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INNOVATIVE CLEAN COAL TECHNOLOGY (CCT)

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DE-FC22-90PC 89652

DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_X) EMISSIONS FROM HIGH-SULFUR COAL-FIRED BOILERS

Final Report

(Appendices A-N)
Volume 2 of 3

October 1996

DOE Contract
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Cleared by DOE Patent Counsel on October 22, 1996

MASTER

NOTE TO THE READER

This report is divided into two volumes. The first volume contains the body of the report with the subsequent volume containing appendices. In most cases, data summaries are contained in the body of the report with detailed data contained in the appendices. The report body has been written in such a way as to provide meaningful data discussions and presentations without the use of the appendices. However, the appendices contain detailed data and data discussions which can be used if the reader chooses to examine a particular subject in-depth. In many cases, the appendices contain stand-alone reports and are therefore numbered as originally written and may include sub-appendices. These sub-appendices should not be confused with the overall final report appendices.

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NOTE TO THE READER

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MATERIAL SAFETY DATA SHEET

PRODUCT: SELECTIVE CATALYTIC REDUCTION (SCR) CATALYST

DATE: January 3, 1991

The following information includes safety data required by OSHA. The recipient of this safety data is responsible for passing the safety information on so that it reaches the ultimate user who may come in contact with the material.

TRADE NAME: SCR CATALYST

CHEMICAL NAME & FAMILY: Titania, Vanadium Oxide and/or Tungsten Oxide or Amorphous Silica

SYNONYMS: None

CHEMICAL NOTATION OR STRUCTURE: Titania, Vanadium Oxide and/or Tungsten Oxide or Amorphous Silica

INGREDIENTS:

Tungsten Oxide (WO_3)
Titanium Dioxide (TiO_2)
Silica Gel (SiO_2)
Vanadium Oxide (V_2O_5)
+ Proprietary Additive

CAS REGISTRY NO:

V_2O_5: 1314-62-1
WO_3: 1314-35-8
TiO_2: 13463-67-7
SiO_2: 63231-67-4 (Revised 1990 SiO_2: 112926-00-8)

RTECS NO:

V_2O_5: YW 2450000
WO_3: YO 7760000
TiO_2: XR 2275000
SiO_2: VV 7322000

HEALTH INFORMATION

PRECAUTIONS IN USE:

Because of the presence of toxic compounds, all necessary measures should be taken to avoid inhalation, ingestion, or skin contact with dust, powder, or leachate from this product. Dust or powder from this material can cause irritation to the mucous membranes of the nose or throat, and irritation of the skin. It can also cause cancer or fibrotic diseases of the lungs with repeated or prolonged exposure.

Should use of this material cause dusty conditions, use a properly fitted NIOSH/MSHA approved respirator fitted with a filter for hightly toxic particulates.

There should be no eating, drinking, or smoking allowed while working with the material. Hands and face should be washed prior to eating, drinking, or smoking.

FIRST AID:

EYES: Immediately wash from eyes for 15 minutes with water, occasionally lifting upper and lower eye lids. Get medical attention immediately.
SKIN: Wash affected areas immediately with soap and water.
INGESTION: Give 2 glasses of milk or water and induce vomiting. Never make an unconscious person vomit.
INHALATION: Remove to fresh air.

TOXICOLOGY

This product may contain up to 1% quartz, which is listed by IARC as a Class 2A carcinogen.

ANIMAL TOXICOLOGY

TESTS FOR DOT HAZARD CLASSIFICATION:

Not tested. Not classified as a hazardous material.

TESTS FOR FDA APPROVAL FOR USE IN FOODS:

Not a food-grade product.

HUMAN TOXICOLOGY:

Toxicology of this product is based on release of materials by leachate or dusting. This product may contain up to 1% quartz, which has been classified by IARC as a Class 2A carcinogen. Quartz can cause cancer, silicosis, or fibrotic lung disease with repeated or prolonged exposure. Vanadium oxide is highly toxic, mutagenic, and causes reproductive effects in experimental animals. Vanadium oxide is a respiratory irritant and can cause skin pallor, papular skin rash, greenish-black tongue, chest pain, cough, dyspnea, lung changes, palpitations, and gastro-intestinal disturbances. The primary routes of entry are inhalation and ingestion.

ENVIRONMENTAL DATA

This product has potential to cause environmental damage because of its toxicity. It contains a material listed as a hazardous waste (see p. 4.)

TYPICAL CHEMICAL & PHYSICAL INFORMATION

APPEARANCE: Yellow-yellowish green monolith

pH IN 5% SLURRY: Not applicable

ODOR: None

SPECIFIC GRAVITY: Not applicable

BULK DENSITY: Not applicable

SOLUBILITY IN WATER: Insoluble

APPROXIMATE ANALYSIS:

		Wt. %	OSHA PEL mg/M^3	ACGIH TLV mg/M^3
Silica	SiO_2	0-60	6	10
Titanium Dioxide	TiO_2	40-95%	10	10
Tungsten Oxide (as W)	WO_3	0-15%	n.l.	1.0
Vanadium Oxide	V_2O_5	0-10%	0.05	0.05
Quartz		0-.5	n.l.	n.l.

n.l. - Not listed.

STABILITY: Stable

REACTIVITY: Inert, other than catalytic activity.

FIRE & EXPLOSION DATA: Will not burn or explode.

REGULATORY STATUS

OSHA— See Approximate Analysis, page 3.

NIOSH— Not included on the list of substances requiring toxicity studies.

EPA— This product contains no toxic chemicals in excess of the applicable de minimis concentration as specified under § 313 of Title III SARA.

ACGIH— See Approximate Analysis, page 3.

USDA— Not applicable.

FDA— Not applicable.

DOT— Not considered a hazardous material.

HANDLING INFORMATION

STORAGE AND TRANSPORTATION: No special requirements.

DISPOSAL: Contains component (V_2O_5) listed as a hazardous waste. Dispose of in an approved landfill in accordance with local, state, and federal regulations.

SPILLAGE AND CLEANUP: Sweep or vacuum up using "Precautions in Use" page 2.

CONTAINERS: Box or crate.

SPECIAL INFORMATION

The information provided by the Material Safety Data Sheet is intended for the product as shipped. Additional precautions would have to be taken if the product comes in contact with toxic chemicals. If additional information is required, contact the Davison representative.

Table 1

TEST CONDITIONS AND SAMPLING LOCATIONS
FOR MASS TRAINS AND IMPACTORS

DATE	LOCATION	UNIT LOAD
7/28	Unit 5 inlet	Low
7/29	Unit 5 inlet	Low
7/30	Unit 5 inlet	High
7/31	Unit 5 inlet	High
8/01	No data--tube leak	
8/02	Unit 5 inlet	High
8/03	Unit 6 inlet	High
8/04	Unit 6 inlet	Low
8/05	Unit 5 outlet	High
8/06	Unit 5 outlet	High
8/07	Unit 6 inlet	High

Table 2

CRIST UNIT 5 ESP INLET
HIGH-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

DATE	PORT	MASS LOADING gr/acf Pt 1	MASS LOADING gr/acf Pt 2	GAS VELOCITY ft/sec Pt 1	GAS VELOCITY ft/sec Pt 2	TEMPERATURE °F Pt 1	TEMPERATURE °F Pt 2
7/30/90	1	1.32	1.33	45.4	52.8	657	657
	2	1.33	1.38	45.4	49.8	657	657
	3	1.40	1.58	44.0	48.5	652	650
	4	1.61	1.67	43.8	45.2	640	646
	5	2.15	1.62	41.7	43.8	642	642
	6	1.65	1.61	41.6	48.4	638	643
	DUCT AVG		1.55		45.9		648
	STD DEVIATION		0.22		3.2		7
	COEFF OF VAR		0.14		0.07		0.01
7/31/90	1	1.45	1.38	46.0	54.2	655	655
	2	1.50	1.41	44.7	51.8	654	656
	3	1.47	1.76	45.6	47.9	654	651
	4						
	5	---- NOT RUN DUE TO CONDENSER LEAK ----					
	6						
	DUCT AVG		1.50		48.4		654
	STD DEVIATION		0.12		3.5		2
	COEFF OF VAR		0.08		0.07		0.00
8/02/90	1	1.23	1.27	44.8	52.4	661	663
	2	1.33	1.41	45.4	49.9	660	661
	3	1.32	1.50	43.3	48.0	659	660
	4	1.59	1.70	44.5	45.9	650	649
	5	1.96	1.97	40.9	43.1	643	644
	6	1.71	1.74	40.1	46.4	638	641
	DUCT AVG		1.56		45.4		652
	STD DEVIATION		0.25		3.4		9
	COEFF OF VAR		0.16		0.07		0.01

NOTES: Port 1 is at top of duct.
Point 1 is closest to West duct wall.

Table 3

CRIST UNIT 5 ESP INLET
LOW-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

DATE	PORT	MASS LOADING gr/acf Pt 1	MASS LOADING gr/acf Pt 2	GAS VELOCITY ft/sec Pt 1	GAS VELOCITY ft/sec Pt 2	TEMPERATURE °F Pt 1	TEMPERATURE °F Pt 2
7/28/90	1	1.62	1.26	29.4	35.6	595	595
	2	1.51	1.43	29.4	33.0	594	591
	3	1.37	1.51	29.4	31.2	594	593
	4	1.55	1.53	28.3	29.3	590	589
	5	1.78	1.40	28.3	29.2	585	584
	6	1.88	1.52	28.1	32.0	577	580
DUCT AVG		1.53		30.3		589	
STD DEVIATION		0.16		2.2		6	
COEFF OF VAR		0.11		0.07		0.01	
7/29/90	1	1.27	1.22	32.3	37.3	598	598
	2	1.25	1.19	32.3	35.7	600	599
	3	1.35	1.36	30.4	36.3	599	598
	4	1.36	1.44	31.3	32.2	594	594
	5	1.49	1.43	29.2	31.2	584	590
	6	1.52	1.51	29.2	33.8	584	587
DUCT AVG		1.37		32.6		594	
STD DEVIATION		0.11		2.6		6	
COEFF OF VAR		0.08		0.08		0.01	

NOTES: Port 1 is at top of duct.
Point 1 is closest to West duct wall.

Table 4

CRIST UNIT 5 ESP INLET
HIGH-LOAD NO, NO_X, AND OXYGEN DISTRIBUTIONS

DATE	PORT	NO CONCENTRATION ppm			NO_X CONCENTRATION ppm			O_2 CONCENTRATION %		
		Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3
7/30/90	1	322	320	352	345	343	352	NA	NA	NA
	2	321	321	337	345	346	354	NA	NA	NA
	3	325	326	335	354	352	360	NA	NA	NA
	4	327	329	348	358	358	361	NA	NA	NA
	5	331	329	330	360	361	362	NA	NA	NA
	6	330	330	341	358	359	367	NA	NA	NA
	DUCT AVERAGE		331			355				
	STD DEV		9			7				
	COEFF OF VAR		0.026			0.019				
7/31/90	1	322	323	345	342	344	352	NA	NA	NA
	2	317	320	326	336	343	346	NA	NA	NA
	3	320	317	320	346	342	345	NA	NA	NA
	4	320	318	338	338	345	354	NA	NA	NA
	5	315	317	321	337	338	341	NA	NA	NA
	6	312	312	324	328	328	337	NA	NA	NA
	DUCT AVERAGE		321			341				
	STD DEV		8			6				
	COEFF OF VAR		0.025			0.019				
8/02/90	1	318	319	335	325	325	335	NA	NA	NA
	2	321	319	327	328	329	331	NA	NA	NA
	3	325	327	336	337	340	343	NA	NA	NA
	4	323	333	337	342	349	347	NA	NA	NA
	5	330	319	335	350	342	350	NA	NA	NA
	6	329	328	338	346	354	350	NA	NA	NA
	DUCT AVERAGE		328			340				
	STD DEV		7			9				
	COEFF OF VAR		0.021			0.026				
8/06/90	1	289	275	294	292	275	298	2.9	3.0	3.0
	2	277	259	317	277	285	317	2.5	2.1	2.9
	3	302	298	314	306	298	318	2.8	2.8	3.0
	4	298	290	314	298	301	321	3.0	3.2	3.4
	5	276	308	282	279	309	286	3.4	3.0	3.0
	6	289	284	296	289	284	299	3.2	3.3	2.8
	DUCT AVERAGE		292			296			3.0	
	STD DEV		15			14			0.3	
	COEFF OF VAR		0.051			0.046			0.103	

NOTES: Port 1 is at the top of the duct.
Point distance is from the West wall of the duct.
NO and NO_X are actual measured concentrations.

Table 5

CRIST UNIT 5 ESP INLET
LOW-LOAD NO, NO_X, AND OXYGEN DISTRIBUTIONS

		NO CONCENTRATION ppm			NO_X CONCENTRATION ppm			O_2 CONCENTRATION %		
DATE	PORT	Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3	Pt 1	Pt 2	Pt 3
7/28/90	1	390	390	380	400	390	380	NA	NA	NA
	2	380	390	380	400	400	390	NA	NA	NA
	3	380	390	380	390	400	400	NA	NA	NA
	4	380	380	380	380	400	390	NA	NA	NA
	5	380	380	380	400	390	400	NA	NA	NA
	6	380	380	390	400	400	400	NA	NA	NA
DUCT AVERAGE			383			395				
STD DEV			4			7				
COEFF OF VAR			0.012			0.017				
7/29/90	1	300	300	310	320	310	310	NA	NA	NA
	2	310	310	310	320	320	320	NA	NA	NA
	3	320	310	310	340	330	330	NA	NA	NA
	4	320	320	330	350	340	340	NA	NA	NA
	5	330	310	320	360	350	350	NA	NA	NA
	6	330	330	330	360	360	360	NA	NA	NA
DUCT AVERAGE			317			337				
STD DEV			10			17				
COEFF OF VAR			0.032			0.051				
8/07/90	1	245	227	224	248	227	224	7.6	7.9	7.2
	2	267	249	229	270	251	235	7.9	7.3	7.1
	3	271	264	260	279	269	261	7.6	7.7	7.5
	4	289	282	261	298	288	266	7.4	7.8	7.8
	5	283	281	275	295	288	284	7.4	7.7	7.6
	6	287	280	283	298	298	313	7.3	7.2	7.1
DUCT AVERAGE			264			272			7.5	
STD DEV			21			26			0.3	
COEFF OF VAR			0.078			0.094			0.035	

NOTES: Port 1 is at the top of the duct.
Point distance is from the West wall of the duct.
NO and NO_X are dry and not corrected for constant O_2.

Table 6

CRIST UNIT 6 ESP INLET
HIGH-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

DATE	POINT	MASS LOADING gr/acf		GAS VELOCITY ft/sec		TEMPERATURE °F	
		PORT 1	PORT 2	PORT 1	PORT 2	PORT 1	PORT 2
8/03/90	1	0.93	1.01	52.0	48.9	724	730
	2	1.10	1.61	79.9	58.6	737	733
	3	1.30	3.11	88.1	70.1	731	728
	4	1.23	2.40	63.2	49.6	726	730
	DUCT AVG		1.59		63.8		730
	STD DEVIATION		0.72		13.6		4
	COEFF OF VAR		0.46		0.21		0.01

NOTES: Port 1 is West of port 2.
Point 1 is at the top of the duct.

Table 7

CRIST UNIT 6 ESP INLET
LOW-LOAD MASS, VELOCITY, AND TEMPERATURE DISTRIBUTIONS

DATE	POINT	MASS LOADING gr/acf PORT 1	MASS LOADING gr/acf PORT 2	GAS VELOCITY ft/sec PORT 1	GAS VELOCITY ft/sec PORT 2	TEMPERATURE °F PORT 1	TEMPERATURE °F PORT 2
8/04/90	1	0.92	0.80	27.8	26.7	630	635
	2	1.10	1.22	47.1	35.2	615	622
	3	1.77	0.95	50.2	42.8	593	591
	4	1.28	0.84	37.3	29.7	557	552
	DUCT AVG		1.11		37.1		599
	STD DEVIATION		0.30		8.3		30
	COEFF OF VAR		0.27		0.22		0.05

NOTES: Port 1 is West of port 2.
Point 1 is at the top of the duct.

Table 8

CRIST UNIT 6 ESP INLET
HIGH-LOAD NO, NO_X, AND OXYGEN DISTRIBUTIONS

DATE	POINT	NO CONCENTRATION ppm		NO_X CONCENTRATION ppm		O_2 CONCENTRATION %	
		PORT 1	PORT 2	PORT 1	PORT 2	PORT 1	PORT 2
8/03/90	1	865	846	903	913	NA	NA
	2	860	824	895	881	NA	NA
	3	830	811	855	868	NA	NA
	4	763	760	815	822	NA	NA
	DUCT AVERAGE		820		869		
	STD DEV		38		34		
	COEFF OF VAR		0.046		0.039		
8/07/90	1	NA	NA	NA	NA	2.6	2.5
	2	NA	NA	NA	NA	2.9	2.8
	3	NA	NA	NA	NA	3.3	3.4
	4	NA	NA	NA	NA	4.4	3.7
	DUCT AVERAGE						3.2
	STD DEV						0.6
	COEFF OF VAR						0.186

NOTES: Point 1 is at the top of the duct.
Port 1 is West of port 2.
NO and NO_X are actual measured concentrations.

Table 9

CRIST UNIT 6 ESP INLET
LOW-LOAD NO, NO_X, AND OXYGEN DISTRIBUTIONS

DATE	POINT	NO CONCENTRATION ppm		NO_X CONCENTRATION ppm		O_2 CONCENTRATION %	
		PORT 1	PORT 2	PORT 1	PORT 2	PORT 1	PORT 2
8/04/90	1	363	385	414	457	9.6	10.0
	2	372	389	417	456	9.5	10.2
	3	370	377	426	418	9.7	10.0
	4	376	379	427	434	9.7	9.5
	DUCT AVERAGE		376		431		9.8
	STD DEV		8		16		0.2
	COEFF OF VAR		0.020		0.037		0.0

NOTES: Point 1 is at the top of the duct.
Port 1 is West of port 2.
NO and NO_X are actual measured concentrations.

Table 10

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD PARTICLE MASS DISTRIBUTION

		MASS LOADING, gr/acf					
DATE	POINT	PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7
8/05/90	1	0.0037			0.0038		0.0018
	2		0.0033	0.0034		0.0028	
	3	0.0040			0.0020		0.0023
			DUCT AVG		0.0030		
			STD DEVIATION		0.0008		
			COEFF OF VAR		0.26		
8/06/90	1	0.0031			0.0051		0.0058
	2		0.0042	0.0018		0.0026	
	3	0.0039			0.0023		0.0048
			DUCT AVG		0.0037		
			STD DEVIATION		0.0013		
			COEFF OF VAR		0.35		

NOTES: Port 1 is on the East side of the duct.
Point 1 is at the top of the duct.

Table 11

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS OXYGEN DISTRIBUTIONS

		O_2 CONCENTRATION, %					
DATE	POINT	PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7
8/05/90	1	4.0	4.2	4.2	4.2	4.2	4.1
	2	4.0	4.1	4.1	4.4	4.4	4.2
	3	3.5	4.3	4.8	5.8	4.7	4.8
				DUCT AVERAGE		4.3	
				STD DEV		0.5	
				COEFF OF VAR		0.107	
8/06/90	1	5.0	4.8	4.9	4.9	5.0	5.2
	2	5.0	4.8	5.0	5.1	5.1	4.6
	3	4.8	4.9	5.1	5.1	5.8	5.0
				DUCT AVERAGE		5.0	
				STD DEV		0.2	
				COEFF OF VAR		0.048	

NOTES: Point 1 is at the top of the duct.
Port 1 is on the East side of the duct.
NO and NO_x are actual measured dry concentrations.

Table 12

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS NO_X DISTRIBUTIONS

DATE	POINT	NO_X CONCENTRATION, ppm					
		PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7
8/05/90	1	347	372	354	347	335	329
	2	356	383	358	352	338	335
	3	366	383	364	357	341	340
			DUCT AVERAGE			353	
			STD DEV			15	
			COEFF OF VAR			0.044	
8/06/90	1	316	305	284	305	311	320
	2	315	296	315	306	305	312
	3	311	300	326	313	317	327
			DUCT AVERAGE			310	
			STD DEV			10	
			COEFF OF VAR			0.033	

NOTES: Point 1 is at the top of the duct.
Port 1 is on the East side of the duct.
NO and NO_X are actual measured dry concentrations.

Table 13

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS NO DISTRIBUTIONS

		NO CONCENTRATION, ppm					
DATE	POINT	PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7
8/05/90	1	347	367	352	345	334	329
	2	357	382	353	351	337	334
	3	359	382	362	356	337	337
				DUCT AVERAGE		351	
				STD DEV		15	
				COEFF OF VAR		0.04	
8/06/90	1	315	301	282	303	310	315
	2	313	295	309	301	301	312
	3	310	298	324	306	313	327
				DUCT AVERAGE		307	
				STD DEV		10	
				COEFF OF VAR		0.03	

NOTES: Point 1 is at the top of the duct.
Port 1 is on the East side of the duct.
NO and NO_x are actual measured dry concentrations.

Table 14

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS TEMPERATURE DISTRIBUTION

		GAS TEMPERATURE, °F					
DATE	POINT	PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7
8/05/90	1	616			620		611
	2		619	617		613	
	3	614			617		615
		DUCT AVG			616		
		STD DEVIATION			3		
		COEFF OF VAR			0.00		
8/06/90	1	611			616		603
	2		607	616		610	
	3	613			616		606
		DUCT AVG			611		
		STD DEVIATION			5		
		COEFF OF VAR			0.01		

NOTES: Port 1 is on the East side of the duct.
Point 1 is at the top of the duct.

Table 15

CRIST UNIT 5 ESP OUTLET
HIGH-LOAD FLUE GAS VELOCITY DISTRIBUTION

		GAS VELOCITY, ft/sec					
DATE	POINT	PORT 2	PORT 3	PORT 4	PORT 5	PORT 6	PORT 7
8/05/90	1	44.3			49.1		51.8
	2		44.7	49.6		47.1	
	3	47.6			51.4		51.3
		DUCT AVG			48.5		
		STD DEVIATION			2.7		
		COEFF OF VAR			0.05		
8/06/90	1	44.5			50.2		50.4
	2		46.3	49.6		45.2	
	3	48.9			52.5		50.5
		DUCT AVG			48.7		
		STD DEVIATION			2.6		
		COEFF OF VAR			0.05		

NOTES: Port 1 is on the East side of the duct.
Point 1 is at the top of the duct.

TESTING AND ANALYTICAL SERVICES FOR THE INNOVATIVE CLEAN COAL TECHNOLOGY DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_x) EMISSIONS FROM HIGH SULFUR COAL-FIRED BOILERS

Revised Technical Proposal

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Section 1
INTRODUCTION

This revised proposal is submitted to Southern Company Services (SCS) in response to their request following the submission of our original proposal (November 15, 1991) for "Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal-Fired Boilers."

This revised proposal is completely responsive to the revised scope of work developed jointly by Southern Research Institute (SRI) and SCS. In particular, the remainder of this proposal presents SRI's position and understanding of the technical and cost issues to be addressed. Specifically, Section 2 provides a technical discussion of the issues addressed in the original RFP. This section includes a review of the testing and analytical methods selected by SRI to perform the measurements required under Tasks 1 through 4. Section 3 describes the Technical Plan for performing the revised scope of work. The schedule and technical approach for each task is presented. Section 4 presents the project organization and management plan for carrying out this work. A review of the capabilities and relevant experience of SRI, its subcontractor, Fossil Energy Research Corporation (FERCo), and résumés were included in our original proposal and are not repeated here. A statement of work suitable for a contract resulting from this proposal is provided in Appendix A. A summary of the proposed costs for performing this work can be found in a separately bound volume.

Section 2

DESCRIPTION OF SAMPLING AND ANALYTICAL METHODS

DETERMINATION OF PARTICULATE CONCENTRATION AND PARTICLE SIZE

Several methods are available for measurement of mass concentration and particle size distribution. For measurement of mass concentration at the various sampling locations within the Unit 5 and pilot plant ducting, Methods 5 and 17 promulgated by the U.S. Environmental Protection Agency can be used. In the Method 5 arrangement the particulate matter is collected on a filter mounted in a heated enclosure outside of the stack or ducting. In Method 17 the filter holder is located in the gas stream at the end of the sampling probe. Method 17 is generally preferred because it eliminates problems associated with particle loss in the probe. Method 17 sampling equipment (Nutech Model 220) will be used for the proposed work.

Particle size distribution of the particulate matter in the flue gas streams can be determined either in the laboratory using samples of particulate matter collected during the measurements of mass concentration described above, or, alternatively, by use of cascade impactors sampling flue gas in situ. While the in situ measurements using cascade impactors result in a more accurate representation of the particle size distribution, the expense of obtaining these data can be excessive. The laboratory technique is much less expensive and is considered the method of choice for the proposed work in which a large number of sample streams must be characterized.

Laboratory determination of the particle size distribution of collected particulate samples will be performed with a Shimadzu Model FACP-4 Particle Classifier. This instrument provides particle size data in the range of 0.1 to 100 microns, while only requiring a small test sample (0.1 to 0.2 grams). The instrument characterizes particle size using an aerodynamic sedigraph (centrifugally-enhanced settling in liquids of various viscosities) technique. In assessing the quality assurance of the laboratory measured particle size distributions, cascade impactor tests are recommended on a very limited scale to demonstrate the relative accuracy of the laboratory technique.

Cascade impactors are the most common technique for measuring particle size in situ. The instruments are small, compact, provide for particle fractionation in up to 13 size ranges (0.5 to 10 microns), and can be inserted directly into the flue gas stream. Quartz fiber substrates are used as

microns), and can be inserted directly into the flue gas stream. Quartz fiber substrates are used as collection media. Particle size distributions are calculated using computer data reduction programs written by SRI.

DETERMINATION OF ASH MINERAL COMPOSITION AND TRACE METAL CONCENTRATIONS

The samples of fly ash to be subjected to analysis will be obtained by use of one of three types of sampling devices: 1) a Method 17 (ceramic filter) sampling train, 2) a set of cyclones in series, and 3) a sampling train consisting of a Method 5 particulate filter, followed by a set of impingers containing aqueous solutions to collect vapors that penetrate the filter.

The particulate matter collected in the Method 17 ceramic thimbles will be subjected to mineral analysis. The constituents of the ash that make up the so-called mineral analysis are, in the context of this proposal, those oxides that usually make up 98-100% of fly ash: Li_2O, Na_2O, K_2O, MgO, CaO, Al_2O_3, Fe_2O_3, SiO_2, TiO_2, P_2O_5, and SO_3.

Size-specific trace metals concentrations can be important factors in determining the cause of catalyst deactivation. Fly ash samples collected with a set of cyclones in series will be subjected to a trace metals analysis to address this issue. The size cutpoints in the six-stage cyclone set with back-up filter are approximately 10.0, 6.0, 3.0, 1.5, 0.8, and 0.6 μm. After the series cyclone samples are weighed, as an additional quality assurance check of the particle size distribution determined in the laboratory, the fly ash in each particle size range will be subjected to a trace metals analysis as described below.

For collecting trace metals, the U.S. EPA has sanctioned the use of a Method 5 filtration device and back-up impingers; two filled with nitric acid and hydrogen peroxide and two filled with potassium permanganate and sulfuric acid. The combination of a particulate filter and the back-up impingers provides a convenient way to collect the trace elements in fly ash and flue gas that are of paramount concern. The trace elements that occur as components of the fly ash are collected on the filter, except from the fractions of certain metals (such as As and Se) that may occur partly in the vapor state. These partly volatile metals are collected in the HNO_3/H_2O_2

impingers. The element Hg is usually completely in the vapor state even at 300°F and will surely be almost exclusively in the vapor state above 600°F in the SCR reactors. Hg is collected from the vapor state in the $KMnO_4/H_2SO_4$ impingers.

Routinely, the analysis defined above as ash mineral analysis will be performed by dissolving the ash in concentrated mineral acids and performing a screening analysis by Inductively Coupled Argon Plasma (ICAP) emission spectrometry. This method yields concentrations on the elements other than silicon and sulfur whose oxides make up most of the composition of fly ash (Li, Na, K, Mg, Ca, Al, Fe, Ti, and P). This method also can be made to yield the concentrations of trace elements, if desired, and will be employed for that purpose in trace metal analysis. The other two major components of fly ash, SiO_2 and SO_3, will be determined separately. SiO_2 will be determined by dissolving the ash in fused NaOH and will be determined colorimetrically with molybdate. SO_3 will be extracted in water and determined as sulfate ion by ion chromatography.

The method used to perform a trace metal analysis depends upon the elements one is concerned about. We presume that, in general, the trace elements that cause adverse effects in an SCR reactor are not yet known (we presume that indications of elements that cause adverse effects will come from this project), although at least arsenic must be regarded as a threat. Our plan, in consonance with EPA's recommendations, is to follow a method that, with relatively little difficulty, allows determination of a wide spectrum of elements. The ICAP method mentioned above will do that. It will give the concentration of As, Ba, Be, Cd, Cr, Co, Cu, Pb, Mn, Hg, Ni, Se, and V, among others (this specific list includes those now of concern to EPRI in its PISCES investigations). ICAP may require auxiliary determination of As and Se by atomic absorption with the elements converted to the hydrides if improved sensitivity to these elements is required. ICAP will definitely require use of a second method -- cold-vapor atomic absorption -- for Hg.

DETERMINATION OF INDIVIDUAL COMPONENTS OF THE FLUE GAS

Nitrogen Oxides (NO and NO_2).

Southern Company Services (SCS) will have the main responsibility for determining oxides of nitrogen and will do so by use of a set of chemiluminescence monitors. In the so-called "NO

mode," this type of analyzer responds only to nitric oxide (NO); the response is due to the emission of light from a reaction cell in which NO from the flue gas is converted to nitrogen dioxide (NO_2) with ozone that is generated within the analyzer. The equation is as follows:

$$NO + O_3 = NO_2 + O_2$$

In the "NO_x mode," the analyzer responds to the combination of NO and NO_2 from the flue gas. It gains sensitivity to NO_2 from the flue gas by thermally decomposing or converting NO_2 to NO. Southern Research Institute will on occasion use a similar portable monitor (specifically the Thermo Electron Model 10) for verifying the data obtained with the SCS monitors. We may also have occasion to use the manual phenol disulfonic acid method for reference. Flue gas is collected in an evacuated bulb that contains an oxidizing solution of hydrogen peroxide and sulfuric acid. Nitrogen oxides are converted to nitric acid, which then is reacted with phenol disulfonic acid to produce a colored compound that is measured colorimetrically.

There is the possibility or even the likelihood that the chemiluminescence analyzers will give an unwanted response to NH_3. This gas may be oxidized to NO in the thermal converter for changing NO_2 to NO. The equation for the oxidation process is as follows:

$$4NH_3 + 5O_2 = 4NO + 6H_2O$$

In the event that this reaction occurs, the concentration of NO_x will include NH_3 in addition to NO and NO_2. Whether this occurrence can be tolerated will depend upon the relative concentrations of NH_3 and NO_2. We expect to find around 20-40 ppm of NO_2 if the total NO_x concentration is about 400 ppm as expected. Only at the outlet of the SCR reactors will the concentration of NH_3 be negligible in comparison to that of NO_2; even there, it will be negligible only for low slippages of NH_3 through the reactors.

For routine purposes, the response to NH_3 may be disregarded. Generally, only the concentration of NO may be required, and that parameter will not be affected by NH_3. When the interference from NH_3 must be overcome, it may be accomplished by drawing the sample gas stream through an acid-packed absortion tube ahead of the analyzer. A tube packed with a silica support for sodium bisulfate, $NaHSO_4$, should effectively remove NH_3.

Nitrous oxide (N_2O).

Whereas most of the oxides of nitrogen issuing from the coal-fired combustor will be NO and NO_2, some small part of the oxides will occur as nitrous oxide, N_2O. This oxide contains nitrogen in the +1 state, in contrast to the +2 and +4 states normally produced in a combustor. Even more of the N_2O oxide may be produced in a SCR reactor. SCS does not plan to maintain a CEM for N_2O. SRI on the other hand, plans to recommend for purchase an instrument of the NDIR type for determining N_2O. At least two commercial vendors supply NDIR analyzers for N_2O. We have investigated the Horiba VIA-510 dual beam analyzer and believe it may be the instrument of choice. We will keep abreast of new instrument developments, however, and may choose another at the time a purchase is to be made. There has been a great deal of activity on development of analyzers for N_2O in the recent past; thus, there may soon be significant new improvements offered.

Ammonia (NH_3).

Sample collection. NH_3 will be collected by drawing a stream of flue gas through a heated probe and a heated particulate filter and then through an air-cooled condenser and a series of bubblers filled with dilute sulfuric acid. A substantial part of the NH_3 that gets through the filter will condense, along with water vapor, in the air-cooled condenser, as the result of the low-temperature reaction of NH_3 with HCl or SO_3 to produce NH_4Cl, NH_4HSO_4, and $(NH_4)_2SO_4$.

Temperatures at which the probe and filter are to be controlled will have to be determined after the operating conditions (duct temperatures and flue gas concentrations) are better known. Attempts will be made to retain on the filter any particulate matter than contains NH_3 (which may be fly ash with adsorbed NH_3 or aerosol particles of ammonium sulfate and bisulfate). Ideally, the probe and filter would be operated at the temperature of the duct being sampled; in this way, in principle, the distribution of NH_3 between the solid phases and the gas phase would not be disturbed. Both NH_3 retained in particles on the filter and collected in the condenser and bubblers would be analyzed separately. In practice, however, some shift in temperature away from that in the duct may prove desirable when tests are conducted at the air heater outlets

downstream of the large reactors. As the following discussion will illustrate, the need for a shift in temperature to cope with solids containing NH_3 will be more likely at the outlet of the air heater than at locations upstream from the air heater.

At high temperatures ahead of the catalyst, there is only a remote possibility that ammonium sulfate or bisulfate aerosol particles will be formed. Actually, the possibility of the sulfate forming can be disregarded and only the possibility of the bisulfate forming need be considered. The equilibrium constant for the formation of ammonium bisulfate has been given by Matsuda et al. (Ind. Eng. Chem. Prod. Res. Dev. 21, 48 (1982)) as $1.14 \times 10^{12} e^{-53000/RT}$ atm^2 (where R is the ideal gas constant and T is the absolute temperature). If at the inlet of the catalyst the concentration of NH_3 has been brought up to 500 ppm, the concentration of SO_3 (or H_2SO_4 vapor) must exceed some threshold value before ammonium bisulfate formation can occur:

Temperature, °F	ppm SO_3
800	78,900
700	2,950
600	59.3

It is unlikely that the SO_3 from the boiler will exceed any of the above concentrations; thus, there is little likelihood of the formation of ammonium bisulfate ahead of the catalyst if the sampling train duplicates the duct temperature.

At the outlet of the catalyst, where the temperature has not changed appreciably, the concentrations of NH_3 and SO_3 are more likely to be of similar magnitude. If it is assumed for illustration that they are precisely equal, the concentrations that will just permit ammonium bisulfate formation to occur are these values:

Temperature, °F	ppm NH_3 and SO_3 (equal)
800	6,280
700	1,210
600	172

The figures above imply that ammonium bisulfate formation in the sampling train will not be a problem at the catalyst outlet, just as it is not at the catalyst inlet, if the sampling temperature is kept at the duct temperature.

In the temperature range below 600 °F, the formation of ammonium bisulfate and, ultimately, ammonium sulfate will take place. Extending the prediction of equal concentrations of NH_3 and SO_3 that are thresholds for the formation of ammonium bisulfate, the following results are obtained at temperatures of 500 and 400 °F:

Temperature, °F	ppm NH_3 and SO_3 (equal)
500	16.25
400	0.855

Surely below 400 °F and maybe even above, the more stable solid will be the normal sulfate rather than the bisulfate. In this lower temperature range, the only gaseous species expected to penetrate a filter at duct temperature will be the species in stoichiometric excess. This may be NH_3 if NH_3 is in excess of that reacting to produce a solid, or it may be SO_3 if that species is in excess.

One reason that the experimentalist may choose to depart from the duct temperature insofar as the filtration temperature is concerned is that, on occasion, penetration of gases through the filter may not follow the prediction of chemical equilibrium in terms of the sulfate and the bisulfate. For example, the species in excess may not penetrate the filter because of physical adsorption. Under circumstances such as this, one may choose to raise the temperature to such a point (above 600 °F) that no formation of these salts is possible and all of the NH_3 present is collected behind the filter. With accurate data on both NH_3 and SO_3 concentrations in all forms, one may decide how the two species are most likely distributed between solid and gaseous phases using available equilibrium constants for the formation of the solids.

Sample analysis. A simple method for determining NH_3 that is collected as the chloride or as a sulfate salt is to make the solution alkaline (converting NH_4^+ ion to free NH_3 in solution) and measure the concentration with an ammonia-selective electrode, associated with a reference electrode and attached to a pH meter. The voltage output of the pH meter, ΔE, is used to calculate the concentration of NH_3 as follows:

$$\ln [NH_3] = (\Delta E)/RT + C$$

where R is the ideal gas constant, T is the absolute temperature, and C is a calibration constant.

While convenient, the electrode does not give a linear relationship between the NH_3 concentration and the parameter measured. Two other instrumental methods will give linearity and are thus preferred. One of the methods involves a chemical reaction between NH_3 and other reagents to give a colored product. Another involves a reaction that produces a fluorescent product. Both methods are reported to detect NH_3 at lower concentrations in the dissolved state than the electrode and are to be preferred for this additional reason. Our present plan is to use the fluorometric method; for this purpose, we are recommending the purchase of a fluorometer.

On occasion, when NH_3 as a component of the particulate matter suspended in the flue gas must be determined, the sample retained on a filter will be analyzed. The filter cake will be extracted with a dilute solution of H_2SO_4; the extract will then be processed as described for samples containing the gaseous fraction.

Parenthetically, it can be suggested that NH_3 is unlikely to appear on the solid matter unless a strong acid is initially present on the solid matter. H_2SO_4 adsorbed on the solid is the most probable acid for picking up NH_3 from the gas phase; it is the strongest acid that is likely to be present. Even the reactivity of H_2SO_4 toward NH_3 is limited at SCR temperatures above 600°F, however. This is shown by the fact that NH_4HSO_4 is not likely to be deposited from the gas phase unless the temperature reaches the lower range found on air heater surfaces.

We concur with the viewpoint in the Request for Proposal that a manual determination of NH_3 is preferred to an instrumental method. None of the detection principles that might be used (chemiluminescent detection of NO produced from NH_3 or absorption of UV or IR radiation) overcomes the inherent difficulty of maintaining NH_3 in the gaseous state if a gas stream containing HCl and SO_3 is cooled to normal measurement temperatures.

Hydrogen chloride (HCl).

HCl will be collected by drawing flue gas through a heated probe and a particulate filter and then through an air-cooled condenser and a series of bubblers filled with dilute NaOH or Na_2CO_3 solution. In principle, the sampling train is the same as the one for NH_3, except that the

absorbent solution contains a base rather than an acid. The resulting solution containing NaCl will be analyzed by ion chromatography.

HCl may react with NH_3 to produce NH_4Cl solid, but we believe this unlikely at the gas temperatures to be encountered. NH_4Cl is similar to the sulfate and bisulfate discussed above but is much less stable and much less likely to form except at relatively low temperatures. If NH_3 is collected in the condenser as NH_4Cl, this salt will be rinsed into the base-containing bubblers and transformed to NaCl. The NH_3 thus released will not interfere in the determination of the chloride ion.

Sulfur trioxide (SO_3) and sulfur dioxide (SO_2).

Sample collection. SO_3 in the flue gas will be collected by the controlled condensation method. The flue gas is sampled with a train consisting of a heated quartz-lined probe, a quartz-fiber filter supported on a frit in a heated quartz filter holder, and finally a Pyrex condensing element maintained around 160° F. The condenser may be a spiral of tubing surrounded by a jacket of heated water; alternatively, as in the sampling train we have used for many years, the condenser may be a bulb with connections on both ends, which contains a packing of glass wool and maintains its temperature with a heated water jacket.

When the gas stream is lowered from a duct temperature in excess of 600°F, the SO_3 present begins to undergo a hydration reaction with the water vapor that is present, making H_2SO_4 as the product. Depending upon the even lower temperature reached subsequently, the H_2SO_4 and the water vapor in excess begin to condense concurrently to produce a condensate of concentrated aqueous H_2SO_4 (perhaps 80% acid by weight). If the concentration of SO_3 (H_2SO_4) is about 75 ppm, condensation will commence around 300°F; it will be essentially complete, leaving a residual vapor concentration well below 1 ppm, when the temperature reaches 160°F.

It will be obvious that the interaction of NH_3 and SO_3 introduces the same problems in regard to solids formation whether the sampling is for one gas or the other. Thus, the same considerations apply with SO_3 as were discussed with NH_3. With SO_3 there is the added problem of tenacious adsorption of SO_3 on even inert filter materials, such as quartz. This problem led several researchers who worked toward the development of the controlled condensation method to

recommend a filter temperature of 500-550 °F, regardless of the temperature in the duct being sampled. This is never an altogether satisfactory procedure, because it causes the risk of vaporizing SO_3 from condensed matter. If the duct temperature is low, there will be an aerosol of sulfuric acid in the duct, but it will be vaporized to SO_3 on the filter. If the duct contains NH_3 in the form of the sulfate or bisulfate, thermal decomposition to the gases at a high filter temperature is likely to occur. Our strategy in the past in field sampling of SO_3 in the presence of NH_3 has been to collect samples at varous filter temperatures, ranging from 550 °F, where complete volatilization of the sulfate or bisulfate should occur, to the actual duct temperature, and to attempt to apportion SO_3 between the solid and gaseous phases on the basis of simultaneous measurements of NH_3 and deductions from the measured concentrations and the literature values of equilibrium constants for the sulfate and bisulfate.

We understand that one practice in Europe is to remove NH_3 from a gas stream with an oxalic acid filter before any attempt is made to sample other gases that react with NH_3. The information we have suggests that the oxalic acid filter must be maintained between the water dew point (about 125 °F) and the decomposition temperature of ammonium oxalate (not specified). We cannot, on the basis of the limited information we have, recommend this approach in regard to the SO_3 sampling problem, because there is the possibility that NH_3 will react with SO_3 before the gas stream is cooled sufficiently for NH_3 to react with oxalic acid. One literature article we have consulted states that the decomposition temperature of ammonium oxalate is lower than the decomposition temperature of ammonium sulfate, which would prevent the oxalic acid filter from having the desired effect.

Sample analysis. When SO_3 is collected in the manner described, SO_2 is usually collected in a bubbler downstream (between the condenser and the pump) in a aqueous solution of hydrogen peroxide. Peroxide oxidizes SO_2 to H_2SO_4. Thus, two solutions of H_2SO_4 are collected -- one a very concentrated solution of limited amount containing the original SO_3 and one a relatively weak solution in far greater amount containing the original SO_2.

Determination of H_2SO_4 in both collectors allows one to express the concentrations of both SO_3 and SO_2 in the flue gas. In a laboratory suitably equipped, as planned for this investigation, the most convenient determination of the sulfate ion in H_2SO_4 is by ion chromatography.
We know of only one possible instrumental analyzer for SO_3. That is the SSL Monitor originally developed by the CEGB in Great Britain. We have made a side-by-side comparison of the

instrument with the manual controlled-condensation method on more than one occasion. Our opinion is that the instrument requires too much attention to be regarded truly as an automatic analyzer and we cannot recommend that it be used during this project.

Oxides of carbon (CO and CO_2).

SCS plans to use NDIR analyzers for determining the concentrations of CO and CO_2. We know of no portable analytical instrument of comparable accuracy that can be used for readings at the several sampling ports of interest. We can only suggest a non-instrumental Fyrite analyzer for verifying the instrumental readings for CO_2. We believe that color-indicating tubes can be used for CO but will have to make a study of other possibilities that may be more attractive.

Oxygen (O_2).

The fixed monitors for O_2 will be based upon ZrO_2 sensing elements. For validation of the data from the fixed CEMs, we will use a portable Teledyne O_2 analyzer that is described as a fuel cell device. The specific operation principle is not distinctly described by the manufacturer's literature, however, the detector is an electrochemical cell in which the measured O_2 is reduced at the cathode and some unidentified material is oxidized at the anode. The Teledyne device operates over a wide concentration of O_2, up to 21% in air.

Section 3

TECHNICAL PLAN

In this section the technical plan for performing the tasks is presented. An overall schedule of activities is presented for each task and the overall project, and tables are provided listing the manhours assigned to key personnel and supporting staff for each task.

PLANNING AND PREPARATION

During the period from July through December 1992 activities will be in progress in preparation for formal startup of the test facility in January 1993. For the convenience of the discussion in this section, as well as the preparation of the cost proposal, activities during this time are referred to as Task 0. During this six-month period there are a number of scheduled meetings to review the status of preparations. Equipment to set up the laboratory at the test facility will be purchased during this time. The equipment will be transported to the site and installed. Toward the end of this period the testing personnel assigned to the project will begin working at the facility. SRI and FERCo will work with SCS in the selection and location of sampling ports and other details related to the performance of sampling protocols on the reactors. Testing enclosures will be erected on the test facility and arrangements for the storage of test equipment will be made. These activities will ensure that the test program will proceed at a normal pace even during inclement weather conditions. During the last month of this preparatory period, intensive activities will begin in Birmingham and at the test facility toward the commissioning of the test facility (Tasks 1, 2, and 3).

COMMISSIONING THE PILOT PLANT

The startup and commissioning of the SCR Pilot Plant at Gulf Power Company's Plant Crist is scheduled for a fifteen week period. Tasks 1, 2, and 3 are to be performed during the commissioning exercises. Table 1 presents a weekly schedule for the completion of these tasks.

Table 1. Startup and Commissioning Test Schedule

Startup and Commissioning Tests	WEEK 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Task 1: Commissioning Without Catalyst and Ammonia															
Calibrate Flow Control Venturis	▒														
Verify Gas Sampling System	▒														
High Load Tests															
Measure Mass Concentration & Collect Ash Samples		▒													
Collect Trace Metal Samples		▒													
Measure Concentrations of O2, NO, N2O, HCl, NH3, SO3		▒													
Measure SO2 & SO3 Concentrations at Reactor Heaters		▒													
Analyse Ash Samples and Trace Metal Samples		▒	▒	▒	▒	▒									
Low Load Tests															
Measure Mass Concentration & Collect Ash Samples			▒												
Collect Trace Metal Samples			▒												
Measure Concentrations of O2, NO, N2O, HCl, NH3, SO3			▒												
Measure SO2 & SO3 Concentrations at Reactor Heaters			▒												
Analyse Ash Samples and Trace Metal Samples			▒	▒	▒	▒									
Complete Verification of Gas Sampling System				▒											
Complete Any Tests From Weeks 1, 2, 3				▒											
Task 2: Commissioning Without Catalyst & With Ammonia															
Monitor Ammonia Oxidation					▒	▒									
Verify Ammonia Flow Control and Ammonia Mass Balance					▒	▒									
Determine Gas Sampling System Equilibrium Times					▒	▒									
Task 3A: Commissioning With Catalyst & Without Ammonia															
Measure SO2/SO3 Conversion Rates							▒	▒	▒						
Task 3B: Commissioning With Catalyst and Ammonia															
Measure Velocity, NOx, and NH3 At Reactor Outlets										▒	▒	▒	▒	▒	▒
Collect Ash Samples At Reactor Outlets										▒	▒	▒	▒	▒	▒
Preliminary Parametric Test Sequence										▒	▒	▒	▒	▒	▒

TASK 1. Commissioning Without Catalyst and Without Ammonia Injection

The objectives of task 1 are to measure the performance of the flue gas extraction system, to define the baseline physical and chemical properties of the flue gas at various points in the pilot plant ducting, and to confirm the accuracy of the flue gas continuous monitoring system. The three full-time on-site SRI personnel will be augmented by an SRI field testing crew during this four-week period. The temporary crew will primarily be engaged in particulate sampling and analysis while the resident crew will be engaged in gaseous sampling and analysis. This task will require four weeks to complete. The details of this work are provided below.

WEEK 1 - Calibrations and Verifications

A. The flow control venturis for each of the nine reactors will be calibrated by measuring gas velocity (Pitot traverses), temperature, and static pressure at three flow rates; minimum, design, and maximum, 3000, 5000, and 7500 scfm for the large reactors and 240, 400, and 600 scfm for the small reactors. This work will be carried out by the field testing crew. We estimate that two to three venturi calibrations can be completed each day. One full week is allotted for this work.

B. The SRI on-site crew will assist in the verification of the gas sampling system. This may include characterization of flue gas composition (O_2, CO, CO_2, NO_x, SO_2) at selected gas sampling points. The following methods will be used:

O_2 - Teledyne Oxygen Analyzer
CO - Fyrite analyzer
CO_2- Fyrite analyzer
NO_x - Portable ThermoElectron Chemiluminescence Monitor
SO_2 - H_2O_2 bubbler, Ion Chromatography

WEEK 2 - High Boiler Load

A. While the unit 5 boiler is at stable high-load operation, particulate mass concentration and particle size distribution will be measured at eleven locations in the pilot plant and unit 5 ducts. These locations are:

Unit 5 Hot-Side ESP Inlet Duct (source of high-dust stream)
Unit 5 Hot-Side ESP Outlet Duct (source of low-dust stream)
Each of the Nine Reactor Inlets

The high load mass concentration at each sampling point will be determined for two, consecutively-run, EPA method 17 mass trains. This sampling will require 22 method 17 runs.

B. The particle size distribution of the combined mass train catches for each pair of method 17 runs will be determined in SRI's Birmingham laboratory using a Shimadzu particle sizing device. Quality assurance for this laboratory work will be provided by a pair of consecutive cascade impactors and a pair of consecutive six-stage series cyclones run at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) to verify the Shimadzu particle size distributions. This activity will require 11 laboratory particle sizings and four in-situ particle sizing runs.

C. The combined mass train catches for the pair of method 17 runs at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) will be subjected to an ash mineral analysis.

D. The high-load baseline trace metals profile of the pilot plant will be documented using modified Method 5 (EPA) metals trains. The metals trains will be run at the high-mass extraction scoop (Unit 5 hot-side ESP inlet duct), at the low-mass extraction scoop (Unit 5 hot-side ESP outlet duct), at the inlet to one of the large reactors, and at the inlet to the low-dust small reactor. The high-load trace metals profile will require 4 sampling runs and the analysis of 4 samples.

E. The fly ash samples collected with the six-stage series cyclone sampling train at the Unit 5 ESP inlet duct will be subjected to a size-specific mineral and trace metals analysis (ICAP).

F. High-load baseline concentrations of HCl, NH_3, SO_2/SO_3, NO, N_2O, and O_2 will be measured in the two main ducts at the extraction points; the unit 5 hot-side ESP inlet and outlet ducts. Three samples will be collected at each location for each species. O_2 will be measured using a portable Teledyne O_2 analyzer. NO will be measured using a portable NO_x analyzer and N_2O will also be measured with a portable instrument. The determinations of HCl, NH_3, and SO_2/SO_3 will require manual sampling methods and subsequent laboratory analysis of individual samples. This sub-task will require 9 instrumental determinations, nine manual stack sampling runs, and nine laboratory analyses all done by the on-site SRI staff temporarily augmented by one SRI chemist.

G. Concentrations of SO_2 and SO_3 will be measured simultaneously in one of the large reactors before and after the reactor heater and at the reactor outlet. Identical SO_2/SO_3 measurements will be made for one of the small reactors. Two samples will be collected at each sampling site (twelve in all). Additional testing on other reactors will be performed if warranted by the results of these tests.

H. Laboratory analysis of particulate samples and trace metals samples will begin. These analyses will be conducted at the SRI Birmingham laboratory. These analyses should be completed prior to the beginning of Task 3 (commissioning with catalyst).

WEEK 3 - Low Boiler Load

A. While the unit 5 boiler is at stable low-load operation, particulate mass concentration and particle size distribution will be measured at twelve locations in the pilot plant and unit 5 ducts. These locations are:

Unit 5 Hot-Side ESP Inlet Duct (source of high-dust stream)
Unit 5 Hot-Side ESP Outlet Duct (source of low-dust stream)
The Economizer Bypass Duct
Each of the Nine Reactor Inlets

The low-load mass concentration at each sampling point will be determined for two, consecutively-run, EPA method 17 mass trains. This sampling will require 24 method 17 runs.

B. The particle size distribution of the combined mass train catches for each pair of method 17 runs will be determined in SRI's Birmingham laboratory using a Shimadzu particle sizing device. Quality assurance for this laboratory work will be provided by a pair of consecutive cascade impactors and a pair of consecutive six-stage series cyclones run at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) to verify the Shimadzu particle size distributions. This activity will require 12 laboratory particle sizings and four in-situ particle sizing runs.

C. The combined mass train catches for the pair of method 17 runs at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) will be subjected to an ash mineral analysis.

D. The low-load baseline trace metals profile of the pilot plant will be documented using modified Method 5 (EPA) metals trains. The metals trains will be run at the high-mass extraction scoop (Unit 5 hot-side ESP inlet duct), at the low-mass extraction scoop (Unit 5 hot-side ESP outlet duct), at the economizer bypass duct, at the inlet to one of the large reactors, and at the inlet to the low dust small reactor. The low-load trace metals profile will require 5 sampling runs and the analysis of 5 samples.

E. The fly ash samples collected with the six-stage series cyclone sampling train at the Unit 5 ESP inlet duct will be subjected to a size-specific mineral and trace metals analysis (ICAP).

F. Low-load baseline concentrations of HCl, NH_3, SO_2/SO_3, NO, N_2O, and O_2 will be measured at two locations; after the point at which the economizer bypass mixes with the flue gas from the hot-side ESP inlet and at the hot-side ESP outlet duct. Three measurements of each species will be made at each location. O_2 will be measured using a portable Teledyne O_2 analyzer. NO will be measured using a portable NO_x analyzer and N_2O will also be measured with a portable instrument. The determinations of HCl, NH_3, and SO_2/SO_3 will require manual sampling methods and subsequent laboratory analysis of individual samples. This sub-task will require 9 instrumental determinations, nine manual stack sampling runs, and

nine laboratory analyses all done by the on-site SRI staff temporarily augmented by one SRI chemist.

