (SID's 2872 vs 2873 at 93% relative humidity).

E 2.3 Characterization of Water-Conditioned Sorbent and Ash Mixtures

In measurements of the uncompacted bulk porosity performed under Task 2, ADVACATE ash responded more to water conditioning than any of the other mixtures of sorbent and ash (Table 3). Its tendency to hold more water, and its higher surface area may combine to distinguish it from the other Task 2 samples. Another characteristic that distinguishes this ash from the other mixtures of sorbents and ashes is its relatively low calcium content (17 wt. % vs 31 to 49 wt. % for the other mixtures.) In fact, its response to water conditioning in these tests of

Table 2
Water Contents of Task 2 Samples Titrated in the Karl Fischer Device
after Baking at 300°C, %

SID	Relative Humidity used to Condition Samples, %						
	1	11	22	50	75	82	93
2870	0.42	0.36		0.59	0.33		
2871	1.3	1.6		2.2	2.0		
2872	1.4	1.2		3.2	> 2.9		5.5
2873	1.6	2.3		3.3	> 3.6		8.8
2884	0.33	0.33		0.42	0.61		1.1
2885	2.1	2.5		> 3.5	> 4.5		
2883	0.53	0.42	0.81	1.9	2.9	3.5	
2890	4.3	6.9		9.9	12		8.8
2907	0.35	0.50		1.9	3.1		4.8

Table 3
Uncompacted Bulk Porosities of Conditioned Ashes and Powders, %

SID	Relative Humidity used to Condition and Test Samples, %					
	7	27	53	75	83	93
2870	61	61		62		66
2871	87	87		86		87
2872	88	87		85		87
2873	87	87		87		89
2884	59		63	64	62	67
2885	83			84		85
2883	89					88
2890	77	78	85	85		89
2907	82			83		86

uncompacted bulk porosity was more like some of the dust cake ashes than the other mixtures of sorbents and ashes.

We also performed tensile strength determinations on samples that had been conditioned at a variety of relative humidities. Results of these measurements are included in Table 2.

Table 2
Tensile Strengths of Ashes and Mixtures of Sorbents and Ashes
from Task 2 Studies as a Function of Relative Humidity, N/m²

SID	Relative Humidity used to Condition and Test Samples, %							
	1	11	22	34	50	75	83	93
2870	19	7.3	7.3	1.1	1.6	5.1	> 30	
2871	> 32	> 32	24	3.1	3.7		3.4	8.0
2872				> 28	> 9.5		15	> 24
2873				> 18	> 6.8		> 14	
2884	1.9			0.6	0.6		0.50	
2885	> 30	18	11	2.8	4.2		6.8	12
2883			> 32	31	7.5	12	> 23	
2890	> 32		13	11	18		> 32	> 32
2907				> 14	9.3		> 21	

Like many of the other ashes and powders we have tested, the ash collected from the furnace injection of lignosulfonate-modified lime (SID 2907) has its lowest tensile strength at a moderate relative humidity.

TASK 3: ANALYSES OF ASHES AND POWDERS

Measurements made under Task 3 during the past quarter included selected bulk porosity and tensile strength measurements, and determinations of water content. Experiment 3.5 consumed the majority of effort under Task 3 during the past quarter.

E 3.2 Characterization of Water Adsorption by Powders and Fly Ashes

Trends observed earlier were confirmed by additional measurements of water content conducted this past quarter. Measurements made on samples conditioned at 82 and 93% relative humidity demonstrated that for all but one of the samples tested, water content increased significantly at these moist conditions. However, the water content of the aluminosilicate powder (SID 3238) did not respond significantly to any of the environments (relative humidities from 1% to 93%) we used to condition it.

Table 4
Water Contents of Task 3 Samples Titrated in the Karl Fischer Device
after Baking at 300°C, %

SID	Relative Humidity used to Condition Samples, %						
	1	11	33	50	75	82	93
2101	1.9	2.3		2.0	3.1		
2029	0.15	0.16		0.18	0.25		0.36
2515	0.25	0.18		0.22	0.27		
1994	1.5	1.9		2.6	2.7		
2101-W	0.62	0.79		1.1	1.3		1.7
2029-W	0.12	0.17		0.26	0.33		1.2
2515-W	2.9	3.3		3.6	3.9		7.0
1994-W	1.3	2.8		3.5	4.2		
1856	0.064	0.15		0.20	0.22	0.51	0.58
3063	0.20	0.27	0.35	0.63	1.4		
3064	0.28	0.36	0.54	2.2	1.7		
3065	0.60	1.4	1.9	5.0	2.6		
3238	2.2	2.0		2.7	2.0		2.2
2769	0.040	0.16		0.20	0.41		
2874	0.048	0.051		0.10	0.16		

E 3.3 Characterization of Water-Conditioned Powders and Fly Ashes

The only additional measurements of the uncompact bulk porosity of Task 3 samples made this last quarter were performed on glass beads (SID 1856) at relative humidities of 27 and

53%. Although the cohesivity of the glass beads seems to remain fairly constant at relative humidities up to 27%, it increases rather rapidly as humidity is increased past that point. Possibly the development of multiple layers of physically adsorbed water on the smooth hydrophobic glass surfaces allows the development of liquid bridges at relatively low moisture levels. (Data that will be measured under E 3.5 may help interpret this behavior.) Table 5 summarizes all uncompacted bulk porosity data that have been measured for Task 3 samples.