G. Concentrations of SO_2 and SO_3 will be measured simultaneously in one of the large reactors before and after the reactor heater and at the reactor outlet. Identical SO_2/SO_3 measurements will be made for one of the small reactors. Two samples will be collected at each sampling site (twelve in all). Additional testing on other reactors will be performed if warranted by the results of these tests.

H. Laboratory analysis of particulate samples and trace metals samples will begin. These analyses will be conducted at the SRI Birmingham laboratory. These analyses should be completed prior to the beginning of Task 3 (commissioning with catalyst).

WEEK 4 - Wrap-up

A. The field test crew will finish any tests scheduled for the first three weeks that were not competed.

B. The on site SRI crew will complete the verification of the gas sampling system begun during week 3.

C. Laboratory chemical analysis of size segregated particulate samples and trace metals samples will continue at SRI's Birmingham laboratory.

The Request For Proposal indicated that an option may be offered related to on-line tracking of changes in particulate characteristics, specifically the particle size distribution. Cascade impactors and series cyclones are the most reliable method for measuring particle size distribution on a routine basis in flue gas streams. Periodic measurements using these instruments will be performed during the test program on an as-needed basis. SRI also proposes to monitor the response of the SCR reactors to transient effects, such as soot blowing, during commissioning and the parametric testing. Depending on the response of the SCR reactors to these transient events, SRI can easily transport instrumentation (real-time optical particle counters with dilution probes, an INSITEC in situ particle classifier) from Birmingham to the test facility to evaluate changes in particulate characteristics during these short term events.

TASK 2 - Commissioning Without Catalyst and With Ammonia Injection

The objective of task 2 is to verify ammonia flow control, establish the ammonia mass balance, and to measure ammonia oxidation across the reactors prior to loading catalyst into the reactors.

Two weeks have been allotted to complete this task. The mass flow rate of ammonia into each of the nine reactors will be determined, the ammonia mass balance for the system will be verified, and the distribution of ammonia across each reactor inlet cross section will be measured. Ammonia oxidation at four combinations of flue gas flow rate and temperature will be measured on one large reactor and on one small reactor.

Weeks 5 & 6: NH_3 Distribution and Mass Balance

A. Ammonia oxidation will be profiled at a NH_3/NO_x ratio of 1 for two typical reactor streams; one through a large reactor and one through a small reactor. The profile will be constructed from samples at these conditions:

High Temperature (750°F), Low Flow Rate (3000 or 240 scfm)
High Temperature (750°F), High Flow Rate (7500 or 600 scfm)
Low Temperature (620°F), Low Flow Rate (3000 or 240 scfm)
Low Temperature (620°F), High Flow Rate (7500 or 600 scfm)

This testing will require simultaneous sampling for NH_3 at the inlet and the outlet of each of the two reactors at each of the above combinations of temperature and flow rate. Following each NH_3 run, the sampling trains will be modified by changing condensers to allow SO_3 to be measured. Thus four NH_3 and four SO_3 runs (two of each at the reactor inlet and two of each at the reactor outlet) will be required at each of the four conditions; 16 NH_3 runs and 16 SO_3 runs in all.

B. Verification of ammonia flow control and confirmation of ammonia mass balance will be monitored by measuring ammonia in the gas phase and on particulate at the inlet and outlet of each of the nine reactors. Measurements will be conducted in the four quadrants of the inlet and outlet cross sections of each of the large reactors at an NH_3/NO_x ratio of 1.0. Due to constraints imposed by the physical size of the small reactors, the cross section available for measurements is limited.

C. The time to reach equilibrium when turning on or shutting off ammonia to each reactor will be determined. This "dead time" will be determined using the gas sampling system augmented by manual sampling as necessary.

TASK 3 - Commissioning with Catalyst, Without Ammonia Injection and With Ammonia Injection

Under Task 3, SRI will complete the following testing: measure the conversion rate of SO_2 to SO_3 across each reactor with catalysts installed but without ammonia injection, collect isokinetic

ash samples at the outlet of each reactor under two operating conditions (with catalyst and ammonia), measure the velocity distribution, NO_x concentration and NH_3 distribution across each reactor outlet cross section at a single operating condition (with catalyst and ammonia), and perform a preliminary parametric test sequence (with catalyst and ammonia). Each of these measurements is described in more detail below. Task 3 will require nine weeks to complete.

Weeks 7, 8, & 9

TASK 3-A Commissioning with Catalyst and Without Ammonia Injection

The primary objective of Task 3-A is to characterize the SO_2/SO_3 conversion across each of the nine reactors with catalyst, but without ammonia injection.

A. To fully characterize conversion over the range of temperatures and flow rates anticipated during parametric testing, SO_2 and SO_3 concentrations will be measured at the inlet and outlet of each reactor at nine conditions; three flow rates (design, minimum, and maximum), and three temperatures (620°F, 700°F, and 750°F). The characterization of SO_2/SO_3 conversion for each reactor (each with a different catalyst) will require simultaneous inlet/outlet SO_2/SO_3 runs at each of the nine combinations of temperature and flow rate. Consecutive pairs of runs will be made to provide minimal statistical validity. Thus 18 pairs of runs will be needed to fully characterize each reactor, a total of 324 sampling runs. The assistance of an additional chemist from the SRI Birmingham laboratory will be required to allow us to work as two, two-man sampling teams, each team testing a single reactor; one chemist/technician sampling at the inlet of a reactor while the other samples simultaneously at the outlet of the same reactor. Each team will sample one reactor at one temperature and three flow rates each day. At this rate each team will complete a test matrix for a single reactor in three days. Allowing for minimal time-loss due to upsets and delays in setting up the desired reactor temperatures and flow rates, we estimate that this subtask will require three weeks for completion.

Weeks 10, 11, 12, 13, 14, and 15

TASK 3-B. Commissioning with Catalyst and With Ammonia Injection: [Preliminary Parametric Test Sequence]

The commissioning activities under Task 3-B will be centered around a preliminary parametric test sequence that will be performed after the catalysts are installed in the reactors and with ammonia injection. The matrix of flue gas temperatures, flow rates, and NH_3/NO_x ratios for this testing is shown in table 2. These 16 tests are a subset of the 35 tests scheduled for the parametric

Table 2. SCR Reactor Preliminary Parametric Test Sequence

Test Parameters						Special Measurements	
Day	Test #	Temperature F	Rank	Flowrate SV, fraction of base case	NH3/NOx Ratio	NH3 Outlet	SO3 Outlet
1	3	700	A	1.5	0.8	X	
1	4**	700	A	1	0.8	X	X
1	5	700	A	1	0.9	X	
1	6	700	A	1.5	0.9	X	
1	7	700	A	1.5	1	X	
1	8	700	A	1	1	X	
2	12	750	A	1.5	0.8	X	X
2	13	750	A	1	0.8	X	
2	15	750	A	1	0.9	X	
2	17	750	A	0.6	1	X	X
2	18	750	A	1.5	1	X	X
3	22	620	A	0.6	0.8	X	X
3	23	620	A	1.5	0.8	X	X
3	24	620	A	1	0.9	X	
3	25	620	A	1	1	X	
3	26	620	A	0.6	1	X	X

Notes: Rank: A, first tier of tests, considered most important

**: This test will also include tests at the reactor outlet for HCl and particulate concentration

Shading: These tests will include gas/particulate ammonia measurements at the reactor outlet to confirm ammonia mass balance

evaluations that will begin after commissioning is completed. Most of the testing will consist of NH_3 runs at the reactor outlets at each of the combinations of space velocity, temperature, and NH_3/NO_x ratio shown in table 2.

A. The NH_3 sample trains will be configured with a condenser and bubblers to capture gas-phase NH_3 and a heated filter to capture particulate for solid-phase NH_3 determinations. The samples will be collected as the probe traverses the duct at sampling points dictated by duct cross-section geometry and sampling rates controlled to maintain isokinetic sample collection. We do not anticipate the need for solid-phase NH_3 determinations of all of the particulate samples but, we will have the capability to analyze these samples as needed.

B. A series of gas/solid phase NH_3 determinations will be run at the outlet of one of the large reactors at the six operating conditions included in table 2 defined by temperatures of 620°F and 700°F, space velocities of 1.0 and the maximum dictated by fan capacity, and NH_3/NO_x ratios of 0.8 and 1.0. The primary purpose of these sampling runs is to provide data to ensure closure of the NH_3 mass balance with catalysts loaded into the reactors.

C. In addition to the routine NH_3 measurements, further testing will be conducted to define possible flow channeling through the reactors. Under test condition 4 (design point for 80% NO_x removal; 700°F, space velocity = 1, and NH_3/NO_x = 0.8), the velocity, NO_x, particulate, HCl, N_2O, and NH_3 profiles across each reactor outlet cross section will be measured. These velocity and concentration profiles will require test runs at the centroids of equal area polygons across the reactor outlet cross section. The selection of testing points may be limited by the availability of ports, and in the case of the small reactors, the size of the probe in relation to the reactor cross section. The ash samples will be combined for subsequent mineral and trace metals analysis.

D. Outlet SO_3 concentration will be measured on each reactor at the seven conditions indicated in table 2. These tests are intended to monitor SO_2 to SO_3 conversion across the reactors. Measurement of HCl and particulate concentration will also occur during test condition 4.

Five or six days will be needed for the three-man SRI test crew to complete the preliminary parametric test sequence on two reactors. Single sample train runs for NH_3 and SO_3 measurements will be made with additional runs as time permits. The following test sequence is envisioned for each reactor:

Day 1: Test condition 4; map the flue gas velocity profile, NO_x concentration profile, and NH_3, , and N_2O concentration profile across the outlets of the two reactors.

Day 2: Test condition 4; map the HCl and particulate concentration profile at the outlets of the two reactors.

Day 3: Test conditions 3, 4, 5, 6, 7, 8; measure NH_3 and SO_3 concentrations at the outlets of the two reactors.

Day 4: Test conditions 12, 13, 14, 15, 17, 18; measure NH_3 and SO_3 concentrations at the outlets of the two reactors.

Day 5: Test conditions 22, 23, 24, 25, 26; measure NH_3 and SO_3 concentrations at the outlets of the two reactors.

Day 6: Contingency day.

Approximately six weeks will be required to complete these tests on all nine reactors (two reactors per five-six days). At the conclusion of the preliminary parametric test sequence, the air heaters will be placed in service and NH_3, SO_3, and particulate concentrations will be measured at the three air heater outlets.

TASK 4. REACTOR PARAMETRIC TESTING AND AIR HEATER PERFORMANCE EVALUATION

Upon completion of commissioning, the test facility is scheduled for two years of long-term operation with parametric tests scheduled at regular intervals for each reactor. During the parametric testing, the performance of each SCR reactor will be evaluated at a variety of operating conditions (variations of space velocity, temperature, and NH_3/NO_x molar ratio). The air heaters associated with the three large SCR reactors will also be closely scrutinized during this operating period. SRI testing activities during this two-year period are included in Task 4. The specific testing activities are described in more detail below.

Task 4-A. Reactor Parametric Testing.

Long-term operation of the nine reactors will begin after completion of the commissioning tests and the preliminary parametric test sequence. Upon completion of the preliminary parametric test sequence under Task 3-B, the reactors will be set up to operate in their design mode. The initial parametric testing will begin after a pre-determined period of routine operation. When parametric testing of a reactor is completed, the reactor will return to its design operating mode or other optimal operating conditions determined during the parametric testing. Seven or eight parametric test sequences are scheduled for each reactor during the two-year long operating period.

Table 3 gives details of the parametric test matrix and also lists additional measurements that will be performed by SRI. Reactor performance will be evaluated at thirty-five combinations of space velocity, temperature, and NH_3/NO_x molar ratio. The parametric tests of each SCR reactor will be run during a four-day period as shown in Table 3. This testing schedule will allow us to evaluate, on average, a single reactor each week. Nine of the thirteen weeks during each three month period will be dedicated to parametric testing.

During each four-day parametric test sequence, testing will include up to 35 reactor outlet NH_3 concentration measurements, 13 reactor outlet SO_3 concentration measurements, four reactor outlet particulate mass concentration measurements (including ash mineral analysis), and four reactor outlet HCl and N_2O concentration measurements. Single sampling runs will be made for each measurement of gaseous concentration with duplicate runs made as time permits.

The four weeks not scheduled for parametric testing will be used by SRI to perform any uncompleted parametric tests, analyze samples, maintain equipment, replenish testing supplies, perform required QA/QC activities, and reporting. In addition to these routine tasks, it is anticipated that special testing will be required from time to time. Among the special tests that we anticipate are additional size-specific trace metals tests using six-stage cyclones and/or modified Method 5 sampling trains and measurements of mid-level NH_3 concentration between catalyst beds. Additional trace metals analyses will most likely be run at the mid-point and end-point of the parametric testing. These tests will be scheduled by the SCS project engineer.

Table 3. SCR Reactor Parametric Test Sequence

Test Parameters						Special Measurements			
Day	Test #	Temperature F	Rank	Flowrate SV, fraction of base case	NH3/NOx Ratio	NH3 Outlet	SO3 Outlet	Particulate	Other Analyses
1	1	700	B	1	0.6	X	X		Coal
1	2	700	B	1.5	0.6	X			
1	3	700	A	1.5	0.8	X			
1	4	700	A	1	0.8	X	X	X	HCl, N2O
1	5	700	A	1	0.9	X			
1	6	700	A	1.5	0.9	X			
1	7	700	A	1.5	1	X			
1	8	700	A	1	1	X			
1	9	700	B	1	1.1	X	X		
1	10	700	B	1.5	1.1	X			
2	11	750	B	1.5	0.6	X	X		Coal
2	12	750	A	1.5	0.8	X	X		
2	13	750	A	1	0.8	X			
2	14	750	B	0.6	0.8	X	X		
2	15	750	A	1	0.9	X			
2	16	750	B	1	1	X			
2	17	750	A	0.6	1	X	X		
2	18	750	A	1.5	1	X	X		
2	19	750	B	1.5	1.1	X	X		
3	20	620	B	1	0.6	X			Coal
3	21	620	B	1	0.8	X			
3	22	620	A	0.6	0.8	X	X		
3	23	620	A	1.5	0.8	X	X		
3	24	620	A	1	0.9	X			
3	25	620	A	1	1	X			
3	26	620	A	0.6	1	X	X		
3	27	620	B	1.5	1	X	X		
3	28	620	B	1	1.1	X			
4	29	660	A	0.6	0.8	X		X	HCl, N2O, Coal
4	30	660	A	1	0.8	X		X	HCl, N2O
4	31	660	A	1.5	0.8	X		X	HCl, N2O
4	32	660	A	1.5	0.9	X			
4	33	660	A	1	0.9	X			
4	34	660	A	1	1	X			
4	35	660	A	1.5	1	X			

Notes: Rank -- A: First tier of tests, most important
B: Second tier of tests, secondary importance

Task 4-B. Air Heater Performance Evaluation

Each of the large pilot SCR reactors includes a downstream air heater. The effect of the SCR process on the performance of these air heaters is an important aspect of the over-all research program. Thus the test plan includes a long-term air heater evaluation. The air heaters will be bypassed during parametric testing to ensure that the data collected will reflect only reactor operation at the design conditions. Table 4 lists the tests that will be performed to characterize air heater performance. In general, these tests will be performed at one, three, or six-month intervals.

Data collected during parametric testing at the large reactor outlets at the design point will be representative of air heater inlet conditions. Thus, only air heater outlet testing before each parametric test begins will be needed to complete the air heater characterizations. Specific metallurgical tests have been scheduled to study air heater basket corrosion rate. These will include measurements of weight loss, metallographic examination, (sample removal, grinding, polishing, mounting, scanning electron microscopy, x-ray diffraction analysis) deposit composition (ash mineral and trace metal analysis), and morphology. It is expected that the air heaters will be washed periodically (every three to six months). Specific tests to analyze the wash water are also outlined in Table 4.

REPORTING REQUIREMENTS AND MEETING ATTENDANCE

Activities related to the preparation of progress reports and the attendance at project meetings are described below. A variety of reports will be required to maintain communication of testing results to the sponsor on a timely basis. All parties involved in the overall project will meet regularly to review progress and plan for future activities on the project.

A. Monthly letter reports will be prepared describing the overall status of the test program, including any exceptions to the original test plan.

B. A Quality Assurance/Quality Control Plan will be prepared. This document will describe the methods for ensuring that data of known and acceptable quality are produced during this project.

Table 4. Air Heater Test Schedule

Measured Parameter	Measurement Location	Number of Measurements per Air Heater	Measurement Frequency
NH3 (ppm)	AH Inlet	1	Quarterly
NH3 (ppm)	AH Outlet	1	Quarterly
SO3 (ppm)	Reactor Inlet	1	Quarterly
SO3 (ppm)	AH Inlet	1	Quarterly
SO3 (ppm)	AH Outlet	1	Quarterly
HCl (ppm)	AH Inlet	1	Monthly
Ash Concentration	Manifold	*	Semi-Annual
Ash Composition	Manifold	*	Monthly
Ash Particle Size	Manifold	*	Semi-Annual
Ash Concentration	AH Inlet	1	Semi-Annual
Ash Composition	AH Inlet	1	Monthly
Ash Particle Size	AH Inlet	1	Semi-Annual
Ash Concentration	AH Outlet	1	Quarterly
Ash Composition	AH Outlet	1	Quarterly
Flue Gas Flowrate	AH Inlet	1	Monthly
AH Basket Analysis			
Corrosion Rate	Air Heater	1	Quarterly
Weight Loss	Air Heater	1	Quarterly
Metallographic Examination	Air Heater	1	Quarterly
Deposit Composition	Air Heater	1	Quarterly
Morphology	Air Heater	1	Quarterly
AH Wash Water Analysis			
Total Suspended Solids	Air Heater	1	Quarterly
Total Dissolved Solids	Air Heater	1	Quarterly
pH, Chlorides	Air Heater	1	Quarterly
Trace Metals	Air Heater	1	Quarterly

*: These tests in ducting prior to split to the three large SCR reactors.

C. As the air heater test program progresses, quarterly reports will be prepared. These reports will include all collected data, as well as assessments of results to date and recommendations for any changes in the scope of the evaluation program.

D. A final report on the activities of Task 1, Commissioning Without Catalysts and Without Ammonia Injection, will be prepared. This report will include data developed during the evaluation of the pilot plant flue gas extraction system.

E. Summary reports will be prepared at the completion of Tasks 2 and 3.

F. SRI will attend monthly project review meetings at Plant Crist during the construction phase of the project. These meetings will be held in July, August, September, and October 1992.

G. During the two-year, long-term process evaluation period, SRI will attend the six Quarterly Technical Progress Review Meetings. It is expected that these meetings will be held in March, June, and September of 1993 and 1994.

H. In addition to the above meetings, SRI will attend three Project Review meetings scheduled for April and November of 1992, and January of 1994. All of the meetings will be held at Plant Crist or in the Pensacola, Florida area.

SUMMARY OF TESTING REQUIREMENTS

Table 5 lists the cumulative number of tests required by Tasks 1, 2, 3, and 4. The table is based on the detailed discussion of each task given previously in this section and represents our understanding and interpretation of the testing program.

TESTING PERSONNEL REQUIREMENTS AND MANHOURS AND COST SUMMARY

A thorough analysis (see Table 5) of the testing requirements outlined in the Request for Proposal was prepared in order to determine the number of chemists, technicians, and support personnel needed at the Crist Test Facility. The on-site test crew will require three people. We have determined that this number of on-site personnel are needed because of the large number of samples that must be collected on a single reactor each week during parametric testing (up to 35 ammonia determinations, 13 SO_3 concentration measurements, four particulate, HCl, and N_2O

Table 5. Number of Individual Tests Scheduled for Tasks 1, 2, 3, and 4

			Mass Concentration (Method 17)	Particle Size for QA (Impactors)	Particle Size for QA (Cyclones)	Particle Size Distribution (Shimadzu)	Ash Mineral Analysis (Method 17)	Trace Metals Filter/Bubbler (Metals Train)	Ash Mineral & Trace Metals Size Segrgted (Cyclones)	Temp,Vel Pressure	SO2/SO3	NH3	HCL	NO	NOx	O2	N2O	Velocity	Venturi Flowmeter Calibration	CEM Confirmation
Task 1	Calibration																		27	
	Confirmation																			200
	High Load	Particulate	22	2	2	11	11		1											
		T,V,P								8										
		NO,NOx,O2												6		6				
		Trace Metals						4												
		Elec. Heaters									12									
		Other Gases									6	6	6				6			
	Low Load	Particulate	24	2	2	2	12		1											
		T,V,P								10										
		NO,NOx,O2												6		6				
		Trace Metals						5												
		Elec. Heaters									12									
		Other Gases									6	6	6				6			
Task 2	Oxidation										16	16								
	Mass Balance	(Gases)										72								
		(Particulate)										72								
Task 3A	Conversion										324									
Task 3B	Vel., NOx, NH3 Profiles											9			9			9		
	Iso. Ash Samples		9				9	9												
	Prelim. Parametric Tests										63	144			152			152		
Task 4	Parametric		252				252				819	2205	252				252			
	Air Heater																			
	Manifold		TBD			TBD	TBD	TBD												
	Reactor Inlet																			
	AH Inlet		TBD			TBD	TBD	TBD			TBD									
	AH Outlet		TBD			TBD	TBD	TBD												
	Wash Water						21	21												
Total Number of Measurements			307			13	305	39			1258	2530**	264	12	161	12	264	161	27	200

**: Based on 35 NH3 determinations per reactor (intermediate level) per quarter.
TBD: To Be Determined

measurements, plus measurements associated with the air heater evaluation program). In order to complete these tests on a timely basis, laboratory preparatory activities and analyses must occur simultaneously with the performance of the test procedures on the reactors. Simultaneous laboratory analysis and sampling will also be required in order to accommodate any unforeseen upsets or delays in the test program and allow time to make preparations for testing the next week on a different reactor.

The on-site test crew will consist of a supervisory engineer, a chemist, and a technician. A supervisory engineer will be necessary because the chemist will not have time to perform these supervisory duties, as well as handle his/her laboratory and testing responsibilities. A brief description of the duties of these three test personnel is presented below:

Site Manager (Research Engineer) - This person will be responsible for the performance of on-site testing during Tasks 1, 2, 3, and 4. He will coordinate with the SCS on-site Process Engineer for day-to-day technical guidance and will report to the SRI administrative staff in Birmingham. He will coordinate all tests conducted by the chemist and technician, conduct tests on the pilot plant (as necessary), assemble and organize the data, and prepare drafts of the monthly reports. He will be responsible for entering all manually-collected data into the on-site data processing computer, as required by SCS. He will supervise his staff, coordinate off-time (vacation, holidays, sick leave), purchase supplies, and maintain an organized working environment within the laboratory.

Chemist I (Associate Chemist) - This person will be responsible for all chemical analyses performed in the pilot plant laboratory. He will organize the laboratory, confirm that adequate test equipment, chemicals, bottled gases, glassware, etc. are available, conduct tests on the pilot plant (as necessary), perform chemical analyses in the pilot plant laboratory, arrange shipment of testing samples to Birmingham for analysis, and oversee the laboratory activities of the technician.

Technician I (Engineering Technician) - This person will assist the chemist on-site in the performance of the testing protocol on the SCR reactors. He will also be trained to perform measurements for mass concentration (Method 5 and 17) and particle size (cascade impactors, series cyclones) and will be primarily responsible for these tests, as well as supporting the chemist during his testing (as necessary).

Table 6 provides documentation of the proposed manhours (SRI) required to perform the work.

As noted in Table 6 , a four person test crew from Birmingham will assist in documenting the existing flue gas conditions at Plant Crist Unit 5 and the test facility during Task 1. This test crew is required in order to complete the testing in the time allotted to this task. Several hundred manhours are included for Birmingham laboratory personnel to perform trace metal analyses for tests during Task 1.

One hundred and fifty (150) manhours are included (not shown in Table 6) for Fossil Energy Research Corporation. These hours will, most likely, split between Task 0 and Task 1. Dr. Larry Muzio will have one hundred (100) manhours with the remaining hours split among Richard Hack, Tami Montgomery, Gary Shiomoto, and Randall Smith.

Table 7 provides a brief summary of the manhours and estimated costs for this project. The average labor rate is based on the manhours shown in Table 6.

Table 6. Manhour Summary for Proposal No. P91.506R1

		1992						1993														
		Planning and Preparation - Task 0						Task 1			Commissioning Task 2			Task 3A				Task 3B				
SRI	Category	JUL	AUG	SEP	OCT	NOV	DEC	JAN	JAN	JAN	JAN	FEB	FEB	FEB	FEB	MAR	MAR	MAR	MAR	APR	APR	APR	SUBTOTAL
Edward Dismukes	Prin. Chem.	8	8	8	8	8	8	8	32	8	8	8	8	8	8	8	8	8	8	8	8	8	192
Kenneth Cushing	Res. Physcst	20	20	20	20	20	20	50	12	12	12	12	12	12	12	12	12	12	12	12	12	12	338
Marvin Steele	Assoc. Chem.							8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	120
Dave Smith	Asst. Chem.							40	40	40	40	40	40	40	40	40							360
Robert Heaphy	Res. Eng.	80	80	173	173	173	173	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	1452
Chem I	Assoc. Chem.						173	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	793
Randy Hinton	Res. Tech.					173	173	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	946
Charles Lindsey	S. Eng. Tech.						40	40	40	40	40												200
David Smith	Eng. Tech.						40	40	40	40	40												200
Colin Duke	Env. Tech.						40	40	40	40	40												200
Charles Bates	Stf. Met. Eng.																						
Lloyd Carlson	S. Eng. Tech.																						
Larry Tillery	S. Met. Tech.																						
Machine Shop	Machinists																						
Bob Adams	Division Head							3	3	3	3												12
Joe Finkel	Stf. Chemist							20	20	20	20												80
Charlotte Lyons	Assoc. Chem.							40	40	40	40												160
Kevin Dorlety	S. Chem. Tech.							40	40	40	40												160
Albert Moody	S. Gls. Tech.							11	11	11	11												44
TOTAL		108	108	201	201	374	667	460	446	422	422	188	188	188	188	188	148	148	148	148	148	148	5237

Table 6. Manhour Summary for Proposal No. P91.506R1, continued

	1993									1994												1995				
										Task 4 - Parametric Testing																
SRI	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	SUBTOTAL	TOTAL
Edward Dismukes	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	192	384
Kenneth Cushing	8	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	468	806
Marvin Steele																										120
Dave Smith	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	192	552
Robert Heaphy	53	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	4032	5484
Chem I	53	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	4032	4805
Randy Hinton	53	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	173	4032	4978
Charles Lindsey																										
David Smith																										200
Colin Duke																										200
																										200
Charles Bates			6			6			6			6			6			6			6			6	48	48
Lloyd Carlson			12			12			12			12			12			12			12			12	96	96
Larry Tillery			12			12			12			12			12			12			12			12	96	96
Machine Shop			3			3			3			3			3			3			3			3	24	24
Bob Adams																										12
Joe Finkel																										80
Charlotte Lyons																										160
Kevin Doriety																										160
Albert Moody																										44
TOTAL	183	555	588	555	555	588	555	555	588	555	555	588	555	555	588	555	555	588	555	555	588	555	555	588	13212	18449

Table 7. Cost Summary for Proposal No. P91506R1

Labor Cost	$1,021,351
Other Direct Costs	258,439
Total Cost	$1,279,790
Manhours	18,449
Ave. Labor Rate	$ 55.36

Section 4

PROJECT ORGANIZATION AND MANAGEMENT PLAN

The proposed work will be conducted by personnel of SRI's Environmental Sciences Research Department. Dr. John P. Gooch is Department Director. Specific individuals assigned to this work will come from the Particulate Sciences Division. Dr. Duane H. Pontius is Head of this division. The project would be under the overall supervision of Mr. Kenneth M. Cushing, Head, Fabric Filter Research Section. Southern Research Institute will provide an on-site test crew for the Crist SCR Test Facility. Additional test personnel will travel to the site as the test schedule requires. As noted in the Technical Plan, the majority of travel for additional testing personnel will occur during the Commissioning Phase of the Test Program. Figure 3 shows the overall management structure for the proposed project.

Since an intensive effort is required for the successful performance of the measurement and analytical tasks described in this proposal, the management and coordination of the project will be the primary assignment for Mr. Cushing. The following list is illustrative of the tasks to be performed by Mr. Cushing in his management role:

- Coordination of technical resources from SRI and FERCo in the preparation of a detailed test plan in cooperation with SCS.
- Mobilization of equipment and personnel required to perform the on-site sampling work.
- Monitoring of sampling activities and data to identify potential problems requiring corrective action.
- Coordination as required between SRI, FERCo, and SCS in the resolution of sampling and analytical issues that will occur during the course of the project.
- Preparation of routine and special reports.
- Attendance at project meetings.
- Interfacing with the SCS Project Manager as required to ensure timely performance of project tasks.

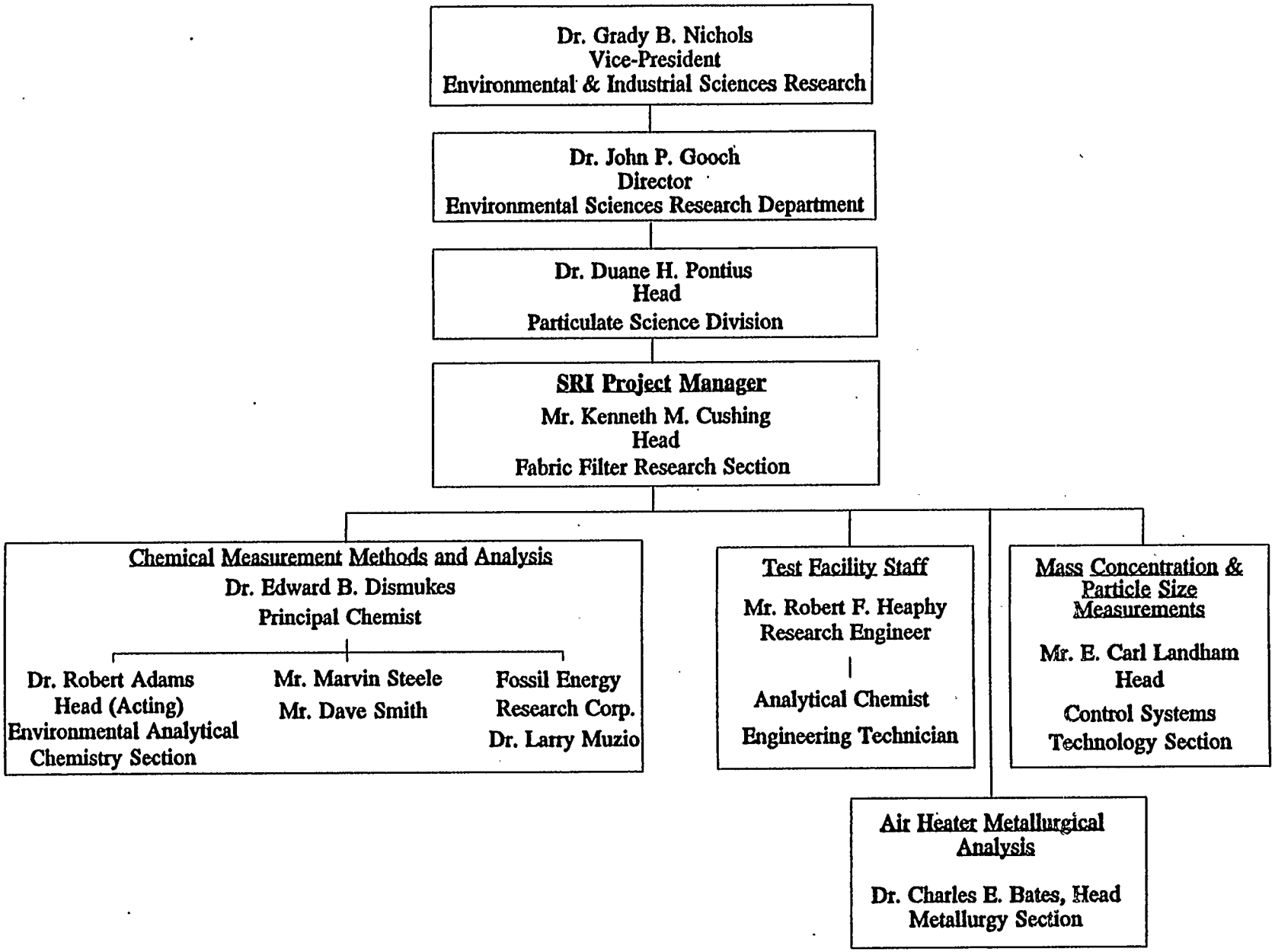

Figure 1. Project Management

SRI proposes to assign Mr. Robert F. Heaphy to head up the test crew at the Crist SCR Test Facility. Mr. Heaphy is currently site manager in charge of testing at EPRI's High Sulfur Fabric Filter Pilot Plant in Florida. This work will be completed toward the end of 1991. Mr. Heaphy is a Research Engineer and has been with SRI since 1984. Mr. Heaphy will be assisted by an analytical chemist and by one engineering technician. They will be assisted by Mr. Marvin Steele, Associate Chemist, and Mr. Dave Smith, Assistant Chemist, during the intensive testing required during the commissioning process. Mr. Steele and Mr. Smith are experienced in performing the gas sampling methods required for this project. These individuals are supervised by Dr. Edward Dismukes, Principal Chemist, with over 20 years experience in the measurement and analysis of flue gas chemistry. Trace metals samples will be evaluated by the Environmental Analytical Chemistry Section headed by Dr. Bob Adams. During the commissioning tests, measurements of mass concentration and particle size distribution will be conducted by personnel from the Control Systems Technology Section, headed by Mr. Carl Landham. Dr. Charles Bates, Head of the Metalurgy Section, will oversee the evaluation of air heater basket corrosion.

Fossil Energy Research Corporation (Dr. Larry Muzio and others) will work with SRI in the selection and development of sampling protocols for the various gaseous species to be measured during this test program. Dr. Muzio has had extensive experience with the demonstration and evaluation of SCR technology and the development of sampling techniques used to monitor these processes. Dr. Muzio will assist in the preparation of the Quality Assurance/Quality Control Plan.

Appendix A

STATEMENT OF WORK

TESTING AND ANALYTICAL SERVICES FOR THE INNOVATIVE CLEAN COAL TECHNOLOGY DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_x) EMISSIONS FROM HIGH-SULFUR COAL-FIRED BOILERS

TASK 0. PLANNING AND PREPARATION

A.) Southern Research Institute (the contractor) will coordinate the purchase and installation of sampling and test equipment for the laboratory at the Crist Test Facility. This equipment will be that authorized for purchase by Southern Company Services.

B.) The contractor will work with Southern Company Services (SCS) in the selection and location of sampling ports and other work details related to the performance of sampling protocols listed under Tasks 1, 2, 3, and 4.

C.) The contractor will install test enclosures on the test facility.

TASK 1. COMMISSIONING WITHOUT CATALYST AND WITHOUT AMMONIA INJECTION

Calibrations and Verifications

A.) The flow control venturis for each of the nine reactors will be calibrated by measuring gas velocity (Pitot traverses), temperature, and static pressure at three flow rates; minimum, design, and maximum, 3000, 5000, and 7500 scfm for the large reactors and 240, 400, and 600 scfm for the small reactors.

B.) The Contractor will assist in the verification of the gas sampling system. This may include characterization of flue gas composition (O_2, CO, CO_2, NO_x, SO_2) at selected gas sampling points. The following methods will be used:

O_2 - Teledyne Oxygen Analyzer
CO - Fyrite analyzer
CO_2- Fyrite analyzer
NO_x - Portable ThermoElectron Chemiluminescence Monitor
SO_2 - H_2O_2 bubbler, Ion Chromatography

High Boiler Load Tests

C.) While the unit 5 boiler is at stable high-load operation, particulate mass concentration and particle size distribution will be measured at eleven locations in the pilot plant and unit 5 ducts. These locations are:

Unit 5 Hot-Side ESP Inlet Duct (source of high-dust stream)
Unit 5 Hot-Side ESP Outlet Duct (source of low-dust stream)
Each of the Nine Reactor Inlets

The high load mass concentration at each sampling point will be determined for two, consecutively-run, EPA method 17 mass trains.

D.) The particle size distribution of the combined mass train catches for each pair of method 17 runs will be determined by the Contractor using a Shimadzu particle sizing device. Quality assurance for this work will be provided by a pair of consecutive cascade impactors and a pair of consecutive six-stage series cyclones run at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) to verify the Shimadzu particle size distributions.

E.) The combined mass train catches for the pair of method 17 runs at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) will be subjected to an ash mineral analysis.

F.) The high-load baseline trace metals profile of the pilot plant will be documented using modified Method 5 (EPA) metals trains. The metals trains will be run at the high-mass extraction scoop (Unit 5 hot-side ESP inlet duct), at the low-mass extraction scoop (Unit 5 hot-side ESP outlet duct), at the inlet to one of the large reactors, and at the inlet to the low-dust small reactor.

G.) The fly ash samples collected with the six-stage series cyclone sampling train at the Unit 5 ESP inlet duct (subtask D.) will be subjected to a size-specific mineral and trace metals analysis (ICAP).

H.) High-load baseline concentrations of HCl, NH_3, SO_2/SO_3, NO, N_2O, and O_2 will be measured in the two main ducts at the extraction points; the unit 5 hot-side ESP inlet and outlet ducts. Three samples will be collected at each location for each species. O_2 will be measured using a portable Teledyne O_2 analyzer. NO will be measured using a portable NO_x analyzer and N_2O will also be measured with a portable instrument. The determinations of HCl, NH_3, and SO_2/SO_3 will require manual sampling methods and subsequent laboratory analysis of individual samples.

I.) Concentrations of SO_2 and SO_3 will be measured simultaneously in one of the large reactors before and after the reactor heater and at the reactor outlet. Identical SO_2/SO_3 measurements will be made for one of the small reactors. Two samples will be collected at each sampling site. Additional testing on other reactors will be performed if warranted by the results of these tests.

J.) Laboratory analysis of particulate samples and trace metals samples will begin. These analyses will be conducted at the Contractor's Birmingham laboratory. These analyses should be completed prior to the beginning of Task 3 (commissioning with catalyst).

Low Boiler Load Tests

K.) While the unit 5 boiler is at stable low-load operation, particulate mass concentration and particle size distribution will be measured at twelve locations in the pilot plant and unit 5 ducts. These locations are:

Unit 5 Hot-Side ESP Inlet Duct (source of high-dust stream)
Unit 5 Hot-Side ESP Outlet Duct (source of low-dust stream)
The Economizer Bypass Duct
Each of the Nine Reactor Inlets

The low-load mass concentration at each sampling point will be determined for two, consecutively-run, EPA method 17 mass trains.

L.) The particle size distribution of the combined mass train catches for each pair of method 17 runs will be determined by the Contractor using a Shimadzu particle sizing device. Quality assurance for this work will be provided by a pair of consecutive cascade impactors and a pair of consecutive six-stage series cyclones run at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) to verify the Shimadzu particle size distributions.

M.) The combined mass train catches for the pair of method 17 runs at the Unit 5 hot-side ESP inlet duct (the source of the high-dust stream) will be subjected to an ash mineral analysis.

N.) The low-load baseline trace metals profile of the pilot plant will be documented using modified Method 5 (EPA) metals trains. The metals trains will be run at the high-mass extraction scoop (Unit 5 hot-side ESP inlet duct), at the low-mass extraction scoop (Unit 5 hot-side ESP outlet duct), at the economizer bypass duct, at the inlet to one of the large reactors, and at the inlet to the low dust small reactor.

O.) The fly ash samples collected with the six-stage series cyclone sampling train at the Unit 5 ESP inlet duct (subtask L.) will be subjected to a size-specific mineral and trace metals analysis (ICAP).

P.) Low-load baseline concentrations of HCl, NH_3, SO_2/SO_3, NO, N_2O, and O_2 will be measured at two locations; after the point at which the economizer bypass mixes with the flue gas from the hot-side ESP inlet and at the hot-side ESP outlet duct. Three measurements of each species will be made at each location. O_2 will be measured using a portable Teledyne O_2 analyzer. NO will be measured using a portable NO_x analyzer and N_2O will also be measured with a portable instrument.

The determinations of HCl, NH_3, and SO_2/SO_3 will require manual sampling methods and subsequent laboratory analysis of individual samples.

Q.) Concentrations of SO_2 and SO_3 will be measured simultaneously in one of the large reactors before and after the reactor heater and at the reactor outlet. Identical SO_2/SO_3 measurements will be made for one of the small reactors. Two samples will be collected at each sampling site. Additional testing on other reactors will be performed if warranted by the results of these tests.

R.) Laboratory analysis of particulate samples and trace metals samples will begin. These analyses will be conducted at the Contractor's Birmingham laboratory. These analyses should be completed prior to the beginning of Task 3 (commissioning with catalyst).

Wrap-up

S.) The Contractor will finish any tests scheduled for the first three weeks that were not competed.

T.) The Contractor will complete the verification of the gas sampling system begun during subtask B.

U.) Laboratory chemical analysis of size segregated particulate samples and trace metals samples will continue at the Contractor's Birmingham laboratory.

TASK 2. COMMISSIONING WITHOUT CATALYST AND WITH AMMONIA INJECTION

NH_3 Distribution and Mass Balance

A.) Ammonia oxidation will be profiled at a NH_3/NO_x ratio of 1 for two typical reactor streams; one through a large reactor and one through a small reactor. The profile will be constructed from samples at these conditions:

High Temperature (750°F), Low Flow Rate (3000 or 240 scfm)
High Temperature (750°F), High Flow Rate (7500 or 600 scfm)
Low Temperature (620°F), Low Flow Rate (3000 or 240 scfm)
Low Temperature (620°F), High Flow Rate (7500 or 600 scfm)

This testing will require simultaneous sampling for NH_3 at the inlet and the outlet of each of the two reactors at each of the above combinations of temperature and flow rate. Following each NH_3 run, the sampling trains will be modified by changing condensers to

allow SO_3 to be measured. Thus four NH_3 and four SO_3 runs (two of each at the reactor inlet and two of each at the reactor outlet) will be required at each of the four conditions.

B.) Verification of ammonia flow control and confirmation of ammonia mass balance will be monitored by measuring ammonia in the gas phase and on particulate at the inlet and outlet of each of the nine reactors. Measurements will be conducted in the four quadrants of the inlet and outlet cross sections of each of the large reactors at an NH_3/NO_x ratio of 1.0. Due to constraints imposed by the physical size of the small reactors, the cross section available for measurements is limited.

C.) The time to reach equilibrium when turning on or shutting off ammonia to each reactor will be determined. This "dead time" will be determined using the gas sampling system augmented by manual sampling as necessary.

TASK 3. COMMISSIONING WITH CATALYST, WITHOUT AMMONIA INJECTION AND WITH AMMONIA INJECTION

Commissioning with Catalyst and Without Ammonia Injection

A.) To fully characterize conversion over the range of temperatures and flow rates anticipated during parametric testing, SO_2 and SO_3 concentrations will be measured at the inlet and outlet of each reactor at nine conditions; three flow rates (design, minimum, and maximum), and three temperatures (620°F, 700°F, and 750°F). The characterization of SO_2/SO_3 conversion for each reactor (each with a different catalyst) will require simultaneous inlet/outlet SO_2/SO_3 runs at each of the nine combinations of temperature and flow rate. Consecutive pairs of runs will be made to provide minimal statistical validity. Thus 18 pairs of runs will be needed to fully characterize each reactor, a total of 324 sampling runs. The assistance of an additional chemist from the SRI Birmingham laboratory will be required to allow us to work as two, two-man sampling teams, each team testing a single reactor; one chemist/technician sampling at the inlet of a reactor while the other samples simultaneously at the outlet of the same reactor. Each team will sample one reactor at one temperature and three flow rates each day. At this rate each team will complete a test matrix for a single reactor in three days. Allowing for minimal time-loss due to upsets and delays in setting up the desired reactor temperatures and flow rates, we estimate that this subtask will require three weeks for completion.

Commissioning with Catalyst and With Ammonia Injection: [Preliminary Parametric Test Sequence]

A.) NH_3 determinations will be conducted on each of the nine reactors during a preliminary parametric test sequence. The sixteen tests are listed in Table 1. The

NH_3 sample trains will be configured with a condenser and bubblers to capture gas-phase NH_3 and a heated filter to capture particulate for solid-phase NH_3 determinations. The samples will be collected as the probe traverses the duct at sampling points dictated by duct cross-section geometry and sampling rates controlled to maintain isokinetic sample collection. We do not anticipate the need for solid-phase NH_3 determinations of all of the particulate samples but, we will have the capability to analyze these samples as needed.

B.) A series of gas/solid phase NH_3 determinations will be run at the outlet of one of the large reactors at the six operating conditions included in table 1 defined by temperatures of 620°F and 700°F, space velocities of 1.0 and the maximum dictated by fan capacity, and NH_3/NO_x ratios of 0.8 and 1.0. The primary purpose of these sampling runs is to provide data to ensure closure of the NH_3 mass balance with catalysts loaded into the reactors.

C.) In addition to the routine NH_3 measurements, further testing will be conducted to define possible flow channeling through the reactors. Under test condition 4 (design point for 80% NO_x removal; 700°F, space velocity = 1, and NH_3/NO_x = 0.8), the velocity, NO_x, particulate, HCl, N_2O, and NH_3 profiles across each reactor outlet cross section will be measured. These velocity and concentration profiles will require test runs at the centroids of equal area polygons across the reactor outlet cross section. The selection of testing points may be limited by the availability of ports, and in the case of the small reactors, the size of the probe in relation to the reactor cross section. The ash samples will be combined for subsequent mineral and trace metals analysis.

D.) Outlet SO_3 concentration will be measured on each reactor at the seven conditions indicated in table 1. These tests are intended to monitor SO_2 to SO_3 conversion across the reactors. Measurement of HCl and particulate concentration will also occur during test condition 4. Single sample train runs for NH_3 and SO_3 measurements will be made with additional runs as time permits. The following test sequence is envisioned for each reactor:

Day 1: Test condition 4; map the flue gas velocity profile, NO_x concentration profile, and NH_3, and N_2O concentration profile across the outlets of the two reactors.

Day 2: Test condition 4; map the HCl and particulate concentration profile at the outlets of the two reactors.

Day 3: Test conditions 3, 4, 5, 6, 7, 8; measure NH_3 and SO_3 concentrations at the outlets of the two reactors.

Day 4: Test conditions 12, 13, 14, 15, 17, 18; measure NH_3 and SO_3 concentrations at the outlets of the two reactors.

Table 1. SCR Reactor Preliminary Parametric Test Sequence

Test Parameters						Special Measurements	
Day	Test #	Temperature F	Rank	Flowrate SV, fraction of base case	NH3/NOx Ratio	NH3 Outlet	SO3 Outlet
1	3	700	A	1.5	0.8	X	
1	4**	700	A	1	0.8	X	X
1	5	700	A	1	0.9	X	
1	6	700	A	1.5	0.9	X	
1	7	700	A	1.5	1	X	
1	8	700	A	1	1	X	
2	12	750	A	1.5	0.8	X	X
2	13	750	A	1	0.8	X	
2	15	750	A	1	0.9	X	
2	17	750	A	0.6	1	X	X
2	18	750	A	1.5	1	X	X
3	22	620	A	0.6	0.8	X	X
3	23	620	A	1.5	0.8	X	X
3	24	620	A	1	0.9	X	
3	25	620	A	1	1	X	
3	26	620	A	0.6	1	X	X

Notes: Rank: A, first tier of tests, considered most important
**: This test will also include tests at the reactor outlet for HCl and particulate concentration
Shading: These tests will include gas/particulate ammonia measurements at the reactor outlet to confirm ammonia mass balance

Day 5: Test conditions 22, 23, 24, 25, 26; measure NH_3 and SO_3 concentrations at the outlets of the two reactors.

Day 6: Contingency day.

At the conclusion of the preliminary parametric test sequence, the air heaters will be placed in service and NH_3, SO_3, and particulate concentrations will be measured at the three air heater outlets.

TASK 4. REACTOR PARAMETRIC TESTING AND AIR HEATER PERFORMANCE EVALUATION

Reactor Parametric Testing.

Long-term operation of the nine reactors will begin after completion of the commissioning tests and the preliminary parametric test sequence. Upon completion of the preliminary parametric test sequence, the reactors will be set up to operate in their design mode. The initial parametric testing will begin after a pre-determined period of routine operation. When parametric testing of a reactor is completed, the reactor will return to its design operating mode or other optimal operating conditions determined during the parametric testing.

Table 2 gives details of the parametric test matrix and also lists additional measurements that will be performed by the Contractor. Reactor performance will be evaluated at thirty-five combinations of space velocity, temperature, and NH_3/NO_x molar ratio. The parametric tests of each SCR reactor will be run during a four-day period as shown in Table 2. This testing schedule will allow the Contractor to evaluate, on average, a single reactor each week. Nine of the thirteen weeks during each three month period will be dedicated to parametric testing.

During each four-day parametric test sequence, testing will include up to 35 reactor outlet NH_3 concentration measurements, 13 reactor outlet SO_3 concentration measurements, four reactor outlet particulate mass concentration measurements (including ash mineral analysis), and four

Table 2. SCR Reactor Parametric Test Sequence

Test Parameters						Special Measurements			
Day	Test #	Temperature F	Rank	Flowrate SV, fraction of base case	NH3/NOx Ratio	NH3 Outlet	SO3 Outlet	Particulate	Other Analyses
1	1	700	B	1	0.6	X	X		Coal
1	2	700	B	1.5	0.6	X			
1	3	700	A	1.5	0.8	X			
1	4	700	A	1	0.8	X	X	X	HCl, N2O
1	5	700	A	1	0.9	X			
1	6	700	A	1.5	0.9	X			
1	7	700	A	1.5	1	X			
1	8	700	A	1	1	X			
1	9	700	B	1	1.1	X	X		
1	10	700	B	1.5	1.1	X			
2	11	750	B	1.5	0.6	X	X		Coal
2	12	750	A	1.5	0.8	X	X		
2	13	750	A	1	0.8	X			
2	14	750	B	0.6	0.8	X	X		
2	15	750	A	1	0.9	X			
2	16	750	B	1	1	X			
2	17	750	A	0.6	1	X	X		
2	18	750	A	1.5	1	X	X		
2	19	750	B	1.5	1.1	X	X		
3	20	620	B	1	0.6	X			Coal
3	21	620	B	1	0.8	X			
3	22	620	A	0.6	0.8	X	X		
3	23	620	A	1.5	0.8	X	X		
3	24	620	A	1	0.9	X			
3	25	620	A	1	1	X			
3	26	620	A	0.6	1	X	X		
3	27	620	B	1.5	1	X	X		
3	28	620	B	1	1.1	X			
4	29	660	A	0.6	0.8	X		X	HCl, N2O, Coal
4	30	660	A	1	0.8	X		X	HCl, N2O
4	31	660	A	1.5	0.8	X		X	HCl, N2O
4	32	660	A	1.5	0.9	X			
4	33	660	A	1	0.9	X			
4	34	660	A	1	1	X			
4	35	660	A	1.5	1	X			

Notes: Rank – A: First tier of tests, most important
B: Second tier of tests, secondary importance

reactor outlet HCl and N_2O concentration measurements. Single sampling runs will be made for each measurement of gaseous concentration with duplicate runs made as time permits.

The four weeks not scheduled for parametric testing will be used by the Contractor to perform any uncompleted parametric tests, analyze samples, maintain equipment, replenish testing supplies, perform required QA/QC activities, and reporting. In addition to these routine tasks, it is anticipated that special testing will be required from time to time. Among the special tests that the Contractor anticipates are additional size-specific trace metals tests using six-stage cyclones and/or modified Method 5 sampling trains and measurements of mid-level NH_3 concentration between catalyst beds. Additional trace metals analyses will most likely be run at the mid-point and end-point of the parametric testing. These tests will be scheduled by the SCS project engineer.

Air Heater Performance Evaluation

Each of the large pilot SCR reactors includes a downstream air heater. The effect of the SCR process on the performance of these air heaters is an important aspect of the over-all research program. Thus the test plan includes a long-term air heater evaluation. The air heaters will be bypassed during parametric testing to ensure that the data collected will reflect only reactor operation at the design conditions. Table 3 lists the tests that will be performed to characterize air heater performance. In general, these tests will be performed at one, three, or six-month intervals.

Data collected during parametric testing at the large reactor outlets at the design point will be representative of air heater inlet conditions. Thus, only air heater outlet testing before each parametric test begins will be needed to complete the air heater characterizations. Specific metallurgical tests have been scheduled to study air heater basket corrosion rate. These will include measurements of weight loss, metallographic examination, (sample removal, grinding, polishing, mounting, scanning electron microscopy, x-ray diffraction analysis) deposit composition (ash mineral and trace metal analysis), and morphology. It is expected that the air heaters will be washed periodically (every three to six months). Specific tests to analyze the wash water are also outlined in Table 3.

Table 3. Air Heater Test Schedule

Measured Parameter	Measurement Location	Number of Measurements per Air Heater	Measurement Frequency
NH3 (ppm)	AH Inlet	1	Quarterly
NH3 (ppm)	AH Outlet	1	Quarterly
SO3 (ppm)	Reactor Inlet	1	Quarterly
SO3 (ppm)	AH Inlet	1	Quarterly
SO3 (ppm)	AH Outlet	1	Quarterly
HCl (ppm)	AH Inlet	1	Monthly
Ash Concentration	Manifold	*	Semi-Annual
Ash Composition	Manifold	*	Monthly
Ash Particle Size	Manifold	*	Semi-Annual
Ash Concentration	AH Inlet	1	Semi-Annual
Ash Composition	AH Inlet	1	Monthly
Ash Particle Size	AH Inlet	1	Semi-Annual
Ash Concentration	AH Outlet	1	Quarterly
Ash Composition	AH Outlet	1	Quarterly
Flue Gas Flowrate	AH Inlet	1	Monthly
AH Basket Analysis			
Corrosion Rate	Air Heater	1	Quarterly
Weight Loss	Air Heater	1	Quarterly
Metallographic Examination	Air Heater	1	Quarterly
Deposit Composition	Air Heater	1	Quarterly
Morphology	Air Heater	1	Quarterly
AH Wash Water Analysis			
Total Suspended Solids	Air Heater	1	Quarterly
Total Dissolved Solids	Air Heater	1	Quarterly
pH, Chlorides	Air Heater	1	Quarterly
Trace Metals	Air Heater	1	Quarterly

*: These tests in ducting prior to split to the three large SCR reactors.

REPORTING REQUIREMENTS AND MEETING ATTENDANCE

Activities related to the preparation of progress reports and the attendance at project meetings are described below. A variety of reports will be required to maintain communication of testing results to the sponsor on a timely basis. All parties involved in the overall project will meet regularly to review progress and plan for future activities on the project.

A.) Monthly letter reports will be prepared describing the overall status of the test program, including any exceptions to the original test plan.

B.) A Quality Assurance/Quality Control Plan will be prepared. This document will describe the methods for ensuring that data of known and acceptable quality are produced during this project.

C.) As the air heater test program progresses, quarterly reports will be prepared. These reports will include all collected data, as well as assessments of results to date and recommendations for any changes in the scope of the evaluation program.

D.) A final report on the activities of Task 1, Commissioning Without Catalysts and Without Ammonia Injection, will be prepared. This report will include data developed during the evaluation of the pilot plant flue gas extraction system.

E.) Summary reports will be prepared at the completion of Tasks 2 and 3.

F.) The Contractor will attend monthly project review meetings at Plant Crist during the construction phase of the project. These meetings will be held in July, August, September, and October 1992.

G.) During the two-year, long-term process evaluation period, the Contractor will attend the six Quarterly Technical Progress Review Meetings. It is expected that these meetings will be held in March, June, and September of 1993 and 1994.

H.) In addition to the above meetings, the Contractor will attend three Project Review meetings scheduled for April and November of 1992, and January of 1994. All of the meetings will be held at Plant Crist or in the Pensacola, Florida area.

Final Laboratory Testing Protocol (Revised 5/20/92)

1. Catalyst Preparation:

Catalyst Volume

SCS requires testing at 50 Nm^3/m^2hr area velocity as a design point for measuring catalyst deactivation. In previous correspondence, the capability of testing at 10 Nm^3/m^2hr area velocity was also required, though now the lower value of area velocity has been set at 20 Nm^3/m^2hr. Catalyst suppliers should use this range of area velocities for determining the appropriate catalyst volume (while meeting mass transfer requirements outlined in section 6). If a portion of the catalyst extracted from the pilot plant is used in the lab reactor, the portion should be obtained from the top of the sample since deactivation would be expected to be greatest there.

Catalyst Source

Catalysts for both activity and analytical testing should be collected near the center of the reactor rather than near the walls. Some suppliers will be obtaining the laboratory catalyst from the catalyst beds and will be replacing with fresh catalyst. The sampling schedule that will be used for the large reactor is shown below.

Large Reactor Sampling Schedule

Time on Stream	Bed 1	Bed 2	Bed 3
3 months	x		
6 months	x		
9 months	x	x	
12 months	x	x	
15 months	x	x	
18 months	x	x	x
21 months	x	x	x
24 months	x	x	x

For the catalyst in the small reactor, there is a potential for extracting a large percentage of catalyst volume from the reactor if separate catalyst holders are not being used. SCS has outlined a sampling schedule that is less intensive than that for the large reactors but still allows adequate measurement of catalyst deactivation. SCS requires that the cored samples be 50mmx50mm from a standard 150mmx150mm element. The core would be replaced by fresh catalyst.

SCS approves suggested sampling schedule shown below for the small reactor (ten samples all together).

Small Reactor Sampling Schedule

Time on Stream	Bed 1	Bed 2	Bed 3
3 months	x		
6 months	x		
9 months		x	
12 months	x		
15 months		x	
18 months			x
21 months		x	
24 months	x	x	x

Flyash Removal and Influence of Ammonium Bisulfate

Loosely adhered flyash should be removed from the catalyst before lab testing with compressed air. However, no attempt need be made to remove flyash from the pores.

Ammonium bisulfate's influence on catalyst activity is considered important. SCS recommends that samples from bed 1 be evaluated for this effect at 3, 15, and 24 months. The procedure would be to first measure deNOx activity at approximately 644°F (340°C) and the other design conditions of 50 Nm^3/m^2hr, 1.0 NH_3/NOx, 400 ppmv NOx, and 2000 ppmv SO_2. The catalyst would then be tested at 700°F (370°C), 752°F (400°C) and finally at 644°F again. Presumably the exposure to the higher temperatures decomposes a portion of the adsorbed ABS/AS. Testing in this manner may reveal whether ABS or AS formation on the catalyst is significant.

2. Catalyst Pretreatment (Startup):

Gas Composition and Sequence of Addition

Presulfiding is unnecessary for spent catalysts, though it is recommended for fresh catalysts to minimize time required to reach equilibrium with the gas stream being treated. Times (up to 1 day of sulfiding) and concentration (up to 3000 ppmv SO_2) vary from supplier to supplier. SCS only requires that activity measurements reflect a catalyst which has reached equilibrium with the flue gas it is treating.

For the spent catalysts (those obtained from the pilot plant), the following sequence of gases is recommended. In all case, the gases should be passed through the heating catalyst bed and not bypass the reactor. First N_2 is passed through, then air, and then water. The water is introduced only after the catalyst has attained a temperature sufficiently above the dew point. The next gases to be sequentially added would be NOx, SO_2, and NH_3. As before, the temperature of the catalyst should be above any dew points.

A 12 hour activation period is recommended for the catalyst activity to stabilize before the first measurements are made. After this activation period, activity (deNOX performance) and selectivity (SO_2 oxidation) should be measured until a steady state is reached. The definition of steady state used will be <2% relative change in activity over a 1 hour period rather than the 1% figure suggested in the earlier correspondence.

Rate of Heatup

The following protocol for heating up the catalyst (with process gas flowing) is recommended: 10°C/min up to 150°C, then 20°C/min up to desired operating temperature. At these rates, the catalyst could be heated up from room temperature to operating temperature in less than half an hour. A slower heatup rate may be used if the supplier is unable to achieve the suggested rates. However, SCS wishes to avoid thermal shock to the catalyst from very high heatup rates. If a high heatup rate is used, it must be demonstrated that there is no adverse effect on activity compared to the recommended heatup rate.

System Pressure

Reactor pressure should not exceed 4 psig.

3. Reactor Design:

Reactor

Single bed measurements will be made. Note that the reactors should be made of glass or lined with an inert material to minimize side reactions. Preheating vessels should also be made of glass or coated internally with some inert material.

Thermocouples should be placed before and after the catalyst bed; the average temperature recorded would be used as the temperature for data reduction. While temperatures taken in the immediate vicinity of the catalyst should be representative of the catalyst temperature, it is recommended that the thermocouples be in direct contact with the catalyst.

Operation

The reactor will be operated isothermally. SCS also requires laminar flow before the catalyst, in the bed and after the catalyst. A premixer or in-line static mixer (e.g. a venturi taper) should be used to ensure a homogeneous gas composition since the flow regime will be laminar before the catalyst bed and not turbulent. The effectiveness of the mixing should be verified by the catalyst suppliers.

All suppliers will also ensure that the reactor and connecting lines are heated to avoid condensation of any substances. Preheaters should be lined with an inert material if possible to prevent reactions from occurring there. If this is impractical, it becomes even more important to analyze gas composition immediately before the reactor rather than much upstream of it. The exit lines should be heated to a minimum temperature of 460°F (or higher if necessary) to avoid condensation.

4. Measurement Devices:

Analytical Instruments

Chemiluminescence will be used for measuring NOx levels.

Sulfur dioxide and sulfur trioxide will be measured by ion exchange chromatography since it appears that this technique is equally as accurate as wet chemical methods such as EPA controlled condensation.

Low levels of ammonia will be measured by a wet chemical method in which the ammonia containing gas is first absorbed into a weak sulfuric acid solution. To avoid interference by sulfur oxides present in the flue gas, an ammonia ion-selective electrode is used to measure the ammonia. At high levels, ammonia will be oxidized to NOx and measured as a difference in the NOx signal.

Oxygen will be measured by a paramagnetic analyzer.

Other Measurements and Sample Handling

Flows from mass flow controllers can be verified periodically using a rotameter, wet, or dry test meter. It is important, though, that the devices be calibrated periodically.

After they are collected from the pilot reactor, samples could be stored in plastic bags or other "contamination-free" containers. This reduces the adsorption of moisture onto the samples.

5. Feed Gas Preparation:

Gases will be kept in separate cylinders. In order to have reasonably controlled flows from the gas cylinders, some of the ppm level gases (NO, SO_2, NH_3) could be stored at low concentrations, e.g. 2% NO in N_2. Concentrations should be verified prior to testing (i.e. for possible adsorption on cylinder walls or change in solubility as pressure changes). If concentrations change, gas flow should be adjusted accordingly to maintain the appropriate concentrations in the mix sent to the catalyst.

Deionized water should be used in these experiments. If N_2 or air is supplied by in-house lines, they should be free of oil from compressors.

The design concentrations that are proposed are (on a wet basis):

NO	400 ppmv, 250 ppmv (lowest value expected in pilot plant)
NO_2	not added, allowed to form in catalyst bed
NH_3/NOx	1.0 (and 0.6 for some tests)
SO_2	2000 ppmv, also test at 1000 ppmv since reaction order for SO_2 oxidation may not be 1
SO_3	not added, allowed to form in catalyst bed
O_2	4 vol%
H_2O	10 vol%
N_2	balance

6. Operating Conditions:

A single set of test conditions was selected for determining activity on the fresh catalyst and subsequent deactivation from measurements on the catalysts sampled every three months. These conditions are: 50 Nm^3/m^2hr, 1.0 NH_3/NOx, 400 ppmv NOx, 2000 ppmv SO_2, and 700°F. One concern, though, is the linear velocity that should be chosen. Depending on the reactor configuration, it is possible to achieve a wide range of linear velocities, though area velocity may be equivalent for all catalysts. Even if the same superficial velocity (based on reactor cross-section) or true velocity (near the catalyst surface) is used, catalysts may still be influenced differently by mass transfer to the catalyst surface.

Many of the catalyst suppliers are concerned that deactivation may be masked by mass transfer resistance if inappropriate linear velocities are chosen. To resolve this problem, SCS has considered the following simplified model for relating an apparent first-order activity constant to the intrinsic rate constant and mass transfer resistance.

$$1/k_a = 1/(eta)(k_i)(S_g) + 1/(k_g)(a_m)$$

k_a = first-order apparent rate constant, $(time)^{-1}$
eta= effectiveness factor accounting for pore diffusion
k_i = intrinsic rate constant, mass*$(internal\ surface\ area)^{-1}(time)^{-1}$
S_g = internal catalyst surface area per mass of catalyst
k_g = mass transfer coefficient, mass*$(geometric\ surface\ area)^{-1}(time)^{-1}$
a_m = external (geometric) surface area per mass of catalyst

SCS requested that the laboratory tests be conducted at conditions where the contribution of mass transfer resistance, expressed by $1/(k_g)(a_m)$, is less than 10% of $1/k_a$. Grace has stated that it cannot meet this requirement. **Please state what the contribution of mass transfer resistance is for both the Noxeram and Synox catalysts.**

SCS has listed below the minimum number of tests to establish catalyst response to changes in process variables. Conducting these tests in the controlled setting of a laboratory will remove the influence of other variables present in the pilot plant study (maldistribution of NH_3 and NOx, non-uniform temperature and velocity profiles, etc.).

The key variables to be examined are temperature, area velocity, inlet NOx level, NH_3/NOx ratio, and SO_2 concentration. Six test conditions are proposed below for the fresh catalyst and each of the samples obtained from the pilot plant. (Recall that additional tests are required infrequently on bed 1 samples for the influence of ABS and AS.) If suppliers are willing to conduct additional tests, SCS would welcome the additional insight that could be shared.

The first four tests listed involve only changes in gas composition and temperature. Initially, SCS felt that the data collected for the two area velocities shown should be at comparable linear velocities, in order to meet the restriction on mass transfer outlined above. However, this would require changing the volume of catalyst in a given reactor while operating at the same gas flow. Since the two different volumes of catalyst could exhibit different degrees of deactivation, the effect of changing area velocity could be obscured. For simplicity, area velocity can be changed by simply changing gas flow and not catalyst volume. Additionally, since some suppliers could not test over the original range of area velocities, the lower area velocity has been increased to 20 from 10.

Test No.	Temp (°F)	AV (Nm^3/m^2h)	Inlet NOx (ppmv)	NH_3/NOx	SO2 (ppmv)
1 (base)	700	50	400 (wet)	1.0	2000
2	700	50	400	0.6	2000
3	700	50	250	1.0	2000
4	640	50	400	1.0	2000
5	700	20	400	1.0	2000
6	700	20	400	1.0	1000

In at least two tests, 1 and 5, SCS would want NOx and NH_3 slip measurements to both be made, to confirm a mass balance. Ammonia slip is particularly important at low area velocities and other conditions of high activity. However, SCS does not require ammonia slip measurements in all tests if NOx conversion measurements allow accurate determinations of apparent rate constants.

Other Operating Conditions

For determining selectivity (SO_2 oxidation activity), SCS recommends that SO_2 and SO_3 measurements be made for tests 1, 4, 5, and 6. The results are not felt to be as critical for tests 2 and 3, but those may be included as well. In addition, when SO_2 oxidation measurements are being made, NH_3 flow should be stopped to minimize any interference from salts that may be formed.

Finally, SCS recommends empty reactor tests for deNOx (under test 1 conditions) and SO_2 oxidation (under test 5 conditions) to verify no reactor effects.

7. Data Reduction and Analysis:

Measurement Procedures

Intermittent analysis of inlet/outlet gas composition is sufficient. Analyses should be performed until steady state is achieved. On the other hand, continuous temperature readings are recommended if possible. If not continuous, they should be taken at the same time as the gas analyses and flow measurements.

Measurement of True Kinetics

Though it would be difficult to operate at conditions that eliminate the two types of diffusional resistance (to the surface and through the pores), differences between catalysts will be minimized if all tests are conducted at the conditions recommended. Even, then, the relative influences of the types of resistance would be expected to differ from catalyst to catalyst. We had requested that the catalyst suppliers share their models with us (or at least the results of applying the models at conditions we might encounter during operation). Grace has agreed to sharing these results. Naturally, the models will incorporate the findings from the laboratory studies.

Priority of Lab Tests

The following first level tests will be conducted for all samples by all vendors. Naturally, these same tests will be conducted on fresh catalyst as a point of comparison.

First Level

1. Specific Surface Area by BET Isotherm
2. Pore Volume Distribution by Mercury or N_2 Porosimetry
3. Chemical Composition by X-ray Fluorescence and wet chemical analysis (wet analysis to include S, Na, K, Ca, Mg, Cl, F, As, Se, Fe)
4. Physical Properties
   - Crystal Structure by XRD
   - Density (bulk measurement)
   - Mechanical Strength by a Compression Strength Test (choice left to catalyst supplier)

If appropriate, it would be useful to check BET area, porosimetry data, and/or wet chemical analysis both before and after lab testing if there is a change in activity during the course of lab testing. This may occur because of desorption of poisons or foulants (e.g. ABS). Note that activity as defined here is $k_a(t)/k_a(0)$, where t represents time and $k_a(0)$ is the apparent first-order activity constant at time equals zero.

If there is greater than 10% relative decline in $k_a(t)$ between three month periods of sampling, the following second level test must also be conducted. Even if the activity decline is not this great, SCS would request that this test be conducted on both fresh and 24 month old catalysts, for all beds.

Second Level

1. Active Sites
   - Acidity by Titration (or temperature programmed desorption) with NH_3. TPD procedure to be determined at a later date.
   - Chemisorption of NH_3 at Operating Temperature
   - Crystallite Size by XRD

Some third level analyses that could be performed are indicated below. These analyses may not need to be done on every sample, but insight may be gained from comparing sampled catalysts periodically to fresh catalyst. At a minimum, SCS requests analyses of the fresh catalyst and that after 24 months for all beds. The need for additional tests will be determined following discussions with each vendor separately and will be based on the results from first and second level analyses.

Third Level

1. Physical Strength
   Erosion Resistance by Abrasion Loss Test (e.g. steel grit dropped on sample or sand-containing air flowing through monolith channels).
2. Active Sites
   Oxidation State by X-ray Photoelectron Spectroscopy or $KMnO_4$ oxidation.
   Migration in Catalyst Structure of Active Metal by some method of profiling, preferably electron microprobe (EMP or EDX).

In all instances, samples should be retained by the catalyst suppliers in the event additional tests are required at a later date.

8. Reactor Shutdown:

The order of shutdown of gases is the reverse of startup. Therefore, the order will be NH_3, SO_2, NOx, water, air, and N_2. No specific cool-down rate is specified. AS/ABS formation, for instance, should not be a concern if the catalyst is cooled under a N_2 purge.

For safety primarily, the catalyst temperature should be below 100°C before it is removed from the reactor. The catalyst should also be stored in plastic bags or other contaminant-free container once the catalysts are sufficiently cool to avoid adsorption of moisture from the air. Care must be taken to preserve the catalyst in the event that activity or analytical tests would have to be repeated in the future. Please advise SCS if additional precautions need to be taken to ensure that the catalyst properties do not change over time.

Table E- 1 Plant Crist Unit 5 Coal Analyses - 1993 Monthly, As-Burned Composites
Alabama Power Company Results, Dry Basis

SCS ID No.			93-082	93-162	93-191	93-265	93-354	93-386	93-415	93-469	93-549	93-614	1993	1993
Test	Method	Units	March	April	May	June	July	August	September	October	November	December	Average	Std. Dev.
Moisture, Total	ASTM D 3302	% by Wt.	11.46	11.43	10.76	9.50	11.04	10.71	9.45	10.23	9.98	9.95	10.45	0.74
Ash	ASTM D 3180	% by Wt.	9.24	8.87	9.26	9.74	10.09	9.36	10.55	10.23	9.87	9.01	9.62	0.56
Gross Calorific Value	ASTM D 3180	Btu/lb	13328	13219	13314	13193	13113	13270	13095	13139	13251	13387	13231	97
Sulfur, Total	ASTM D 3180	% by Wt.	2.83	3.01	2.93	2.91	3.02	2.86	2.94	2.51	2.28	2.62	2.79	0.24
Sulfur, lb/MMBtu	ASTM D 3180	lb/MMBtu	2.12	2.28	2.20	2.21	2.30	2.16	2.25	1.91	1.72	1.96	2.11	0.19
Carbon	ASTM D 3180	% by Wt.	75.05	74.86	75.06	74.87	74.23	74.77	73.95	73.74	74.62	75.51	74.67	0.54
Hydrogen	ASTM D 3180	% by Wt.	5.09	5.04	5.09	5.10	4.98	5.06	4.96	5.00	4.95	5.04	5.03	0.06
Nitrogen	ASTM D 3180	% by Wt.	1.52	1.57	1.60	1.52	1.55	1.57	1.57	1.57	1.63	1.66	1.58	0.04
Oxygen	ASTM D 3180	% by Wt.	6.27	6.65	6.06	5.86	6.13	6.38	6.03	6.95	6.65	6.16	6.31	0.34
Carbon, Fixed	ASTM D 3180	% by Wt.	51.43	51.21	51.14	51.28	50.13	52.43	51.44	50.53	54.43	52.03	51.61	1.19
Volatile Matter	ASTM D 3180	% by Wt.	39.33	39.92	39.60	38.98	39.78	38.21	38.01	39.24	35.70	38.96	38.77	1.25
Aluminum	ASTM D 3682	% by Wt.	0.96	1.07	1.22	0.94	0.97	1.07	1.24	1.23	1.18	1.02	1.09	0.12
Antimony	ASTM D 3683	mg/kg	---	<1	<1	1	<1	<1	7	<1	2	1	<1	---
Arsenic	Spec. Chem. Acta. 44B	mg/kg	<1.0	1.4	2.0	<1.0	2.3	2.9	7.6	5.3	7.1	4.1	3.4	2.6
Barium	ASTM D 3683	mg/kg	43	31	35	41	44	36	72	74	96	55	53	21
Beryllium	ASTM D 3683	mg/kg	2	2	3	3	3	2	3	3	3	3	3	0
Cadmium	ASTM D 3683	mg/kg	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	---
Calcium	ASTM D 3682	% by Wt.	0.29	0.23	0.30	0.30	0.27	0.28	0.26	0.20	0.24	0.27	0.26	0.03
Chlorine	ASTM D 4208	mg/kg	1514	1882	1345	293	1341	1429	1716	812	1210	1395	1294	453
Chromium	ASTM D 3683	mg/kg	23	16	17	13	18	16	23	21	19	19	19	3
Cobalt	ASTM D 3683	mg/kg	7	6	7	6	7	5	9	9	10	9	8	2
Copper	ASTM D 3683	mg/kg	8	9	9	3	8	7	12	13	11	13	9	3
Fluorine	ASTM D 3761	mg/kg	49	36	27	10	24	92	90	47	58	66	50	27
Iron	ASTM D 3682	% by Wt.	1.16	0.78	0.96	1.17	1.13	0.95	1.24	1.11	1.20	1.15	1.08	0.14
Lead	ASTM D 3683	mg/kg	22	18	19	8	7	15	9	7	8	10	12	6
Lithium	ASTM D 3683	mg/kg	4	6	6	6	5	5	7	11	14	6	7	3
Magnesium	ASTM D 3682	% by Wt.	0.05	0.04	0.06	0.06	0.05	0.06	0.05	0.02	0.06	0.06	0.05	0.01
Manganese	ASTM D 3682	mg/kg	---	22	24	24	22	21	28	24	23	22	23	2
Mercury	ASTM D 3684	mg/kg	<0.02	0.04	0.03	0.03	<0.02	0.10	0.14	0.17	0.15	0.15	0.09	0.06
Molybdenum	ASTM D 3683	mg/kg	---	8	8	7	11	13	16	5	<1	6	8	4
Nickel	ASTM D 3683	mg/kg	15	13	14	12	14	11	16	15	18	17	15	2
Phosphorus	ASTM D 3682	% by Wt.	<0.01	0.03	0.03	0.03	0.01	0.05	0.12	0.04	0.04	0.02	0.04	0.03
Potassium	ASTM D 3682	% by Wt.	0.23	0.22	0.22	0.25	0.18	0.31	0.25	0.17	0.32	0.16	0.23	0.05
Selenium	Spec. Chem. Acta. 44B	mg/kg	<2	<2	<2	<2	<2	2	2	2	<2	<2	<2	---
Silica	ASTM D 3682	% by Wt.	2.31	2.15	2.26	2.31	2 42	2.15	2.61	2.45	2.63	2.01	2.33	0.20
Sodium	ASTM D 3682	% by Wt.	0.06	0.05	0 05	0 07	0 11	0 05	0 04	0 05	0 06	0.06	0.06	0.02
Titanium	ASTM D 3682	% by Wt.	0.06	0.05	0.06	0.06	0 06	0 07	0 06	0.05	0.07	0.06	0.06	0.01
Vanadium	ASTM D 3683	mg/kg	46	45	52	53	66	38	56	45	40	44	49	8
Zinc	ASTM D 3683	mg/kg	39	28	35	43	32	28	29	23	25	43	33	7

< Less Than Detection Limit.

Table E- 3 Plant Crist Unit 5 Coal Analyses - 1995 Monthly, As-Burned Composites
Alabama Power Company Results, Dry Basis

SCS ID No.			95-047	95-155	95-185	95-220	1995	1995	*Total	*Total
Test	Method	Units	January	May	June	July	Average	Std. Dev.	Average	Std. Dev.
Moisture, Total	ASTM D 3302	% by Wt.	12.42	10.62	10.96	10.15	11.04	0.98	10.87	0.97
Ash	ASTM D 3180	% by Wt.	9.46	9.73	8.40	7.75	8.84	0.92	9.30	0.63
Gross Calorific Value	ASTM D 3180	Btu/lb	13080	13349	13444	13584	13364	213	13268	130
Sulfur, Total	ASTM D 3180	% by Wt.	2.24	2.19	1.89	1.14	1.87	0.51	2.58	0.40
Sulfur, lb/MMBtu	ASTM D 3180	lb/MMBtu	1.71	1.64	1.41	0.84	1.40	0.39	1.95	0.31
Carbon	ASTM D 3180	% by Wt.	74.26	73.71	76.12	77.40	75.37	1.70	74.82	0.81
Hydrogen	ASTM D 3180	% by Wt.	4.99	4.81	5.07	5.11	5.00	0.13	5.00	0.07
Nitrogen	ASTM D 3180	% by Wt.	1.60	1.58	1.56	1.61	1.59	0.02	1.58	0.03
Oxygen	ASTM D 3180	% by Wt.	7.45	7.98	6.96	6.99	7.35	0.48	6.73	0.66
Carbon, Fixed	ASTM D 3180	% by Wt.	53.42	53.90	54.28	55.26	54.22	0.78	52.83	1.31
Volatile Matter	ASTM D 3180	% by Wt.	37.12	36.37	37.32	36.99	36.95	0.41	37.88	1.17
Aluminum	ASTM D 3682	% by Wt.	1.10	1.11	1.00	0.94	1.04	0.08	1.09	0.11
Antimony	ASTM D 3683	mg/kg	<0.2	0.8	0.6	0.4	0.5	0.3	<1.0	---
Arsenic	Spec. Chem. Acta. 44B	mg/kg	3.6	5.0	2.7	4.8	4.0	1.1	3.2	1.9
Barium	ASTM D 3683	mg/kg	22	35	26	48	33	12	40	18
Beryllium	ASTM D 3683	mg/kg	2	2	2	2	2	0	3	1
Cadmium	ASTM D 3683	mg/kg	0.22	0.26	0.09	<0.04	0.15	0.10	<1.00	---
Calcium	ASTM D 3682	% by Wt.	0.25	0.20	0.22	0.26	0.23	0.03	0.24	0.03
Chlorine	ASTM D 4208	mg/kg	3073	1477	2538	185	1818	1275	1767	812
Chromium	ASTM D 3683	mg/kg	20	16	14	12	16	3	19	4
Cobalt	ASTM D 3683	mg/kg	8	7	6	5	7	1	7	2
Copper	ASTM D 3683	mg/kg	10	11	9	9	10	1	9	2
Fluorine	ASTM D 3761	mg/kg	72	13	65	67	54	28	56	27
Iron	ASTM D 3682	% by Wt.	1.10	1.06	0.88	0.62	0.92	0.22	1.08	0.17
Lead	Spec. Chem. Acta. 44B	mg/kg	11.1	14.9	9.7	7.4	10.8	3.1	11.7	4.5
Lithium	ASTM D 3683	mg/kg	18	15	10	8	13	5	9	5
Magnesium	ASTM D 3682	% by Wt.	0.06	0.06	0.07	0.11	0.08	0.02	0.06	0.02
Manganese	ASTM D 3683	mg/kg	23	17	22	32	24	6	24	4
Mercury	ASTM D 3684	mg/kg	<0.02	0.04	0.07	0.05	0.05	0.02	0.07	0.04
Molybdenum	ASTM D 3683	mg/kg	---	---	---	---	---	---	7.78	4.33
Nickel	ASTM D 3683	mg/kg	18	13	12	12	14	3	15	2
Phosphorus	ASTM D 3682	% by Wt.	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02
Potassium	ASTM D 3682	% by Wt.	0.18	0.15	0.12	0.11	0.14	0.03	0.20	0.06
Selenium	Spec. Chem. Acta. 44B	mg/kg	1.4	2.7	3.1	2.1	2.3	0.7	<2	---
Silica	ASTM D 3682	% by Wt.	2.05	2.31	2.22	2.07	2.16	0.12	2.27	0.19
Sodium	ASTM D 3682	% by Wt.	0.09	0.09	0.06	0.07	0.08	0.02	0.06	0.02
Titanium	ASTM D 3682	% by Wt.	0.06	0.07	0.06	0.05	0.06	0.01	0.06	0.01
Vanadium	ASTM D 3683	mg/kg	28	31	27	25	28	3	41	10
Zinc	ASTM D 3683	mg/kg	52	29	27	13	30	16	39	29

*Total Includes Average and Standard Deviation from March '93 through Latest Month Shown
< Less Than Detection Limit.

Table E- 2 Plant Crist Unit 5 Coal Analyses - 1994 Monthly, As-Burned Composites
Alabama Power Company Results, Dry Basis

SCS ID No.			94-042	94-072	94-114	94-159	94-177	94-241	94-300	94-334	94-413	94-468	94-514	94-540	1994	1994	*Total	*Total
Test	Method	Units	January	February	March	April	May	June	July	August	September	October	November	December	Average	Std. Dev.	Average	Std. Dev.
Moisture, Total	ASTM D 3302	% by Wt.	9.30	9.72	9.73	11.76	11.46	12.00	11.50	11.87	11.01	12.23	10.74	12.60	11.16	1.08	10.84	0.99
Ash	ASTM D 3180	% by Wt.	9.84	9.39	9.69	8.86	8.92	8.65	8.63	8.91	9.08	9.18	8.96	10.04	9.18	0.46	9.38	0.55
Gross Calorific Value	ASTM D 3180	Btu/lb	13389	13448	13336	13334	13277	13242	13279	13262	13212	13165	13277	12988	13267	116	13251	107
Sulfur, Total	ASTM D 3180	% by Wt.	2.80	2.88	2.78	2.60	2.78	2.68	2.64	2.44	2.63	2.54	2.42	2.51	2.64	0.15	2.71	0.21
Sulfur, lb/MMBtu	ASTM D 3180	lb/MMBtu	2.09	2.14	2.08	1.95	2.09	2.02	1.99	1.84	1.99	1.93	1.82	1.93	1.99	0.10	2.04	0.16
Carbon	ASTM D 3180	% by Wt.	75.27	75.08	75.31	75.06	75.10	74.69	74.97	74.73	74.36	74.31	74.92	73.29	74.76	0.56	74.72	0.54
Hydrogen	ASTM D 3180	% by Wt.	4.97	4.94	4.99	4.91	4.96	5.04	5.02	4.95	4.99	4.97	5.00	4.93	4.97	0.04	5.00	0.05
Nitrogen	ASTM D 3180	% by Wt.	1.59	1.58	1.59	1.59	1.57	1.56	1.59	1.62	1.58	1.57	1.61	1.59	1.59	0.02	1.58	0.03
Oxygen	ASTM D 3180	% by Wt.	5.53	6.13	5.64	6.98	6.67	7.38	7.15	7.35	7.36	7.43	7.09	7.64	6.86	0.72	6.61	0.63
Carbon, Fixed	ASTM D 3180	% by Wt.	54.00	54.15	53.10	53.41	53.02	53.21	52.94	53.46	52.73	53.91	53.41	53.24	53.38	0.44	52.57	1.24
Volatile Matter	ASTM D 3180	% by Wt.	36.16	36.46	37.21	37.73	38.06	38.14	38.43	37.63	38.19	36.91	37.63	36.72	37.44	0.74	38.05	1.19
Aluminum	ASTM D 3682	% by Wt.	1.09	1.13	1.09	1.06	1.11	1.09	0.93	0.98	1.15	1.28	1.18	1.31	1.12	0.11	1.10	0.11
Antimony	ASTM D 3683	mg/kg	2.0	<1.0	0.9	1.3	0.4	0.6	0.9	0.7	1.5	0.2	0.3	0.9	<1.0	---	<1.0	---
Arsenic	Spec. Chem. Acta. 44B	mg/kg	4.8	2.0	2.6	1.7	1.1	1.6	3.3	1.1	1.9	4.6	5.6	2.7	2.8	1.5	3.1	2.0
Barium	ASTM D 3683	mg/kg	33	15	38	41	17	29	37	37	40	45	41	20	33	10	42	19
Beryllium	ASTM D 3683	mg/kg	3	3	3	2	2	3	2	2	2	2	3	3	3	1	3	1
Cadmium	ASTM D 3683	mg/kg	<1.00	<1.00	0.30	0.30	0.19	0.21	0.23	0.16	0.33	0.31	0.46	0.14	<1.00	---	<1.00	---
Calcium	ASTM D 3682	% by Wt.	0.23	0.18	0.22	0.23	0.22	0.21	0.25	0.19	0.22	0.20	0.24	0.27	0.22	0.03	0.24	0.04
Chlorine	ASTM D 4208	mg/kg	858	1116	1759	3403	2236	2092	2391	1957	1801	2630	2445	3039	2144	726	1757	743
Chromium	ASTM D 3683	mg/kg	21	26	20	27	21	28	21	17	19	18	20	19	21	4	20	4
Cobalt	ASTM D 3683	mg/kg	8	4	6	7	9	9	7	7	9	7	7	9	7	2	7	2
Copper	ASTM D 3683	mg/kg	12	4	10	8	9	10	10	7	9	9	11	12	9	2	9	3
Fluorine	ASTM D 3761	mg/kg	<1	41	87	98	63	70	47	33	47	82	75	85	61	28	56	27
Iron	ASTM D 3682	% by Wt.	1.33	1.17	1.34	1.11	1.17	1.16	1.13	1.10	0.78	0.95	1.00	1.23	1.12	0.16	1.11	0.15
Lead	Spec. Chem. Acta. 44B	mg/kg	13	14	14	6	7	19	13	12	10	5	16	9	11	4	12	5
Lithium	ASTM D 3683	mg/kg	7	8	6	15	4	9	3	9	9	13	17	18	10	5	9	4
Magnesium	ASTM D 3682	% by Wt.	0.08	0.07	0.07	0.05	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.07	0.06	0.01	0.06	0.01
Manganese	ASTM D 3683	mg/kg	29	35	28	22	22	26	24	24	19	23	23	26	25	4	24	3
Mercury	ASTM D 3684	mg/kg	0.09	0.10	0.08	0.07	0.08	0.08	0.07	<0.02	0.04	0.07	0.03	0.04	0.06	0.03	0.07	0.05
Molybdenum	ASTM D 3683	mg/kg	5.0	13.0	5.2	3.5	12.3	1.7	8.7	---	---	---	---	---	7.1	4.4	7.8	4.3
Nickel	ASTM D 3683	mg/kg	17	9	17	19	17	17	14	15	16	14	15	14	15	3	15	2
Phosphorus	ASTM D 3682	% by Wt.	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.00	0.02	0.02
Potassium	ASTM D 3682	% by Wt.	0.29	0.19	0.18	0.15	0.16	0.15	0.29	0.25	0.17	0.12	0.10	0.17	0.19	0.06	0.21	0.06
Selenium	Spec. Chem. Acta. 44B	mg/kg	2.0	<2.0	1.2	1.6	1.5	1.3	1.3	1.8	1.8	2.3	2.5	<1.0	<2.0	---	<2.0	---
Silica	ASTM D 3682	% by Wt.	2.58	2.50	2.21	2.09	2.16	2.10	2.02	2.22	2.42	2.22	2.06	2.45	2.25	0.19	2.29	0.19
Sodium	ASTM D 3682	% by Wt.	0.06	0.05	0.06	0.06	0.07	0.05	0.06	0.06	0.07	0.06	0.08	0.09	0.06	0.01	0.06	0.02
Titanium	ASTM D 3682	% by Wt.	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.05	0.06	0.07	0.06	0.01	0.06	0.01
Vanadium	ASTM D 3683	mg/kg	50	26	49	34	40	47	47	37	38	34	37	38	40	7	44	9
Zinc	ASTM D 3683	mg/kg	36	31	36	28	30	37	39	177	56	39	31	36	48	41	41	31

*Total Includes Average and Standard Deviation from March '93 through Latest Month Shown
< Less Than Detection Limit.

SRI-ENV-92-933-7613

QUALITY ASSURANCE PROGRAM PLAN

Submitted by

Southern Research Institute

Prepared for

Southern Company Services, Inc.
Bi . ingham, AL

As Required by SCS Contract Number C-92-000320

Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration for Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal-Fired Boilers

November 2, 1992

SRI Project Number 7613.07

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INTRODUCTION

This document describes the Quality Assurance Program Plan (QAPP) instituted by Southern Research Institute (SRI) as required under the contract with Southern Company Services (SCS) for "Testing and Analytical Services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the Control of Nitrogen Oxide (NO_x) Emissions from High Sulfur Coal-Fired Boilers."

The QAPP includes the following elements: sampling procedures; sample custody; calibration procedures and frequency; analytical procedures; data reduction, validation, and reporting; internal quality control checks, performance and systems audits; preventive maintenance; and corrective action.

The objectives of this QA Program Plan are to ensure:

That a consistent QA policy is observed by SRI for all work performed under this contract;

That all QA requirements for the work performed by SRI under this contract are satisfied;

That available resources are effectively utilized to resolve technical problems related to the implementation of the QA program, as necessary;

That usable data are obtained.

The methods SRI will use to perform the tasks required under this contract are described in the revised technical proposal to SCS dated June 9, 1992. Data will be collected regarding three species occurring in the aerosol in the high-sulfur coal SCR process. In general, applicable EPA reference methods will be used to collect data. These test methods are described in detail in Title 40 Code of Federal Regulations Part 60, Appendix A - Test Methods, U.S. General Services Administration, Office of the Federal Register, National Archives and Records Service, July 1, 1991. The test methods detailed in that document are hereafter referred to as EPA Method 5, etc. Particulate mass concentration, particle size and mineralogical composition will be determined from samples collected using EPA Method 17. Sampling with Method 17 type sampling trains will include particulate filters, cascade impactors, and five-stage series cyclones. Trace metals concentrations in the solid and vapor phases will be determined using EPA modified Method 5 to collect samples to be analyzed by Inductively Coupled Argon Plasma Emission Spectrometry (ICAPES), atomic absorption spectrometry (AAS), and cold-vapor atomic absorption. Liquid samples collected with a controlled condensation sampling method similar to EPA Method 8 will be analyzed by ion-specific electrodes or ion chromatography to determine the concentrations of the gaseous species of interest. A single component, nitrous oxide, will be analyzed by gas chromatography of carefully conditioned grab samples of the flue gas.

The scope of work under this contract requires SRI to determine flue gas velocity to calculate volumetric flow rates for flow meter calibrations and to determine particulate sampling train flow rates to maintain isokinetic sampling conditions. SRI will use "S" type pitot tubes, standard pitot tubes, and hot-wire anemometers designed for high-temperature operation to measure flue gas velocity. The methods used for this work are described in EPA Methods 1 and 2. Supporting measurements of temperature and static pressure will be made with appropriate thermocouples and manometers as described in EPA Methods 2 and 5 (1).

Southern Research Institute will follow the guidelines published by the United States Environmental Protection Agency; von Lehdem, D. J., DeWees, W. G., and Nelson, C., Quality Assurance Handbook for Air Pollution Measurement System, Volume III - Stationary Source Specific Methods, EPA-600/4-77-027b, U. S. Environmental Protection Agency, Research Triangle Park, North Carolina, January 1980 with subsequent updates; (hereafter referred to as EPA Volume III) for quality assurance and quality control for the sampling and analysis for the SCR project. The remainder of this document will indicate sections of EPA Volume III that apply to the testing to be performed under this contract, and discuss specific instances where we will vary from the recommended procedures .

SAMPLING PROCEDURES

PARTICULATE SAMPLING

Mass Concentration.

A comprehensive chemical and physical profile of the particulate component of the aerosol entering the SCR reactors is essential because catalyst plugging and catalyst deactivation are expected to be important issues. EPA Method 5 is commonly used to measure particulate emissions from industrial processes. However, we believe that superior results will be obtained with EPA Method 17 because the particulate concentration and chemical composition of the particulate component of the aerosol may be dependent on stack temperature. At the temperatures encountered in the SCR process, in a stack environment rich in water and sulfur oxides in the presence of slip ammonia, the formation of ammonium bisulfate and ammonium sulfate is unlikely. However, if a nominal reference temperature of 250°F is established for particulate, as in EPA Method 5, a significant portion of the ammonia in the gas stream may be collected as particulate. For these reasons, SRI has elected to use EPA Method 17 for the required mass concentration measurements.

EPA Method 17 is an in-stack sampling system designed to be used in conjunction with Methods 1, 2, 3, and 4, along with appropriate sampling and analytical procedures. Method 17, a gas sample is extracted isokinetically from the source and particulate collected on a filter situated in the flue gas stream. The mass is determined after the removal of uncombined water. Method 17 is not applicable in projected cross-sectional area of the filter holder exceeds 5% of the area. This restriction would prohibit the use of Method 17 for

sampling in the small SCR reactors being evaluated at Plant Crist. However, we propose to use a sampling strategy whereby the filter holder will be housed in a sampling port; a 4-in. diameter nipple that is 12 in. long. A nipple made of 1/2 in. stainless steel pipe will connect the body of the filter holder to the sampling nozzle. This nipple will be sized to locate the nozzle at the centroid of the duct cross-section. We will not attempt to traverse the small reactor ducts because the cross-sectional area is less than one square foot. Temperature sensors will be included in the apparatus so that, if necessary, filter temperature can be maintained at the gas temperature by means of electric heaters. The large reactors will be traversed as required in EPA Methods 1, 5, and 17.

Quality control for the EPA Method 17 sampling protocol is addressed in Sections 3.0, 3.1, 3.2, 3.4, and 3.11 of EPA Volume III. SRI will adhere closely to the QA/QC procedures described in the applicable portions of that document.

The methods SRI will use to measure stack gas velocity to determine isokinetic sampling flow rates are described in EPA Method 1 and in EPA Method 2. These methods will also be used to calibrate venturi flow meters in the SCR pilot plant. The technical considerations necessary to insure the quality of the data produced with these methods are presented in Sections 3.0 and 3.1 of EPA Volume III. SRI will adhere to the QA/QC recommendations presented there.

Particle Size Distribution.

Fly ash particle size distribution will be determined in SRI's Birmingham laboratories from particulate samples collected with Method 17 mass trains. The determination of particle size distribution will be performed with a Shimadzu SA-CP4 centrifugal particle size analyzer. This instrument is reliable, simple to use, and gives reproducible results. It employs combined gravitational/centrifugal sedimentation with photometric detection to determine the particle size distribution of the sample. This technique requires only a 0.1 g sample to perform a triplicate analysis. Thus, sufficient particulate will remain for subsequent chemical analysis.

During start-up, two pairs of cascade impactors and two pairs of six-stage series cyclones will be run at the unit 5 hot-side ESP inlet to compare the laboratory particle sizing results to well-established field sampling techniques for measuring particle size distributions. Cyclones provide adequate resolution of the size distribution and permit longer sampling times so that the inlet samples, where the particle concentration will be high, represent better temporal averages of the entrained particulate matter. The particulate collected with the cyclones will also be used to obtain size-specific mineralogical and trace metals concentration information. The approximate cuts in particle-size distribution with the two types of samplers are as follows:

Series cyclones - 8, 4, 2, 1, and 0.5 μm
University of Washington impactors - 8, 3, 2, 1, 0.5, 0.2, and 0.06 μm

In either device, the last stage is a back-up filter.

The reliability of the particle-size cut-points of impactor and series cyclones is an important issue. We establish cut-points by relating physical properties of the device such as jet-to-plate spacing and jet diameter to a theoretical performance factor.

Quartz fiber impactor substrates will be used to avoid weight increases due to the reaction of the substrate with SO_2 in the flue gas. An impactor with a high-efficiency particulate filter in the place of the sampling nozzle will be run on each test day as a quality control measure to quantify whatever weight change may occur as a result of chemical reactions.

GAS SAMPLING

SRI will measure the concentrations of four gases with manual sampling methods and subsequent chemical analysis under this contract. The species to be resolved are sulfuric acid vapor (SO_3), ammonia (NH_3), hydrochloric acid (HCl), and nitrous oxide (N_2O). EPA Method 8 describes a method for determining SO_3 concentration. However, we prefer an alternate sampling method for SO_3 as described in our technical proposal. The methods we will use to sample for NH_3 and HCl are also described in the technical proposal. The application of these sampling methods and relevant quality control topics are described below.

Sulfur Trioxide Vapor Concentration (SO_3)

SO_3 in the flue gas will be collected by the controlled condensation method. In this method, the flue gas is sampled with a train of a heated, quartz-lined probe, a quartz-fiber filter supported on a frit in a heated quartz filter holder, and finally a Pyrex condensing element maintained around 160°F. The condenser used by SRI is a bulb with connections on both ends containing a packing of glass wool. The temperature of the condenser is maintained with a heated water jacket.

As the gas stream is cooled from a duct temperature above 600°F, the SO_3 present begins to undergo a hydration reaction with the water vapor that is present, producing H_2SO_4. As the temperature of the gas stream continues to drop, the H_2SO_4 and excess water vapor begin to condense concurrently to produce a condensate of concentrated aqueous H_2SO_4. If the concentration of SO_3 in the gas stream is about 75 ppm, condensation begins at around 300°F. At 160°F, condensation is essentially complete, leaving a residual vapor concentration of SO_3 well below 1 ppm.

The potential interaction of SO_3 and NH_3 can introduce problems in regard to solids formation. Thus, it is critical that the probe, the quartz-fiber filter, and its holder, be maintained at the flue gas temperature to avoid solids formation ahead of the condenser. Under these sampling conditions, all of the SO_3 present in the flue gas is collected for subsequent analysis, whether as H_2SO_4, NH_4HSO_4, or as $(NH_4)_2SO_4$.

Other than the use of a heated quartz-fiber filter to remove particulate, and the condenser for collecting H_2SO_4, the controlled condensation sampling train is similar to that described in EPA Method 8. This method, along with detailed quality control considerations, is described in detail in Section 3.7 of EPA Volume III. The quality control procedures detailed there, along with those described for EPA Methods 1, 2, 3, and 4, will be adhered to for this work.

Ammonia Concentration, (NH_3)

Ammonia will be collected by drawing a stream of flue gas through a heated probe, a heated particulate filter, an air-cooled condenser, and finally a series of bubblers filled with dilute sulfuric acid. The methods we intend to use are discussed in detail in our technical proposal. The sampling method is not described by an official EPA method, but it shares many characteristics with the methods described for sampling other gas-phase pollutants. SRI will follow the quality control procedures detailed in EPA Methods 7 and 8 and in applicable portions of EPA Volume III, especially Section 3.7.

Hydrogen Chloride Concentration, (HCl)

HCl will be collected by drawing flue gas through a heated probe, a heated particulate filter, an air-cooled condenser, and a series of bubblers filled with dilute NaOH or Na_2CO_3 solution. In principle, the sampling train for HCl is similar to the apparatus used to collect NH_3, except that the absorbent solution contains a base rather than an acid. The quality control considerations described in Section 3.7 of EPA Volume III will be employed, as applicable, for the sampling activities for HCl. QA/QC techniques for the required IC analysis are described in EPA Method 300.0 and in Section 3.15.2 of EPA Volume III.

Nitrous Oxide Concentration, (N_2O)

At least two N_2O monitors of the NDIR type are commercially available. However, these instruments are a poor choice for measuring small N_2O concentrations in flue gas because of overwhelming interferences caused by several common flue gas constituents. For this reason, SRI will measure N_2O concentrations by withdrawing grab samples of the SCR inlet and outlet gas for laboratory determination of N_2O concentration. These samples will be conditioned by passing them through phosphorous pentoxide to remove water and a sodium carbonate solution to remove SO_2. Sample conditioning in this manner is needed to prevent the formation of an N_2O artifact in the sample bag. This sampling artifact can be as much as several hundred parts per million where no N_2O was originally present.

SAMPLE CUSTODY

The objective of our sample custody procedures is to create an accurate written record which can be used to track the possession and handling of each sample from the moment of its collection through its analysis and storage.

FIELD SAMPLING OPERATIONS

A label will be affixed to each sample or to its container when the sample is collected. A sample number with encoded information identifying the location from which the sample was collected, the type of sample, and the test series of the sample will appear on this label. The identity of the scientist who collected the sample will also appear on the label. A permanent marker (Sharpie) will be used to place this information on the sample label.

A bound logbook will be maintained in which a permanent record of all samples will be entered. Each category of sample, i.e. Method 17 mass train, will be assigned a serial number including alphanumeric characters identifying the sample category and the sampling location. The sample log book will contain a permanent record of these sample identification serial numbers, and a description of the sample, its collection method, the time and date of collection, and a description of any pertinent physical characteristic.

A field record of each sampling run will be recorded as the sample is collected. The pitot tube velocity traverse used to determine isokinetic flow rates, and summary data (flow rates, temperatures, etc.) recorded during the sampling run will be recorded. These run sheets will be stored in a three-ring notebook and can also be used to track individual samples.

LABORATORY OPERATIONS

Appropriate log books will be used to provide records of sample analysis. Sample identification numbers will be used to refer to all samples throughout all analytical work and subsequent reporting. An instrument logbook will contain a record of the calibration, maintenance and use of each instrument or balance used in the project. For example, the GC logbook will contain sample identities, concentrations of standards, type of GC column and detectors, project number and initials of the analyst. In addition, the logbook will provide a permanent record of instrument failures, corrective action taken and preventive maintenance.

A standard logbook will contain a permanent record of reagents or reference standards and the preparation of standard stock solutions or mixtures. The source, lot numbers, purity, amount of standards measured, the dilution solvents and the responsible analyst will be noted.

The SRI supervisor or other designated person will review and sign all notebook entries. Data summaries will be compiled by the SRI supervisor with the assistance of the analyst and submitted to the SCS process engineer at regular intervals.

CALIBRATION PROCEDURES AND FREQUENCY

In most particulate sampling involving mass trains, cascade impactors, and series cyclones, the accuracy, precision, and comparability of gas volume and flow rate measurements are critical to achieving data quality objectives. For this reason the flow metering systems must have dependable calibrations.

We propose to calibrate our orifices and dry gas meters using a laminar flow element rather than a wet test meter as prescribed in the EPA Method 5 and in EPA Volume III. We currently use the Meriam Model No. 50MJ10 Laminar Flow Element which has been calibrated against Meriam flow standards which are traceable to the National Institute of Standards and Technology. The calibration supplied by Meriam with these devices indicates that the laminar flow element agrees with the Meriam flow standard within 0.5%.

Type S pitot tubes will be calibrated according to the procedure in EPA Method 2. All temperature sensors in the sampling systems will be checked periodically against mercury in glass thermometers for proper calibration using the procedures outlined in EPA Method 5.

High-accuracy oil manometers with inclined scales are considered calibration standards for pressure measurements. SRI will also have occasion to use U-tube or well-type manometers with mercury or water as the working fluid. These are also considered standards for pressure measurements.

Calibration and maintenance of analytical balances will be performed at one-year intervals. A standard weight check with control weights is performed by the analyst for each set of weighings.

ANALYTICAL PROCEDURES

Volumes and weights of Method 17 sampling elements will be measured according to EPA specifications in the respective sampling methods (EPA Methods 1, 2, 3, 4, 5, and 17). Many physical elements, such as the volume of water or of a solution need not be measured with high accuracy. However, calibrated glassware will be used for most volumetric measurements, and ASTM Class S weights will be used for weighing.

The impactor substrates used to collect particulate matter for weighing, will be weighed on a Cahn micro balance, which has a resolution of 0.001 mg. Thimble-type filters used to collect particulate where mass loading is higher will be weighed on a Mettler analytical balance with a resolution of 0.1 mg. Calibration and maintenance of analytical balances will be performed at regular intervals by professional service personnel. A standard weight check with control weights will be performed by the analyst for each set of weighings. Mass measurements requiring less resolution, such as determinations of the mass of water collected in desiccant columns, will be determined on a triple beam balance having a resolution of 0.1 grams.

We will use ion chromatography to analyze condensate samples for sulfate ion to determine the concentration of SO_3, and to analyze impinger liquid for chloride ion to determine the concentration of HCl in the flue gas.. EPA Test Method 300.0, "The Determination of Inorganic Anions in Water by Ion Chromatography", details the analytical procedure that will be used. The quality control measures recommended there will be adopted for our analytical work using ion chromatography. In addition to the EPA recommendations, the operating instructions provided by the manufacturer of the instrument will be closely followed.

An ammonia-selective electrode, associated with a reference electrode and attached to a pH meter provides a simple, convenient method to determine concentrations of ammonia collected as the chloride or as a sulfate salt.. The solution is made alkaline thus converting NH_4+ ion to free NH_3 in solution. The voltage output of the pH meter is used to calculate the concentration of NH_3 as follows:

$$\ln [NH_3] = (E)/RT + C$$

where R is the ideal gas constant, T is the absolute temperature, E is the meter output voltage, and C is a calibration constant. The procedures that we will use are discussed in greater detail in our technical proposal.

Flue gas samples conditioned by removing water vapor and sulfur dioxide and stored in Tedlar gas sample bags will be analyzed for N_2O with a gas chromatograph equipped with an electron capture detector (GC/ECD). The analyst will prepare a calibration curve for the gas chromatograph using an external standard technique. A minimum of three standards will be used to prepare the calibration curve. When flue gas samples are analyzed, the expected concentrations of N_2O should be within the range of the calibration curve. The calibration curve will be verified on each working day by the measurement of a calibration standard . If the response for the calibration check varies from the predicted response by more than two standard deviations, the test will be repeated with a fresh calibration standard. Alternatively, a new calibration curve will be prepared.

Inorganic analyses for trace metals and to determine ash mineralogy will be performed in the SRI Birmingham laboratories by Inductively Coupled Argon Plasma Emissions Spectrometry (ICAPES) and by Atomic Absorption Spectrometry (AAS) methods. ICAPES or AAS analyses will use the method of standard additions for calibration (in the latter case, the graphite furnace method, the cold-vapor method, or the hydride generation method as required for some specific analytes).