Table 5
Uncompacted Bulk Porosities of Conditioned Ashes and Powders

SID	Relative Humidity used to Condition and Test Samples, %					
	7	27	53	75	83	93
2101	77	76	78	82	84	87
2029	64	67	68	69	70	80
2515	74	76	75	76		78
1994	90	88	90	89		91
2101-W	73	72	72	72	73	80
2029-W	65	63	64	64		80
2515-W	77	74	76	76		80
1994-W	90	89	91	90		91
2101-L		72				
2029-L		64				
2515-L		79				
1994-L						
1856	44	45	57	70	73*	77*
3238	94					95
2769	91					92
2874	77			79		81

* powder got quite moist, forcing it through screen created "gummy spindles"

E 3.5 Determination of the Effects of the Deposition of Chemical Compounds on Particle Surfaces

Experiment 3.5 is designed to determine if the characteristics of ashes or powders can be significantly altered by the surface deposition of soluble salts, silanes, or SO_3 . We have begun

by conditioning selected ashes and powders with organosiloxane, and will continue with SO₃ conditioning and deposition of soluble salts on the particle surfaces. Table 7 details the division of Experiment 3.5 into three parts based on the type of compound to be deposited on the particles. Table 8 identifies which samples will be tested under Experiment 3.5. Key characteristics of these conditioned materials will be measured. Potential effects of these compounds include changes in appearance, surface area, affinity for adsorption of water, and tensile strength. The results of these analyses will be compared with analyses performed on unconditioned samples under Experiments 3.1, 3.2, 3.3, and 3.4.

Table 7
Areas of Investigation under Experiment 3.5

Experiment/Area	compound(s) to be deposited
3.5.1	soluble salts: (NH ₄) ₂ SO ₄ , NH ₄ HSO ₄ , and CaCl ₂
3.5.2	organosiloxane (Trade name Prosil 28; proprietary formula)
3.5.3	SO ₃

Table 8
Samples to be Tested under Experiment 3.5

SID	Description of sample	sample to be conditioned under		
		E 3.5.1	E 3.5.2*	E 3.5.3
2101	Scholz dust cake ash			X
2029	Monticello dust cake ash			X
2515	Harrington dust cake ash			X
1994	TVA 20 MW AFBC dust cake ash			X
2101-L	leached Scholz dust cake ash	X	2101-L-S	X
2029-L	leached Monticello dust cake ash	X	2029-L-S	X
2515-L	leached Harrington dust cake ash	X	2515-L-S	X
1994-L	leached TVA 20 MW AFBC dust cake ash	X	1994-L-S	X
1856	glass beads	X	1856-S	X
3238	aluminosilicate (Neutralite)	X	3238-S	X
2769	silicon dioxide (Kenite 900)	X	2769-S	X
2874	alumina powder	X	2874-S	X

* SID numbers followed by a -S designation have already been generated.

As discussed last quarter, our efforts to condition ashes and powders under E 3.5.1 with soluble salts using a small-scale spray drying system were unsuccessful. We will probably apply these soluble salts by mixing a water slurry of ash (or powder) with the soluble salt, and then dry the slurry by filtration and oven baking. Under E 3.5.2 we have completed the conditioning of the eight ashes and powders specified in Table 8 with organosiloxane. To condition these samples with organosiloxane, we mixed 1 part by weight of organosiloxane concentrate with 100 parts by weight of sample in a water slurry. The mixture was stirred for 15 minutes, filtered and then oven baked to remove excess water. Testing of these conditioned samples will begin in the near future. Under E 3.5.3, we have nearly completed the assembly of our SO₃ conditioning system. This system generates SO₃ vapor by the passage of metered, dry N₂ over a container of fuming sulfuric acid. We may cool the bed of powder or ash to condense sulfuric acid on the particles. Several trials will be made to establish the proper operating settings to get the desired range of SO₃ for conditioning (10 - 30 ppm SO₃). The system for deposition of SO₃ on particle surfaces consists of a flowing stream of SO₃ vapor passing through a porous bed of the powder or ash and then on through a water bath or a NaOH solution to absorb or neutralize excess SO₃.

Following the deposition of the various compounds on the particle surfaces, we plan to perform the following analyses:

Measure the water content of samples (with the Karl Fischer Device) after they have been conditioned in atmospheres having specific relative humidities.

Measure tensile strengths of samples (with the Electrostatic Tensiometer) after they have been conditioned in atmospheres having specific relative humidities.

Measure specific surface area of the samples exposed to the various chemical compounds.

Perform chemical analyses to determine the concentration of compound that was successfully deposited on the particles.

Take SEM photographs of the samples prepared under E 3.5 if other data warrant visual observation of the particle surface.

PLANS FOR THE UPCOMING QUARTER

Under Task 2, we will be characterizing a selection of the mixtures of ashes and sorbents with specially designed electrostatic reentrainment experiments to prepare for upcoming pilot-scale tests. The remainder of the ashes and powders specified under section 3.5 will be conditioned using the methods described in this report. After conditioning, the ashes and powders will be characterized with a variety of laboratory analyses including Karl Fischer titration, tensile strength measurements, resistivity measurements, and uncompact bulk porosity determinations. Preparations will also begin for the pilot-scale evaluation of water conditioning. (The scheduling of these pilot-scale tests will depend on when SRI's 6 million Btu/hr combustor will be in operation.)

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Approved by

A handwritten signature in black ink, appearing to read "Duane H. Pontius", is written over a horizontal line.

Duane H. Pontius Director, Particulate Sciences Research

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