In most instances, duplicate samples will be collected to provide a minimal assessment of the precision of the sampling techniques. In so far as possible, each sample will be split and duplicate analyses performed, again to provide an assessment of the precision of the analytical technique. Ideally, more than two replicates would be performed, but budgetary constraints limit us to two analyses of each sample. Several analytical techniques will be used, either separately or in combination, to insure the quality of our analytical work. These are as follows:

Standards. The standards used for analytical work are of the highest quality. In most cases, these standards come from EPA or commercial sources. As standards for coal and fly ash, the Standard Reference Materials provided by the National Institute of Standards and Technology are employed. A record of the origin, lot number, and purity of each standard is maintained.

Reagent Blank Analysis. Reagent blanks are routinely analyzed to establish background interferences and possible analyte detection limits. Duplicate analyses are used to establish analytical precision and spiked blanks and matrix samples are analyzed to determine analytical accuracy.

Standards Analysis. Authentic analytical standards or reference materials, either from commercial and government sources or prepared in-house, are analyzed alongside routine samples to check the accuracy of analytical procedures.

Sample Blank Analysis. Sample blanks are analyzed to assess possible contamination or interferences in an analysis and to establish a zero base line or background value which may be used to adjust or correct routine analytical results. Sample blanks include:

> *Reagent blanks (Method blanks).* These blanks are used as a base for the analytical portion of a method. The blank is processed exactly as a real sample is processed (same glassware, reagents, solvent, etc.). A method blank is processed for each set of analyses and whenever a new source of reagent or solvent is introduced into an analytical scheme.
>
> *Field blanks.* These blanks are sent to a monitoring site, left at the site for the normal period of sampling, returned to the laboratory and analyzed. The field blank is not exposed to the analyte.

Matrix spike analysis. Samples that contain additions of known amounts of authentic standards are processed and analyzed in the same manner as the field samples. The calculated concentration of the spiked compound is compared with the true amount of compound added to the matrix. The recovery of the compound of interest is an estimated measurement of accuracy. Matrix spiked samples are used to check the performance of a routine analysis or the recovery efficiency of an analytical method.

Replicate analysis. Replicate analyses (at least two analyses) are performed to determine the precision of the analysis. For those determinations where a sufficient number of results were accumulated over time, precision criteria may be developed. A minimum of 15 replicates at a particular concentration or concentration range where linearity exists are required to establish an on-going program for QC charts.

Surrogate spike analysis. Surrogate standards are added to GC samples prior to analysis. The use of surrogate standards cannot detect all possible problems, but this method can help to eliminate several sources of error. Surrogate standards are chemically similar to the compounds in the sample being analyzed. Also, surrogate standards should be compounds that would not likely be found in the matrix. The purpose of the surrogate spikes is to provide QC on every sample by constantly monitoring for unusual matrix

effects, gross sample-processing error, etc. Surrogate spikes are generally not used as internal standards for quantification purposes.

Internal standard analyses. Authentic standards are added to the sample or extract of the sample prior to its injection into the analytical instrument to minimize the possibility of losses due to evaporation, adsorption, or chemical reaction and to compensate for variation in injection volumes. The internal standard is chemically similar to compounds in the fraction being analyzed. Compounds used as internal standards are not to be used as surrogate standards.

Standard (calibration) curve. Prior to the analysis of samples, a standard curve that covers the entire working range of the method must be constructed with at least three to five concentrations of authentic standards. The standard should include one near the upper limit of the concentration range and one near the lower limit of the concentration range. The other standards should be equally spaced throughout the operating concentration range. Each day, if operation is continuous, or prior to analyzing each group of samples, if operation is discontinuous, standards must be analyzed to establish the validity of the original standard curve. If this standard falls outside the established limits, a new standard curve must be constructed. These limits are specified in the standard methods to be used.

Internal audits. Internal audits of specific work will be periodically conducted. Audits involve an independent check of the performance of the laboratory analysts to determine if prescribed procedures are being followed.

DATA REDUCTION, VALIDATION AND REPORTING

Data processing includes handling, transmission, storage, validation, verification and reduction of data. The necessary procedures will be used to protect the integrity of any results reported from this project. Without established procedures, data may be lost, distorted, misinterpreted, incorrectly transcribed, improperly transposed, or overlooked. The analyst will develop the raw data by performing the analysis. The calculated results require verification to eliminate outliers or extraneous results.

The analyst in the laboratory read measurements from balances, spectrometers, chromatographs, meters and other instruments and equipment. All data, calculations, and final results will be kept in bound notebooks reserved for this project. Entries in these notebooks will be made and initialed by the analysts doing the sample collection, preparation and analysis. The importance of accuracy in recording laboratory results will be stressed. Acceptance criteria for specific methods will be established and data will be flagged when values fall outside of the criteria.

The analytical information reported will include the measured physical characteristic, significant details of the analysis, and the reported data values. Laboratory observations, information, data, calculations and final results may be maintained in one or more of the following forms:

Performance logbook. This will provide a permanent record of performance audits. These audits may be internal or external in origin and consist of quantitative or qualitative analyses or evaluations with chemical standards, materials, or devices with known properties and characteristics.

Project notebook. A permanent record of the sample preparations, data calculations and final results. Data that may be found in a sample logbook are often recorded in this notebook. Some projects may have individual notebooks, whereas others are assigned to a general project notebook.

IC and GC chromatograms. Coded to pages in project notebooks will be stored digitally on disc, and hard copies will be stored in separate folders.

The majority of the data reported by SRI will be derived from laboratory analysis of samples collected manually in the field. Laboratory data will be recorded manually or by computerized data acquisition. In either case, the analyst who generates the data will be responsible for its documentation. Data that are not available on computer printout are to be recorded by the analyst in research laboratory notebooks assigned to the project . Data on computer printouts (chromatograms, mass spectra and computerized data) are to be dated, coded and initialed by the analyst and to be traceable to the project research-laboratory notebooks and/or to the instrument logbook.

PERFORMANCE AND SYSTEMS AUDITS

Quality assurance audits provide an independent assessment of the measurement efforts. The primary objective of an audit is to ensure that reliable, useful data are produced. Further, an audit may identify problems with the effort and thus provide a means to implement corrective action. These audits should be directed toward evaluating the performance of the effort and of the technical systems employed.

TECHNICAL SYSTEMS

A periodic review of the total sampling and analytical system is needed to review the overall effectiveness of the operation. Necessarily, these technical systems audits are a subjective evaluation of all systems in use with respect to strengths, weaknesses, and potential problem areas. The audit is a comprehensive review of all aspects of the measurements.

Typically, the audit involves a review of calibration procedures and documentation, a check of data recording practices and reporting, a review of data validation procedures, sample custody procedures, overall quality control practices, and equipment operation and maintenance.

The technical audit is simply a review of equipment use and standard operating procedures. It does not address question s regarding data quality or the methods used to evaluate the quality of the data.

PERFORMANCE EVALUATIONS

The performance evaluation audit assesses the quality of the data. Specifically, this audit addresses the capabilities of the measurement systems to generate quality data. Generally, this is accomplished by comparing the various systems with accepted reference standards. The performance audit evaluates the accuracy and precision of the measurement system, compares quality control data against actual data, evaluates each system against its established control limits, and searches for deviations in data quality over time. The performance evaluation audit indicates when the system is not performing within the desired quality control constraints but does not necessarily identify appropriate corrective action.

QUALITY ASSURANCE REPORTS

SRI will submit a quarterly quality assurance report to allow an assessment of the usefulness of the data reported. This report will summarize quality control measures including any audits that may have been conducted. It will also describe any problems that were encountered and summarize corrective actions.

TESTING AND ANALYTICAL SERVICES FOR THE INNOVATIVE CLEAN COAL TECHNOLOGY DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_x) EMISSIONS FROM HIGH SULFUR COAL

Final Report

Task 1: Commissioning without Catalysts and without Ammonia Injection

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Section 1

INTRODUCTION

This is the first in a series of final reports describing the results of testing and analytical services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the control of nitrogen oxides (NO_x) emissions from high-sulfur, coal-fired boilers. The tests are being conducted at the Plant Crist SCR Test Facility located at Gulf Power Company's Plant Crist Unit 5 in Pensacola, Florida. The test results for Task 1: Commissioning without Catalysts and without Ammonia Injection, are summarized in this final report. Task 1 testing and sample analysis began on January 29, 1993 and concluded during August 1993.

Task 1 testing began with the calibration of the venturis upstream of each reactor. These venturis are used for flow rate control. The next phase of Task 1 testing included measurement of the particulate (fly ash) mass concentration at the inlet and outlet of the Plant Crist Unit 5 hot-side electrostatic precipitator (ESP) at high and low load conditions, measurement of the particulate mass concentration in the economizer bypass duct at low load, and verification of similarity among the particulate mass concentrations inside the eight high-dust reactors. Particle size distribution tests were also conducted to verify that the size distribution of the fly ash inside the eight high-dust reactors was similar. Baseline gas-phase constituents of the flue gas were measured. These included SO_2, SO_3, HCl, and NH_3. Although planned for Task 1 testing, instrumentation problems prevented the measurement of NO_x and O_2 concentrations in the flue gas. The conversion of SO_2 to SO_3 across one large and one small reactor heater was measured. Fly ash chemical analyses were performed, as well as laboratory measurement of ash resistivity. Finally, concentrations of volatile and non-volatile trace metals were measured in the Unit 5 hot-side ESP inlet and outlet duct, the economizer bypass, and the inlet to Reactor A.

The test data are summarized in several sections. These sections include Venturi Calibration, Mass Concentration, Particle Size Distribution, Flue Gas Chemistry, Fly Ash and Coal Chemistry, Fly Ash Resistivity, and Trace Metals Analysis.

Section 2

VENTURI CALIBRATION

Flue gas flow rate through each of the nine reactors at the Plant Crist SCR Test Facility is controlled by individual venturis. These venturis were calibrated using both S-type and standard pitots. The venturis on the three large reactors (A, B, C) were calibrated with 12-point traverses on two diameters 90° apart. The duct diameter for the large reactors is 23.25 inches. Because of the small diameter of the ducts on the small reactors (6 inches) and the existence of only a single sampling port, only four-point traverses (centriods of equal areas) on a single diameter were possible. Each venturi was calibrated at three flow rates; approximately 3000, 5000, and 7500 wet standard cubic feet per minute (wscfm) for the large reactors and 240, 400, and 600 wscfm for the small reactors. In some cases more than one calibration was performed at a particular flow rate. After each test, data from the Bailey Distributive Control System (DCS), which calculates the flow rate through the venturi based on the venturi manufacturer's design equation, was gathered to determine the average calculated flow rate during the specific time of the calibration procedure. By comparing the pitot data (measured) and the Bailey DCS data (calculated) for each reactor venturi, a correction factor was developed to be used to provide correct flow rate data from the Bailey DCS during later operation. In one instance a recalibration of the Reactor B venturi was performed because the initial calibration demonstrated that the programmed constants in the Bailey DCS for this reactor venturi's equation were not correct.

Table 2-1 summarizes the venturi calibration test data for each of the reactors. Included in the table are the test date, test identification number, measured flow rate (S-type and standard pitot), Bailey DCS calculated flow rate (venturi design equation), individual correction factor for each test, and the average correction factor for each venturi. It is anticipated that as the test program progresses, additional venturi calibration checks will be made at regular intervals to confirm that the flow rate through each reactor provided by the Bailey DCS is accurate.

Table 2-1. Plant Crist SCR Test Facility - Venturi Calibration Data

Test Date	Test ID Number	Measured Flow Rate (S-Type & Standard Pitot) (wscfm)	Calculated Flow Rate (Venturi Equation) (wscfm)	Correction Factor	Average Correction Factor
Reactor A					
2/1/93	VTL-011	5552	5459	1.017	
2/1/93	VTL-012	5441	5123	1.062	
2/1/93	VTL-014	3330	3005	1.108	
2/8/93	VTL-022	7700	7247	1.063	1.062
Reactor B					
2/1/93	VTL-007	7750	4998	1.551	
2/1/93	VTL-008	7853	4986	1.575	
2/1/93	VTL-009	4539	3066	1.480	
2/1/93	VTL-010	4564	2995	1.524	
2/8/93	VTL-021	3078	1997	1.541	1.534
Reactor B (Recalibration)					
3/18/93	VTL-029	5238	4994	1.049	
3/18/93	VTL-030	5507	5000	1.101	
3/18/93	VTL-031	3969	3540	1.121	
3/18/93	VTL-032	3992	3457	1.155	
3/18/93	VTL-033	7790	7390	1.054	
3/18/93	VTL-034	8283	7392	1.121	1.100
Reactor C					
1/29/93	VTL-001	5350	4967	1.077	
1/29/93	VTL-002	5018	5020	1.000	
1/29/93	VTL-003	3575	3001	1.191	
1/29/93	VTL-004	3528	3002	1.175	
1/29/93	VTL-005	8385	7513	1.116	
1/29/93	VTL-006	8113	7505	1.081	
2/5/93	VTL-015	5275	5002	1.055	
2/5/93	VTL-016	5320	4999	1.064	
2/5/93	VTL-017	3016	2983	1.011	
2/5/93	VTL-018	3004	2998	1.002	
2/5/93	VTL-019	7928	7521	1.054	
2/5/93	VTL-020	7977	7498	1.064	1.074
Reactor D					
3/23/93	VTS-015	449	400	1.123	
3/23/93	VTS-016	253	240	1.055	
3/23/93	VTS-017	696	602	1.156	1.111
Reactor E					
3/22/93	VTS-005	428	401	1.068	
3/22/93	VTS-006	268	240	1.119	
3/22/93	VTS-007	268	240	1.115	
3/22/93	VTS-008	628	595	1.056	1.089
Reactor F					
3/19/93	VTS-002	431	401	1.071	
3/19/93	VTS-003	233	240	0.966	
3/19/93	VTS-004	631	595	1.074	1.037
Reactor G					
3/23/93	VTS-012	412	397	1.037	
3/23/93	VTS-013	682	600	1.137	
3/23/93	VTS-014	228	239	0.953	1.042
Reactor H					
3/22/93	VTS-009	464	413	1.124	
3/22/93	VTS-010	263	241	1.090	
3/22/93	VTS-011	632	599	1.056	1.090
Reactor J					
3/23/93	VTS-019	221	240	0.921	
3/23/93	VTS-020	414	399	1.038	
3/23/93	VTS-021	619	601	1.030	0.966

Section 3

PARTICULATE (FLY ASH) MASS CONCENTRATION

The eight high-dust reactors take their flue gas from the inlet ducting to the Plant Crist Unit 5 hot-side ESP. A major goal of the Task 1 test phase was to demonstrate that each of the eight high-dust reactors was receiving fly ash that was similar in concentration and particle size to that of the fly ash at the inlet to the ESP. Mass concentration measurements during Task 1 testing used a sampling train similar to that defined in the EPA Reference Test Method 17. A schematic drawing of the train used for mass concentration sampling is shown below in Figure 3-1.

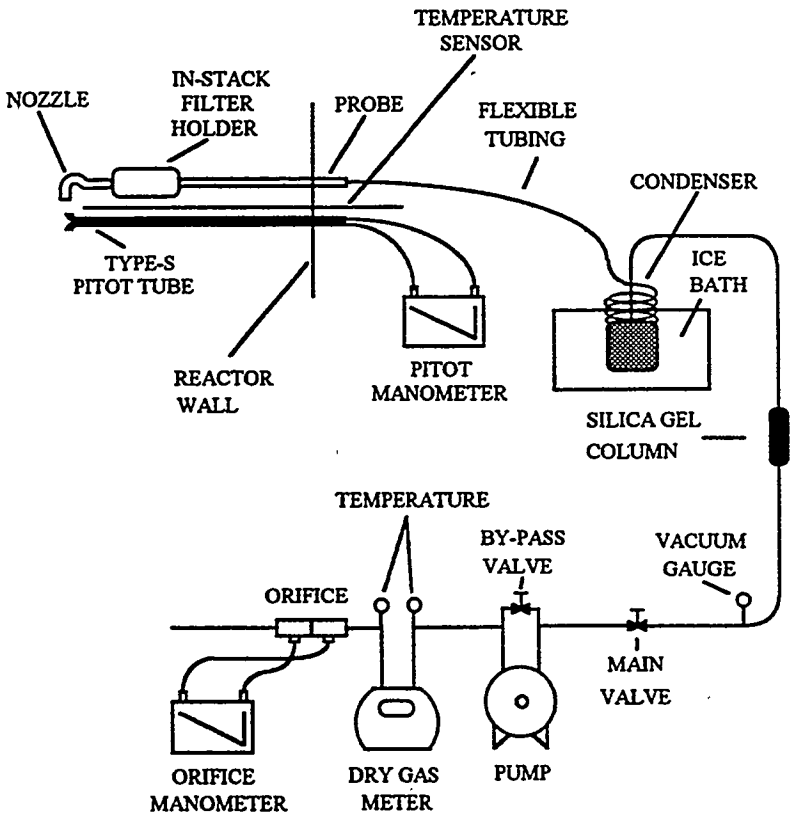

Figure 3-1. Schematic drawing of the mass concentration sampling train.

This train consists of a filter holder and nozzle that is designed to operate in the flue gas stream, followed by a heated sampling probe, a condenser, a drying column, a gas meter, a pump, and finally a flow control mechanism, usually a calibrated orifice. An S-type pitot and thermocouple located near the nozzle provide a means for sampling isokinetically during each test. Depending on the expected mass concentration at the point of sampling, either glass fiber thimbles or flat quartz fiber filter disks are used. The filters are desicated before and after sampling and then weighed on an electronic microbalance.

Task 1 testing began by measuring the particulate mass concentrations of the fly ash in the Unit 5 hot-side ESP inlet and outlet ducting at both high (84 MW) and low (43 MW) load conditions. Two samples were

collected at each condition. Table 3-1 summarizes the test data. Mass concentrations at the ESP inlet averaged 3.19 and 2.71 gr/dscf @ 3% O_2 for high and low load, respectively. Mass concentrations at the ESP outlet averaged 0.0041 and 0.0007 gr/dscf @ 3% O_2 for high and low load, respectively. The measured flow rates at the ESP inlet and outlet are different because we were only sampling a portion of the total flow into and out of the Unit 5 hot-side ESP. (There are several ESP inlet and outlet ducts.) Also, it should be noted that the moisture levels in the flue gas are different at high and low load. These differences are taken into account when measuring and calculating the concentration of nitrogen oxides and other gas phase constituents in the flue gas.

In order to verify that the mass concentration into each of the eight high-dust reactors was similar in magnitude to that measured in the main hot-side ESP inlet duct, mass concentrations were measured at the reactor inlet test ports located immediately upstream of each reactor's flow measuring venturi. Initial measurements indicated a large disparity among the eight reactors as shown in Table 3-2. Values ranged from a high of 11.9 gr/dscf @ 3% O_2 (Reactor G) to a low of 2.8 gr/dscf @ 3% O_2 (Reactor A).

Also shown in this table are the data for reactor J, the low-dust small reactor. The data for reactor J were well behaved and of the expected magnitude for high-load conditions. The fact that the measured inlet loadings on Reactor J (0.0034 and 0.0037 lb/MBtu) were about half that measured at the ESP outlet (0.0073 lb/MBtu) can be explained by the fact that the ESP outlet test was performed with a detailed traverse of the entire outlet duct cross section, while the Reactor J take-off duct samples from only a fraction of the total duct cross-sectional area. (Reactor J inlet mass concentrations were not measured at low load because of the extremely low values expected and the very long sampling times that would have been required to collect sufficient mass for accurate weighing.)

As a result of the large differences between the mass concentration values in the eight high-dust reactors, additional mass concentration tests were performed just upstream of the inlet transition to the eight reactors. Figure 3-2 shows the locations of the nine test positions in the transition piece. The test results are presented in Table 3-3. These data, together with the discovery that the original design of the inlet transition did not provide for proper isokinetic flow transition between the transition piece and the ducting to the five, high-dust, small reactors, provided sufficient evidence that modification to the design of the inlet transition was required.

After modifications to the inlet transition were complete, a repeat series of tests were performed. Because of the difficulty of collecting proper samples at the inlet to the five, high-dust, small reactors, a decision was made to repeat all of the mass concentration measurements in the eight high-dust reactors at a position downstream of the third catalyst layer (the reactor outlet test location). To validate this method, tests were conducted on the three large reactors both at the inlet and outlet of the reactor. These tests confirmed the validity of this sampling protocol. Tests were performed at both high and low load conditions. Two measurements were performed at each reactor outlet. At the large reactors a nine-point matrix was traversed (three, equally-spaced, positions in each of three ports). On the small reactors a single port provided for a three point traverse. The test results are shown in Table 3-4. The mass concentrations were much more uniform after the modification to the inlet transition. In general, the mass concentrations at low load were slightly less variable compared to high load. For all reactors the average high load mass concentration was 3.90 ± 0.41 gr/dscf @ 3% O_2, with a relative standard deviation of 10.6%. At low load conditions the average mass concentration for all eight reactors was 3.52 ± 0.22 gr/dscf @ 3% O_2, with a relative standard deviation of 6.3%.

The mass concentration was measured in the economizer bypass duct at low load conditions. The test data are presented in Table 3-5. The average mass concentration, 3.60 gr/dscf @ 3% O_2, was about 33%

Table 3-1. Plant Crist Unit 5 Hot-Side ESP Mass Concentration Data

Location Boiler Load	Inlet High	Inlet High	Outlet High	Outlet High	Inlet Low	Inlet Low	Outlet Low	Outlet Low
% Moisture	9.8	10.4	10	9.2	8.5	8.8	8.4	7.8
% Oxygen	3.4	3.2	4.2	4.0	7.7	7.3	6.8	6.5
Velocity, ft/s	47.7	48.9	39.1	40.1	30.6	30.3	22.0	21.1
Gas Temp., F	661	664	619	620	597	599	547	542
ACFM	206,000	221,000	158,000	162,000	132,000	131,000	88,800	84,900
DSCFM	86,500	87,800	68,500	70,800	59,900	59,200	42,300	40,900
WSCFM	96,000	98,000	76,100	77,900	65,500	64,900	46,200	44,400
DSCFM @ 0% O_2	72,400	74,400	54,700	57,200	37,900	38,500	28,500	28,200
gr/acf @ 3% O_2	1.43	1.24	0.0019	0.0019	1.26	1.20	0.0005	0.0003
gr/dscf @ 3% O_2	3.40	2.98	0.0044	0.0042	2.77	2.66	0.0009	0.0005
mg/acm @ 3% O_2	3,275	2,844	4.43	4.27	2,879	2,752	1.03	0.50
mg/dscm @ 3% O_2	7,806	6,834	10.18	9.75	6,345	6,097	2.16	1.03
#/10^6 Btu	5.58	4.88	0.0073	0.007	4.53	4.35	0.0015	0.0007

Table 3-2. Plant Crist SCR Mass Concentration Data (Reactor Inlets @ High Load)

Location	Reactor A		Reactor B		Reactor C		Reactor D		Reactor E	
% Moisture	8.83	9.40	8.94	9.16	8.78	9.42	8.38	9.07	8.70	8.61
% Oxygen	3.2	3.3	3.6	3.2	3.2	3.3	4.2	3.5	4.3	3.2
Velocity, f/s	68.1	67.8	66.3	66.8	69.4	69.2	98.3	105.8	90.4	94.3
Gas Temp., F	711	708	700	703	697	698	766	771	747	780
ACFM	12,832	12,777	12,495	12,579	13,067	13,036	1,157	1,247	1,064	1,110
DSCFM	5,155	5,111	5,090	5,095	5,346	5,292	448	475	418	425
WSCFM	5,655	5,642	5,590	5,609	5,861	5,842	489	522	458	465
DSCFM @ 0% O2	4,292	4,255	4,213	4,315	4,528	4,456	358	396	332	360
gr/acf @ 3% O2	1.23	1.12	1.31	1.27	1.32	1.33	2.37	2.50	2.18	2.11
gr/dscf @ 3% O2	3.07	2.81	3.22	3.13	3.22	3.27	6.12	6.57	5.56	5.50
mg/acm @ 3% O2	2,829	2,575	3,011	2,911	3,025	3,042	5,439	5,739	5,008	4,830
mg/dscm @ 3% O2	7,041	6,437	7,392	7,187	7,395	7,496	14,041	15,060	12,752	12,620
#/10^6 Btu	5.12	4.65	5.28	5.13	5.28	5.35	10.03	10.76	9.11	9.02

Location	Reactor F		Reactor G		Reactor H		Reactor J	
% Moisture	8.50	9.45	9.25	8.53	8.66	6.76	8.0	8.0
% Oxygen	3.3	3.2	3.2	3.3	3.5	4.3	5.5	5.0
Velocity, f/s	93.1	93.6	94.1	92.1	93.5	90.8	84.1	83.9
Gas Temp., F	721	729	744	747	773	769	673	728
ACFM	1,096	1,102	1,109	1,084	1,102	1,069	991	988
DSCFM	441	436	434	427	421	421	415	395
WSCFM	482	481	478	467	461	452	451	430
DSCFM @ 0% O2	371	369	367	360	351	335	346	301
gr/acf @ 3% O2	3.35	3.26	4.40	4.68	2.57	2.53	0.0009	0.0008
gr/dscf @ 3% O2	8.32	8.24	11.25	11.87	6.73	6.43	0.0023	0.0020
mg/acm @ 3% O2	7,674	7,472	10,090	10,721	5,894	5,808	2.20	1.89
mg/dscm @ 3% O2	19,086	18,898	25,800	27,210	15,421	14,748	5.24	4.72
#/10^6 Btu	13.63	13.50	18.43	19.44	11.02	11.04	0.0037	0.0034

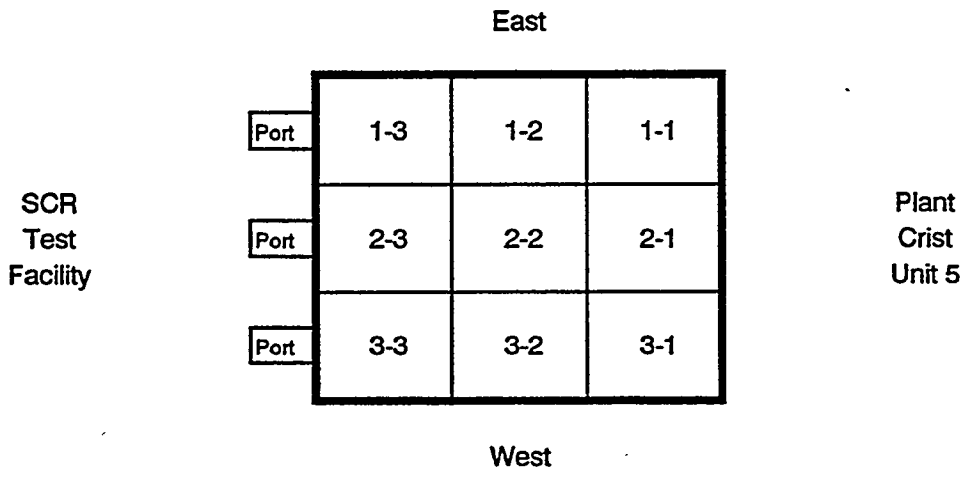

Figure 3-2. Identification of sampling locations at the SCR Inlet Transition.

Table 3-3. Plant Crist SCR Mass Concentration Data (Special Tests at the Inlet Transition @ 70 MW)

Port (See Figure 3-1)	1-1	1-2	1-3	2-1	2-2	2-3	3-2	3-2	3-3	Average
		Note 1		Note 1			Note 2	Note 1		
% Moisture	8.77	8.84	9.90	10.91	9.29	9.98	9.10	9.41	8.90	9.45
% Oxygen	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Velocity, f/s	49.3	46.0	58.0	53.5	56.0	60.7	51.7	49.9	65.2	54.5
Gas Temp., F	662	652	670	649	664	670	648	662	668	661
ACFM	36,224	33,799	42,595	39,358	41,189	44,616	38,033	36,654	47,900	40,041
DSCFM	15,269	14,362	17,601	16,376	17,222	18,417	16,165	15,330	20,043	16,754
WSCFM	16,736	15,755	19,534	18,382	18,985	20,458	17,783	16,922	22,000	18,506
DSCFM @ 0% O2	10,593	9,964	12,211	11,362	11,948	12,778	11,215	10,635	13,905	11,624
gr/acf @ 3% O2	1.32	1.12	1.36	1.23	1.21	1.31	1.49	1.41	1.29	1.30
gr/dscf @ 3% O2	2.53	2.64	3.29	2.95	2.89	3.18	3.50	3.36	3.09	3.05
mg/acm @ 3% O2	2,447	2,571	3,122	2,818	2,772	3,009	3,408	3,226	2,964	2,926
mg/dscm @ 3% O2	5,806	6,050	7,555	6,772	6,629	7,290	8,019	7,713	7,085	6,991
#/10^6 Btu	5.12	5.34	6.66	5.97	5.85	6.43	7.07	6.80	6.25	6.17

1. Plant lost feeder and load dropped resulting in early termination of run.
2. Inadvertant repeat of point 2-3. The test point should have been 3-1.

Table 3-4. Mass Concentrations at the 3rd Catalyst Level

Reactor	Run Number	Date	Start Time	Unit 5 Load	Measured Oxygen (%)	Mass Concentration (gr/dscf @ 3% O_2)
A	022-A3-M17-02	6/1/93	0850	High	3.0	4.01
	022-A3-M17-07	6/2/93	1325	High	3.1	3.81
	022-A3-M17-09	6/3/93	0624	Low	7.9	3.59
	022-A3-M17-11	6/3/93	0813	Low	7.8	3.60
B	022-B3-M17-01	6/1/93	0850	High	2.5	4.21
	022-B3-M17-03	6/1/93	1117	High	3.1	4.05
	022-B3-M17-12	6/3/93	1045	Low	7.5	3.41
	022-B3-M17-14	6/3/93	1238	Low	7.7	3.41
C	023-C3-M17-01	6/7/93	1021	High	2.4	3.77
	023-C3-M17-02	6/7/93	0916	High	2.5	3.91
	022-C3-M17-08	6/3/93	0628	Low	7.6	3.53
	022-C3-M17-10	6/3/93	0816	Low	7.4	3.49
D	019-D3-M17-04	5/14/93	1255	High	5.7	3.18
	019-D3-M17-06	5/14/93	1424	High	5.2	3.08
	022-D3-M17-21	6/4/93	1013	Low	9.3	3.52
	022-D3-M17-23	6/4/93	1149	Low	9.2	3.39
E	021-E3-M17-03	5/27/93	0954	High	3.3	4.31
	022-E3-M17-06	6/2/93	1122	High	4.8	4.08
	022-E3-M17-17	6/4/93	0642	Low	8.6	3.85
	022-E3-M17-19	6/4/93	0826	Low	8.4	3.90
F	021-F3-M17-04	5/27/93	0958	High	5.0	4.84
	022-F3-M17-05	6/2/93	1119	High	3.9	3.91
	022-F3-M17-16	6/4/93	0640	Low	8.7	3.67
	022-F3-M17-18	6/4/93	0823	Low	8.9	3.81
G	021-G3-M17-05	5/27/93	1320	High	4.6	3.94
	021-G3-M17-07	5/27/93	1544	High	3.9	3.81
	022-G3-M17-13	6/3/93	1041	Low	8.6	3.30
	022-G3-M17-15	6/3/93	1235	Low	8.6	3.28
H	021-H3-M17-06	5/27/93	1307	High	4.2	3.96
	021-H3-M17-08	5/27/93	1534	High	4.0	3.54
	022-H3-M17-20	6/4/93	1018	Low	8.7	3.48
	022-H3-M17-22	6/4/93	1152	Low	8.1	3.09

Table 3-5. Economizer Bypass Mass Concentration Data

Test ID #	010-MT-01	010-MT-02
% Moisture	6.6	6.6
% Oxygen	8.6	8.6
Velocity, f/s	70.1	70.8
Gas Temp., F	868	878
ACFM	5,171	5,227
DSCFM	1,911	1,917
WSCFM	2,046	2,053
DSCFM @ 0% O2	1,125	1,128
gr/acf @ 3% O2	1.35	1.30
gr/dscf @ 3% O2	3.67	3.52
mg/acm @ 3% O2	3,103	2,966
mg/dscm @ 3% O2	8,394	8,088
#/10^6 Btu	5.99	5.78

higher than the value measured in the main Unit 5 hot-side ESP inlet duct under similar load conditions, 2.71 gr/dscf @ 3% O_2 (see Table 3-1).

Section 4

PARTICLE SIZE DISTRIBUTION

Part of the Task 1 program was to demonstrate that fly ash characteristics (mass concentration and particle size distribution) at the inlet of each of the high-dust reactors were similar under both high-load and low-load conditions. Therefore, the fly ash samples collected during the tests to measure mass concentration (both high and low load conditions) were submitted for size analysis by laboratory technique. The instrument used to determine particle size distribution of the fly ash was a Shimadzu Model SA-CP4 Centrifugal Particle Size Analyzer. It is able to size the particles into approximately 25 size intervals between 0.056 and 56.2 micrometers physical diameter (or Stokes diameter, assumed spherical shape and true (actual) particle density). In addition to the fly ash tests for the eight high-dust reactors, particle size tests were also conducted on ash samples collected at the Unit 5 hot-side ESP inlet duct at high and low load conditions.

To supplement the laboratory determination of particle size and to demonstrate the accuracy of the laboratory technique to measure a particle size distribution on a redispersed ash sample (Shimadzu), cascade impactors and series cyclones were used at the Unit 5 hot-side ESP inlet duct to measure the fly ash particle size distribution in situ. Two tests were conducted at high load and two at low load for each instrument. The cascade impactors (University of Washington Mark III (seven stage) Source Test Cascade Impactor) fractionate the fly ash into eight size ranges with stage cut points of 8.0, 5.2, 2.7, 1.4, 0.7, 0.3, and 0.16 micrometers physical diameter. The series cyclones (SRI/EPA Five-Stage Series Cyclone) fractionate the fly ash into six size ranges with stage cut points of 5.3, 3.3, 1.8, 1.19 and 0.44 micrometers physical diameter.

The particle size distributions of the fly ash at the Unit 5 ESP inlet duct at high and low load are presented in Figures 4-1 and 4-2, respectively. Figures 4-1a and 4-2a present the data as a differential particle size distribution (per cent of total mass in each size range) on a linear scale. Figures 4-1b and 4-2b present the same data with a logarithmic scale. The data in Figures 4-1c and 4-2c are presented on a cumulative per cent basis (cumulative per cent less than the indicated size). The mass median diameter at high load was measured to be 13 microns with the Shimadzu, 9.5 microns with the cascade impactor and approximately 6 microns with the series cyclone. At low load the mass median diameter was 9.4 microns with the Shimadzu, 12.6 microns with the cascade impactor and 8 microns with the series cyclone. The difference in these mass median diameters is likely caused by the more detailed nature of the Shimadzu distribution (25 size fractions) compared to the particle size distributions fitted to the cascade impactor (8 size fractions) and series cyclone (6 size fractions) data. The graphs show a best fit spline curves for the impactor and cyclone data.

The individual particle size distributions for the fly ash collected downstream of the third catalyst layer on each of the high-dust reactors (the reactor outlet test location) are shown in Figure 4-3 (high load) and Figure 4-4 (low load). Figures 4-3a and 4-4a present the data as differential particle size distributions (per cent of total mass in the indicated size range) on a linear scale, Figures 4-3b and 4-4b present the same data on a probability scale, Figures 4-3c and 4-4c present the same data on a logarithmic scale, and Figures 4-3d and 4-4d present the cumulative per cent particle size distributions. A comparison of the high and low load data show that the low load data are much more tightly grouped. Since the reactors were operating at the same conditions during each set of tests (high and low load) and the fly ash sampling techniques were identical, the more tightly grouped low load data may be caused by more favorable isokinetic flow patterns either at the inlet scoop in the main Unit 5 hot-side ESP inlet duct or in the inlet transition piece where the flow splits to the eight high-dust reactors. (Particle size distributions were not measured for Reactor J

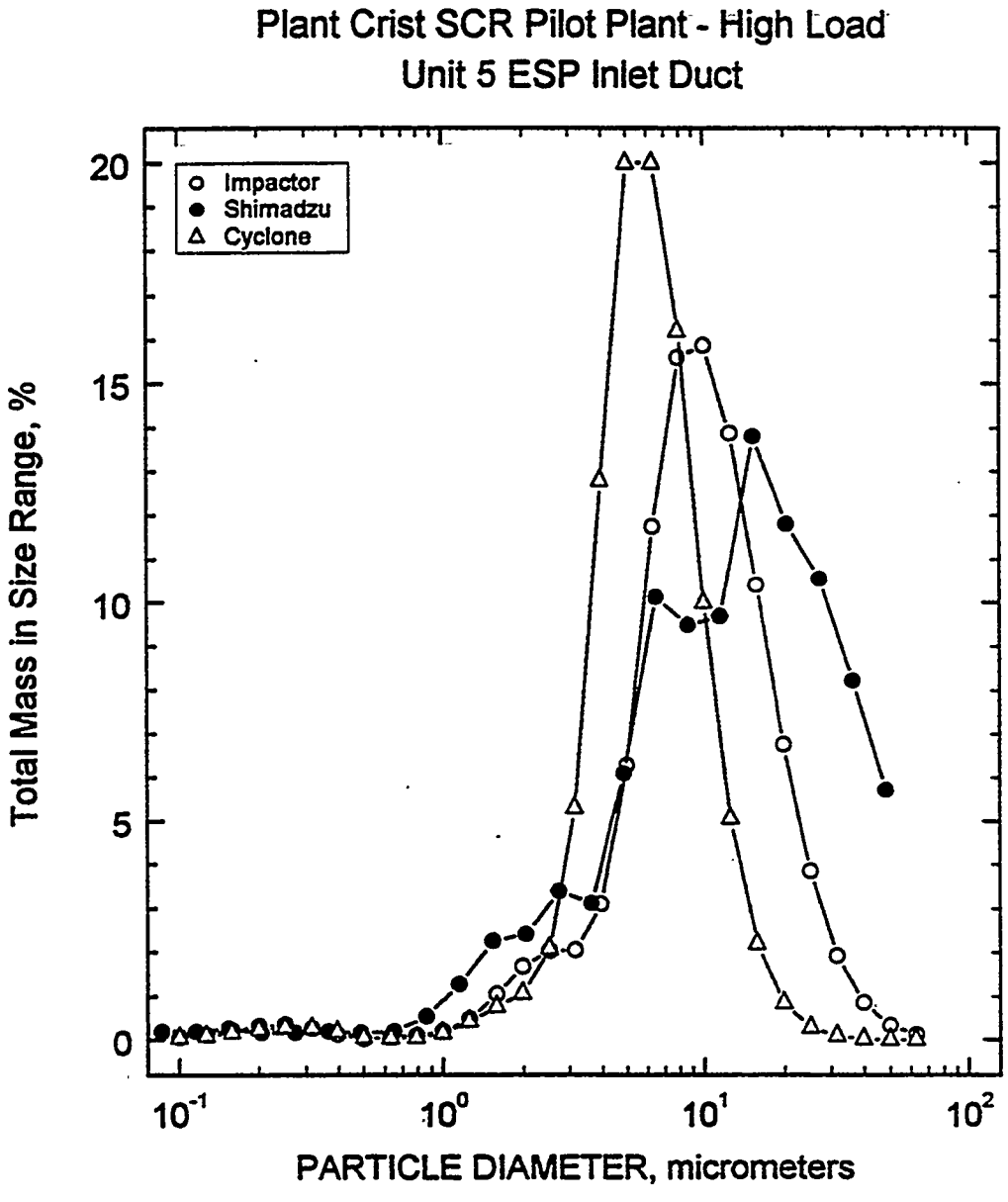

Figure 4-1a. Differential particle size distribution for fly ash at the Plant Crist Unit 5 hot-side ESP inlet during high load (linear scale).

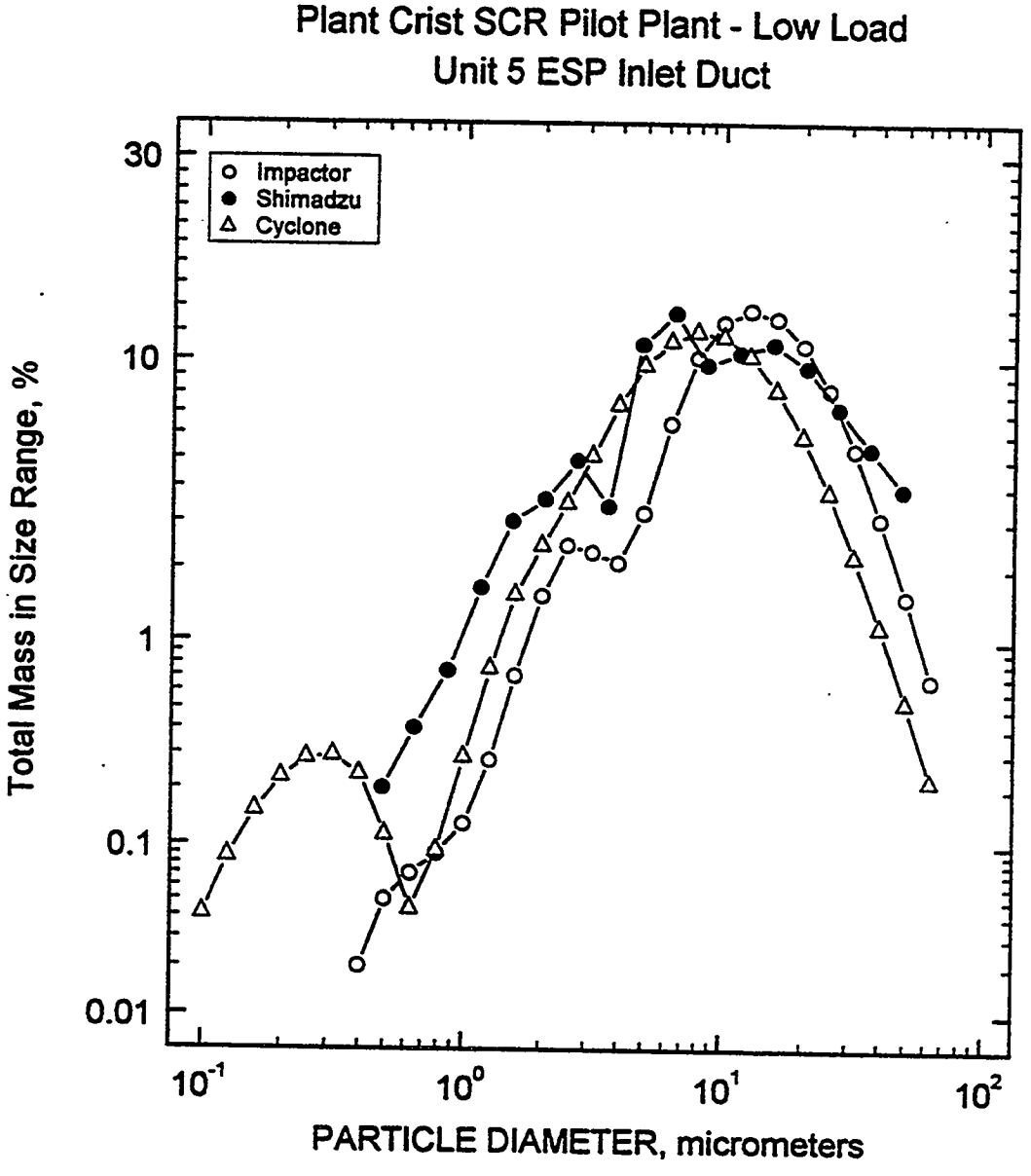

Figure 4-1b. Differential particle size distribution for fly ash at the Plant Crist Unit 5 hot-side ESP inlet during high load (logarithmic scale).

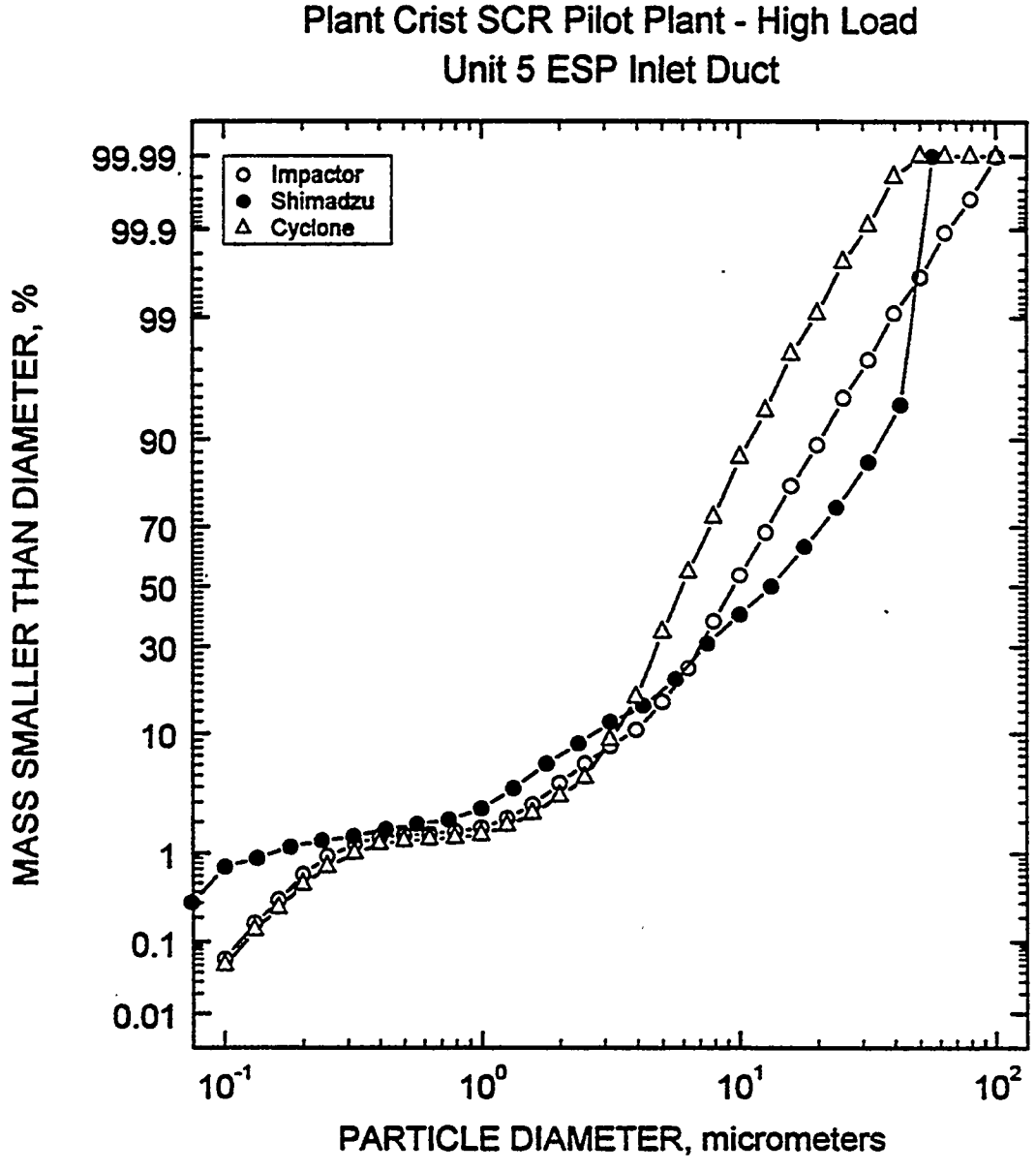

Figure 4-1c. Cumulative (percent) particle size distribution for fly ash at the Plant Crist Unit 5 hot-side ESP inlet during high load.

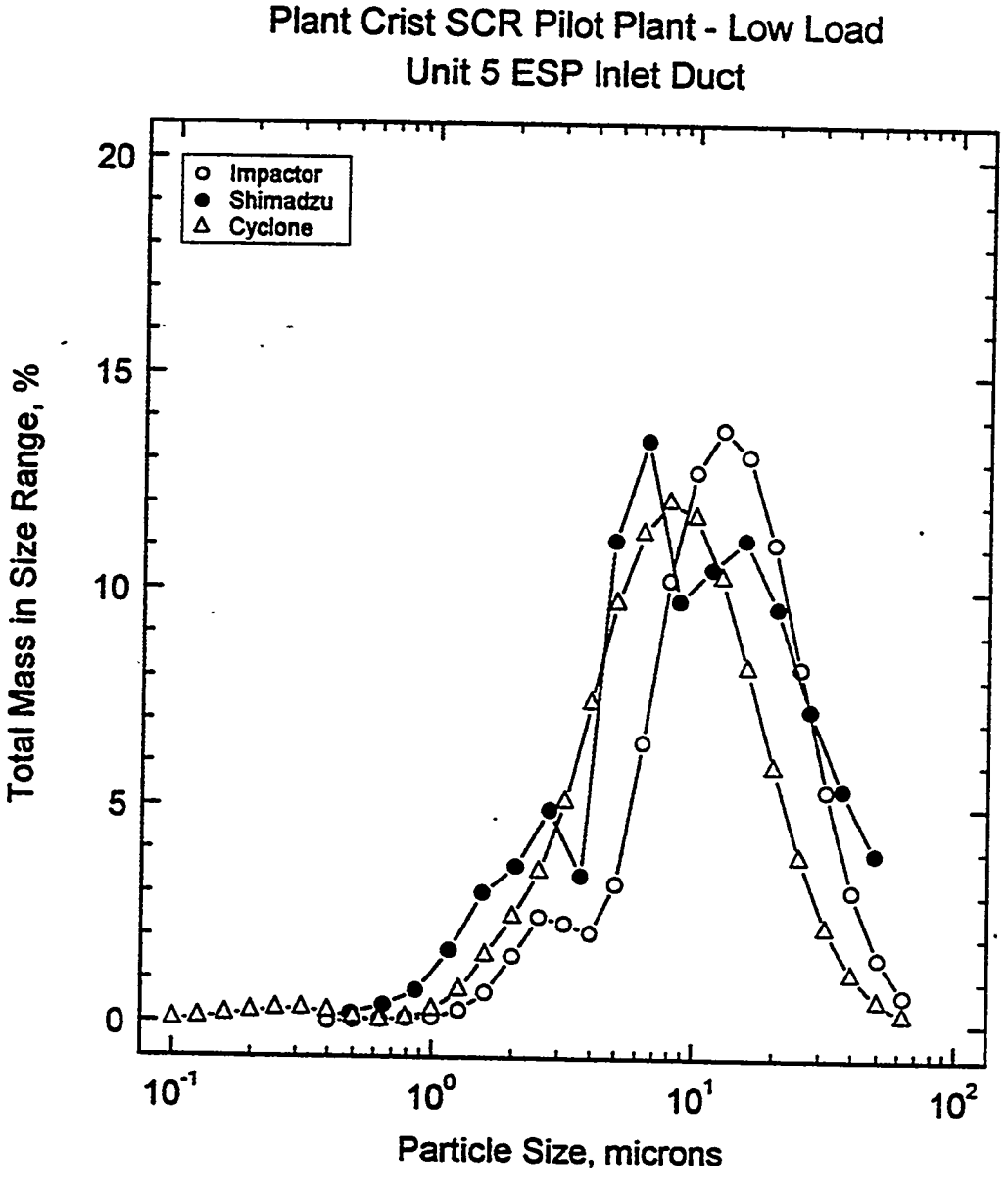

Figure 4-2a. Differential particle size distribution for fly ash at the Plant Crist Unit 5 hot-side ESP inlet during low load (linear scale).

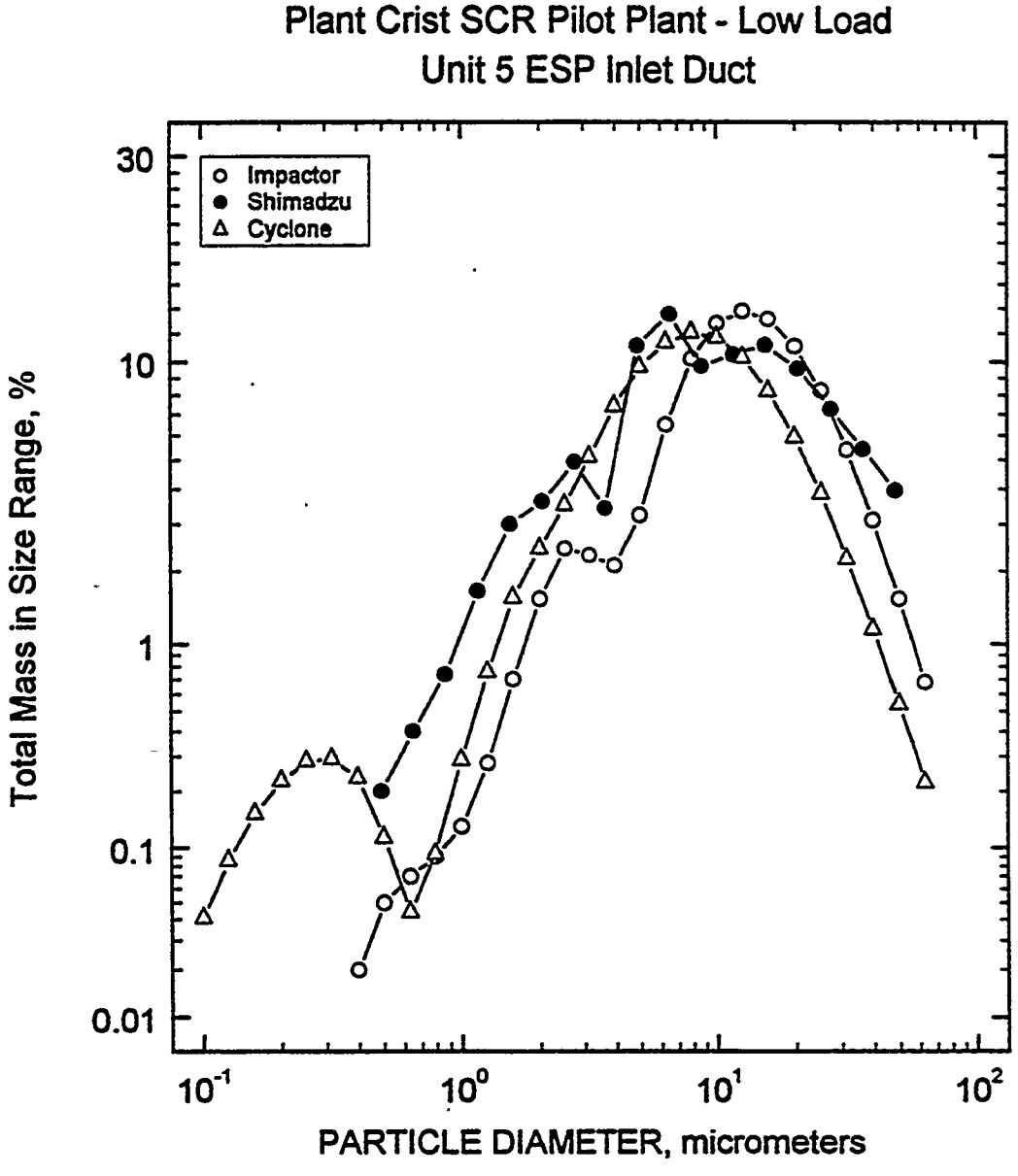

Figure 4-2b. Differential particle size distribution for fly ash at the Plant Crist Unit 5 hot-side ESP inlet during low load (logarithmic scale).

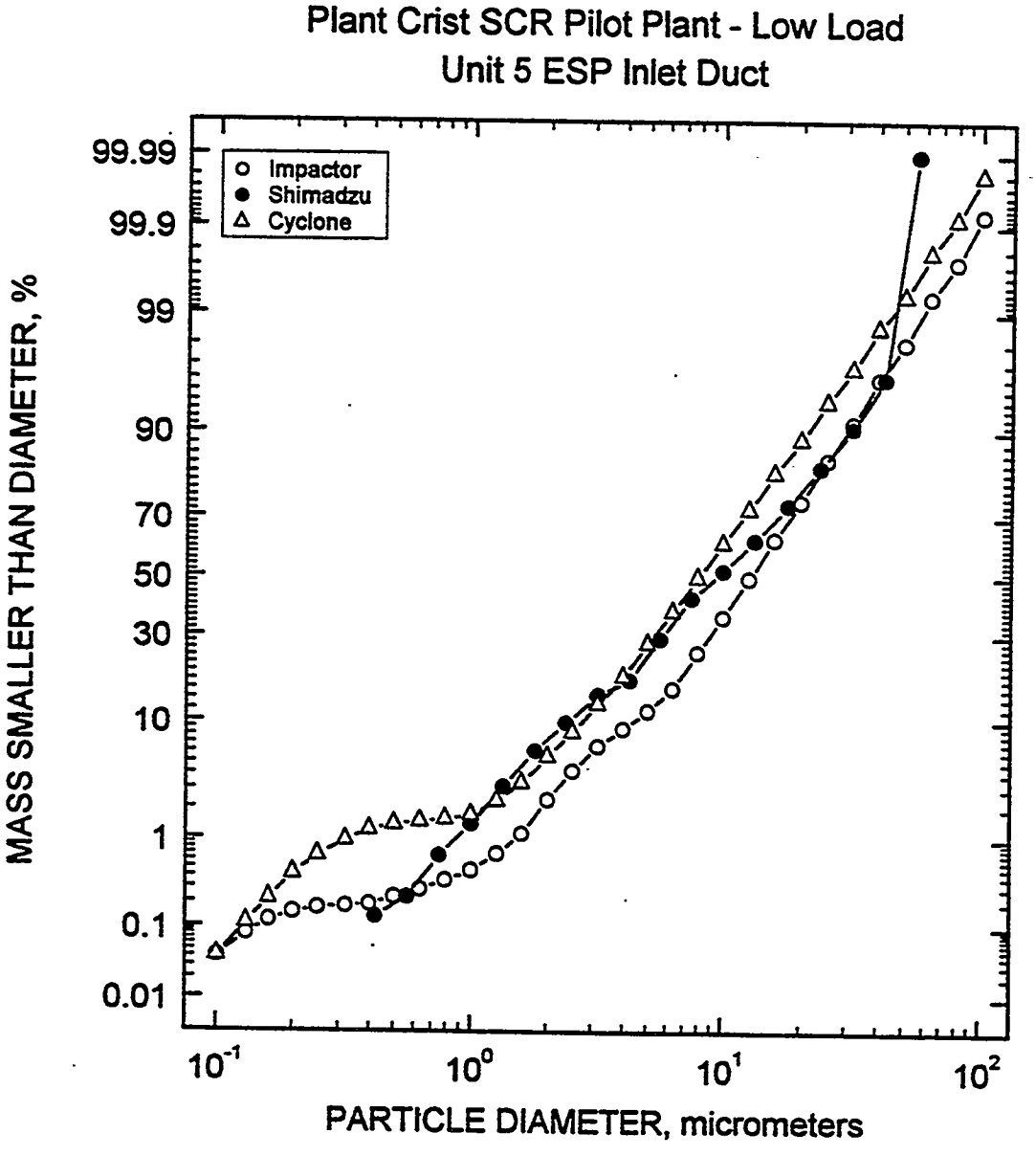

Figure 4-2c. Cumulative (percent) particle size distribution for fly ash at the Plant Crist Unit 5 hot-side ESP inlet during low load.

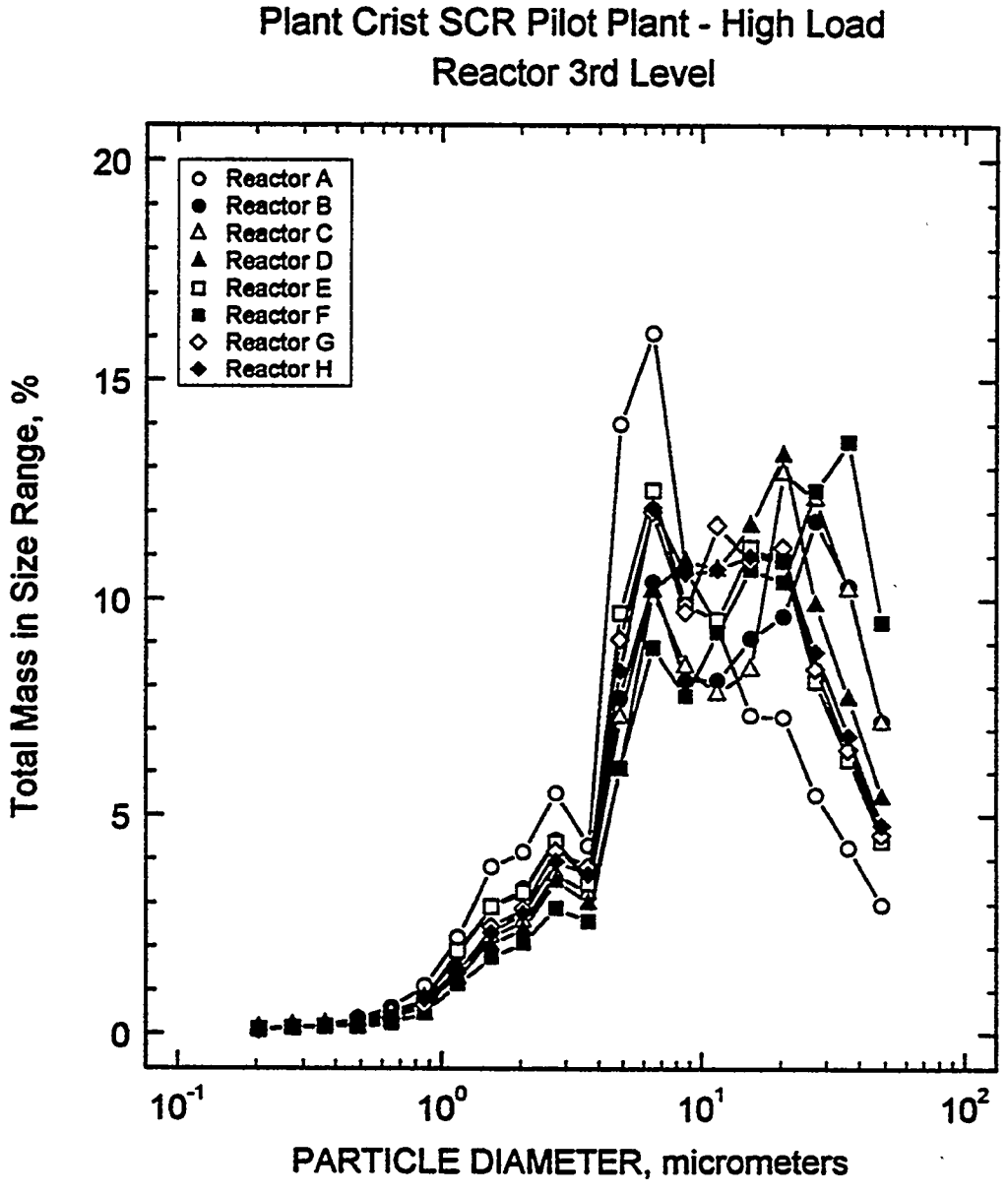

Figure 4-3a. Differential particle size distribution for fly ash downstream of the third reactor level (high dust reactors) during high load (linear scale).

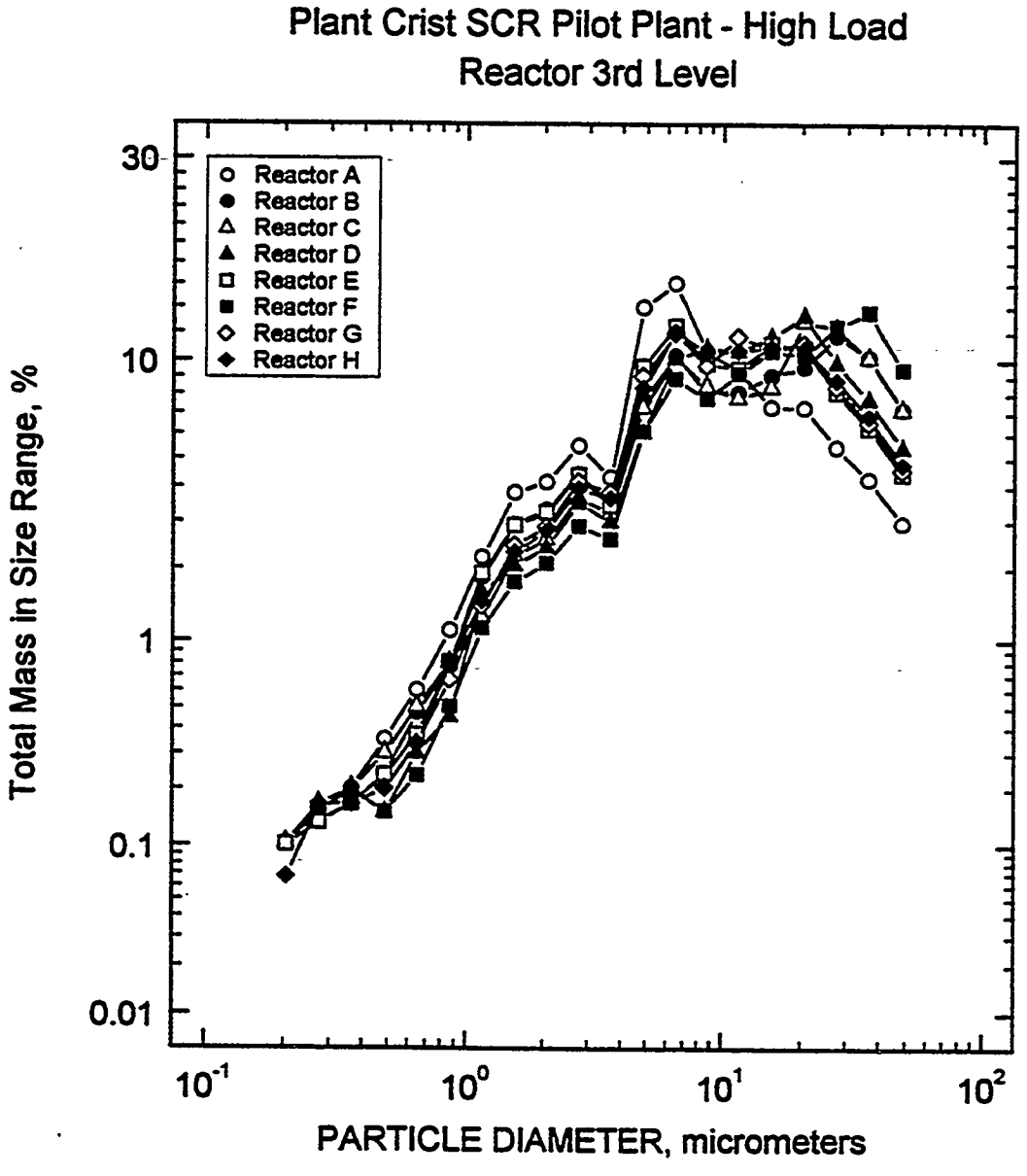

Figure 4-3b. Differential particle size distribution for fly ash downstream of the third reactor level (high dust reactors) during high load (probability scale).

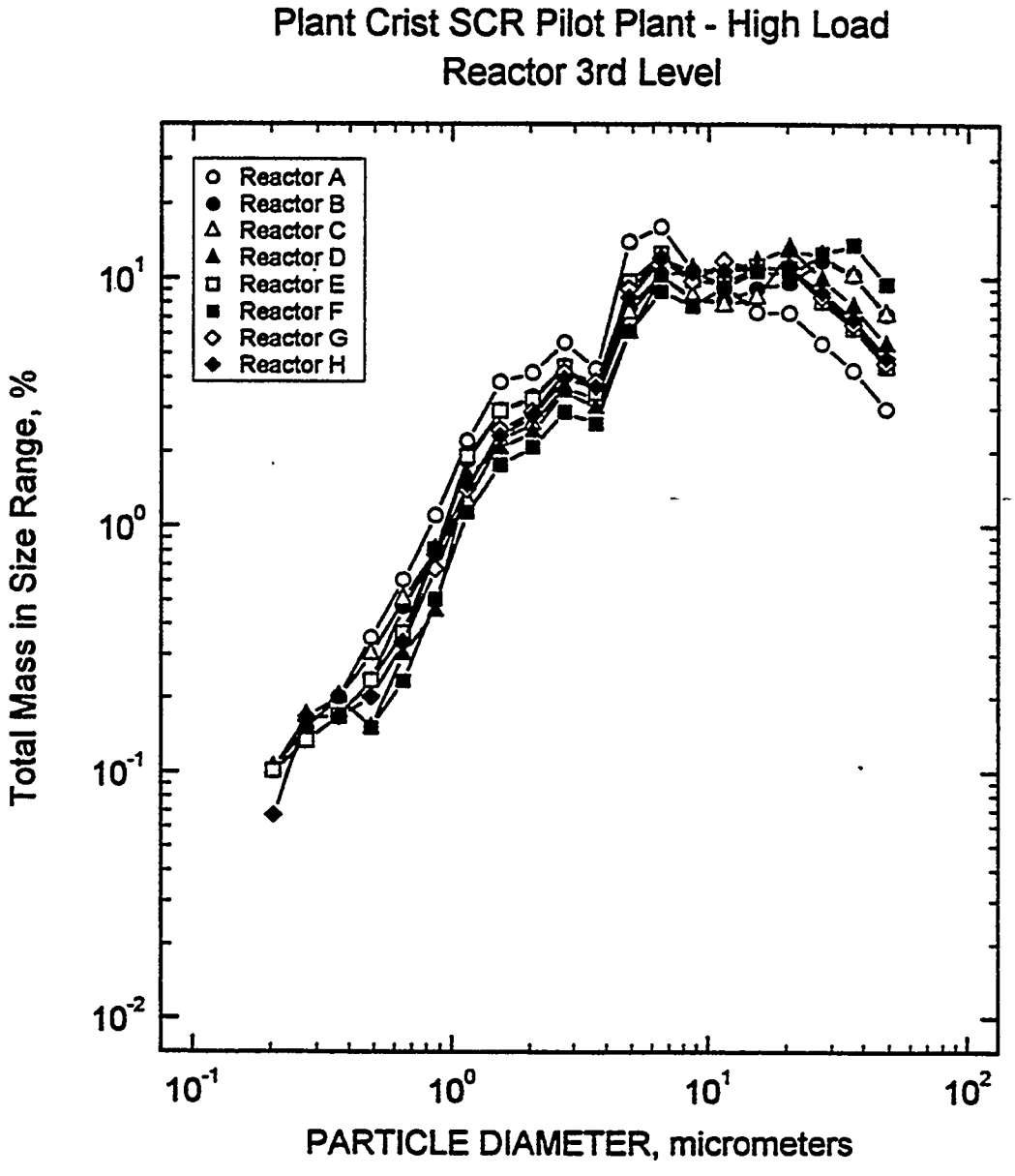

Figure 4-3c. Differential particle size distribution for fly ash downstream of the third reactor level (high dust reactors) during high load (logarithmic scale).

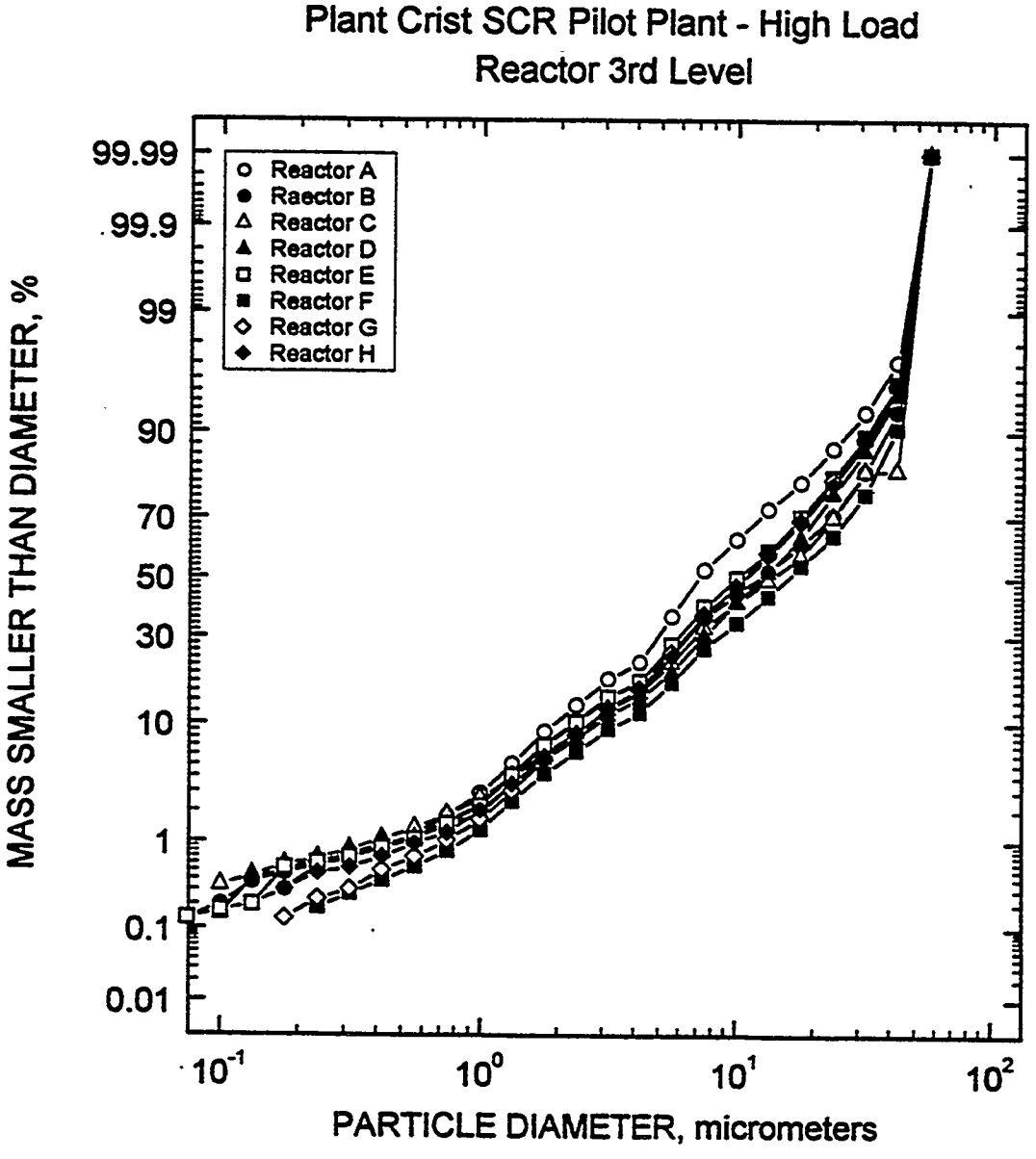

Figure 4-3d. Cumulative (percent) particle size distribution for fly ash downstream of the third reactorlevel (high dust reactors) during high load.

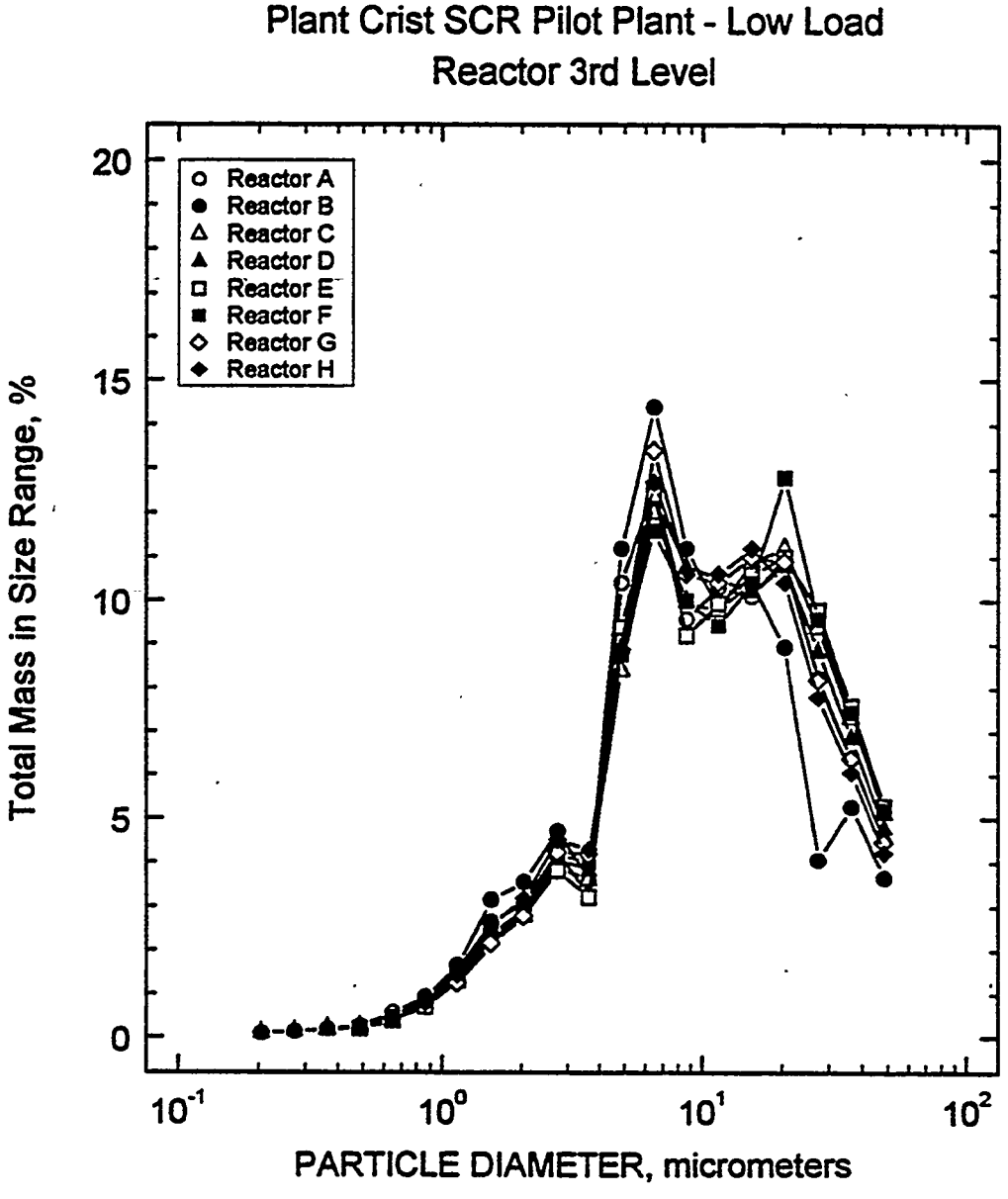

Figure 4-4a. Differential particle size distribution for fly ash downstream of the third reactor level (high dust reactors) during low load (linear scale).

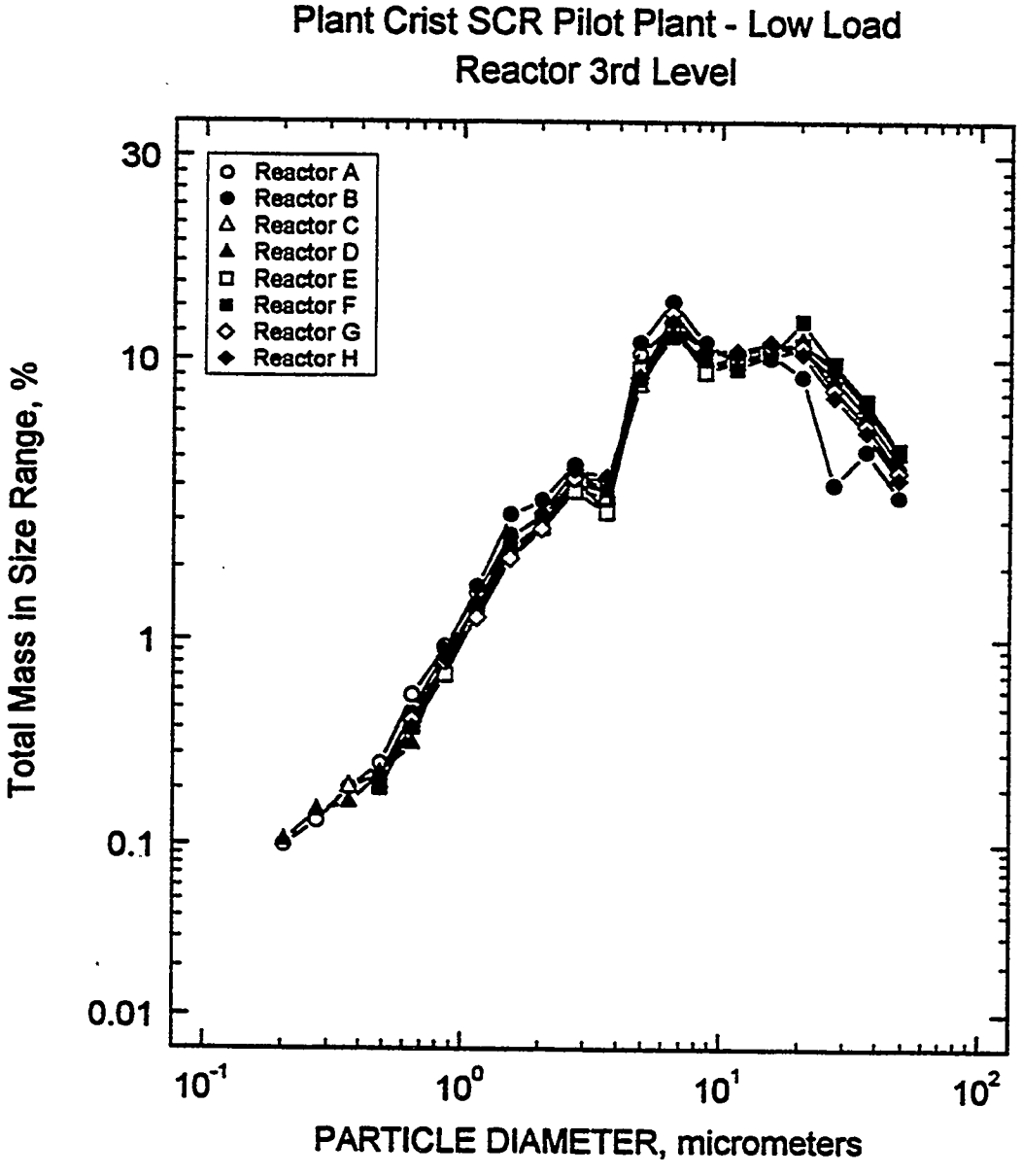

Figure 4-4b. Differential particle size distribution for fly ash downstream of the third reactor level (high dust reactors) during low load (probability scale).

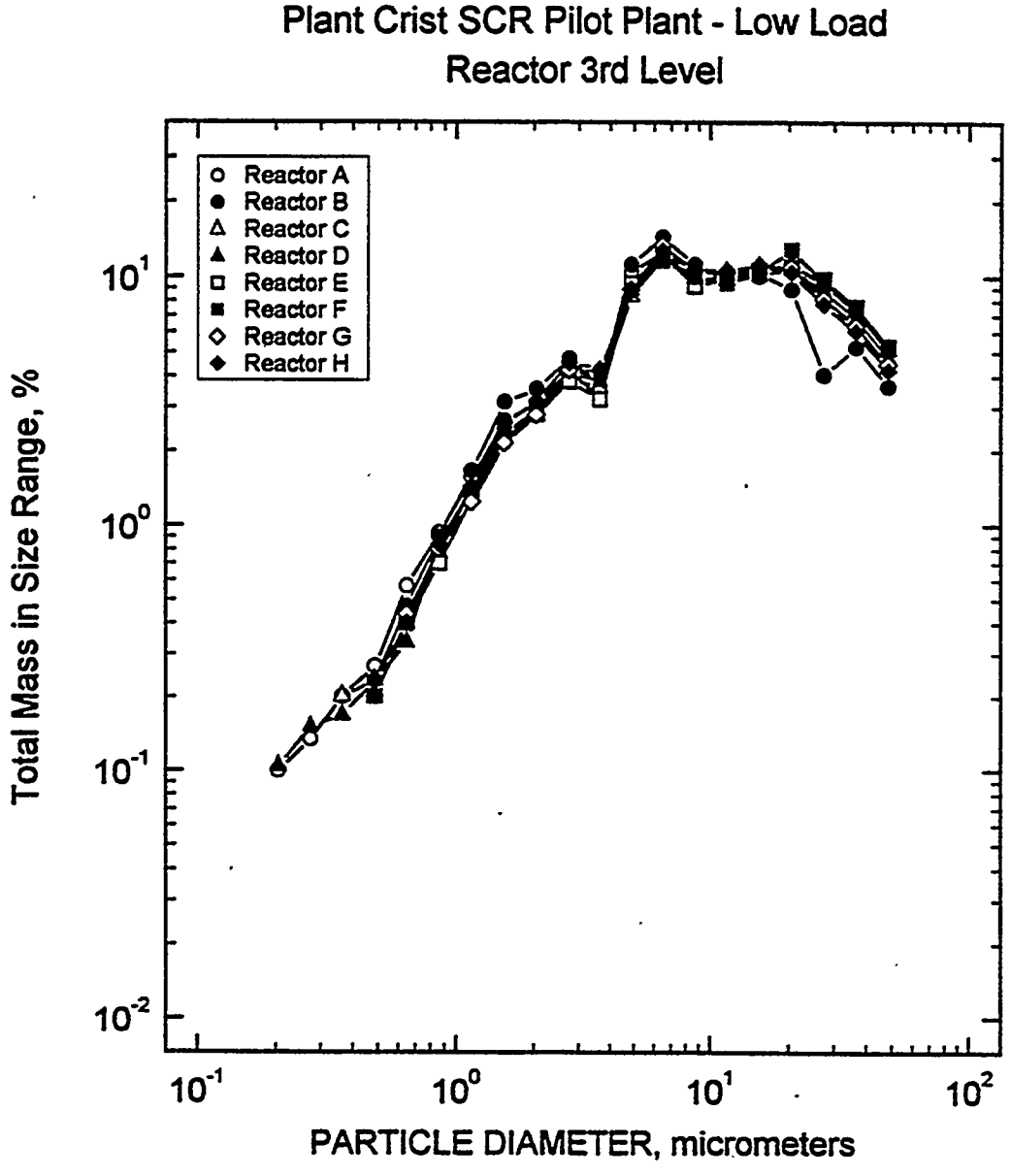

Figure 4-4c. Differential particle size distribution for fly ash downstream of the third reactor level (high dust reactors) during low load (logarithmic scale).

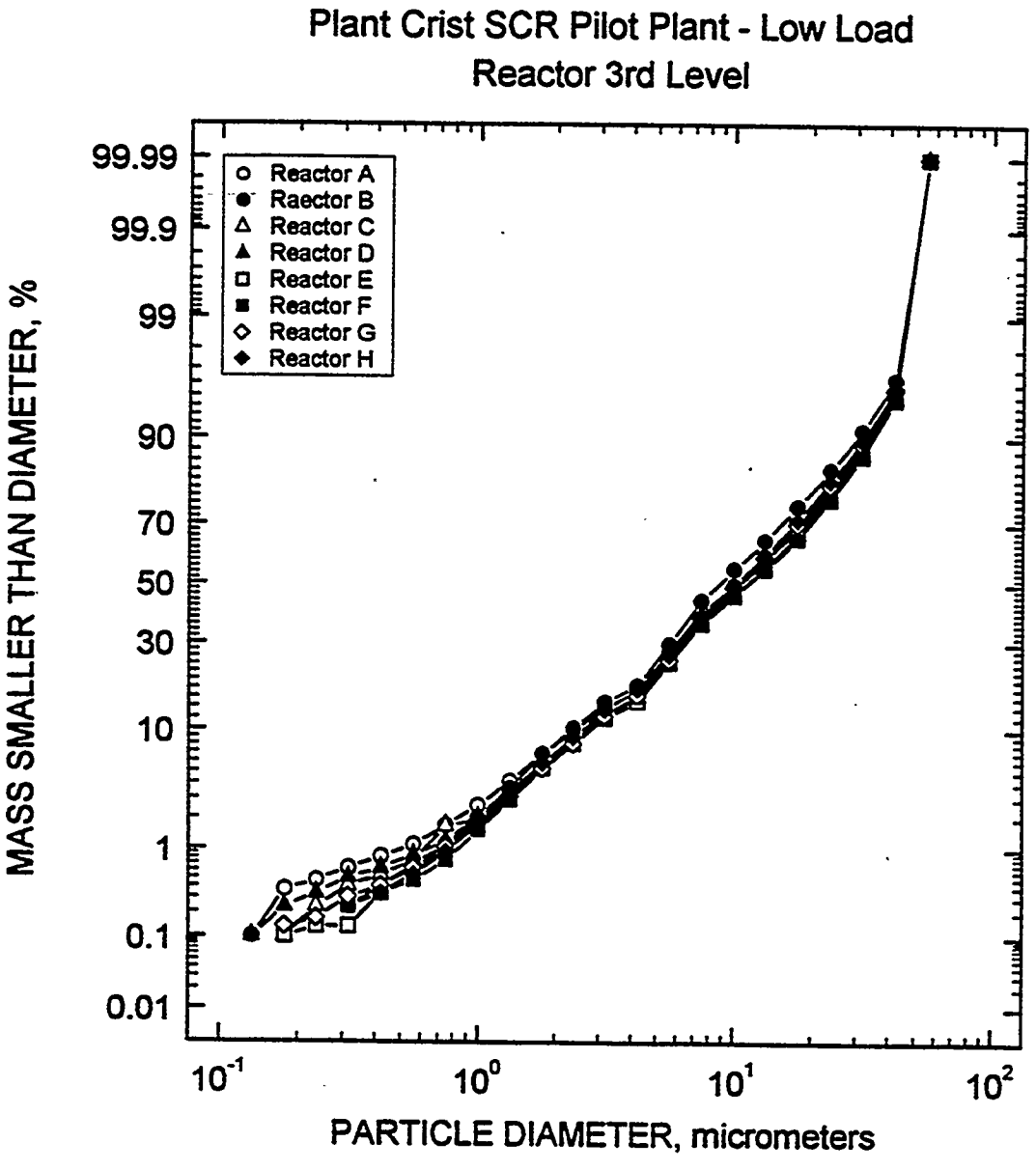

Figure 4-4d. Cumulative (percent) particle size distribution for fly ash downstream of the third reactorlevel (high dust reactors) during lowload

because the low mass concentration precluded collection of adequate fly ash samples on each stage for accurate weighing.)

The particle size distributions measured at the main duct at high and low load conditions (shown in Figures 4-1 and 4-2, respectively) are compared to the average of the eight, high-dust, reactor outlet particle size distributions in Figures 4-5 (high load) and 4-6 (low load). The data are shown as differential particle size distributions (per cent of total mass in the indicated size range) on three scales, linear (Figures 4-5a and 4-6a), probability (Figures 4-5b and 4-6b) and logarithmic (Figures 4-5c and 4-6c). On each graph a pair of lines without data points are shown. They represent the range of one standard deviation about the average of the eight individual reactor size distributions. For both high and low load conditions the main inlet size distribution agrees very well with the average for the eight, high-dust, reactors.

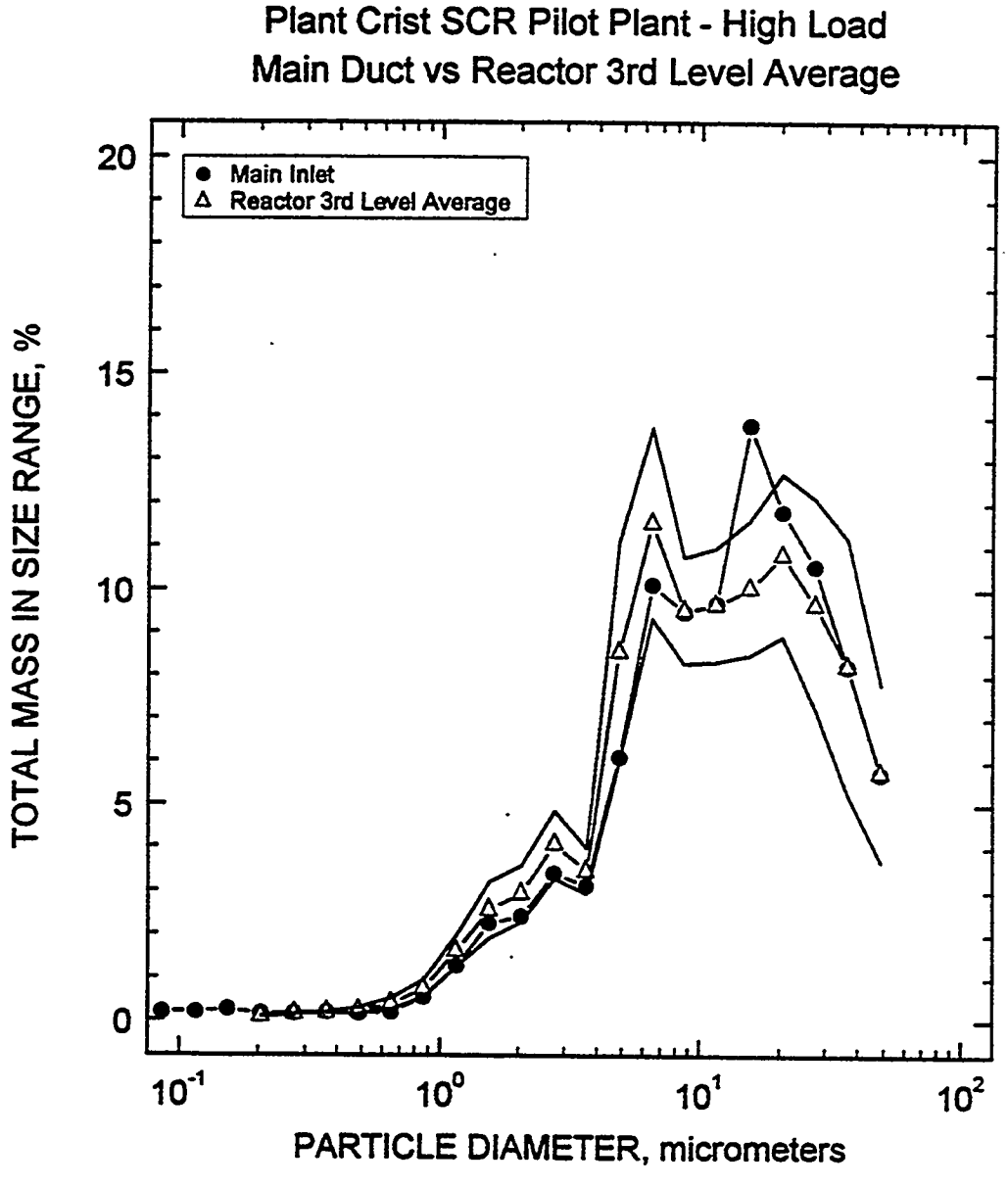

Figure 4-5a. Comparison of differential particle size distributions (linear scale): Unit 5 hot-side ESP inlet versus average of high dust reactors (downstream of third catalyst level) at high load.

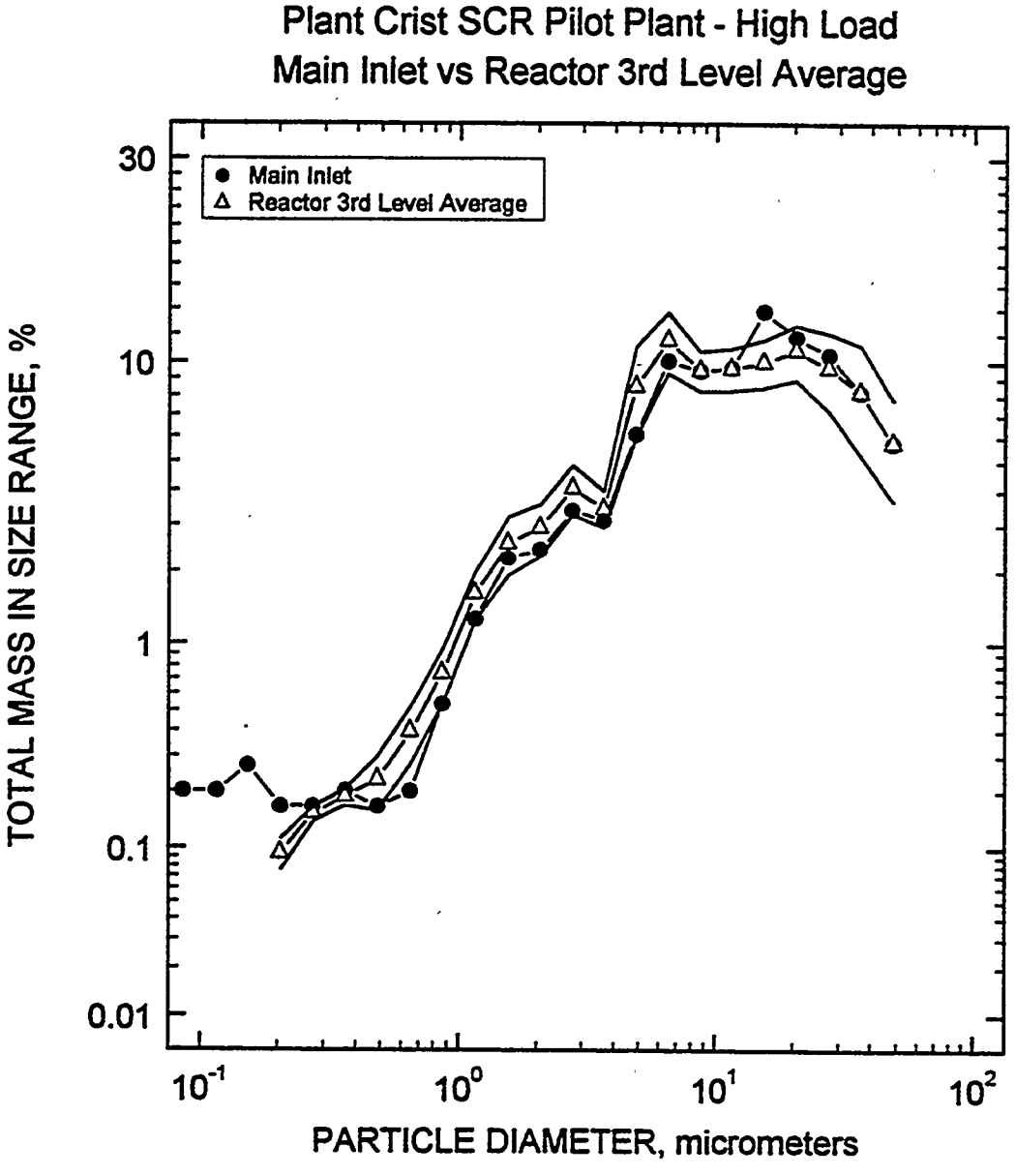

Figure 4-5b. Comparison of differential particle size distributions (probability scale): Unit 5 hot-side ESP inlet versus average of high dust reactors (downstream of third catalyst level) at high load.

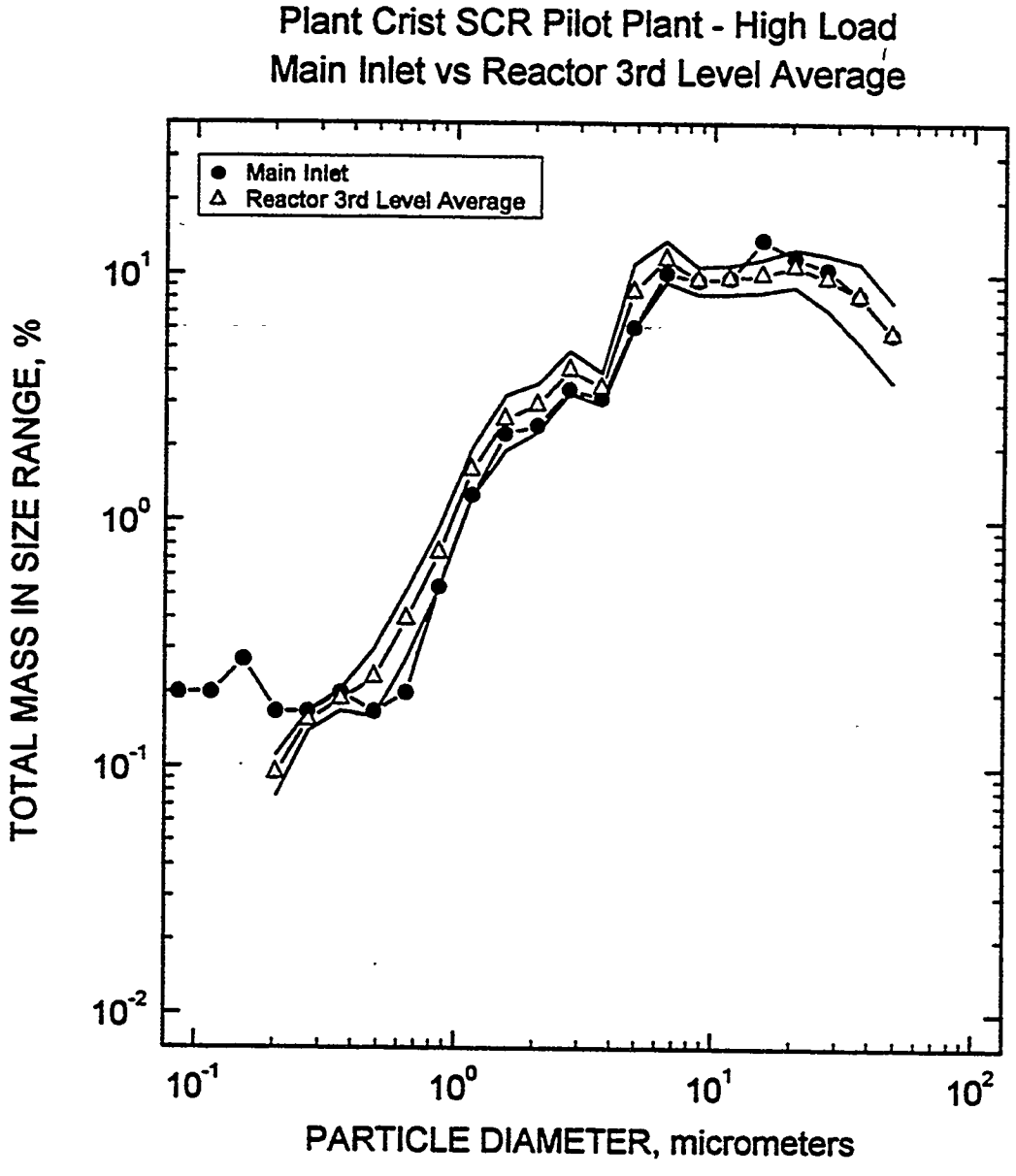

Figure 4-5c. Comparison of differential particle size distributions (logarithmic scale): Unit 5 hot-side ESP inlet versus average of high dust reactors (downstream of third catalyst level) at high load.

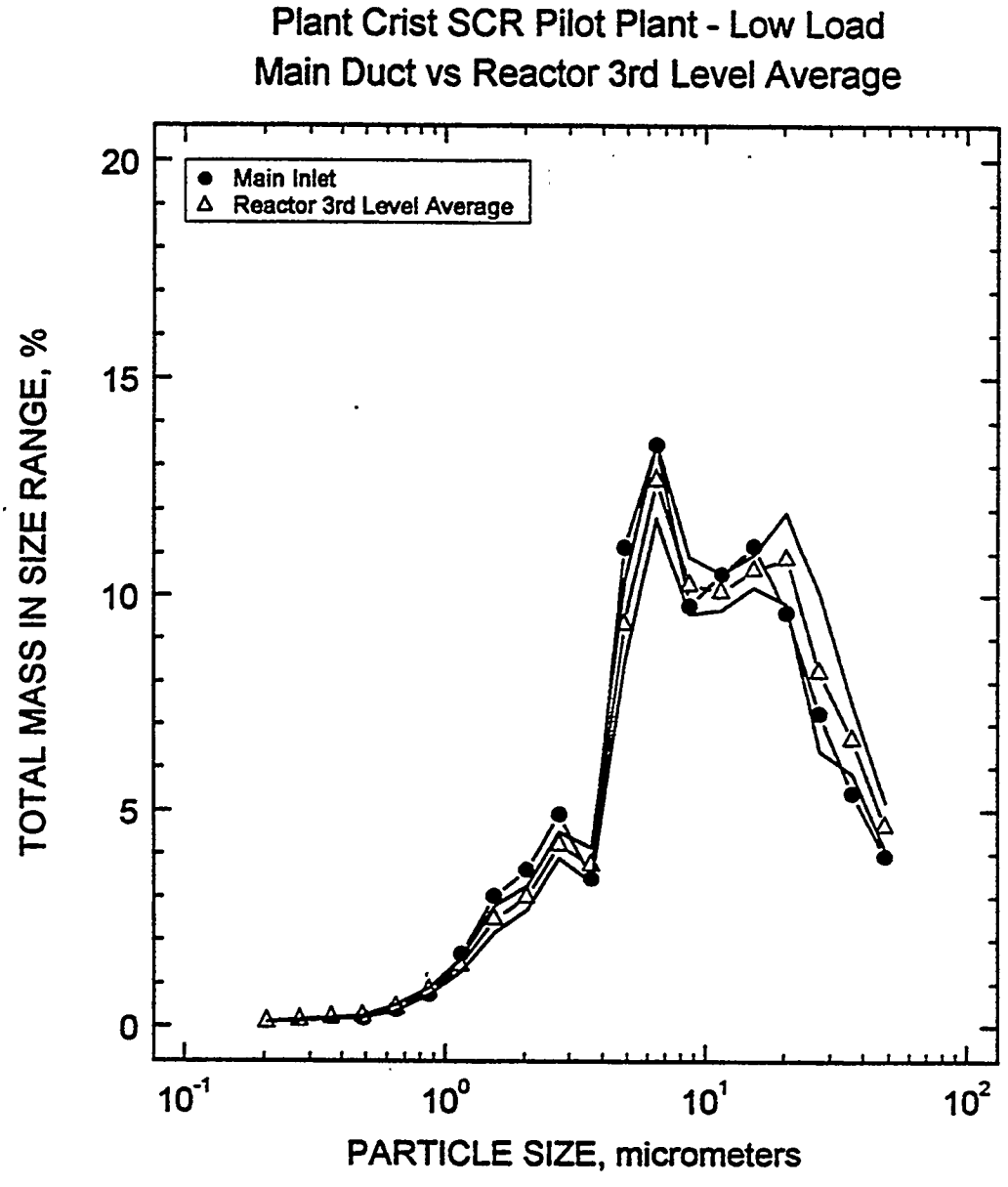

Figure 4-6a. Comparison of differential particle size distributions (linear scale): Unit 5 hot-side ESP inlet versus average of high dust reactors (downstream of third catalyst level) at low load.

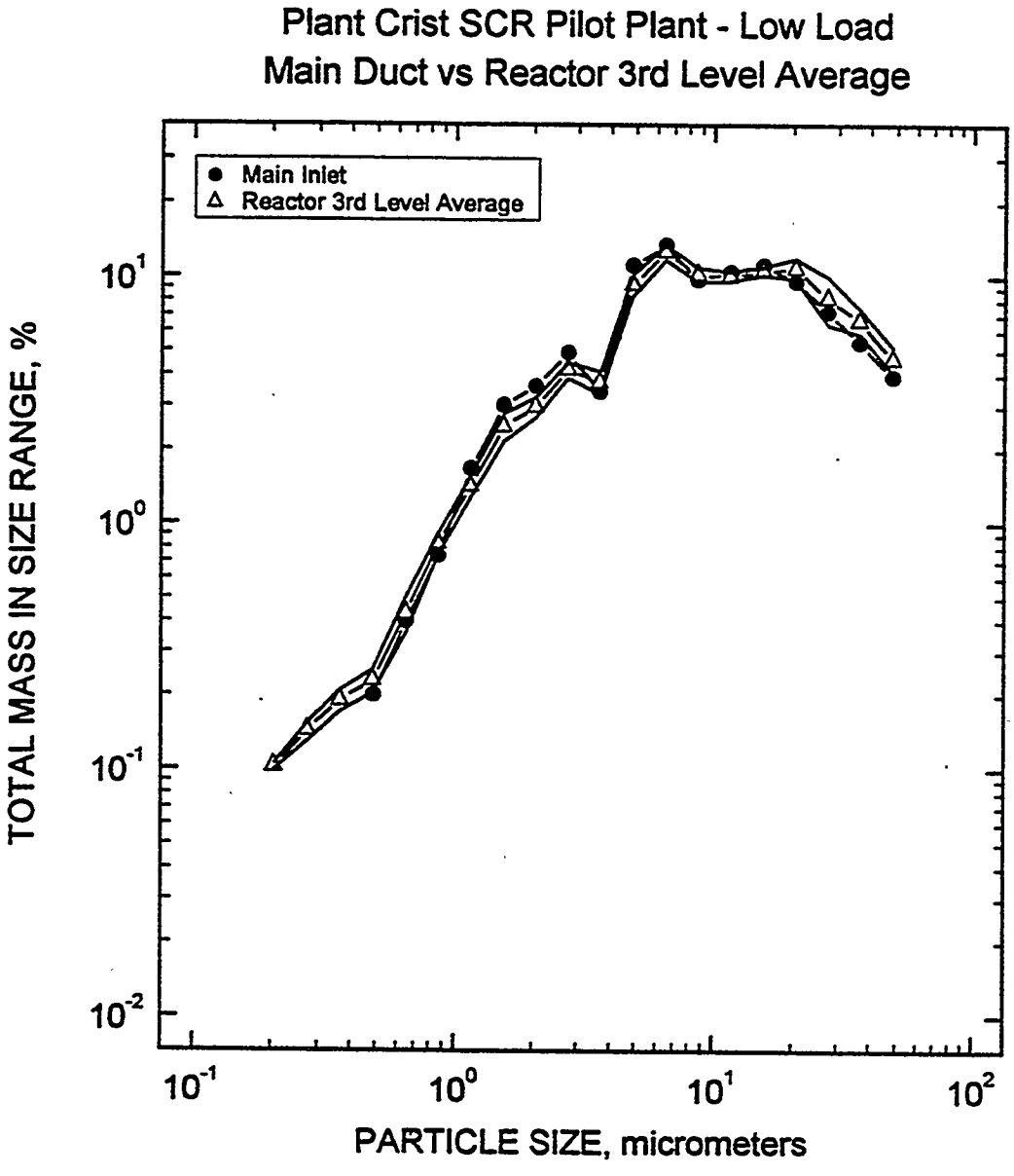

Figure 4-6b. Comparison of differential particle size distributions (probability scale): Unit 5 hot-side ESP inlet versus average of high dust reactors (downstream of third catalyst level) at low load.

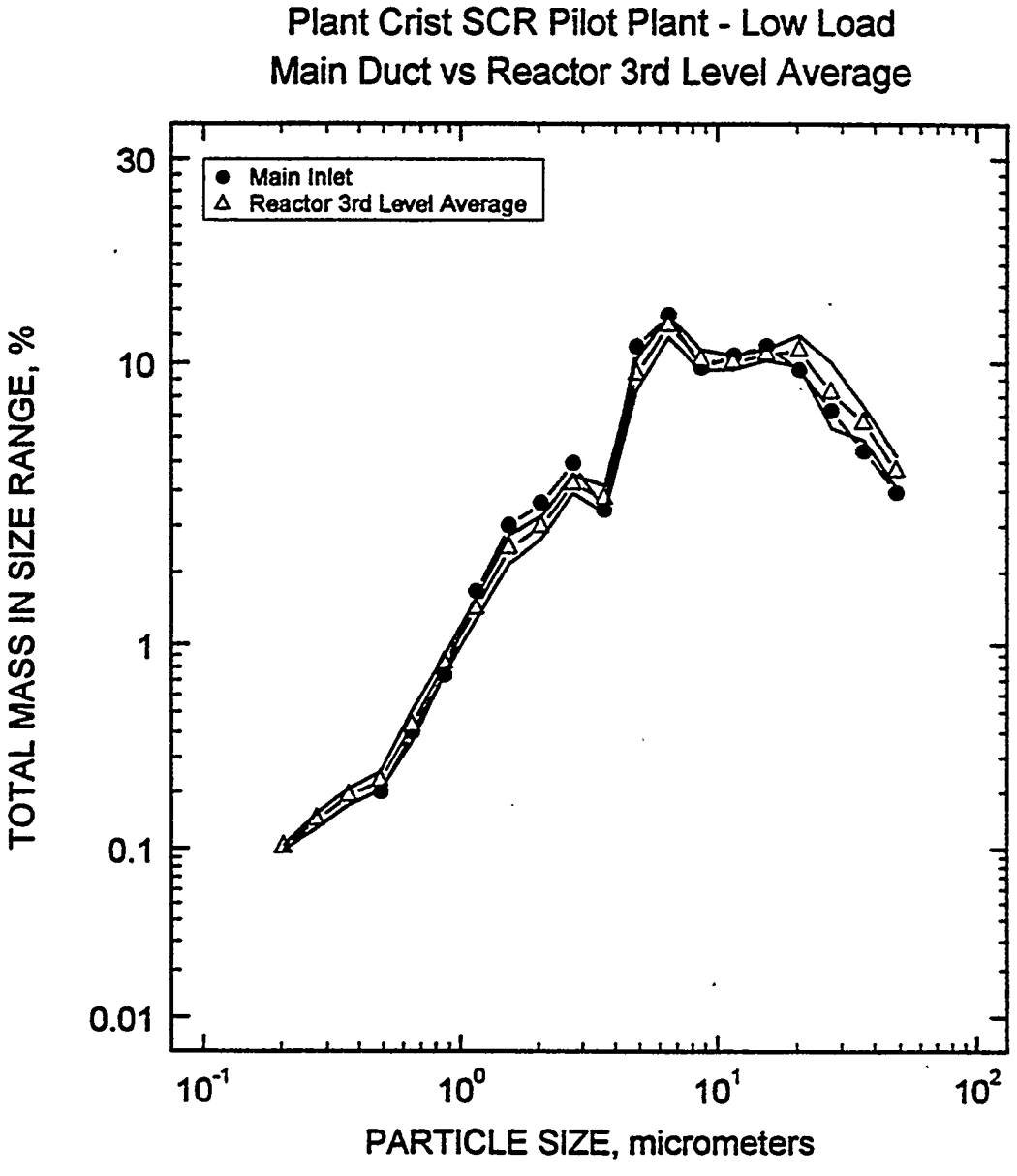

Figure 4-6c. Comparison of differential particle size distributions (logarithmic scale): Unit 5 hot-side ESP inlet versus average of high dust reactors (downstream of third catalyst level) at low load.

Section 5

FLUE GAS CHEMISTRY

The baseline concentrations of the chemical constituents of the flue gas in the Unit 5 hot-side ESP inlet and outlet ducts were measured at both high and low load conditions. The concentrations of the following gases were measured: NH_3, HCl, SO_2 and SO_3. Because of instrument problems, we were not able to measure the concentrations of oxygen and NO_x during this test period. In addition, the concentrations of SO_2 and SO_3 were measured upstream and downstream of the in-duct heaters on one large and one small reactor to determine whether there was measurable conversion of SO_2 to SO_3 across the heaters.

TEST METHODS

Ammonia

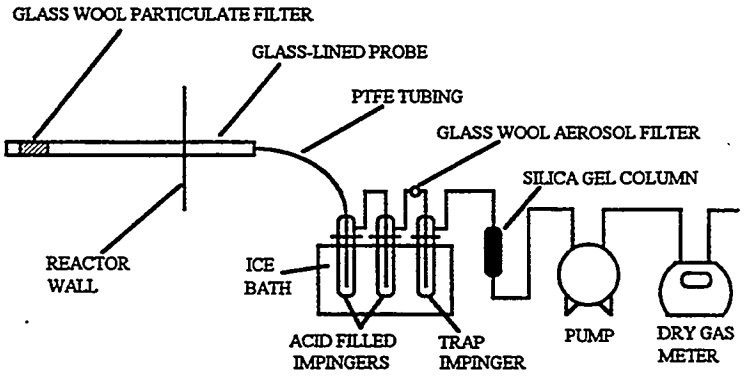

Figure 5-1. Schematic diagram of the ammonia sampling train.

A schematic drawing of the ammonia sampling train is shown in Figure 5-1. The flue gas sample is drawn through a glass-lined probe containing a plug of glass wool to remove particulate. The gas sample passes through a length of PTFE tubing to a set of three impingers in an ice bath. The first two impingers contain a 0.1 normal solution of sulfuric acid. The third impinger serves as a trap to prevent the solutions from accidentally being drawn into the pump. A second glass wool plug is placed in the line between the last two impingers to collect any ammonia aerosols that may escape the second impinger. The remainder of the train consists of a silica gel column to remove the last traces of water from the flue gas sample, a leak-free pump, and a dry gas meter to measure the volume of the sample.

The impinger solutions are made alkaline in the laboratory (converting the NH_4^+ ion to free NH_3 in solution). The concentration of ammonia is then determined with an ammonia ion specific electrode, Orion Model 920A. In most cases three independent measurements of ammonia concentration are made for each test condition. Two independent determinations of the ammonia concentration are then conducted on each sample.

Sulfur Dioxide and Sulfur Trioxide

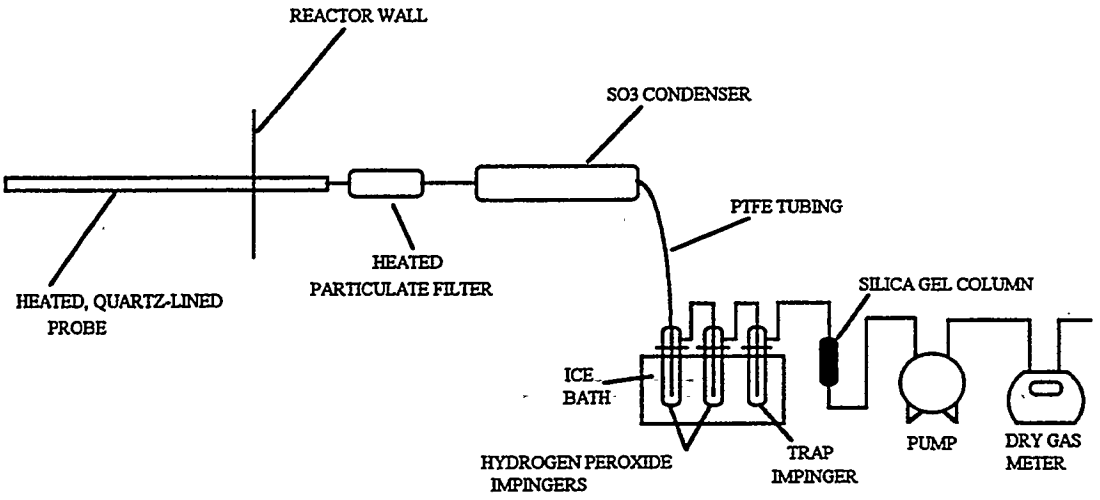

Figure 5-2. Schematic diagram of the controlled condensation sampling train for SO_2 and SO_3.

A schematic drawing of the SO_2/SO_3 sampling train is shown in Figure 5-2. The flue gas sample is drawn through a heated, quartz-lined probe maintained above 550 °F. The sample then passes through a quartz filter housed in a heated quartz filter holder, also maintained at 550 °F. The next element in the train is the SO_3 condenser. The condenser is a length of quartz tubing packed with quartz wool and maintained between 120 °F and 130 °F in a heated water bath. The sample next passes through a length of PTFE tubing to a set of three impingers in an ice bath. The first two impingers contain a 3% solution of hydrogen peroxide to oxidize SO_2. The third impinger serves as a trap to prevent the solutions from accidentally being drawn into the pump. The remainder of the train consists of a silica gel column to remove the last traces of water from the sample, a leak-free pump, and a dry gas meter to measure the volume of the sample.

While the SO_3 is removed in the condensing element, the SO_2 is removed in the bubblers by oxidation to H_2SO_4. In the condenser the SO_3 present begins a hydration reaction with the water vapor present making H_2SO_4. The excess water vapor also condenses to produce a condensate of concentrated aqueous H_2SO_4. Thus, two solutions of H_2SO_4 are collected; one a very concentrated solution of limited amount containing the original SO_3 and the other a relatively weak solution in far greater amount containing the original SO_2. The concentrations of the sulfate ion are determined by ion chromatography using a DIONEX Model DX-100 Ion Chromatograph.

Hydrogen Chloride

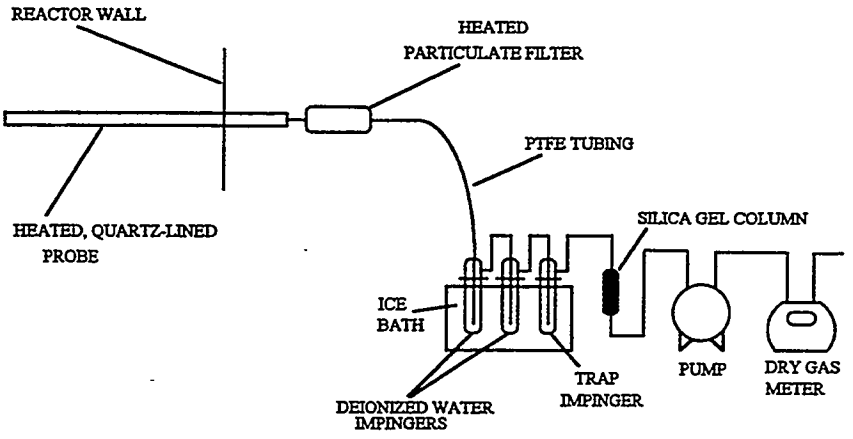

Figure 5-3. Schematic diagram of the chloride sampling train.

A schematic sketch of the chloride sampling train is shown in Figure 5-3. The flue gas sample is drawn through a heated, quartz-lined probe maintained above 550 °F. The sample then passes through a quartz filter housed in a heated quartz filter holder, also maintained at 550 °F. The sample next passes through a length of PTFE tubing to a set of three impingers in an ice bath. The first two impingers contain type 1 de-ionized water for removal of HCl vapor. The third impinger serves as a trap to prevent the solutions from accidentally being drawn into the pump. The remainder of the train consists of a silica gel column to remove the last traces of water from the sample, a leak-free pump, and a dry gas meter to measure the volume of the sample.

The chloride ion concentration is determined by ion chromatography using a DIONEX Model DX-100 Ion Chromatograph. Hydrogen chloride concentrations were determined by single-point sampling.

BASELINE CONCENTRATIONS OF GAS PHASE FLUE GAS CONSTITUENTS

Table 5-1 summarizes the measured gas-phase pollutant concentrations at the Unit 5 hot-side ESP inlet and outlet ducts for both high and low load conditions. The concentrations of the gases are presented on a parts per million basis adjusted to a 3% oxygen concentration. The standard deviation for each value is presented.

The data in Table 5-1 show that the concentrations of SO_2 and HCl decrease between high and low load at both the ESP inlet and outlet, while the concentration of SO_3 increases. For all three species there is a somewhat smaller concentration at the ESP outlet compared to the ESP inlet. In all cases the concentration of NH_3 in the flue gas was below the detection limit. (The absence of detectable NH_3 was expected, since NH_3 is not typically found in flue gas unless it is injected from an outside source. The injection of NH_3 to react with NO_x had not started when these analyses were made.)

Table 5-1. Baseline Gas-Phase Pollutant Concentrations (@ 3% O_2)

	Unit 5 ESP Inlet Duct (High Dust Source)				Unit 5 ESP Outlet Duct (Low Dust Source)			
	84 MW (High Load)		43 MW (Low Load)		84 MW (High Load)		43 MW (Low Load)	
	Concentration		Concentration		Concentration		Concentration	
	Average ppm(v)	Std. Dev. ppm(v)	Average ppm(v)	Std. Dev. ppm(v)	Average ppm(v)	Std. Dev. ppm(v)	Average ppm(v)	Std. Dev. ppm(v)
SO_2	2383	20	1973	39	2166	97	1893	21
SO_3	33	1	47	1	15	1	21	1
HCl	106	14	99	4	123	7	106	1
NH_3	<0.4	na	<0.4	na	<0.4	na	<0.4	na

SO_2 to SO_3 Conversion Across Reactor Heaters

Test data were acquired to document any SO_2 to SO_3 conversion across the flue gas heaters installed upstream of each reactor. Tests were conducted on a large reactor (B) and a small reactor (D). Three simultaneous SO_2 and SO_3 measurements were performed downstream of the inlet transition (upstream of the reactor heaters), downstream of each reactor heater at the port used for venturi flow calibration, and at the reactor outlet downstream of the third catalyst layer. Tests were conducted at both high and low load. Two tests were performed at each condition. As can be seen in Table 5-2, the increase in SO_3 concentration across the in-duct heaters ranged from 21% to 51% depending on the reactor and load condition. Somewhat unexpected was the apparent reduction in SO_3 concentration across each reactor. This could possibly be explained by localized cool spots within each reactor.

Table 5-2. SO_2 to SO_3 Conversion Across Reactor B and D In-Duct Heaters

Location	Reactor B High Load SO_2 ppm(v) dry @ 3% O_2	Reactor B Low Load SO_2 ppm(v) dry @ 3% O_2	Reactor B High Load SO_3 ppm(v) dry @ 3% O_2	Reactor B Low Load SO_3 ppm(v) dry @ 3% O_2	Reactor D High Load SO_2 ppm(v) dry @ 3% O_2	Reactor D Low Load SO_2 ppm(v) dry @ 3% O_2	Reactor D High Load SO_3 ppm(v) dry @ 3% O_2	Reactor D Low Load SO_3 ppm(v) dry @ 3% O_2
Before Flue Gas Heater	2205 +- 26	2006 +- 90	11.8 +- 1.5	34.5 +- 0.7	1797 +- 28	2030 +- 5	8.1 +- 0.9	29.8 +- 1.3
After Flue Gas Heater	2071 +- 36	1791 +- 162	14.3 +- 0.3	44.3 +- 3.6	1851 +- 60	2064 +- 22	12.3 +- 0.9	40.8 +- 0.1
Reactor Outlet	2248 +- 10	2068 +- 48	9.6 +- 1.4	36.7 +- 5.6	1927 +- 19	2093 +- 15	8.2 +- 1.6	29.4 +- 0.3

Section 6

FLY ASH AND COAL CHEMISTRY, FLY ASH RESISTIVITY

Fly Ash and Coal Chemistry

Mineral analyses were performed on fly ash samples collected at the Unit 5 hot-side ESP inlet at high and low load conditions. Mineral analyses were also performed on ashed coal samples collected from Unit 5 corresponding to the days on which the fly ash samples were collected. The data are presented on a weight percent basis in Table 6-1. The analysis shows very similar weight percents for the various chemical constituents for both high and low load conditions. These data match very well with the values for the ash generated from the ignited coal samples.

Seven Plant Crist Unit 5 coal samples were sent to the University of Missouri-Columbia Research Reactor Facility for Neutron Activation Analysis to determine the concentrations of major (5) and trace (31) elements. These samples included five monthly composite samples prepared by Southern Company Services, Inc. (four from 1992 and one from 1993) and two daily samples obtained near the time when the Task 1 tests were being conducted (CRST-10 from February 10, 1993 and CRST-20 from March 6, 1993). The test results are presented in Table 6-2. Also included in this table are the results from NIST SRM-1632a Standard Bituminous Coal samples tested for quality control purposes. The last line of the table presents average reference values for each element as found in the literature. Average values and standard deviations are presented for each set of samples. There is good agreement between the average concentrations of the 36 elements between the five monthly composite samples and the two daily samples. Also, there is very good agreement between the quality control test values for the standard coal and the reference values.

Using a series cyclone sampling system, size segregated samples of fly ash were collected at the Unit 5 hot-side ESP inlet at high and low load conditions. The main purpose of this test was to determine the concentration of trace metals in each particle size range. As an additional step we requested that the concentrations of lithium, sodium, potassium be measured by Flame Atomic Emission Spectroscopy and that the concentrations of magnesium, calcium, iron, and aluminum be measured using Inductively Coupled Argon Plasma (ICAP) emission spectroscopy. These test data are presented in Table 6-3. (The trace metal data can be found in Section 7 of this report.) At the top of each column the cut size of the cyclone stage is presented. An analysis of the data in the table indicates that while there is an enrichment of element concentration as particle size decreases for lithium, sodium and magnesium, this trend does not exist for potassium, calcium, iron, and aluminum.

Fly Ash Resistivity

Fly ash resistivity was measured in the laboratory on a fly ash sample collected at the Unit 5 hot-side ESP at high load conditions. The technique for measuring resistivity was based on the IEEE 548 (1984) test method, commonly referred to as a descending temperature method. The atmosphere in the laboratory oven holding the sample was controlled to a moisture content of 7.6%, comparable to that occurring in the actual Unit 5 flue gas. Figure 6-1 presents the relationship between resistivity (ohm-cm) and inverse temperature (1000/°K). This is a relatively high resistivity ash (3.9×10^{11} ohm-cm @ 293°F) and demonstrates the requirement for flue gas conditioning in cold-side ESPs treating ashes of this type, as well as the reason hot-side ESPs were selected for Crist Unit 5.

Table 6-1. Ash Mineral Analyses (weight percent basis)

Sample Description	CRST-SCRI-1,2 Hot Side ESP Inlet Fly Ash - High Load 2/9/93	CRST-SCRI-3,4 Hot Side ESP Inlet Fly Ash - Low Load 2/10/93	Crist Unit 5 Coal As Fired 2/10/93	Crist Unit 5 Coal As Fired 2/11/93
SRI Sample No.	E1035-100-4	E1035-100-5	E1035-100-6	E1035-100-7
Li2O	0.02	0.02	0.02	0.02
Na2O	0.79	0.87	0.80	0.66
K2O	2.8	2.5	2.3	2.0
MgO	0.97	0.97	0.91	0.78
CaO	4.6	4.0	4.6	2.8
Fe2O3	17.8	18.1	19.9	20.6
Al2O3	22.7	22.7	22.6	22.5
SiO2	48.9	48.4	44.3	47.4
TiO2	1.0	1.0	0.83	0.83
P2O5	0.18	0.16	0.18	0.16
SO3	0.99	1.2	4.0	2.5
LOI	9.4	2.9	91.3 *	90.9 *
Loss on Drying @ 110 C	included in LOI	included in LOI	9.1	9.6

* : LOI performed on samples that had been dried @ 110 C.
Remainder of coal analyses performed on ignited samples.

Table 6-2. Concentrations of major and trace elements in coal samples for SRI and SCS (July 1993).

Identification	Al (%)	As (ppm)	Ba (ppm)	Ca (%)	Ce (ppm)	Co (ppm)	Cr (ppm)	Cs (ppm)	Dy (ppm)	Eu (ppm)	Fe (%)	Hf (ppm)
Analysis of SCS coal samples:												
92-323	0.92	3.8	36	0.31	10.4	2.5	16.8	0.9	0.67	0.171	1.11	0.54
92-599	0.90	3.8	46	0.21	10.0	2.4	17.3	0.9	0.75	0.154	1.11	0.55
92-607	1.05	3.4	45	0.17	11.6	2.4	16.9	0.9	0.65	0.161	1.03	0.55
92-747	0.98	3.7	48	0.29	10.6	2.7	18.4	1.0	0.77	0.164	1.09	0.54
93-082	1.00	4.0	50	0.39	9.7	2.4	14.5	0.7	0.96	0.166	0.90	0.41
Average	0.97	3.7	45	0.27	10.5	2.5	16.8	0.9	0.76	0.163	1.05	0.52
Stand. Dev.	0.061	0.22	5.4	0.086	0.73	0.13	1.42	0.09	0.12	0.006	0.089	0.061
Analysis of SRI coal samples:												
CRST-10	0.92	1.5	27	0.30	11.4	2.92	12.7	1.01	0.87	0.201	0.72	0.44
CRST-20	0.97	4.1	41	0.22	10.3	3.26	15.0	0.89	0.83	0.193	1.25	0.47
Average	0.95	2.80	34	0.26	10.9	3.09	13.9	0.95	0.85	0.20	0.99	0.46
Stand. Dev.	0.04	1.84	9.9	0.06	0.78	0.24	1.63	0.08	0.03	0.01	0.37	0.02
Analysis of SRM-1632a bituminous coal for quality control:												
1632a (sam1)	2.84	9.3	100	0.25	30.4	6.42	33.2	2.25	1.86	0.482	1.07	1.63
1632a (sam2)	2.92	9.2	107	0.23	30.3	6.41	33.4	2.24	1.94	0.490	1.07	1.47
1632a (sam3)	2.95	9.1	107	0.22	29.3	6.41	33.4	2.22	2.04	0.483	1.07	1.47
Average	2.90	9.20	105	0.23	30.0	6.41	33.3	2.24	1.95	0.49	1.07	1.52
Stand. Dev.	0.06	0.10	4.0	0.02	0.61	0.01	0.12	0.02	0.09	0.00	0.00	0.09
Reference Value	2.95	9.2	120	0.24	29.0	6.7	34.0	2.3	2.06	0.52	1.11	1.62

Table 6-2. Concentrations of major and trace elements in coal samples for SRI and SCS (July 1993), continued.

Identification	Hg (ppb)	K (%)	La (ppm)	Lu (ppm)	Mn (ppm)	Mo (ppm)	Na (ppm)	Nd (ppm)	Ni (ppm)	Rb (ppm)	Sb (ppm)	Sc (ppm)
Analysis of SCS coal samples:												
92-323	< 20	0.21	4.57	0.088	21.0	8.0	437	5.58	< 13	12.4	1.00	2.21
92-599	< 23	0.20	4.41	0.095	20.1	10.2	406	5.56	< 13	12.6	1.35	2.13
92-607	< 29	0.20	5.16	0.095	22.3	10.2	405	6.14	< 13	12.9	1.05	2.14
92-747	< 20	0.18	4.74	0.104	22.7	11.1	432	5.72	< 13	14.5	1.08	2.28
93-082	< 20	0.18	4.14	0.108	26.8	10.5	471	5.24	< 11	10.1	0.70	1.91
Average	—	0.19	4.60	0.098	22.6	10.0	430	5.65	—	12.5	1.04	2.13
Stand. Dev.	—	0.01	0.38	0.008	2.6	1.2	27	0.33	—	1.6	0.23	0.14
Analysis of SRI coal samples:												
CRST-10	< 20	0.17	5.09	0.084	44.4	6.5	527	6.55	< 13	14.5	0.29	2.20
CRST-20	< 23	0.16	4.63	0.101	28.8	10.0	364	5.26	< 13	12.3	0.86	2.10
Average	—	0.17	4.86	0.093	36.6	8.3	446	5.91	—	13.4	0.58	2.15
Stand. Dev.	—	0.01	0.33	0.01	11.0	2.5	115	0.91	—	1.6	0.40	0.07
Analysis of SRM-1632a bituminous coal for quality control:												
1632a (sam1)	116	0.40	13.47	0.161	30.3	2.6	800	15.59	< 23	26.9	0.57	5.98
1632a (sam2)	158	0.46	13.46	0.161	30.7	2.8	745	14.43	< 21	27.4	0.54	5.98
1632a (sam3)	132	0.40	13.41	0.158	30.2	2.4	783	13.55	< 20	26.7	0.57	5.93
Average	135	0.42	13.45	0.160	30.4	2.6	776	14.52	—	27.0	0.56	5.96
Stand. Dev.	21	0.03	0.03	0.002	0.26	0.20	28	1.02	—	0.4	0.02	0.03
Reference Value	136	0.41	15.00	0.170	29.0	3.9	828	12.00	19	30.0	0.60	6.30

Table 6-2. Concentrations of major and trace elements in coal samples for SRI and SCS (July 1993), continued.

Identification	Se (ppm)	Sm (ppm)	Sr (ppm)	Ta (ppm)	Tb (ppm)	Th (ppm)	Ti (%)	U (ppm)	V (ppm)	Yb (ppm)	Zn (ppm)	Zr (ppm)
Analysis of SCS coal samples:												
92-323	0.67	0.86	< 17	0.14	0.14	1.42	0.056	1.96	52	0.43	30	27
92-599	0.71	0.90	< 17	0.13	0.16	1.46	0.061	2.47	75	0.42	46	29
92-607	0.72	0.89	< 16	0.06	0.12	1.49	0.056	2.65	59	0.48	43	29
92-747	0.77	1.02	< 16	0.13	0.11	1.56	0.068	3.24	61	0.45	36	35
93-082	0.79	0.98	10	< .01	< .01	1.27	0.062	4.12	47	0.47	38	34
Average	0.73	0.93	—	0.115	0.13	1.44	0.061	2.89	59	0.45	39	31
Stand. Dev.	0.05	0.07	—	0.037	0.02	0.11	0.005	0.83	11	0.03	6.2	3.5
Analysis of SRI coal samples:												
CRST-10	0.70	0.99	10	0.14	0.14	1.62	0.034	1.92	27	0.51	22	17
CRST-20	0.73	1.01	< 16	0.13	0.16	1.44	0.054	3.67	33	0.50	28	36
Average	0.72	1.00	—	0.14	0.15	1.53	0.044	2.80	30	0.51	25	27
Stand. Dev.	0.02	0.01	—	0.01	0.01	0.13	0.014	1.24	4.2	0.01	4.2	13
Analysis of SRM-1632a bituminous coal for quality control:												
1632a (sam1)	1.45	2.30	90	0.40	0.34	4.26	0.154	1.50	46	1.19	27	41
1632a (sam2)	1.42	2.30	89	0.39	0.35	4.24	0.154	1.46	44	1.21	28	64
1632a (sam3)	1.54	2.29	60	0.40	0.36	4.16	0.168	1.38	42	1.24	30	46
Average	1.47	2.30	80	0.40	0.35	4.22	0.159	1.45	44	1.21	28	50
Stand. Dev.	0.06	0.01	17	0.006	0.01	0.05	0.008	0.06	2.0	0.03	1.5	12
Reference Value	2.70	2.40	85	0.42	0.31	4.50	0.163	1.26	44	1.08	27	53

Table 6-3. Metals Concentrations in Fractionated Fly Ash Samples

Cyclone Stage	1	2	3	4	5	Combined
High Load						
Stage Cut Point, µm	5.3	3.3	1.8	1.18	0.44	
Percent of Total Mass	62.3	29.8	6.4	1.19	0.3	100
Lithium, µg/g	63	87	113	119	364	73.9
Sodium, µg/g	0.38	0.55	0.9	1.982	3.61	0.5
Potassium, µg/g	1.59	2.01	2.61	2.72	2.08	1.8
Magnesium, µg/g	0.44	0.51	0.69	0.8	1.04	0.5
Calcium, µg/g	3.08	1.84	1.94	2.24	3.06	2.6
Iron, µg/g	13.2	7.92	8.65	9.4	12.1	11.1
Aluminum, µg/g	9.05	10.8	12.8	12.6	10.6	9.7
Low Load						
Stage Cut Point, µm	5.5	3.5	1.9	1.26	0.47	
Percent of Total Mass	69.3	17	10.1	2.8	0.85	100
Lithium, µg/g	65.8	99.1	122	130	493	81.4
Sodium, µg/g	0.53	0.88	1.13	0.96	1.08	0.7
Potassium, µg/g	1.79	2.38	3.95	2.7	3.08	2.1
Magnesium, µg/g	0.48	0.57	0.67	0.83	1.13	0.5
Calcium, µg/g	2.64	1.33	1.15	1.62	2.45	2.2
Iron, µg/g	10.3	5.34	5.1	6.29	7.6	8.7
Aluminum, µg/g	9.24	9.18	19.26	14.58	17.3	10.3

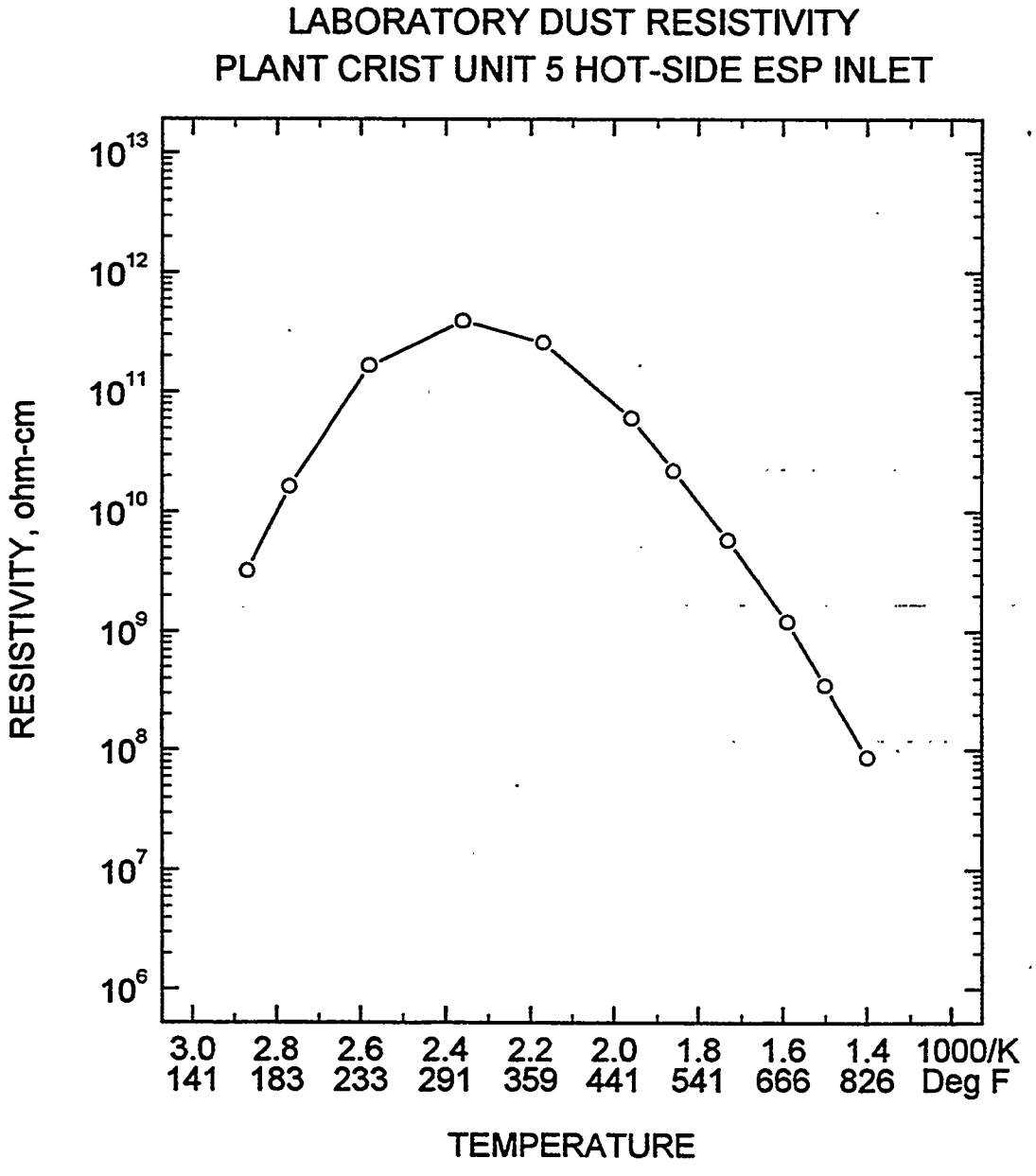

Figure 6-1. Resistivity of fly ash at the Unit 5 hot-side ESP inlet (high load).

Section 7

TRACE METALS ANALYSIS

Trace metal concentrations were measured at the Unit 5 hot-side ESP inlet (high and low load), at the reactor A inlet (high and low load), at the Unit 5 hot-side ESP outlet (high load only) and at the economizer bypass duct (low load only). For collecting trace metals, the U.S. EPA has sanctioned the use of a Method 5 filtration device and back-up impingers - two filled with nitric acid and hydrogen peroxide and two filled with potassium permanganate and sulfuric acid. This test method is commonly referred to as Method 29 - Determination of Metals Emissions from Stationary Sources. This is a proposed method and has not been formally promulgated. We used Method 29 to collect samples at the locations described above. The combination of a particulate filter and the back-up impingers provides a convenient way to collect the trace elements both in the solid and gaseous phases that are of paramount concern. The trace elements that occur as components of the fly ash (solids) are collected on the filter, except for the fractions of certain metals (such as arsenic and selenium) that may occur partly in the vapor state. These partly volatile metals are collected in the HNO_3/H_2O_2 impingers. Mercury is usually completely in the vapor state at temperatures above 300°F and is collected both in the HNO_3/H_2O_2 and $KMnO_4/H_2SO_4$ impingers.

Analysis was performed separately on the fly ash (front end) and impinger (back end) samples. The ash was dissolved as completely as possible in concentrated mineral acids and the screening analysis was performed by Inductively Coupled Argon Plasma Emission Spectroscopy (ICAP). ICAP required auxiliary determination of arsenic and selenium by atomic absorption with the elements converted to hydrides for improved sensitivity. Cold vapor atomic absorption was used for mercury determination.

The concentrations of the following elements were determined with Method 29: antimony (Sb), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), cesium (Cs), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), molybdenum (Mo), nickel (Ni), rubidium (Rb), selenium (Se), strontium (Sr), tin (Sn), vanadium (V), and zinc (Zn). Analysis of the Method 29 samples was conducted at SRI laboratories in Birmingham.

Finally, trace element concentrations were determined for size segregated fly ash samples collected at the Unit 5 hot-side ESP inlet at high and low load. The samples were collected using a five-stage series cyclone sampling system. These ash samples were analyzed by ICAP in our Birmingham laboratory.

Additional tests for mercury were performed with iodated carbon mercury vapor traps. Tests were conducted at the Unit 5 hot-side ESP inlet (high and low load), reactor A inlet (high and low load), the Unit 5 hot-side ESP outlet (high and low load) and the economizer bypass duct (low load only). These traps were analyzed by Brooks Rand, Ltd. of Seattle, Washington.

Trace Elements Determined By Method 29 and Series Cyclones

The concentrations of metal species determined by the Method 29 Multiple Metals Train are presented in Tables 7-1, 7-2, and 7-3. Table 7-1 gives the metal concentrations as weight fractions (μg/g) of the total solids collected in the probe and on the filter (front half). Table 7-2 presents cumulative data for the metal concentrations in the front half and in the impingers (back half), also as weight fractions (μg/g) of the total solids. Table 7-2 reflects differences from Table 7-1 due only to the amounts of some elements that were in the vapor state. The third table, Table 7-3, expresses the total of each element (front and back halves) as a concentration in the gas stream ($\mu g/Nm^3$); it also includes values for total solids in the gas stream (last line

Table 7-1. Volatile Metals Concentrations (µg/g)
Multiple Metals Trains (Front Half Only)

	ESP inlet 2/9/93 High load Run 1	A inlet 3/6/93 High load Run 7	ESP inlet 2/11/93 Low load Run 5	ESP inlet 2/11/93 Low load Run 6	A inlet 3/6/93 Low load Run 9	Econ.B.P. 3/6/93 Low Load Run 10	ESP outlet 2/9/93 High load Run 3	Avg. ± s.d. except Run 3
Sb	9	6.1	2.9	<3.6	8.3	<3.8	<180.0	5.0± 3.2
As	139	51.3	69.7	97.9	47.2	38.5	110	73.9± 38.2
Ba	298	302	377	563	259	261	339	343.0±116.0
Be	11.3	9.6	14.5	21	10.3	9	<35.0	12.6± 4.5
Cd	5.9	4.6	10.3	20	7.2	55.4	39.1	17.2± 19.5
Cs	85.5	72.9	74.6	<80.0	69.9	<76.0	<3500.0	63.5± 19.7
Cr	124	132	148	152	124	125	241	134.0± 13.0
Co	23	27.4	30.6	30.7	22.8	22.8	<70.0	26.2± 3.9
Cu	71.6	66.2	86.4	93.2	65.4	63	215	74.3± 12.5
Pb	221	227	286	404	239	223	426	267.0± 72.0
Mn	152	225	172	174	169	163	226	176.0±25.0
Hg	0.35	0.12	0.13	0.21	0.18	3.6	<7.0	0.76± 1.39
Mo	72.9	82.6	77	85.7	74.6	88.5	880	80.2± 6.3
Ni	86.5	100	104	106	89.5	87.3	<180.0	95.5± 8.8
Rb	134	132	126	125	123	119	<1800.0	126.0± 6.0
Se	99.3	1.37	8.02	13.7	7.1	9.9	514	23.2± 37.4
Sr	186	188	237	252	175	172	228	202.0± 34.0
Sn	26.8	21.5	27.6	22.7	20	19.2	<180.0	23.0± 3.5
V	683	467	458	428	531	565	577	522.0± 94.0
Zn	311	436	647	1118	353	336	3320	534.0±311.0

Table 7-2. Volatile Metals Concentrations (µg/g) Multiple Metals Trains (Front Half plus Back Half)

	ESP inlet 2/9/93 High load Run 1	A inlet 3/6/93 High load Run 7	ESP inlet 2/11/93 Low load Run 5	ESP inlet 2/11/93 Low load Run 6	A inlet 3/6/93 Low load Run 9	Econ.B.P. 3/6/93 Low Load Run 10	ESP outlet 2/9/93 High load Run 3	avg.±s.d. except Run 3
Sb	9	6.1	2.9	<3.6	8.3	<3.8	<180.0	5.0±3.2
As	141	51.7	69.7	98.6	49	39.2	154	74.9±38.6
Ba	298	303	377	563	264	261	339	344±115
Be	11.3	9.6	14.5	21	10.3	9	<35.0	12.6± 4.5
Cd	6.1	4.6	10.4	20.2	7.4	55.4	356	17.4±19.5
Cs	85.5	72.9	74.6	<80.0	69.9	<76.0	<3500.0	63.5±19.7
Cr	124	132	148	153	126	125	310	135± 3
Co	23	27.4	30.6	30.7	23.3	22.8	<70.0	26.3±3.8
Cu	71.8	66.7	86.6	93.5	67.4	63.8	286	75.0±12.2
Pb	221	227	286	404	239	223	426	267± 72
Mn	152	226	172	174	174	164	226	177± 25
Hg	1.41	1.4	0.74	1.53	2.38	2.58	285	1.67±0.69
Mo	72.9	83	77	85.7	76.9	88.5	880	80.7± 6.0
Ni	86.8	100	104	106	91.8	87.3	<180.0	96.0± 8.5
Rb	134	132	126	125	123	119	<1800.0	126± 6
Se	102.6	3.41	10.1	15.8	9	13.6	197.5	25.8±37.9
Sr	186	189	237	252	177	172	228	202± 34
Sn	30.7	40.6	31.1	27.7	25.3	23.5	<180.0	29.8± 6.0
V	683	468	458	428	544	565	577	524± 94
Zn	314	439	648	1120	362	337	3545	537±311

Table 7-3. Volatile Metals Concentrations (µg/Nm3) Multiple Metals Trains (Front Half plus Back Half) Solids Concentrations (g/Nm3)

	ESP inlet 2/9/93 High load Run 1	A inlet 3/6/93 High load Run 7	ESP inlet 2/11/93 Low load Run 5	ESP outlet 2/11/93 Low load Run 6	A inlet 3/6/93 Low load Run 9	Econ. B.P. 3/6/93 Low Load Run 10	ESP outlet 2/9/93 High load Run 3	avg.±s.d. except Run 3
Sb	71.2	68	32.3	<23.0	80	<36.0	<4.0	34.5±20.9
As	1120	574	768	640	473	375	3.98	658±264
Ba	2370	3360	4150	3650	2550	2500	7.72	3100±730
Be	89.8	106	160	136	98.9	86	<0.8	113± 29
Cd	48.7	50.5	115	131	69.9	530	9.24	158±186
Cs	680	810	822	<460.0	674	<730.0	<80.0	597±244
Cr	989	1470	1640	988	1220	1200	5.48	1250±260
Co	183	304	337	199	182	219	<1.6	237± 67
Cu	571	741	954	606	650	611	6.5	689±142
Pb	1760	2530	3160	2620	2300	2130	9.7	2420±480
Mn	1210	2500	1890	1130	1670	1566	5.16	1660±500
Hg	11.2	15.6	8.2	10.2	22.9	24.7	6.48	15.5± 6.9
Mo	580	922	858	555	730	848	20	749±154
Ni	690	1120	1150	687	886	836	<4.0	895±202
Rb	1070	1460	1380	809	1190	1140	<40.0	1170±230
Se	816	37.9	112	103	86.4	130	45	214±296
Sr	1480	2100	2607	1630	1710	1650	5.2	1860±420
Sn	244	451	343	179	244	225	24.1	281±99
V	5430	5200	5050	2770	5250	5410	13.1	4850±1030
Zn	2500	4870	7140	7240	3490	3230	80.7	4740±2040
Solids	7.952	11.111	11.019	6.48	9.646	9.576	0.0228	9.297±1.800

of the table). The right-hand column in each table shows the average and the standard deviation of all of the tests, except the one at the ESP outlet at high load (next to last column, Run 3). To calculate averages when data are reported only as upper limits, the true value was assumed to be half the limit.

Table 7-4 lists the concentrations of elements based on analyses of the back half of each train when detected in the back half. The data in the second column (in μg/g) are the differences between the averages (columns 9) in Tables 7-1 and 7-2; they are to be interpreted as vapor concentrations but are expressed as weight fractions of the total particulate matter. The data in the third column express apparent vapor concentrations as percentages of the total of front and back halves. Thus, on a percentage basis, the most volatile element is mercury; the next most volatile is tin; and the third most volatile is selenium.

It is important to realize that the apparent distributions of the metals between the particulate and vapor states are controlled by the temperature of the filter (250 °F) in the multiple metals sampling train (Method 29). The indicated ratios of vapor to particulate are undoubtedly lower in the train than they are in the gas streams sampled at 700 °F. Unfortunately, there is no sanctioned method for sampling flue gas and preserving the in-duct distributions between particulate and vapor states. Given the uncertainty of error from this source, we would expect that both mercury and selenium were mostly in the vapor state at 700 °F. However, these data indicate that only 50% of the mercury and 10% of the selenium were in the vapor state. Perhaps arsenic, considered a threat to the long-term performance of SCR catalysts, occurred mostly in the vapor state at 700 °F, although in these tests it was found to be insignificant in the vapor state.

As a first approximation, all of the runs except that at the ESP outlet at high load were expected to show the same metal concentrations in either μg/g or μg/Nm^3. All tests except that at the ESP outlet were made at sampling locations that were uneffected by the ESP (ESP inlet, Reactor A inlet, and economizer bypass). Conceivably, stratification of the gas and particulate matter could have made compositions different at these three sampling locations. Also, differences could be attributed to the different dates when the tests were performed and the differences in boiler load during each test. Nevertheless, any variations at these locations would have been expected to be relatively subtle.

No significant effect is evident between high and low load at the same sampling location, except possibly for selenium, vanadium, and zinc at the ESP inlet and selenium at the Reactor A inlet. Selenium is known for difficult-to-reproduce results, however, it is not clear why there was such a spread in the vanadium and zinc results. The difficulty in obtaining reproducible results in these types of measurements is represented by the data for selenium and cadmium in Tables 7-1, 7-2, and 7-3. In each case the standard deviation of the average is larger than the average concentration for each element. This is not a necessarily surprising result. Also, there are insufficient test data to draw any conclusions regarding effects on trace metal concentrations by surface area and temperature losses created by the pilot plant ductwork.

The ESP outlet data, however, are very different from all of the other data. The test results show much higher values on a μg/g basis as a general rule. This is expected, since the outlet dust is finer in particle size and contains a higher concentration of any metal that at some time existed as a vapor that underwent condensation or adsorption onto existing particle nuclei. On a μg/Nm^3 basis, however, Table 7-3 shows much lower values for the ESP outlet since most of any metal not in the vapor state has been collected in the ESP.

Table 7-5 compares data precision for all runs except the test at the ESP outlet on the basis of concentrations as μg/g and μg/Nm^3. The comparison suggests that variability was due more to imprecision in analyses than to imprecision in the determination of total particulate concentration, although there was considerable variation in the latter.

Table 7-4. Volatile Metals Concentrations (µg/g) Multiple Metals Trains (Back Half Only)

Metal	Concentration	% of Total
As	1.0	1.3
Ba	1.0	0.3
Cd	0.2	1.0
Cr	1.0	0.7
Cu	0.7	0.9
Mn	1.0	0.6
Hg	0.9	54.0
Mo	0.5	0.6
Ni	0.5	0.5
Se	2.6	10.0
Sn	6.8	23.0
V	2.0	0.4
Zn	3.0	0.6

Table 7-5. Data Precision for Metals Concentrations

	Relative std. dev (%)	
	Table 7-2 (µg/g)	Table 7-3 (µg/Nm3)
Sb	64	60
As	52	40
Ba	33	24
Be	36	26
Cd	112	118
Cs	31	41
Cr	2	21
Co	14	28
Cu	16	21
Pb	27	20
Mn	14	31
Hg	50	45
Mo	7	21
Ni	9	23
Rb	5	20
Se	147	138
Sr	17	23
Sn	20	5
V	18	21
Zn	58	43

Tables 7-6 and 7-7 present the metal concentrations in the dust fractions obtained from the five-stage series cyclone at high and low load, respectively. The tables show the cut points for each stage and give the percentage of the total mass on each stage. By use of the metal concentrations and the weight percentages on each stage, it is possible to calculate the apparent metal concentration in the total ash sample. The results of these calculations are given in the final column in each table.

The data in Tables 7-6 and 7-7 suggest that increasing concentration of an element in the solid (μg/g) as particle size decreases is more the rule than the exception. There were very few elements where this did not occur. It suggests that nearly all of the elements, if not exactly all, were in the vapor state at some time in the time-temperature history of the flue gas and became enriched more in the small particles than the larger ones, because of the greater ratios of surface area to mass in the smaller particles. This explanation, however, is contrary to the widely held belief that some metals (barium and other elements of low volatility, some of which are subsequently identified in Table 7-9) partition evenly between bottom ash and fly ash. Therefore, some alternative, and as yet undetermined, explanation accounts for some of the apparent trends.

Two of the metals shown in Tables 7-6 and 7-7, mercury and selenium, are volatile. This fact may account for the poor data quality for these metals. The concentrations of some metals appear to increase with decreasing particle size even though the data given are only limits. Limits that increase in magnitude as particle size decreases do not imply that actual concentrations increase; they merely signify that the sample amount decreases with particle size and thus the detection limit increases.

There are some differences between the high-load and low-load data in Tables 7-6 and 7-7 that are difficult to associate with just the difference in load conditions. For example, Sb, As, Pb, and Mn appear at higher concentrations in the high-load samples, and Mo was high at low load. Conceivably, there was a change in coal composition accounting for these differences, but there may have been unknown problems in the analytical laboratory that account for the differences.

Table 7-8 compares specific concentrations in the solids (concentrations on the μg/g basis) for samples from the Method 29 Multiple Metals Train and samples from the cyclones (high load only). The data for the metals train are from Table 7-1, Columns(2 and 3). The data for the cyclones are from Table 7-6, Column 7. There are outstanding differences for four elements: Sb, As, Se, and Sn. The first three of these are known to be relatively volatile. As and Se follow a logical pattern; they are more concentrated in the solids collected on the filter of the metals train (at 250°F) than they are in the solids collected in the cyclones (at temperatures exceeding 600 - 700°F). In other words, they show evidence of having been absorbed at the lower collection temperature. Sb seems not to have followed this pattern. Sn shows evidence of being relatively volatile. Sn, like As and Se, appears to have been removed from the vapor state in the filtration step.

Table 7-9 lists ratios of ESP outlet concentrations to ESP inlet concentrations (in μg/g, the single ESP outlet test compared to the average of the other tests). The smaller the ratio the more the element is indicated as a matrix element with low volatility. All of the elements with ratios below 2 are plausible as matrix elements; the element with the highest ratio, Hg, is the one expected to be the most volatile. Some of the other elements seem misplaced; for example, Zn seems to be in the wrong place in the company with Se and Sn. Cd and Mo give evidence of being relatively volatile, although we would not expect this.

Mercury Concentrations Determined From Iodated Carbon Traps

The concentration of mercury in the flue gas at the Plant Crist SCR Test Facility was also measured by sampling flue gas through iodated carbon mercury vapor traps. Tests were performed at both the Plant

Table 7-6. Particle Size Dependent Concentrations (µg/g) (High Load)

Stage	1	2	3	4	5	ALL
cut point, µm	5.5	2.3	1.8	1.2	0.43	
% of mass	62.3	29.8	6.4	1.19	0.3	100
Sb	40.9	44.5	92	173	24	46.8
As	8.84	26.6	22.2	42.7	38.2	15.5
Ba	496	420	669	917	1484	492
Be	15.1	20.4	33	41.4	59.3	18.3
Cd	7.37	11.1	37	59.9	153	11.5
Cs	no data available					
Cr	148	195	312	412	606	177
Co	23.9	24.8	37.7	36.9	33.1	25.2
Cu	68.7	89.8	147	175	212	81.7
Pb	212	473	1060	1378	1703	363
Mn	170	127	200	260	375	363
Hg	no data available					
Mo	50.8	122	222	287	286	86.5
Ni	98.9	121	206	274	461	116
Rb	111	114	137	<398	<1400	<121
Se	1.04	1.2	1.33	<4.98	<20	<1.21
Sr	198	199	293	339	412	207
Sn	10.1	15.7	14.5	<5	<5	<12.0
V	565	577	1024	1451	1856	612
Zn	372	797	1950	2825	6116	646

Table 7-7. Particle Size Dependent Concentrations (µg/g) (Low Load)

Stage	1	2	3	4	5	ALL
cut point, µm	5.5	3.5	1.9	1.26	0.47	
% of mass	69.3	17	10.1	2.8	0.85	100
Sb	<1.0	<1.0	<2.0	<6.0	<25.0	na
As	1.97	0.87	6.45	7.44	62.1	2.9
Ba	340	418	504	531	670	378.1
Be	11.1	18.3	23.9	27.4	32.5	14.3
Cd	13.2	9.48	14.3	20.4	29.4	13.0
Cs	115	529	475	1378	6600	312.3
Cr	168	324	253	323	337	209.0
Co	27.6	36.5	47	59.7	<100	<32.6
Cu	68.2	107	144	198	264	87.8
Pb	78.4	218	356	426	462	143.2
Mn	195	181	211	257	346	197.4
Hg	<0.2	<0.4	<0.7	<2.5	<10.0	na
Mo	176	379	559	703	761	269.0
Ni	103	193	196	280	341	134.7
Rb	122	144	167	<221	<985	<140
Se	0.74	1.08	<2.0	<6.0	<25.0	<1.28
Sr	245	291	272	348	392	259.8
Sn	19.6	20.4	26.6	<60	<250	<23.5
V	434	492	628	801	1067	479.3
Zn	246	624	1016	1350	2830	441.0

Table 7-8. Comparison of Specific Concentrations (µg/g) in Particulate From Metals Trains and Cyclones

	Metals train Table 7-1, Columns 2 & 3	Cyclones Table 7-5, Column 7
Sb	7.6	46.8
As	95.2	15.5
Ba	300	492
Be	10.5	18.3
Cd	5.3	11.5
Cs	79.2	(no data)
Cr	128	177
Co	25.2	25.2
Cu	68.9	81.7
Pb	224	363
Mn	189	161
Hg	0.24	(no data)
Mo	77.8	86.5
Ni	93.3	116
Rb	133	<121
Se	50.3	<1.21
Sr	187	207
Sn	24.2	<12.0
V	575	612
Zn	374	646

Table 7-9. Ratios of ESP Outlet Concentration to Average ESP Inlet Concentrations Data from Table 7-2, Columns 3 and 9

	R<2	R<5	R<10	R<100	R<1000
Sb				<36	
As		2.06			
Ba	0.985				
Be		<2.78			
Cd				20.5	
Cs				<55.1	
Cr		2.3			
Co		<2.66			
Cu		3.81			
Pb	1.6				
Mn	1.28				
Hg					171
Mo				10.9	
Ni	<1.88				
Rb				<14.3	
Se			7.66		
Sr	1.13				
Sn			6.04		
V	1.1				
Zn			6.6		

Crist Unit 5 hot-side ESP inlet and outlet ducts at high and low load conditions. Tests were also performed at the Reactor A inlet at high and low load and in the economizer bypass duct at low load conditions. For the purpose of material balance calculations, both Plant Crist Unit 5 and NIST certified coal samples were submitted for determination of mercury concentration. The carbon traps and coal samples were analyzed by Brooks Rand, Ltd. of Seattle, WA. The test results are summarized in Table 7-10.

The mercury concentration in each trap was measured and reported as nanograms per trap. Based on the volume of flue gas sampled through each trap, we calculated the mercury concentration in the flue gas as nanograms per standard dry liter corrected to 3% oxygen. The values generally fell in the range of 9 to 14 nanograms per liter. In two cases (CRST-Hg-2 and CRST-Hg-7) Brooks Rand performed triplicate analyses to provide a level of quality assurance. For CRST-Hg-2 the relative standard deviation (rsd) was 2% and for CRST-Hg-7 the rsd was 5%. Another quality assurance test was to spike blank samples with a known quantity of mercury. (For each test two iodated carbon traps are run in series. The second trap is analyzed and treated as a blank. The mercury concentration measured in the blank trap is then used to adjust the concentration measured in the first trap. Generally the blank mercury concentration averages approximately 1 nanogram per trap.) Mercury spiking was done on two samples, CRST-Hg-3 and CRST-Hg-7. The recovery was 102% and 91%, respectively.

Two coal samples were submitted for analysis. Brooks Rand, as part of their normal service, also tested NIST certified coal samples. The NIST certified value is 0.13 µg/g. In both cases this value was recovered. The mercury concentration in the Plant Crist coal samples differed significantly between the two dates, 0.11 µg/g for 2/10/93 and 0.081 µg/g for 3/6/93. A triplicate of tests was performed on the 3/6/93 sample. The rsd was 4%. Using the mercury concentration values for the coal, the approximate coal feed rate for Unit 5 at high and low load conditions, and the measured flue gas flow rate at the hot-side ESP inlet (the number was doubled to account for the two inlet ducts), the predicted mercury vapor concentration in the flue gas was calculated. The values, ranging from 9.7 to 14.6 nanograms per dry standard liter @ 3% oxygen, agree well with the range of values measured by the iodated carbon mercury vapor traps (9.2 to 14.1 nanograms per dry standard liter @ 3% oxygen).

Table 7-10. Mercury Concentrations Determined from Iodated Carbon Traps

Sample ID #	Date	Location	Load	Hg Concentration (nanograms/trap)	Flue Gas Temperature (F)	Flue Gas Sampled St. Dry Liters @ 3%O2	Hg Concentration in Flue Gas (nanograms/liter) St. Dry Liters @ 3% O2	Comments
Iodated Carbon Traps								
CRST-Hg-2	2/9/93	ESP Inlet	High	220 + 4.4	663	24.0	9.2	A
CRST-Hg-3	2/10/93	ESP Outlet	High	224	620	20.4	11.0	
CRST-Hg-4	2/10/93	ESP Outlet	Low	140	544	20.3	6.9	
CRST-Hg-6	2/11/93	ESP Inlet	Low	308	598	21.8	14.1	
CRST-Hg-7	3/6/93	Reac. A Inlet	High	265 + 13.3	733	21.6	12.3	A
CRST-Hg-8	3/6/93	Reac. A Outlet	Low	187	738	16.6	11.3	
CRST-Hg-9	3/6/93	Econ. Bypass	Low	149	870	15.0	9.9	
Coal Samples								
				(micrograms/gram)				
Crist Unit 5	2/10/93			0.11				
NIST-1630 Coal				0.13				B
Crist Unit 5	3/6/93			0.081 + 0.0032				A
NIST-1630 Coal				0.13				B
Predicted Mercury Vapor Concentration in Flue Gas								
	2/10/93		High				14.6	C
	2/10/93		Low				13.2	C
	3/6/93		High				10.8	C
	3/6/93		Low				9.7	C

A: Test performed 3 times to provide level of uncertainty

B: NIST-1630 certified value is 0.13 micrograms per gram

C: Based on coal feed rate (42 tons/h @ high load & 20 tons/h @ low load) and measured flue gas flow rate at Unit 5 hot-side ESP inlet

TESTING AND ANALYTICAL SERVICES FOR THE INNOVATIVE CLEAN COAL TECHNOLOGY DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_x) EMISSIONS FROM HIGH SULFUR COAL

Final Report for Task 2

Commissioning without Catalysts and with Ammonia Injection

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February 15, 1995

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Section 1

INTRODUCTION

This report represents the second in a series of interim reports describing the results of testing and analytical services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the control of nitrogen oxides (NO_x) emissions from high-sulfur, coal-fired boilers. The tests are being conducted at the Plant Crist SCR Test Facility located at Gulf Power Company's Plant Crist Unit 5 in Pensacola, Florida. The test results for Task 2, Commissioning Without Catalysts and With Ammonia Injection, are summarized in this report. Task 2 testing and sample analysis was conducted during May and June 1993.

The objective of Task 2 was to verify ammonia flow control, establish an ammonia mass balance, and measure ammonia loss in the absence of catalyst. Verification of ammonia flow control and confirmation of ammonia mass balance was accomplished by conducting ammonia distribution measurements immediately downstream of the dummy layer on each reactor. On the three large reactors a six-point distribution matrix was used, while on the six small reactors a four-point distribution matrix was used.

Ammonia loss in the absence of catalyst was measured on one large reactor and one small reactor. Ammonia measurements were conducted both at the dummy layer and at the reactor outlet at several combinations of flue gas flow rate and flue gas temperature.

Section 2 of this report summarizes the ammonia distribution testing. Ammonia loss tests are described in Section 3. Conclusions are briefly reviewed in Section 4. Data sheets for each set of tests are compiled in Appendices A and B.

Section 2

AMMONIA DISTRIBUTION

Ammonia concentrations were measured in cross section at the inlet of each reactor, at a position just above the first catalyst layer, in order to determine the effectiveness of the ammonia injection nozzles and turning vanes to evenly distribute the ammonia across the inlet to the first catalyst bed, as well as to determine an ammonia mass balance relative to the predicted rate of ammonia injection. Ammonia is injected in a horizontal section of ducting upstream of the dummy catalyst bed of each reactor. In the large reactors an array of twenty-five nozzles is used. In the six small reactors sixteen nozzles are used. Just upstream of the ammonia injection port the duct makes a transition from round to square. Immediately downstream of the ammonia injection port the duct makes a transition from horizontal to vertical. In this 90° transition piece turning vanes are installed to uniformly distribute the flue gas. The dummy catalyst layer, located just below this horizontal to vertical transition, is also used to assist in evening out the flow prior to the first catalyst bed.

Ammonia concentrations were measured at six cross-sectional positions above the first catalyst bed in each of the three large reactors. There are three ports that allow horizontal entry into the reactor at this location. Tests were conducted in the two outer ports. For each of the six small reactors ammonia concentrations were measured at four cross-sectional positions (the middle of the four quadrants of the cross section) at a position just above the first catalyst bed. Although the small reactors only had a single horizontal sampling port into the reactor, the test probe and nozzle were turned to the side to allow sampling at the selected points. In addition to these measurements upstream of the first catalyst bed, the on-site SCS process engineer requested that the distribution of ammonia also be measured upstream of the dummy layer on Reactor F.

The reactors were operated at design conditions. For the large reactors this included 100% of the design flow rate (5000 scfm (wet)), a flue gas temperature of 700°F, and an ammonia injection rate equivalent to an NH_3/NO_x ratio of 0.8. The small reactors were also operated at design conditions: 100% of the design flow rate (400 scfm (wet)), a flue gas temperature of 700°F, and an ammonia injection rate equivalent to an NH_3/NO_x ratio of 0.8. Boiler load on the host unit was not maintained at a set value during these tests. However, based on the flue gas oxygen concentrations measured during each test (see Appendix A), most of the tests were conducted when the boiler was at full load conditions (84 MW).

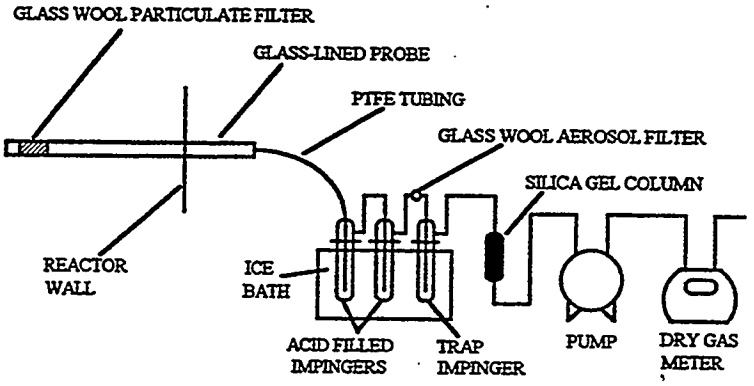

Figure 2-1. Schematic diagram of the ammonia sampling train.

A schematic drawing of the ammonia sampling train is shown in Figure 2-1. The flue gas sample is drawn through a glass-lined probe containing a plug of glass wool to remove fly ash particles. The gas sample passes through a length of PTFE tubing to a set of three impingers in an ice bath. The first two impingers contain a 0.1 normal solution of sulfuric acid. The third impinger serves as a trap to prevent the solutions from accidentally being drawn into the pump. A second glass wool plug is placed in the line between the last two impingers to collect any ammonia aerosol that may escape the second impinger. The remainder of the train consists of a silica gel column to remove the last traces of water from the flue gas sample, a leak-free pump, and a dry gas meter to measure the volume of the sample.

After testing, the impinger solutions were made alkaline in the laboratory (converting the NH_4^+ ion to free NH_3 in solution). The concentration of ammonia was then determined with an ammonia ion specific electrode, Orion Model 920A. In most cases three independent measurements of ammonia concentration were made for each test condition. This, however, was not done on Reactors B and C, where only a single ammonia concentration measurement was made at each sampling point. Two independent determinations of the ammonia concentration were conducted on each sample.

The test data for each reactor, A through J, are presented graphically in Figures 2-2 through 2-11, respectively. Each figure shows a plan view of the cross section of the reactor (and the location of the test port(s)) with the average ammonia concentration values (if applicable) positioned at the point of measurement. At the bottom of each figure is the average ammonia concentration for the six or four measurements plus the standard deviation and relative standard deviation. All of the data have been adjusted to represent dry flue gas with an oxygen concentration of 3%. The raw test data are summarized in Appendix A.

Average ammonia concentrations for the three large reactors (A, B, and C) were 323 ± 63, 381 ± 57, and 240 ± 59 ppm(v) @ 3% O_2 (dry), respectively. Average ammonia concentrations for the six small reactors (D, E, F (dummy layer), F (first catalyst layer), G, H, and J) were 396 ± 47, 405 ± 39, 290 ± 8, 262 ± 27, 319 ± 29, 348 ± 37, and 426 ± 64 ppm(v) @ 3% O_2 (dry), respectively. For the most part, the variations in ammonia concentration across the reactor cross sections were low to moderate. The relative standard deviations for the three large reactors (A, B, and C) were somewhat higher (19.6%, 14.9%, and 24.7%, respectively) than for the six small reactors (D, E, F (dummy layer), F (first catalyst layer), G, H, and J) (11.7%, 9.6%, 2.7%, 10.4%, 9.1%, 10.5%, and 14.9%, respectively). After test was completed, the ammonia mass flow meter for each reactor was subjected to an extensive recalibration because of the variability of the average ammonia concentrations among the reactors determined by these tests.

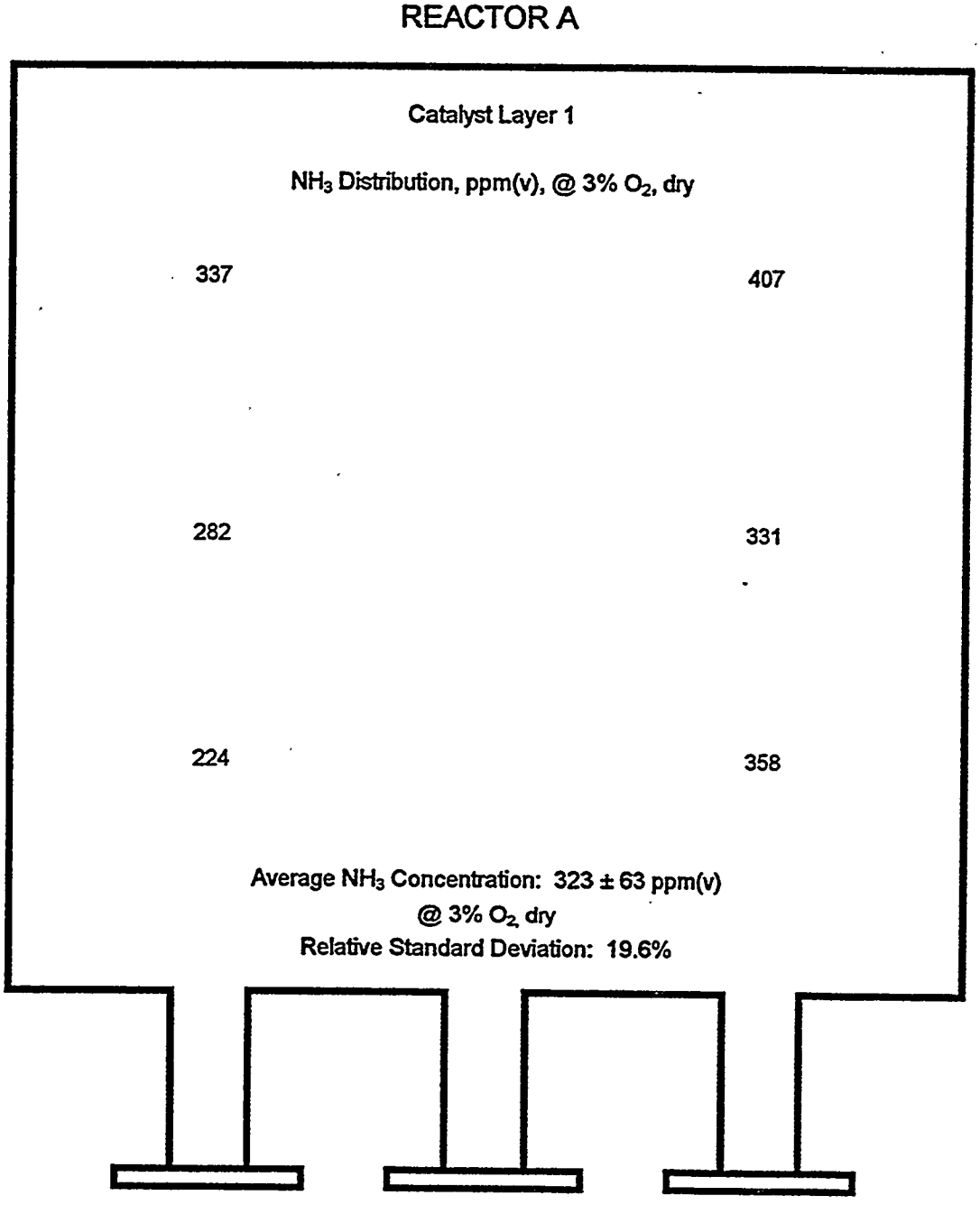

Figure 2-2. Ammonia distribution on Reactor A upstream of the first catalyst layer.

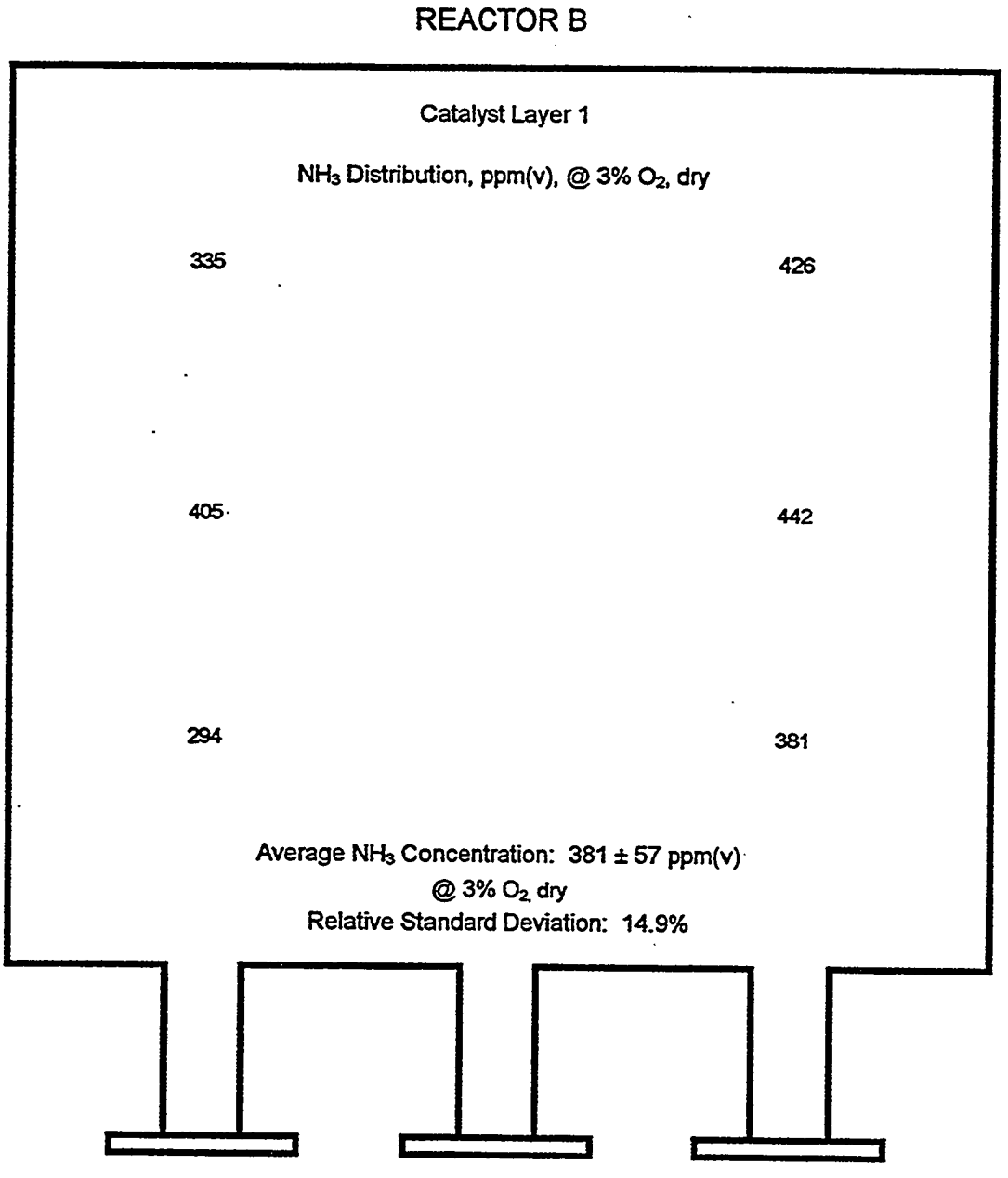

Figure 2-3. Ammonia distribution on Reactor B upstream of the first catalyst layer.

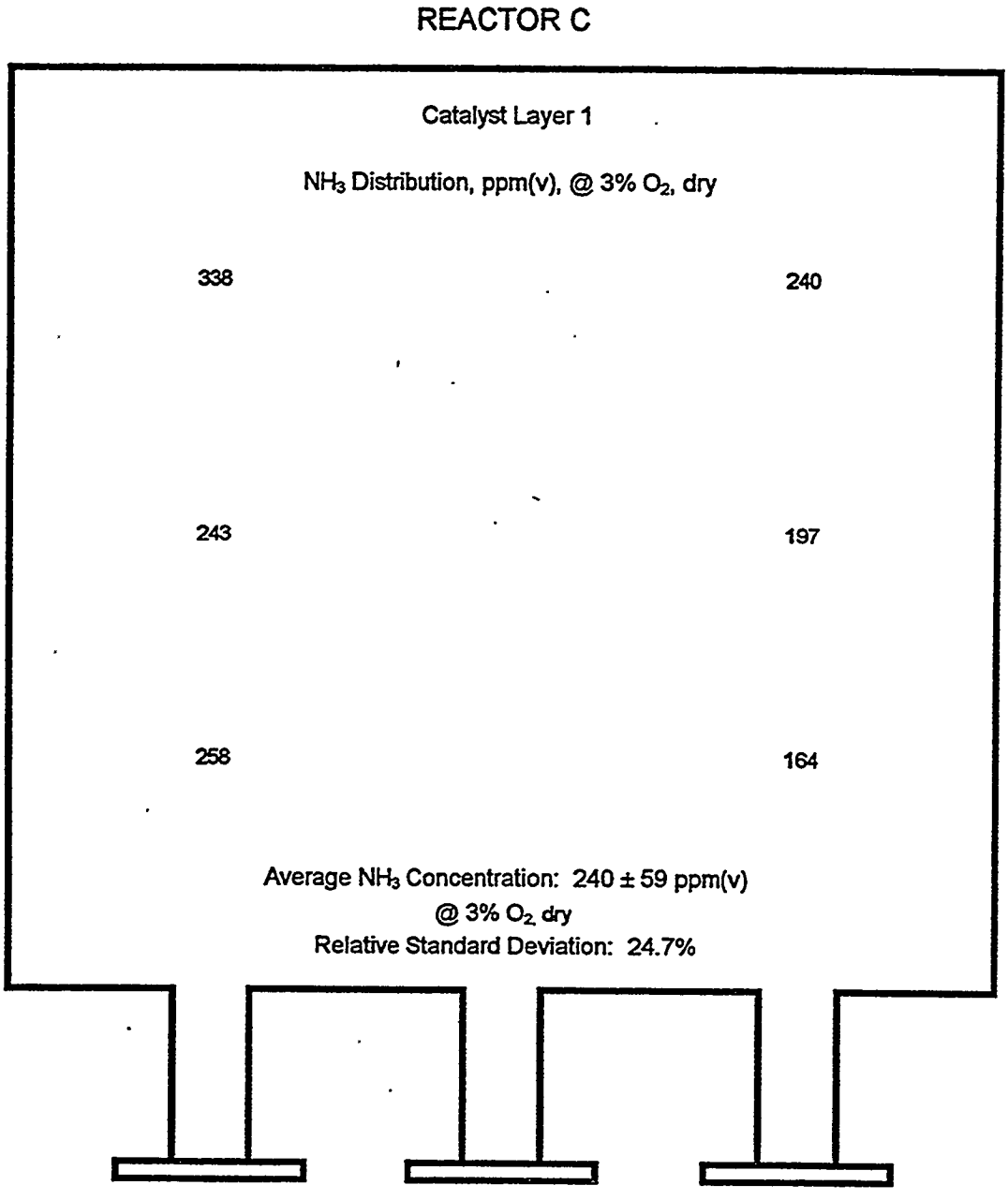

Figure 2-4. Ammonia distribution on Reactor C upstream of the first catalyst layer.

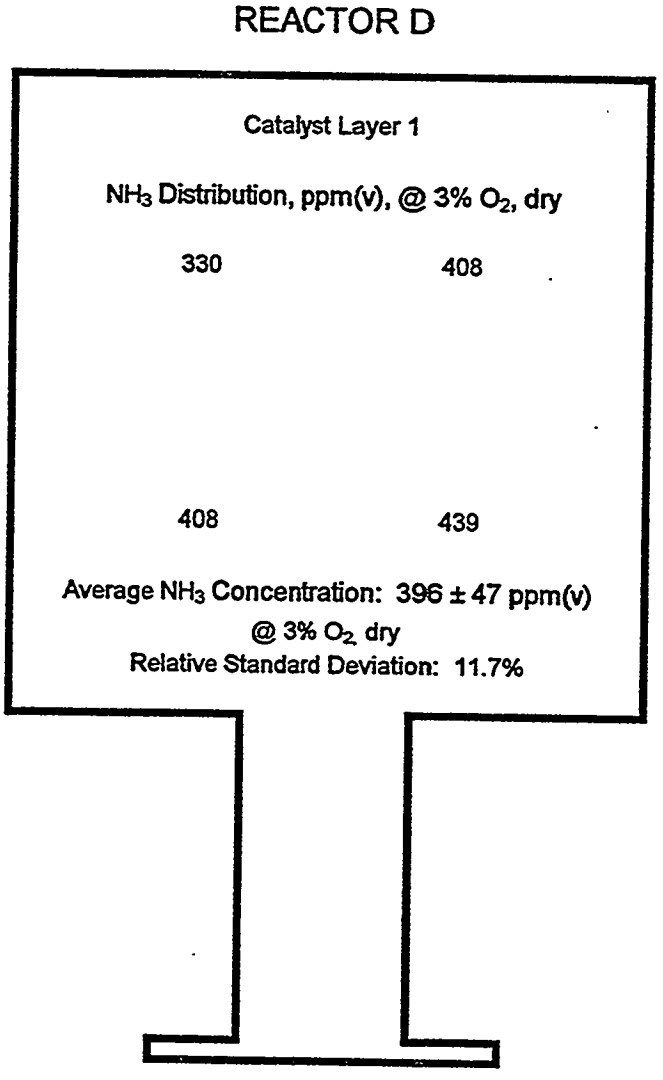

Figure 2-5. Ammonia distribution on Reactor D upstream of the first catalyst layer.

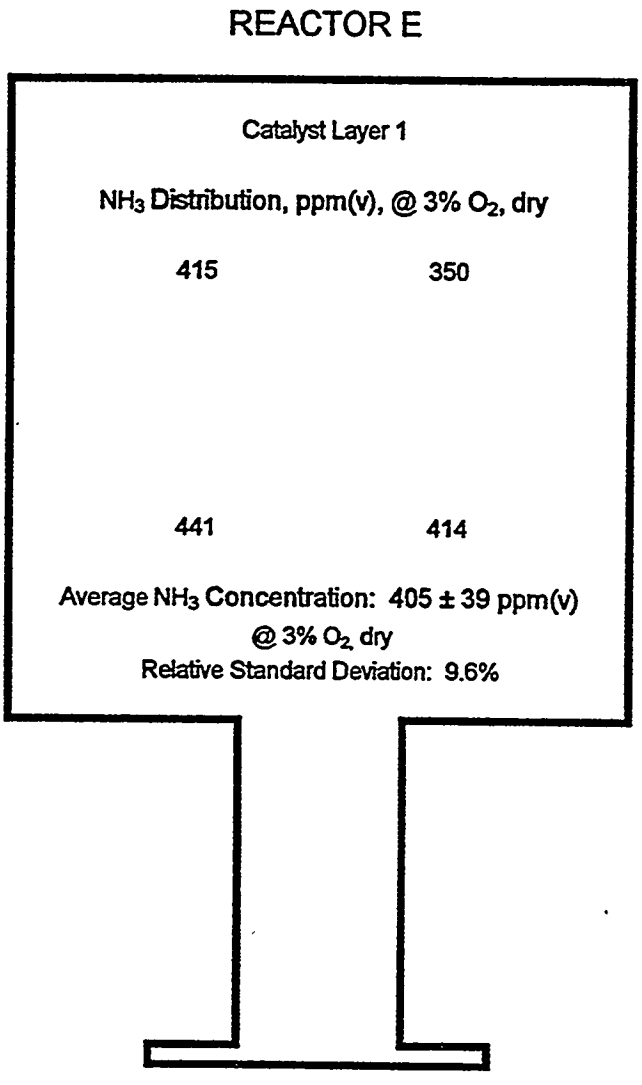

Figure 2-6. Ammonia distribution on Reactor E upstream of the first catalyst layer.

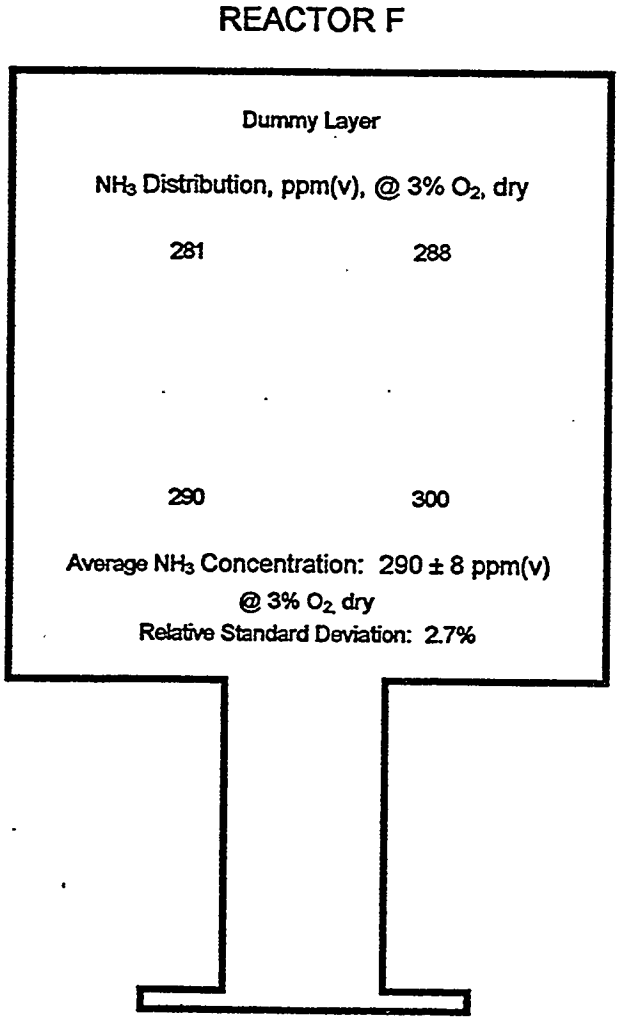

Figure 2-7. Ammonia distribution on Reactor F upstream of the dummy catalyst layer.

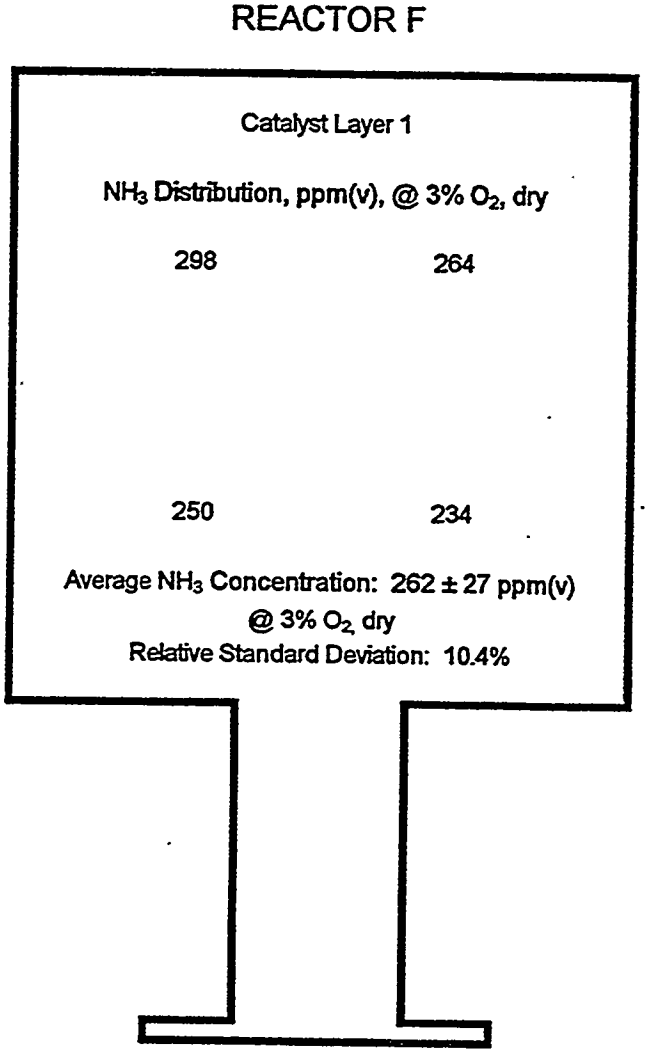

Figure 2-8. Ammonia distribution on Reactor F upstream of the first catalyst layer.

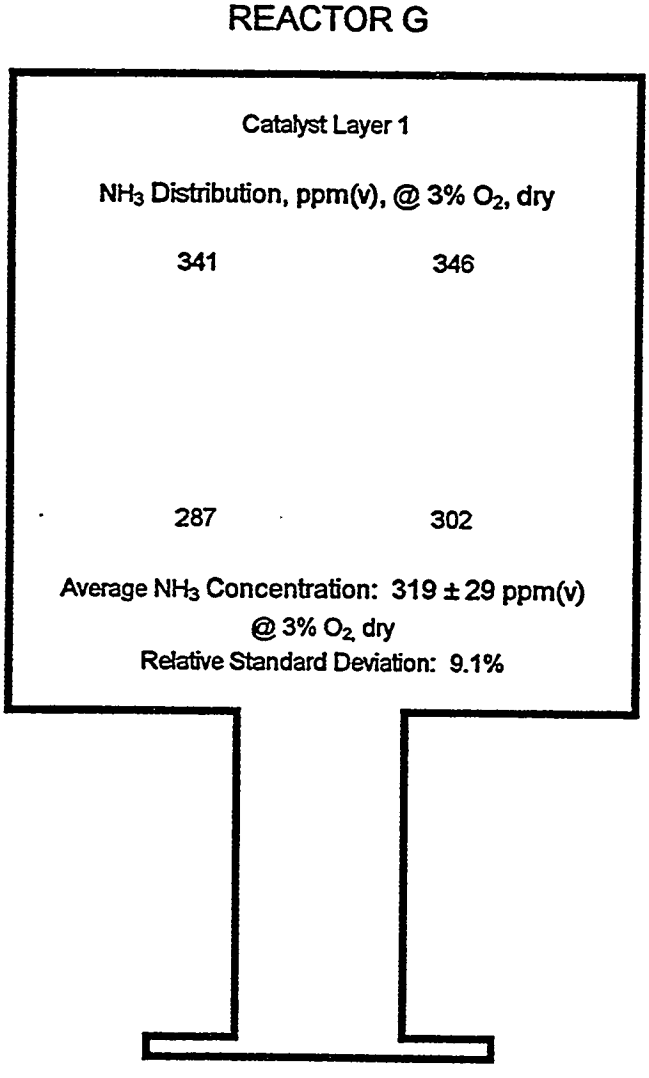

Figure 2-9. Ammonia distribution on Reactor G upstream of the first catalyst layer.

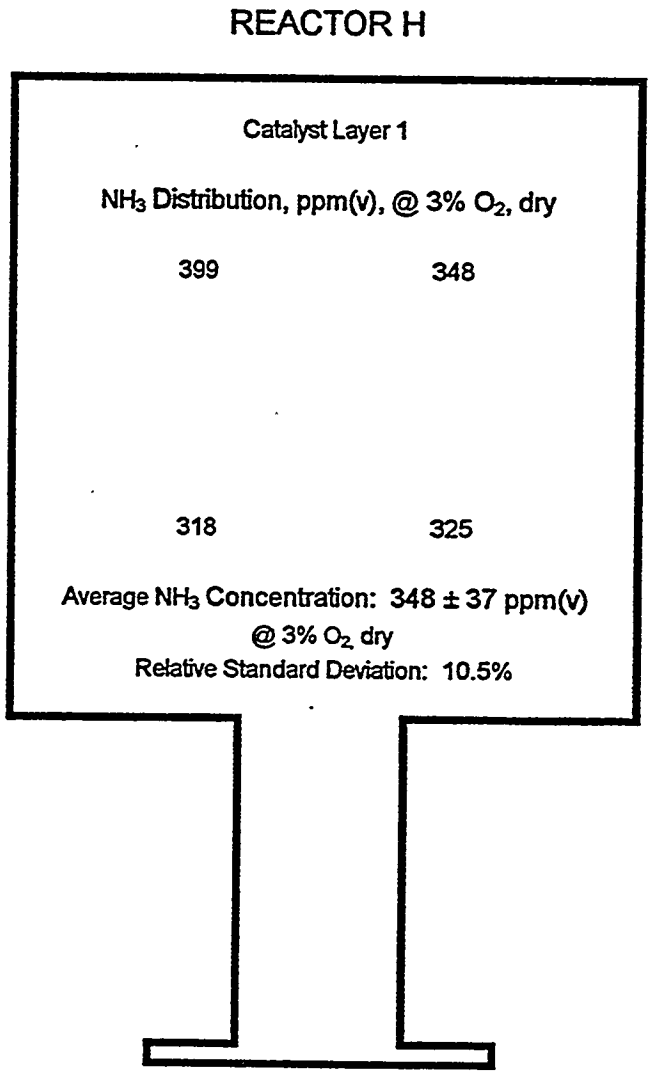

Figure 2-10. Ammonia distribution on Reactor H upstream of the first catalyst layer.

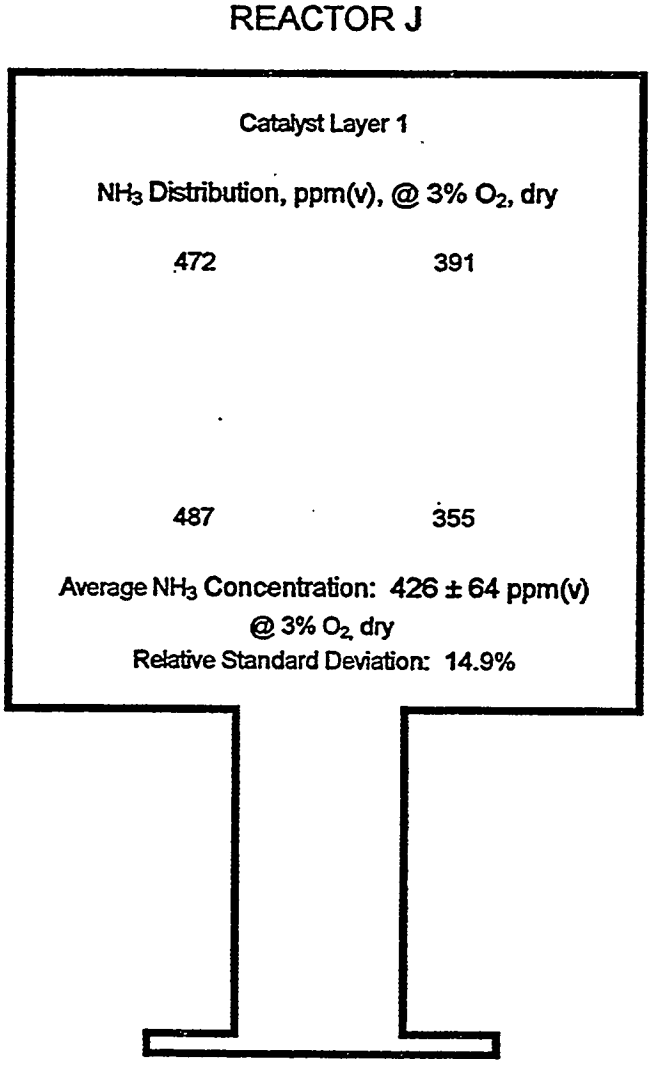

Figure 2-11. Ammonia distribution on Reactor J upstream of the first catalyst layer.

Section 3

AMMONIA LOSS IN THE ABSENCE OF CATALYST

The second part of Task 2 testing involved the determination of ammonia loss in the absence of catalyst within the reactor caused by ammonia oxidation by oxygen or nitrogen oxides. The host boiler at the Plant Crist SCR Test Facility burns a high-sulfur coal. As a result, the flue gas contains high concentrations of sulfur dioxide and sulfur trioxide. There was a concern that ammonia concentrations within the SCR reactors could be lowered by the reaction of sulfur trioxide with ammonia. To document whether ammonia loss, in the absence of catalyst, was taking place, ammonia concentrations were measured simultaneously upstream of the dummy layer and upstream of the third catalyst layer. Tests were conducted on a single large reactor (B) and a single small reactor (E) at four separate operating conditions.

Three tests were performed at each operating condition. Test conditions included high temperature and high flow rate, high temperature and low flow rate, low temperature and high flow rate, and low temperature and low flow rate. The high temperature was 750°F. The low temperature was 620°F. The high flow rate was 150% of the design flow rate. The low flow rate was 60% of the design flow rate. For the large reactor the high and low flow rates corresponded to 7500 and 3000 scfm (wet), respectively. For the small reactor the high and low flow rates corresponded to 600 and 240 scfm (wet), respectively. The ammonia injection rate during the tests was maintained at a value corresponding to an NH_3/NO_x ratio of 0.8. During each test the oxygen content of the flue gas was measured which enabled the final ammonia concentrations to be corrected to 3% O_2 (dry). Although boiler load was not intentionally held constant during these tests, a review of the oxygen concentrations measured in the flue gas during the tests showed that all tests occurred during full load conditions (84 MW).

Ammonia concentrations were determined by a manual extraction method. In this procedure a flue gas sample is pulled through a series of bubblers filled with dilute sulfuric acid (see the previous section of this report). (At each test location on the large reactor a nine point (3 x 3) traverse was conducted covering the cross-section of the duct. On the small reactor with its single sampling port, a three point matrix was sampled.) The bubbler solutions were then made alkaline in the laboratory (converting the NH_4^+ ion to free NH_3 in solution). The concentration of ammonia was then determined with an ammonia ion specific electrode, Orion Model 920A. Two ammonia determinations were made for each sample. As mentioned above, triplicate tests were conducted at each sampling location.

The test results are presented in Table 3-1. Ammonia concentrations were typically in the range of 215 to 275 ppm(v) @ 3% O_2 (dry). Within the limits of our measurement technique, no significant ammonia loss in the absence of catalyst was detected between the dummy layer and the third catalyst layer on either reactor. For the data shown in Table 3-1, relative standard deviations ranged from 2.6 to 18.1%. In fact, for the eight pairs of tests, four resulted in an increase in ammonia concentration (ranging from 4 to 13%) and four resulted in a reduction in ammonia concentration (ranging from 1 to 8%). There was no apparent relationship between change in ammonia concentration and flue gas temperature or flue gas flow rate. The raw test data for the ammonia loss tests are summarized in Appendix B.

Table 3-1. Test Results for Ammonia Loss
In the Absence of Catalyst

Reactor	Temp., °F	Flow Rate, % of Design Value	Ammonia Concentration, ppm(v), @3% O_2, dry					
			Dummy Layer			Catalyst Layer 3		
			Conc.		σ	Conc.		σ
B	750	150	225	±	37	222	±	18
B	750	60	219	±	13	202	±	22
B	620	150	215	±	39	237	±	15
B	620	60	235	±	16	226	±	12
E	750	150	282	±	38	260	±	7
E	750	60	221	±	11	230	±	6
E	620	150	244	±	9	276	±	18
E	620	60	241	±	33	266	±	10

Section 4

CONCLUSIONS

As a part of Task 2 testing, Commissioning without Catalysts and with Ammonia Injection, ammonia distribution measurements were conducted upstream of the first catalyst layer on each of the nine reactors. Also ammonia loss tests in the absence of catalyst were conducted simultaneously upstream of the dummy layer and upstream of the third catalyst layer on one large reactor and one small reactor.

Ammonia distribution measurements indicated low to moderate variability of ammonia concentration at the reactor inlet cross-section. Ammonia distributions were somewhat more uniform for the small reactors compared to the large reactors. Relative standard deviations for the large reactors ranged from 14.9 to 24.7%, while relative standard deviations for the small reactors ranged from 2.7 to 14.9%. As a consequence of these tests, the ammonia flow control system for each reactor was thoroughly recalibrated.

No significant ammonia loss in the absence of catalyst was observed across either a large reactor (B) or small reactor (E). Actual ammonia concentrations ranged from 215 to 275 ppm(v) @ 3% O_2 (dry). For the eight pairs of tests, four resulted in an increase in ammonia concentration (ranging from 4 to 13%) and four resulted in a reduction in ammonia concentration (ranging from 1 to 8%). There was no apparent relationship between change in ammonia concentration and flue gas temperature or flue gas flow rate.

APPENDIX A

AMMONIA DISTRIBUTION TEST DATA

REACTOR A

Week Stack Gas Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR A, HIGH LOAD (84MW)																	
019 A1 NHX 05	1,1	378	1107	1121	12-May-93	7.03	994.6	372.1	77.28	297	76	76	29.95	SCR-SRI-3	0.9900	86.20	83.20
							1025.4	383.6									
019 A1 NHX 11	1,1	296	1440	1440	12-May-93	3.06	1011.8	299.8	75.86	303	88	88	29.95	SCR-SRI-3	0.9900	95.70	92.70
							988.2	292.8									
AVERAGE		337															
019 A1 NHX 03	1,2	303	1023	1038	12-May-93	6.75	818.6	303.8	76.35	301	83	82	29.95	SCR-SRI-3	0.9900	82.80	79.80
							814.2	302.2									
019 A1 NHX 09	1,2	261	1406	1422	12-May-93	3.59	635.3	258.9	56.85	302	82	88	29.95	SCR-SRI-3	0.9900	92.34	90.10
							647.0	263.6									
AVERAGE		282															
019 A1 NHX 01	1,3	185	0912	0921	12-May-93	6.95	554.4	181.9	87.62	300	80	81	29.95	SCR-SRI-3	0.9900	79.53	76.10
							576.4	189.1									
019 A1 NHX 07	1,3	262	1323	1339	12-May-93	3.03	902.9	263.9	76.77	299	77	82	29.95	SCR-SRI-3	0.9900	89.60	86.60
							888.2	259.6									
AVERAGE		224															
019 A1 NHX 06	3,1	463	1103	1120	12-May-93	7.03	1230.1	460.1	77.29	297	75	75	29.95	SCR-SRI-4	0.9883	269.50	266.50
							1245.5	465.9									
019 A1 NHX 12	3,1	350	1437	1453	12-May-93	3.06	1182.4	348.3	76.29	301	82	82	29.95	SCR-SRI-4	0.9883	279.10	276.10
							1194.1	351.8									
AVERAGE		407															
019 A1 NHX 04	3,2	413	1022	1039	12-May-93	6.75	1104.6	408.8	76.57	300	80	80	29.95	SCR-SRI-4	0.9883	266.30	263.30
							1128.8	417.7									
019 A1 NHX 10	3,2	248	1404	1419	12-May-93	3.59	823.5	248.9	76.64	299	79	80	29.95	SCR-SRI-4	0.9883	275.90	272.90
							820.6	248.0									
AVERAGE		331															
019 A1 NHX 02	3,3	458	0914	0921	12-May-93	6.95	1210.2	452.6	76.86	299	77	79	29.95	SCR-SRI-4	0.9883	263.10	260.10
							1241	464.1									
019 A1 NHX 08	3,3	257	1324	1340	12-May-93	3.03	897	259.4	77.58	296	73	73	29.95	SCR-SRI-4	0.9883	272.70	269.70
							882.4	255.2									
AVERAGE		358															

REACTOR B

Week Site Gas Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 mM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure in. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR B, HIGH LOAD (84MW)																	
018 B1 NHX 05	1,1	335	1525	1542	5-May-93	2.12	1164.7 1176.5	333.8 337.2	74.50	309	92	100	30.18	SCR-SRI-5	0.9822	156.95	153.95
018 B1 NHX 03	1,2	405	1446	1505	5-May-93	2.29	1411.8 1405.9	405.9 404.2	74.93	306	91	92	30.18	SCR-SRI-5	0.9822	153.85	150.86
018 B1 NHX 01	1,3	294	1400	1422	5-May-93	2.54	1014.7 1017.6	293.8 294.6	75.43	306	91	91	30.18	SCR-SRI-5	0.9822	150.67	147.66
018 B1 NHX 06	3,1	426	1526	1542	5-May-93	2.12	1500.0 1526.5	422.7 430.2	75.75	305	89	91	30.18	SCR-SRI-4	0.9883	241.70	238.70
018 B1 NHX 04	3,2	442	1444	1502	5-May-93	2.29	1550.0 1564.7	439.6 443.8	75.96	304	88	89	30.18	SCR-SRI-4	0.9883	238.50	235.50
018 B1 NHX 02	3,3	381	1400	1419	5-May-93	2.54	1320.6 1341.2	378.3 384.2	76.24	303	86	87	30.18	SCR-SRI-4	0.9883	235.30	232.30

REACTOR C

Week	Site	Gas	Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure in. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR C, HIGH LOAD (84MW)																				
018	C1	NHX	05	1,1	338	1405	1433	7-May-93	2.32	1202.9 1126.5	349.4 327.2	74.30	308	95	94	30.03	SCR-SRI-5	0.9822	172.20	169.20
018	C1	NHX	03	1,2	243	1317	1333	7-May-93	2.31	852.9 826.5	246.9 239.3	74.51	307	92	94	30.03	SCR-SRI-5	0.9822	168.90	165.90
018	C1	NHX	01	1,3	258	1037	1057	7-May-93	2.55	894.1 888.2	258.9 257.2	75.46	303	84	88	30.03	SCR-SRI-5	0.9822	165.30	162.30
018	C1	NHX	06	3,1	240	1405	1428	7-May-93	2.32	850 826.5	243.6 236.8	75.31	306	90	91	30.03	SCR-SRI-4	0.9883	257.60	254.60
018	C1	NHX	04	3,2	197	1317	1334	7-May-93	2.31	700 676.5	199.9 193.2	75.52	305	88	90	30.03	SCR-SRI-4	0.9883	254.30	251.30
018	C1	NHX	02	3,3	164	1040	1056	7-May-93	2.55	576.5 570.6	164.5 162.8	76.56	301	81	82	30.03	SCR-SRI-4	0.9883	241.70	238.70

REACTOR D

Week Site Gas Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter I.D	Corr. Factor	Volume, End ft³	Volume, Begin ft³
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR D, HIGH LOAD (84MW)																	
020 D1 NHX 01	1,1	391	1031	1045	17-May-93	5.96	1094	389.2	75.44	300	81	81	30.06	SCR-SRI-1	0.9719	282.10	279.10
							1103	392.4									
020 D1 NHX 02	1,1	269	1110	1125	17-May-93	5.93	747.1	267.7	74.75	303	85	87	30.06	SCR-SRI-1	0.9719	285.60	282.60
							752.9	269.8									
AVERAGE		330															
020 D1 NHX 03	1,2	381	1142	1157	17-May-93	5.37	1094	379.6	74.40	304	88	89	30.06	SCR-SRI-1	0.9719	289.20	286.20
							1100	381.7									
020 D1 NHX 04	1,2	435	1318	1332	17-May-93	5.34	1265	436.5	74.68	303	86	87	30.06	SCR-SRI-1	0.9719	292.60	289.60
							1259	434.4									
AVERAGE		408															
020 D1 NHX 05	2,1	389	1347	1402	17-May-93	5.40	1112	386.6	74.40	304	88	89	30.06	SCR-SRI-1	0.9719	296.30	293.30
							1124	390.8									
020 D1 NHX 06	2,1	427	1425	1438	17-May-93	5.45	1235	424.1	75.58	305	89	89	30.06	SCR-SRI-1	0.9719	300.35	297.30
							1250	429.2									
AVERAGE		408															
020 D1 NHX 07	2,2	313	1453	1508	17-May-93	5.58	879.4	309.6	74.34	305	89	89	30.06	SCR-SRI-1	0.9719	303.90	300.90
							897.1	315.8									
020 D1 NHX 08	2,2	565	1542	1557	17-May-93	5.52	1612	565.8	74.27	305	90	89	30.06	SCR-SRI-1	0.9719	307.40	304.40
							1606	563.7									
AVERAGE		439															

REACTOR E

Week	Site	Gas	Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR E, HIGH LOAD (84MW)																				
019	E1	NHX	01	2,1	401	1022	1038	13-May-93	7.22	1076.5	406.8	77.56	296	73	74	29.92	SCR-SRI-3	0.9900	108.30	105.30
										1047.0	395.7									
019	E1	NHX	07	2,1	429	1536	1550	13-May-93	3.55	1426.0	426.9	77.20	297	76	76	29.92	SCR-SRI-3	0.9900	129.10	126.10
										1438.0	430.5									
AVERAGE					415															
019	E1	NHX	02	2,2	479	1115	1129	13-May-93	7.29	1279.4	487.8	77.27	297	76	75	29.92	SCR-SRI-3	0.9900	111.70	108.70
										1235.3	471.0									
019	E1	NHX	08	2,2	403	1615	1631	13-May-93	3.54	1347.0	402.4	77.31	298	77	77	29.92	SCR-SRI-3	0.9900	132.51	129.50
										1353.0	404.2									
AVERAGE					441															
019	E1	NHX	03	1,2	298	1320	1334	13-May-93	3.01	1061.8	299.5	79.46	297	76	76	29.92	SCR-SRI-3	0.9900	115.40	112.31
										1050.0	296.1									
019	E1	NHX	05	1,2	401	1425	1440	13-May-93	3.57	1335.0	400.1	77.20	297	76	76	29.92	SCR-SRI-3	0.9900	122.20	119.20
										1344.0	402.8									
AVERAGE					350															
019	E1	NHX	04	1,1	397	1349	1404	13-May-93	3.16	1356.0	397.7	77.05	298	78	76	29.92	SCR-SRI-3	0.9900	118.80	115.80
										1350.0	396.0									
019	E1	NHX	06	1,1	431	1510	1525	13-May-93	3.80	1403.0	426.9	77.05	298	77	77	29.92	SCR-SRI-3	0.9900	125.6	122.6
										1432.0	435.8									
AVERAGE					414															

REACTOR F (DUMMY LAYER)

Week Site Gas Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure in. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR F,(DUMMY LAYER) HIGH LOAD (84MW)																	
020 FD NHX 01	1,1	292	1035	1051	18-May-93	2.87	1011.8	294.4	76.43	301	82	84	30.01	SCR-SRI-3	0.9900	163.10	160.10
							994.1	289.2									
020 FD NHX 02	1,1	270	1108	1125	18-May-93	2.91	926.5	271.2	76.15	302	84	86	30.01	SCR-SRI-3	0.9900	166.60	163.60
							917.6	268.6									
AVERAGE		281															
020 FD NHX 03	1,2	297	1304	1320	18-May-93	2.77	1011.8	297.6	75.18	306	92	92	30.01	SCR-SRI-3	0.9900	170.00	167.00
							1005.9	295.9									
020 FD NHX 04	1,2	282	1343	1357	18-May-93	2.76	973.5	285.3	75.41	306	90	91	30.01	SCR-SRI-3	0.9900	173.60	170.60
							952.9	279.3									
AVERAGE		290															
020 FD NHX 05	2,1	296	1414	1429	18-May-93	2.57	1038.2	301.5	75.32	306	91	91	30.01	SCR-SRI-3	0.9900	177.00	174.00
							1000.0	290.4									
020 FD NHX 06	2,1	281	1445	1501	18-May-93	2.50	970.6	279.8	75.59	305	89	89	30.01	SCR-SRI-3	0.9900	180.50	177.50
							976.5	281.5									
AVERAGE		288															
020 FD NHX 07	2,2	299	1514	1530	18-May-93	2.36	1052.9	300.5	75.78	304	88	88	30.01	SCR-SRI-3	0.9900	184.00	181.00
							1044.1	298.0									
020 FD NHX 08	2,2	301	1544	1559	18-May-93	2.58	1041.2	299.8	76.01	303	86	86	30.01	SCR-SRI-3	0.9900	187.50	184.50
							1050.0	302.3									
AVERAGE		300															

REACTOR F (FIRST CATALYST LAYER)

Week Site Gas Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR F,(CATALYST LAYER 1) HIGH LOAD (84MW)																	
020 F1 NHX 01	1,1	324	1033	1049	18-May-93	2.87	1097.0	325.4	74.86	302	83	84	30.01	SCR-SRI-1	0.9719	310.90	307.90
							1088.2	322.8									
020 F1 NHX 04	1,1	273	1340	1355	18-May-93	2.76	929.4	275.8	74.48	304	87	87	30.01	SCR-SRI-1	0.9719	321.00	318.00
							908.8	269.7									
AVERAGE		298															
020 F1 NHX 02	1,2	253	1106	1121	18-May-93	2.91	855.9	255.2	74.76	302	85	85	30.01	SCR-SRI-1	0.9719	314.30	311.30
							841.2	250.8									
020 F1 NHX 03	1,2	246	1302	1317	18-May-93	2.77	811.8	248.9	72.13	303	86	86	30.01	SCR-SRI-1	0.9719	317.70	314.80
							794.1	243.5									
AVERAGE		250															
020 F1 NHX 05	2,1	269	1411	1427	18-May-93	2.57	914.7	267.6	74.76	302	85	85	30.01	SCR-SRI-1	0.9719	324.40	321.40
							923.5	270.2									
020 F1 NHX 06	2,1	258	1442	1447	18-May-93	2.49	891.2	259.9	74.69	303	85	86	30.01	SCR-SRI-1	0.9719	327.70	324.70
							879.4	256.4									
AVERAGE		264															
020 F1 NHX 07	2,2	237	1512	1528	18-May-93	2.36	814.7	236.3	74.55	303	87	86	30.01	SCR-SRI-1	0.9719	331.00	328.00
							820.6	238.0									
020 F1 NHX 08	2,2	230	1542	1553	18-May-93	2.58	788.2	231.2	74.62	303	86	86	30.01	SCR-SRI-1	0.9719	334.30	331.30
							779.4	228.6									
AVERAGE		234															

REACTOR G

Week	Site	Gas	Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR G, HIGH LOAD (84MW)																				
019	G1	NHx	01	1,1	412	1019	1032	13-May-93	6.11	1388.2	426.4	88.25	297	75	75	29.92	SCR-SRI-1	0.9719	253.70	250.21
										1291.2	396.6									
019	G1	NHx	05	1,1	271	1430	1450	13-May-93	2.65	961.8	278.8	75.79	297	76	76	29.92	SCR-SRI-1	0.9719	267.10	264.10
										908.8	263.5									
AVERAGE					341															
019	G1	NHx	02	1,2	391	1053	1107	13-May-93	6.23	1147	412.6	75.98	297	76	75	29.92	SCR-SRI-1	0.9719	257.11	254.10
										1029.4	370.3									
019	G1	NHx	06	1,2	183	1510	1523	13-May-93	2.65	644.1	186.4	75.93	297	75	75	29.92	SCR-SRI-1	0.9719	270.60	267.60
										623.5	180.4									
AVERAGE					287															
019	G1	NHx	03	2,2	333	1318	1331	13-May-93	2.18	1241.2	349.5	76.07	296	74	74	29.92	SCR-SRI-1	0.9719	260.60	257.60
										1126.5	317.2									
019	G1	NHx	04	2,2	358	1400	1415	13-May-93	2.85	1255.9	368.1	75.79	297	76	76	29.92	SCR-SRI-1	0.9719	263.70	260.70
										1185.3	347.4									
AVERAGE					346															
019	G1	NHx	07	2,1	292	1544	1557	13-May-93	2.92	1000	294.5	75.72	298	76	77	29.92	SCR-SRI-1	0.9719	274.00	271.00
										982.4	289.3									
019	G1	NHx	08	2,1	312	1615	1629	13-May-93	2.71	914.7	307.3	65.62	298	78	75	29.92	SCR-SRI-1	0.9719	277.00	274.40
										941.2	316.2									
AVERAGE					302															

REACTOR H

Week Site Gas Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure in. Hg	Meter I.D	Corr. Factor	Volume, End ft³	Volume, Begin ft³
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR H, HIGH LOAD (84MW)																	
020 H1 NHx 01	1,1	375	1030	1045	17-May-93	3.50	1250.0	375.9	76.63	301	82	83	30.06	SCR-SRI-3	0.9900	135.90	132.90
							1241.2	373.2									
020 H1 NHx 02	1,1	424	1123	1138	17-May-93	3.27	1417.6	424.6	75.93	304	86	89	30.06	SCR-SRI-3	0.9900	139.30	136.30
							1411.8	422.9									
AVERAGE		399															
020 H1 NHx 03	1,2	331	1154	1210	17-May-93	2.95	1126.5	333.5	75.45	306	91	91	30.06	SCR-SRI-3	0.9900	142.60	139.60
							1111.8	329.2									
020 H1 NHx 04	1,2	304	1322	1337	17-May-93	2.87	1026.5	302.4	75.49	306	89	92	30.06	SCR-SRI-3	0.9900	146.00	143.00
							1038.2	305.8									
AVERAGE		318															
020 H1 NHx 05	2,2	394	1421	1436	17-May-93	2.99	1311.8	393.9	74.56	309	97	98	30.06	SCR-SRI-3	0.9900	149.50	146.50
							1314.7	394.7									
020 H1 NHx 06	2,2	303	1503	1519	17-May-93	3.01	994.1	299.6	74.36	310	99	99	30.06	SCR-SRI-3	0.9900	152.80	149.80
							1014.7	305.8									
AVERAGE		348															
020 H1 NHx 07	2,1	268	1535	1551	17-May-93	3.03	885.3	267.1	74.36	310	99	99	30.06	SCR-SRI-3	0.9900	156.20	153.20
							891.2	268.9									
020 H1 NHx 08	2,1	383	1603	1618	17-May-93	3.51	1235.3	382.7	74.43	310	98	99	30.06	SCR-SRI-3	0.9900	159.60	156.60
							1235.3	382.7									
AVERAGE		325															

REACTOR J

Week	Stack Gas	Number	Sample Location	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter I.D	Corr. Factor	Volume, End ft^3	Volume, Begin ft^3
TASK 2, NH3 DISTRIBUTION TESTS, REACTOR J, HIGH LOAD (84MW)																			
019	J1	NHx 01	1,2	526	1018	1033	13-May-93	9.70	1144	530.4	77.21	297	75	75	29.92	SCR-SRI-4	0.9883	283.30	280.30
									1126	522.1									
019	J1	NHx 07	1,2	417	1524	1541	13-May-93	7.95	1035	413.1	77.57	296	72	73	29.92	SCR-SRI-4	0.9883	302.70	299.70
									1056	421.5									
AVERAGE				472															
019	J1	NHx 02	1,1	517	1054	1109	13-May-93	9.72	1108	515.2	76.99	298	77	76	29.92	SCR-SRI-4	0.9883	286.60	283.60
									1115	519.4									
019	J1	NHx 08	1,1	456	1556	1612	13-May-93	7.69	1168	458.7	77.28	297	74	75	29.92	SCR-SRI-4	0.9883	306.00	303.00
									1153	452.8									
AVERAGE				487															
019	J1	NHx 03	2,1	396	1315	1330	13-May-93	7.60	1021	396.4	77.65	295	72	72	29.92	SCR-SRI-4	0.9883	289.80	286.80
									1018	395.3									
019	J1	NHx 05	2,1	386	1425	1439	13-May-93	7.89	958.8	380.6	77.65	295	72	72	29.92	SCR-SRI-4	0.9883	296.30	293.30
									985.3	391.1									
AVERAGE				391															
019	J1	NHx 04	2,2	357	1353	1409	13-May-93	7.87	902.9	358.5	77.50	296	73	73	29.92	SCR-SRI-4	0.9883	293.10	290.10
									897.1	356.2									
019	J1	NHx 06	2,2	352	1453	1508	13-May-93	7.89	894.1	354.9	77.65	295	72	72	29.92	SCR-SRI-4	0.9883	299.50	296.50
									879.4	349.0									
AVERAGE				355															

APPENDIX B

AMMONIA OXIDATION TEST DATA

REACTOR B

Week	Site	Case	Number	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Reactor Flowrate, % of Design Value	Reactor Temp, °F	Sample O_2 %	NH_3 µM	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter ID	Corr. Factor	Volume, End ft³	Volume, Begin ft³
TASK 2, TEST DATA FOR AMMONIA LOSS IN THE ABSENCE OF CATALYST, REACTOR B, 84 (MW)																					
023	BD	NHX	01	251	0950	1012	9-Jun-93	150	750	2.52	864	249.7	75.50	306	86	96	30.08	SCR-SR1-3	0.9900	288.300	285.300
											871	251.7									
023	BD	NHX	02	466	1037	1107	9-Jun-93	150	750	2.55	1536	453.0	74.08	312	98	105	30.08	SCR-SR1-3	0.9900	291.400	288.400
											1557	459.2									
023	BD	NHX	03	199	1130	1145	9-Jun-93	150	750	2.55	661	198.3	72.85	317	109	113	30.08	SCR-SR1-3	0.9900	294.500	291.500
											663	198.9									
AVERAGE				225																	
023	B3	NHX	01	203	0950	1010	9-Jun-93	150	750	2.61	698	199.8	76.59	306	89	92	30.08	Stack-1	1.0038	563.801	560.802
											721	206.4									
023	B3	NHX	02	240	1037	1108	9-Jun-93	150	750	2.86	814	237.7	76.12	308	93	96	30.08	Stack-1	1.0038	567.552	564.550
											829	242.1									
023	B3	NHX	03	223	1130	1147	9-Jun-93	150	750	2.86	757	222.4	75.64	310	97	99	30.08	Stack-1	1.0038	571.202	568.200
											764	224.5									
AVERAGE				222																	
023	BD	NHX	04	211	1402	1422	9-Jun-93	60	750	2.55	709	209.9	73.82	313	104	103	30.08	SCR-SR1-3	0.9900	297.800	294.800
											714	211.3									
023	BD	NHX	05	235	1456	1516	9-Jun-93	60	750	2.54	793	233.8	74.08	312	100	103	30.08	SCR-SR1-3	0.9900	300.900	297.900
											800	235.8									
023	BD	NHX	06	213	1535	1554	9-Jun-93	60	750	2.48	721	213.0	73.69	313	104	105	30.08	SCR-SR1-3	0.9900	304.100	301.100
											721	213.0									
AVERAGE				219																	
023	B3	NHX	04	197	1402	1419	9-Jun-93	60	750	2.84	666	195.3	75.72	309	97	97	30.08	Stack-1	1.0038	574.600	571.600
											676	198.2									
023	B3	NHX	05	183	1456	1514	9-Jun-93	60	750	3.15	604	182.0	74.98	312	101	104	30.08	Stack-1	1.0038	577.900	574.900
											613	184.7									
023	B3	NHX	06	226	1537	1554	9-Jun-93	60	750	2.77	757	223.7	74.85	313	103	104	30.08	Stack-1	1.0038	581.200	578.200
											771	227.8									
AVERAGE				202																	
023	BD	NHX	07	223	0915	0934	10-Jun-93	150	620	2.8	779	223.3	77.29	299	79	80	30.15	SCR-SR1-3	0.9900	309.900	306.900
											775	222.1									
023	BD	NHX	08	250	0953	1010	10-Jun-93	150	620	2.9	861	249.3	76.93	301	82	82	30.15	SCR-SR1-3	0.9900	313.000	310.000
											864	250.2									
023	BD	NHX	09	173	1039	1058	10-Jun-93	150	620	2.97	600	174.2	77.00	301	81	82	30.15	SCR-SR1-3	0.9900	316.100	313.100
											593	172.2									
AVERAGE				215																	
023	B3	NHX	07	231	0915	0933	10-Jun-93	150	620	3.3	793	231.7	77.98	301	81	83	30.08	Stack-1	1.0038	591.700	588.701
											786	229.6									
023	B3	NHX	08	254	0953	1011	10-Jun-93	150	620	2.98	886	256.0	77.43	303	85	87	30.08	Stack-1	1.0038	595.100	592.100
											875	252.8									
023	B3	NHX	09	225	1040	1101	10-Jun-93	150	620	3.01	775	226.0	76.87	305	89	91	30.08	Stack-1	1.0038	598.500	595.500
											771	224.8									
AVERAGE				237																	
023	BD	NHX	10	236	1308	1329	10-Jun-93	60	620	2.84	796	235.0	75.19	308	100	89	30.15	SCR-SR1-3	0.9900	319.300	316.300
											804	237.4									
023	BD	NHX	11	251	1346	1405	10-Jun-93	60	620	2.81	889	258.2	76.31	303	86	85	30.15	SCR-SR1-3	0.9900	322.500	319.505
											839	243.7									
023	BD	NHX	12	219	1422	1437	10-Jun-93	60	620	2.69	754	217.8	76.23	304	85	89	30.15	SCR-SR1-3	0.9900	325.700	322.700
											761	219.8									
AVERAGE				235																	
023	B3	NHX	10	212	1308	1325	10-Jun-93	60	620	3.16	700	208.9	75.72	310	98	99	30.15	Stack-1	1.0038	602.001	599.000
											718	214.3									
023	B3	NHX	11	230	1346	1404	10-Jun-93	60	620	3.87	754	231.3	76.75	311	100	100	30.15	Stack-1	1.0038	605.350	602.300
											746	228.8									
023	B3	NHX	12	235	1421	1439	10-Jun-93	60	620	3.06	786	234.8	75.25	312	101	103	30.15	Stack-1	1.0038	608.701	605.700
											789	235.7									
AVERAGE				228																	

REACTOR E

Test Number	Gas	Average NH_3 Concentration ppm (v), dry, @ 3% O_2	Time, Begin	Time, End	Date	Reactor Flowrate, % of Design Value	Reactor Temp, °F	Sample O_2 %	NH_3 µl	NH_3 Concentration ppm (v), dry, @ 3% O_2	Volume, Total STD Liters, dry	Temp, Avg. °K	Temp, Begin °F	Temp, End °F	Barometric Pressure In. Hg	Meter I.D	Corr. Factor	Volume, End ft³	Volume, Begin ft³
TASK 2, TEST DATA FOR AMMONIA LOSS IN THE ABSENCE OF CATALYST, REACTOR E, 84 (MW)																			
023	ED	NHX 01	303	0950	1005	9-Jun-93	150	750	2.08	1057	303.3	74.25	305	89	91	30.08	SCR-SRI-1	0.9719	391.150	388.150
										1054	302.4								
023	ED	NHX 02	306	1105	1121	9-Jun-93	150	750	2.19	1054	305.9	73.85	307	91	95	30.08	SCR-SRI-1	0.9719	394.350	391.350
										1054	305.9								
023	ED	NHX 03	238	1411	1426	9-Jun-93	150	750	2.15	811	235.7	73.58	308	95	95	30.08	SCR-SRI-1	0.9719	397.640	394.640
										829	240.9								
		AVERAGE	282																
023	E3	NHX 01	256	0950	1004	9-Jun-93	150	750	2.68	889	253.8	77.07	307	94	93	30.08	Stack-2	1.0152	399.700	396.700
										904	258.1								
023	E3	NHX 02	256	1105	1120	9-Jun-93	150	750	3.57	846	254.2	77.00	307	92	96	30.08	Stack-2	1.0152	403.000	400.000
										857	257.5								
023	E3	NHX 03	269	1410	1425	9-Jun-93	150	750	2.85	857	266.3	71.48	309	97	97	30.08	Stack-2	1.0152	406.000	403.200
										871	270.7								
		AVERAGE	260																
023	ED	NHX 04	234	1455	1515	9-Jun-93	60	750	2.18	814	236.4	73.76	308	95	96	30.08	SCR-SRI-1	0.9719	400.850	397.840
										796	231.1								
023	ED	NHX 05	211	1538	1555	9-Jun-93	60	750	2.12	729	211.9	73.45	309	96	96	30.08	SCR-SRI-1	0.9719	404.050	401.050
										725	210.7								
023	ED	NHX 06	219	1620	1635	9-Jun-93	60	750	2.2	750	218.9	73.45	309	96	96	30.08	SCR-SRI-1	0.9719	407.310	404.310
										750	218.9								
		AVERAGE	221																
023	E3	NHX 04	232	1458	1512	9-Jun-93	60	750	3.28	779	232.7	76.17	311	99	101	30.08	Stack-2	1.0152	409.200	406.200
										771	230.3								
023	E3	NHX 05	235	1541	1556	9-Jun-93	60	750	3.24	789	235.2	76.17	311	101	99	30.08	Stack-2	1.0152	412.500	409.500
										789	235.2								
023	E3	NHX 06	224	1635	1635	9-Jun-93	60	750	3.31	757	226.3	76.24	311	99	100	30.08	Stack-2	1.0152	416.000	413.000
										739	220.9								
		AVERAGE	230																
023	ED	NHX 07	247	0906	0924	10-Jun-93	150	620	2.39	868	250.6	75.04	303	84	87	30.15	SCR-SRI-1	0.9719	410.550	407.550
										846	244.2								
023	ED	NHX 08	250	0955	1012	10-Jun-93	150	620	2.46	857	250.4	74.42	305	90	90	30.15	SCR-SRI-1	0.9719	413.800	410.800
										857	250.4								
023	ED	NHX 09	234	1053	1055	10-Jun-93	150	620	2.5	800	234.5	74.36	306	90	91	30.15	SCR-SRI-1	0.9719	417.150	414.150
										796	233.3								
		AVERAGE	244																
023	E3	NHX 07	256	0907	0923	10-Jun-93	150	620	2.98	889	256.6	77.53	306	90	93	30.15	Stack-2	1.0152	419.300	416.300
										882	254.5								
023	E3	NHX 08	290	0952	1006	10-Jun-93	150	620	3.03	986	286.9	77.11	308	94	95	30.15	Stack-2	1.0152	422.700	419.700
										1004	292.2								
023	E3	NHX 09	282	1035	1050	10-Jun-93	150	620	3.04	971	284.2	76.69	309	97	98	30.15	Stack-2	1.0152	425.900	422.900
										957	280.1								
		AVERAGE	276																
023	ED	NHX 10	205	1310	1325	10-Jun-93	60	620	2.67	689	204.0	74.29	306	91	91	30.15	SCR-SRI-1	0.9719	320.360	317.360
										693	205.2								
023	ED	NHX 11	251	1350	1405	10-Jun-93	60	620	2.66	850	251.3	74.36	306	89	92	30.15	SCR-SRI-0	0.9719	423.590	420.590
										850	251.3								
023	ED	NHX 12	267	1430	1445	10-Jun-93	60	620	2.51	904	267.2	73.75	308	95	95	30.15	SCR-SRI-1	0.9719	426.890	423.890
										904	267.2								
		AVERAGE	241																
023	E3	NHX 10	261	1308	1323	10-Jun-93	60	620	3.55	857	257.8	76.83	309	96	97	30.15	Stack-2	1.0152	429.100	426.100
										879	264.4								
023	E3	NHX 11	277	1347	1401	10-Jun-93	60	620	3.56	921	277.4	76.76	309	96	98	30.15	Stack-2	1.0152	432.300	429.300
										921	277.4								
023	E3	NHX 12	260	1428	1443	10-Jun-93	60	620	3.45	857	257.9	76.35	311	99	101	30.15	Stack-2	1.0152	435.500	432.500
										868	261.2								
		AVERAGE	268																

FIRST PARAMETRIC DATA SPREADSHEET KEY

Column Heading	Description
Parametric Operation Condition	Arbitrarily assigned number to particular, flow, temperature and NH_3/NO_x combination
Reactor Flow Rate	Nominal reactor flowrate in SCFM/1000 where T = 0 °F, P = 1.0 ATM
Reactor Inlet Temp.	Nominal parametric condition operating temperature °F
NH_3/NO_x Ratio	Nominal parametric condition NH_3 - to - NO_x ratio
Date	Date that sample was taken
Start time	Start time of three triplicate sample runs
End time	End time of three triplicate sample runs
Conc.	Constituent concentration, ppm by volume, based on wet phase gas (10% by volume moisture)
ρ	Standard deviation of measurement based on triplicate runs
Flow measured (scfm)	measured average flow from archive (0 °C 1 atm.)
NO_x inlet (ppmv)	measured average pilot plant inlet NO_x, wet, not O_2 corrected, from archive
O_2 inlet (%)	measured average plant inlet O_2 from archive, wet
O_2 rxr inlet (%)	measured reactor inlet O_2 (at verturi) wet, from archive
O_2 rxr outlet (%)	measured average reactor outlet O_2 wet, from archive
NH_3 actual (Kg/hr)	measured average NH_3 injection rate from mass flow controller, from archive
NO_x out measured (ppmv)	measured average outlet NO_x concentration, wet, not O_2 corrected, from archive
FLOW corrected (scfm)	corrected reactor flow at inlet O_2 concentration (using post-test calibrations)
FLOW corrected out (scfm)	reactor flow corrected to outlet O_2 concentration (calculated outlet flow w/inleak)
NO_x corrected in (ppmv)	reactor inlet NOx corrected to inlet O_2 concentration
NH_3 actual (ppmv)	calculated actual NH_3 concentration corrected to inlet O_2 concentration, wet
INT NH_3 corrected (ppmv)	manual NH_3 concentration corrected to inlet O_2, measured at exit to catalyst layer #1, or at reactor exit for SO_3
NH_3 /NO_x ratio actual	actual NH_3/NO_x ratio using corrected NO_x and NH_3 values at reactor inlet O_2 concentration
NO_x out corrected (ppmv)	measured outlet NO_x corrected to inlet O_2
NO_x out pred (ppmv)	predicted outlet NO_x w/ 100% NH_3 reaction, corrected to inlet O_2 concentration
LOAD unit #5 (MW)	average unit load from archive
SO_2 plant inlet (ppmv)	average inlet SO_2 to pilot plant, wet, not O_2 corrected from archive
SO_2 corrected in (ppmv)	average reactor inlet SO_2 corrected to rxr inlet O_2
SO_2 corrected out (ppmv)	average reactor exit SO_2 calculated by corrected to rxr exit O_2
SO_3 predicted in (ppmv)	predicted reactor outlet SO_3 using correlation based on unit load
SO_3 corrected out (ppmv)	manual measured SO_3 out corrected to outlet O_2 concentration
SO_2 Ox rate (%)	oxidation rate of SO_2 based on corrected SO_2 and SO_3 outlet measured (as % of SO_2 oxidized)

TASK 3

PRELIMINARY PARAMETRIC TEST RESULTS

REACTOR A

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP flow in F	TEMP flow out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	9/2/93	0935	1126	5.3	+-	0.5	627	582	2926	295	2.402	2.914	3.341	0.6658		48
4	3	620	1.0	9/2/93	1429	1622	38.7	+-	9.2	625	583	2986	302	2.177	2.731	3.240	1.1117		0
11	7.5	620	0.6	9/28/93	1015	1138	23.2	+-	2.2	624	603	7505	336	5.897	4.989	5.723	1.9483		45
14	7.5	620	1.0	9/28/93	1340	1460	99.7	+-	4.5	624	606	7511	347	6.314	5.414	6.185	3.3768		1
22	5	700	0.8	9/29/93	0946	1105	16.6	+-	4.8	707	674	4947	348	4.713	5.765	6.884	1.7772		0
31	3	750	0.6	8/30/93	0950	1124	3.4	+-	1.0	757	701	3018	283	1.280	1.916	2.346	0.642		47
34	3	750	1.0	8/30/93	1320	1511	11.2	+-	na	757	705	2981	386	1.233	1.842	2.292	1.025		0
41	7.5	750	0.6	9/29/93	1344	1500	15.4	+-	2.6	753	722	7122	348	4.167	5.503	6.342	1.9327		55
44	7.5	750	1.0	9/3/93	1349	1436	32.2	+-	6.5	753	723	6557	305	2.073	3.191	3.079	2.5913		2
Slip NH3																			
14	7.5	620	1.0	9/23/93	0904	1141	25.8	+-	3.1	632	612	7418	334	3.620	4.630	4.907	3.2032		1
22	5	700	0.8	9/23/93	1320	1530	5.5	+-	0.7	707	672	5078	292	1.840	2.239	2.389	1.5248		0
22	5	700	0.8	12/16/94	1021	1127	1.4	+-	0.4	707	676	5001	342	4.996	5.868	6.952	1.738	13	8
Outlet SO3 (Cat. Layer 4)																			
1	3	620	0.6	9/10/93	0919	1048	4.8	+-	1.3	630	582	2892	301	2.545	3.016	3.265	0.702		41
4	3	620	1.0	9/10/93	1323	1449	8.3	+-	1.4	628	588	2998	318	3.861	4.332	4.633	1.231		0
11	7.5	620	0.6	9/13/93	0936	1107	7.9	+-	1.0	627	608	7494	308	2.293	3.243	3.117	1.786		54
14	7.5	620	1.0	9/13/93	1305	1413	3.1	+-	0.1	631	614	7501	287	2.112	3.085	2.884	2.785		2
22	5	700	0.8	9/24/93	1015	1105	13.4	+-	6.8	710	675	4944	241	1.724	1.877	1.986	1.238		10
31	3	750	0.6	9/24/93	1257	1335	53	+-	4.1	758	694	2963	294	2.484	2.402	3.055	0.674		61
34	3	750	1.0	9/24/93	1342	1427	39.9	+-	22.8	757	698	2959	301	2.426	2.366	3.023	1.134		0
41	7.5	750	0.6	9/24/93	1500	1546	27.5	+-	3.9	762	724	6741	301	2.250	2.634	2.603	1.319		90
44	7.5	750	1.0	9/27/93	1035	1115	13.2	+-	0.9	764	728	7073	328	6.583	6.001	6.462	3.001		0

REACTOR A CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	INT NH3 corr. (ppmv)	NH3/NOx ratio actual	NOx corr. out (ppmv)	NOx pred. out (ppmv)	INT. NOx RED. %							
1	2688	2650	287	199	5.3	0.694	49	92	67.6			0.000513				
4	2641	2717	293	328	39.3	1.112	0	-26	97.8							
11	6637	6856	356	227	20.6	0.638	47	133	68.0							
14	6643	6988	368	393	86.3	1.068	1	-17	83.4							
22	4375	4722	326	315	14.1	0.966	0	17	92.3							
31	2667	2729	274	186	3.6	0.680	48	91	66.7							
34	2619	2682	374	303	11.9	0.810	0	77	77.8							
41	6299	6659	320	238	13.3	0.742	58	87	70.0							
44	5799	5763	287	346	31.9	1.206	2	-52	109.6							
14	6560	6673	315	378	23.6	1.202	1	-58								
22	4491	4527	286	263	5.7	0.919	0	28								
22	4884	5261	323	297	1.2	0.918	9	32								
									LOAD unit #6 (MW)	SO2 plant inlet (ppmv)		SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	2646	2683	293	205		0.700	42	92	74.0	2004		2002	1974	13.9	4.7	-0.46
4	2650	2698	309	360		1.164	0	-44	74.0	1791		1658	1629	13.9	7.6	-0.39
11	6628	6581	292	209		0.714	54	88	87.0	1988		1941	1955	8.4	7.8	-0.03
14	6634	6560	272	325		1.194	2	-46	88.0	1856		1947	1969	8.0	3.1	-0.25
22	4372	4398	239	219		0.917	10	24	85.0	2086		2216	2204	9.3	14.1	0.22
31	2620	2716	295	199		0.674	63	100	82.0	2013		2080	2007	10.5	53.3	2.13
34	2617	2713	302	336		1.111	0	-27	83.0	2011		2082	2008	10.1	39.8	1.48
41	5962	5952	295	171		0.581	90	127	85.0	2025		2068	2070	9.3	28.1	0.91
44	6255	6454	341	371		1.089	0	-23	64.0	1634		1278	1239	22.2	10.7	-0.93

TASK 3

PRELIMINARY PARAMETRIC TEST RESULTS

REACTOR B

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP flow in F	TEMP flow out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	9/3/93	1011	1148	7.4	+-	0.7	626	593	3061	294	1.890	2.157	2.610	0.689		101
4	3	620	1.0	9/28/93	1356	1532	52.4	+-	7.1	625	585	2901	337	5.740	5.024	5.922	1.299		0
11	7.5	620	0.6	9/2/93	1040	1133	33.7	+-	0.4	627	606	7539	297	2.411	2.762	2.780	1.6935		74
14	7.5	620	1.0	9/2/93	1440	1643	117.6	+-	0.8	629	607	7361	297	2.169	2.541	2.702	2.8455		3
22	5	700	0.8	9/28/93	1021	1150	34.0	+-	0.3	708	666	5031	336	5.863	4.902	5.608	1.7404		1
31	3	750	0.6	8/31/93	0850	1021	3.8	+-	0.6	757	698	3013	287	1.807	2.052	2.240	0.677		92
34	3	750	1.0	8/31/93	1340	1455	12.8	+-	2.0	753	704	2998	287	1.882	2.080	2.268	1.102		0
41	7.5	750	0.6	8/30/93	0945	1105	23.2	+-	0.4	754	721	7421	281	1.329	1.699	1.713	1.601		81
44	7.5	750	1.0	8/30/93	1320	1510	47.7	+-	1.6	752	722	7269	286	1.914	2.264	2.212	2.6695		2
Slip NH3																			
14	7.5	620	1.0	9/22/93	0925	1440	33.0	+-	19.2	626	605	7442	298	2.139	2.770	2.793	2.8407		3
22	5	700	0.8	9/23/93	0920	1405	0.9	+-	0.2	708	672	5028	316	2.608	3.106	3.298	1.6462		7
22	5	700	0.8	12/15/94	1408	1448	1.5	+-	0.4	707	678	5002	362	6.149	6.863	6.793	1.868	3	6
Outlet SO3 (Cat. Layer 4)																			
1	3	620	0.6	9/8/93	1015	1400	5.6	+-	1.8	627	582	2992	311	3.877	3.763	4.162	0.722		96
4	3	620	1.0	9/8/93	1331	1458	4.2	+-	2.3	623	612	3004	314	2.415	3.059	3.672	1.216		0
11	7.5	620	0.6	9/13/93	0940	1123	5.8	+-	0.7	629	604	7496	308	2.271	2.608	2.864	1.787		68
14	7.5	620	1.0	9/13/93	1400	1505	2.1	+-	1.0	634	612	7505	287	2.247	2.335	2.342	2.75		2
22	5	700	0.8	9/24/93	1024	1323	1.4	+-	1.0	703	673	4961	272	2.163	1.673	1.860	1.392		11
31	3	750	0.6	9/10/93	0834	1015	24.0	+-	2.7	759	699	3004	304	3.246	3.350	3.717	0.707		77
34	3	750	1.0	9/10/93	1052	1446	15.9	+-	1.8	755	703	3000	303	3.825	3.853	4.293	1.198		0
41	7.5	750	0.6	9/9/93	0833	1009	21.3	+-	2.7	767	726	7330	302	2.768	3.447	3.622	1.712		62
44	7.5	750	1.0	9/9/93	1048	1229	9.1	+-	2.7	765	728	7368	299	2.181	2.956	2.961	2.843		0

REACTOR B CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	INT NH3 corr. (ppmv)	NH3/NOx ratio actual	NOx corr. out (ppmv)	NOx pred. out (ppmv)	INT. NOx RED. %	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	2562	2625	290	208	7.7	0.718	103	88	69.2							
4	2428	2573	353	414	46.5	1.174	0	-53	104.2							
11	6310	6323	292	208	34.1	0.713	74	88	59.6							
14	6161	6215	291	358	120.6	1.228	3	-59	81.4							
22	4211	4404	357	320	30.4	0.896	1	44	81.0							
31	2622	2647	283	208	4.1	0.734	93	80	71.9							
34	2509	2535	284	340	13.4	1.198	0	-50	116.1							
41	6211	6216	276	200	24.9	0.724	81	80	63.4							
44	6084	6067	281	340	49.7	1.210	2	-52	103.3							
14	6229	6237	288	353	33.4	1.226	3	-58								
22	4208	4264	307	303	0.9	0.985	7	11								
22	5129	5468	369	370	1.2	1.002	8	7								
1	2504	2564	313	223		0.713	98	94		65.0	1804	1728	1688	17.6	5.2	-0.73
4	2514	2588	303	374		1.235	0	-64		86.0	1957	1951	1895	8.9	4.0	-0.25
11	6274	6280	302	221		0.729	58	86		87.0	1964	2007	2002	8.4	5.9	-0.13
14	6282	6284	286	339		1.187	2	-47		88.0	1935	2006	2006	8.0	2.2	-0.29
22	4152	4191	279	260		0.930	11	25		83.0	2047	2198	2178	10.1	1.5	-0.39
31	2514	2568	302	218		0.720	79	89		67.0	1923	1886	1846	16.8	23.1	0.34
34	2511	2577	303	369		1.221	0	-60		73.0	1828	1741	1697	14.3	14.8	0.03
41	6135	6162	291	216		0.743	62	79		75.0	1860	1814	1806	13.5	20.7	0.40
44	6167	6165	287	357		1.245	0	-63		86.0	1985	1970	1970	8.9	9.2	0.01

TASK 3

PRELIMINARY PARAMETRIC TEST RESULTS

REACTOR C

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP flow in F	TEMP flow out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	8/30/93	0939	1059	8.1	+-	0.6	626	599	2996	283	1.329	1.853	2.213	0.603		49
4	3	620	1.0	8/30/93	1320	1530	54.1	+-	0.5	625	592	2970	280	2.414	2.697	3.049	1.1076		3
11	7.5	620	0.6	8/31/93	0908	1025	24.2	+-	2.0	629	609	7499	281	1.530	1.931	2.007	1.629		66
14	7.5	620	1.0	8/31/93	1336	1446	82.0	+-	3.2	630	610	7513	286	1.862	2.250	2.527	2.768		0
22	5	700	0.8	9/28/93	1022	1151	30.6	+-	1.9	706	678	4975	336	5.859	5.169	5.854	1.7288		11
31	3	750	0.6	9/3/93	1000	1131	6.6	+-	1.0	756	699	3023	284	1.830	2.320	3.076	0.6863		66
34	3	750	1.0	9/28/93	1348	1511	44.0	+-	10.0	756	704	2897	346	4.984	5.713	6.293	1.3043		0
41	7.5	750	0.6	9/2/93	1340	1517	18.3	+-	0.2	760	728	7360	291	2.062	2.518	2.860	1.6747		
44	7.5	750	1.0	9/2/93	0935	1112	52.7	+-	1.2	762	727	7386	295	2.367	2.868	3.210	2.824		
Slip NH3																			
14	7.5	620	1.0	9/21/93	1045	1510	66.3	+-	0.4	633	617	7466	289	1.362	1.836	2.867	2.5889		4
22	5	700	0.8	9/23/93	1103	1448	5.3	+-	0.8	709	680	5006	301	1.770	1.988	2.847	1.5569		13
22	5	700	0.8	12/15/94	1059	1358	2.4	+-	0.3	706	671	5016	358	5.943	6.108	6.755	1.844	NA	82
Outlet SO3 (Cat. Layer 4)																			
1	3	620	0.6	9/8/93	0848	1040	18.7	+-	3.8	753	705	3001	310	4.657	4.522	4.851	0.7236		64
4	3	620	1.0	9/9/93	1128	1421	6.7	+-	1.7	625	594	2998	310	2.605	3.046	3.259	1.1987		0
11	7.5	620	0.6	9/24/93	1401	1446	2.7	+-	0.8	628	614	7350	301	2.197	2.015	3.032	1.713		78
14	7.5	620	1.0	9/10/93	0848	1034	6.8	+-	1.2	629	613	7502	304	2.927	3.128	3.364	2.9409		8
22	5	700	0.8	9/27/93	1040	1122	32.1	+-	5.2	706	682	5003	328	2.580	5.884	6.313	1.703		8
31	3	750	0.6	9/8/93	1031	1425	71.2	+-	9.7	753	710	2997	314	3.736	3.991	4.321	0.7303		75
34	3	750	1.0	9/13/93	0936	1117	56.8	+-	5.3	753	706	2991	308	2.271	2.805	3.134	1.19		0
41	7.5	750	0.6	9/13/93	1307	1439	38.7	+-	3.5	757	732	7502	286	2.139	2.372	2.533	1.6615		77
44	7.5	750	1.0	9/10/93	1325	1527	29.9	+-	1.4	751	728	7502	320	3.981	4.233	4.468	2.9051		7

REACTOR C CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	INT NH3 corr. (ppmv)	NH3/NOx ratio actual	NOx corr. out (ppmv)	NOx pred. out (ppmv)	INT. NOx RED. %
1	2526	2575	275	185	8.7	0.671	50	94	64.0
4	2504	2554	286	342	55.1	1.199	3	-50	100.6
11	6323	6348	275	199	25.6	0.725	68	80	63.2
14	6335	6430	280	338	85.5	1.207	0	-51	90.2
22	4195	4385	351	319	26.9	0.909	11	38	83.2
31	2549	2656	286	208	6.9	0.728	69	82	70.4
34	2443	2539	330	413	37.4	1.252	0	-75	113.9
41	6208	6323	284	209	18.8	0.736		79	67.0
44	6228	6348	287	351	53.1	1.223		-57	103.8
14	6295	6653	283	318	70.6	1.213	4	-50	
22	4221	4421	298	286	5.6	0.960	14	18	
22	5451	5699	354	244	2.0	0.688	88	116	

	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	51.0	1779	1629	1596	23.5	16.7	-0.42
4	84.0	1926	1921	1898	9.7	6.6	-0.16
11	46.0	978	1032	976	25.5	2.7	-2.34
14	70.0	1959	1945	1919	15.5	6.6	-0.46
22	84.0	1696	1415	1384	9.7	26.2	1.19
31	68.0	1805	1706	1673	16.4	66.0	2.97
34	86.0	1964	1985	1948	8.9	56.3	2.43
41	88.0	1951	2019	2002	8.0	39.7	1.68
44	73.0	1777	1655	1632	14.3	27.5	0.81

TASK 3

PRELIMINARY PARAMETRIC TEST RESULTS

REACTOR D

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet (3%O2)		σ	TEMP flow in F	TEMP flow out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	0.24	620	0.6	9/30/93	0952	1116	9.5	+-	2.1	625	498	240	343	4.280	6.083	10.140	0.063		123
4	0.24	620	1.0	9/30/93	1335	1500	34.4	+-	4.9	626	510	247	359	4.060	5.784	9.816	0.114		16
11	0.6	620	0.6	10/6/93	0933	1040	32.1	+-	2.9	628	559	571	291	4.030	5.151	6.339	0.13		100
14	0.6	620	1.0	10/1/93	1323	1443	123.4	+-	3.2	625	584	600	343	4.250	6.204	7.470	0.212		38
22	0.4	700	0.8	9/29/93	1012	1131	27.5	+-	2.3	708	607	377	348	4.800	6.336	8.803	0.142		49
31	0.24	760	0.6	9/29/93	1342	1500	6.7	+-	1.0	753	690	245	348	4.170	6.067	10.148	0.065		107
34	0.24	760	1.0	10/4/93	1345	1454	12.5	+-	1.8	758	670	243	268	0.950	2.980	6.322	0.085		21
41	0.6	760	0.6	10/5/93	1350	1504	25.6	+-	2.1	754	670	597	285	1.570	3.419	4.247	0.13		120
44	0.6	760	1.0	10/4/93	0959	1114	70.2	+-	7.3	745	613	601	271	1.240	3.638	4.656	0.207		17
Slip NH3																			
14	0.6	620	1.0	10/25/93	1319	1554	82.3	+-	3.3	625	557	601	311	2.710	4.560	5.380	0.242		20
22	0.4	700	0.8	10/26/93	0942	1414	2.5	+-	0.6	706	592	399	330	2.320	4.020	5.690	0.137		28
22	0.4	700	0.8	12/21/94	1102	1155	1.9	+-	0.5	707	601	397	340	4.472	6.994	8.999	0.1313	37	48
Outlet SO3 (Cat. Layer 4)																			
1	0.24	620	0.6	10/20/93	0926	1030	7.0	+-	1.5	627	505	240	317	1.886	3.768	8.089	0.059		94
22	0.4	700	0.8	10/21/93	1402	1505	24.1	+-	0.5	706	611	400	327	2.608	4.408	6.194	0.135		41
31	0.24	760	0.6	10/15/93	1344	1513	31.6	+-	0.8	756	601	240	284	1.881	3.936	7.689	0.0528		73
34	0.24	760	1.0	10/22/93	0945	1100	45.1	+-	2.0	755	594	240	325	2.057	4.160	7.960	0.1007		1
41	0.6	760	0.6	10/19/93	1000	1125	23.3	+-	2.5	758	684	589	325	1.985	4.199	4.371	0.1468		80
44	0.6	760	1.0	10/19/93	1331	1434	15.9	+-	0.9	756	684	588	334	2.641	4.409	5.009	0.2535		8

REACTOR D CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	INT NH3 corr. (ppmv)	NH3/NOx ratio actual	NOx corr. out (ppmv)	NOx pred. out (ppmv)		INT. NOx RED. %							
1	224	307	306	218	7.9	0.713	169	92		68.7							
4	230	313	322	384	29.1	1.190	22	-54		110.0							
11	532	575	272	189	28.2	0.696	108	86		59.2							
14	559	611	303	294	101.5	0.969	42	15		83.4							
22	351	426	316	313	22.4	0.994	59	8		92.2							
31	228	314	309	220	5.6	0.714	147	93		69.6							
34	226	278	241	291	12.5	1.207	26	-44		115.6							
41	556	584	258	181	26.0	0.702	126	80		60.5							
44	560	595	238	286	67.7	1.202	18	-42		91.8							
14	560	589	280	335	75.2	1.197	21	-48									
22	372	412	300	285	2.4	0.951	31	20									
22	412	481	288	247	1.4	0.857	58	46									
										LOAD unit #5 (MW)	SO2 plant inlet (ppmv)		SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	224	298	286	204		0.715	125	86		85.0	1980		1896	1420	6.9	5.0	-0.13
22	373	418	295	280		0.951	46	20		83.0	1869		1723	1537	7.5	19.8	0.80
31	224	287	253	183		0.721	94	74		87.0	1948		1847	1441	6.3	23.4	1.19
34	224	289	289	349		1.207	1	-53		86.0	2165		2025	1568	6.6	32.7	1.66
41	549	555	287	207		0.721	81	84		83.0	1800		1680	1663	7.5	21.5	0.84
44	548	568	302	358		1.187	8	-49		80.0	1769		1631	1572	8.4	14.1	0.36

TASK 3

PRELIMINARY PARAMETRIC TEST RESULTS

REACTOR E

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet (3%O2)		σ	TEMP flow in F	TEMP flow out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	0.24	620	0.6	10/14/93	0937	1036	2.7	+-	0.8	623	488	239	305	2.037	3.655	7.786	0.0558		0
4	0.24	620	1.0	10/5/93	0930	1041	4.2	+-	1.8	627	493	238	291	4.029	5.583	7.947	0.0847		68
11	0.6	620	0.6	10/6/93	0924	1030	16.3	+-	1.4	625	568	606	298	4.750	5.320	7.296	0.1388		83
14	0.6	620	1.0	10/6/93	1322	1425	80.7	+-	1.2	626	564	599	294	1.708	3.026	6.009	0.2283		91
22	0.4	700	0.8	10/8/93	0952	1056	12.8	+-	0.2	708	601	393	297	3.301	4.314	6.479	0.1245		14
31	0.24	750	0.6	10/5/93	1330	1439	1.3	+-	0.3	755	577	242	279	1.497	3.504	6.062	0.052		78
34	0.24	750	1.0	10/4/93	0957	1116	4.6	+-	0.8	757	585	244	270	1.344	3.718	6.427	0.0836		6
41	0.6	750	0.6	10/11/93	0931	1044	12.9	+-	0.4	751	653	684	302	5.448	5.969	8.297	0.1364		
44	0.6	750	1.0	10/4/93	1340	1450	41.0	+-	2.5	732	654	600	269	0.954	2.934	4.582	0.2104		4
Slip NH3																			
14	0.6	620	1.0	10/25/93	1325	1605	62.2	+-	2.0	626	568	601	323	2.714	3.699	4.902	0.25		6
22	0.4	700	0.8	10/26/93	0934	1407	BDL	+-	BDL	707	614	400	334	2.326	3.929	5.455	0.1378		4
22	0.4	700	0.8	12/21/94	1027	1159	0.1	+-	0.1	703	555	402	341	4.513	5.761	7.849	0.1318	28	25
Outlet SO3 (Cat. Layer 4)																			
1	0.24	620	0.6	10/20/93	0923	1038	7.9	+-	0.7	624	500	240	316	1.886	3.876	6.683	0.059		46
22	0.4	700	0.8	10/21/93	1400	1513	16.7	+-	1.9	706	616	400	325	2.603	4.356	5.608	0.1344		22
31	0.24	750	0.6	10/22/93	1317	1420	43.1	+-	6.5	756	595	240	326	1.981	4.142	6.312	0.0608		148
34	0.24	750	1.0	10/22/93	0949	1113	17.8	+-	5.4	755	595	237	325	2.057	4.149	6.324	0.1006		0
41	0.6	750	0.6	10/19/93	0955	1108	15.3	+-	1.5	756	666	577	328	2.007	3.320	4.930	0.146		65
44	0.6	750	1.0	10/19/93	1329	1451	10.4	+-	1.5	757	665	568	332	2.581	4.152	5.559	0.243		1

REACTOR E CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr..in (ppmv)	NH3 actual (ppmv)	INT NH3 corr. (ppmv)	NH3/NOx ratio actual	NOx corr. out (ppmv)	NOx pred. out (ppmv)		INT. NOx RED. %							
1	223	282	279	194	2.6	0.695	0	89		68.6							
4	222	262	265	298	3.6	1.117	80	-25		110.4							
11	585	648	288	180	14.2	0.668	95	99		81.7							
14	558	627	274	317	90.6	1.156	102	-37		82.6							
22	366	421	280	263	11.8	0.940	16	22		89.8							
31	226	264	250	179	1.3	0.713	89	75		70.8							
34	227	270	237	285	4.4	1.199	7	-42		118.1							
41	544	644	292	194	10.8	0.665		102		62.8							
44	559	614	242	291	41.1	1.202	4	-43		103.2							
14	660	602	308	346	59.8	1.131	8	-33									
22	373	409	305	286	BDL	0.938	4	25									
22	327	378	315	312	0.1	0.991	29	9									
										LOAD unit #5 (MW)	SO2 plant inlet (ppmv)		SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	224	267	283	204		0.722	55	83		85.0	1980		1884	1575	6.9	6.3	-0.04
22	373	403	294	279		0.950	24	20		83.0	1871		1730	1600	7.5	14.3	0.43
31	224	257	289	211		0.728	170	83		86.0	2181		2043	1780	6.6	35.1	1.60
34	221	254	289	353		1.220	0	-57		86.0	2165		2027	1765	6.6	14.5	0.45
41	538	592	305	210		0.689	72	99		83.0	1800		1768	1607	7.5	13.7	0.38
44	629	678	304	355		1.171	1	-45		80.0	1774		1660	1522	8.4	8.9	0.03

TASK 3

PRELIMINARY PARAMETRIC TEST RESULTS

REACTOR F

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet (3%O2)		σ	TEMP flow in F	TEMP flow out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	0.24	620	0.6	10/13/93	1335	1448	5.3	+-	0.4	625	493	229	313	2.732	3.512	5.581	0.0678		138
4	0.24	620	1.0	10/13/93	1005	1135	21.9	+-	2.3	627	504	239	328	2.566	3.265	4.952	0.09967		28
11	0.6	620	0.6	10/6/93	0925	1024	37.7	+-	3.3	627	561	598	286	4.592	4.913	5.955	0.137		
14	0.6	620	1.0	10/6/93	1040	1342	94.5	+-	18.6	628	572	594	295	3.063	2.166	2.879	0.2248		10
22	0.4	700	0.8	10/8/93	0955	1100	31.3	+-	2.1	707	607	395	294	3.027	3.248	5.005	0.1225		34
31	0.24	750	0.6	10/12/93	0921	1035	5.4	+-	0.5	755	688	240	332	5.892	6.218	7.842	0.0622		100
34	0.24	750	1.0	10/12/93	1335	1500	12.2	+-	1.4	753	686	242	292	2.372	3.732	5.383	0.0902		21
41	0.6	750	0.6	10/11/93	1054	1441	34.0	+-	0.9	750	668	594	210	5.286	6.123	6.830	0.1394		
44	0.6	750	1.0	10/14/93	1335	1433	71.4	+-	1.0	754	674	596	289	1.876	1.867	3.448	0.2216		0
Slip NH3																			
14	0.6	620	1.0	10/25/93	1320	1600	31.7	+-	2.9	628	568	600	311	2.714	2.956	4.267	0.2417		7
22	0.4	700	0.8	10/26/93	0935	1420	76.3	+-	7.1	709	605	395	331	2.323	2.884	4.233	0.1368		36
22	0.4	700	0.8	12/21/94	1449	1504	0.83	+-	0.6	708	601	403	336	4.471	5.979	7.164	0.1286	28	75
Outlet SO3 (Cat. Layer 4)																			
1	0.24	620	0.6	10/20/93	0925	1055	3.3	+-	0.7	626	504	204	316	1.914	2.679	3.696	0.0587		122
22	0.4	700	0.8	10/21/93	1355	1519	8.2	+-	1.1	705	614	400	326	2.557	2.872	3.602	0.1345		42
31	0.24	750	0.6	10/22/93	1320	1438	11.5	+-	3.8	755	590	240	326	1.982	2.842	3.833	0.0606		153
34	0.24	750	1.0	10/22/93	0942	1104	9.8	+-	1.2	754	590	240	325	2.057	2.898	3.887	0.1008		1
41	0.6	750	0.6	10/19/93	0950	1057	9.1	+-	0.5	758	674	568	328	1.913	2.316	2.930	0.1416		88
44	0.6	750	1.0	10/19/93	1330	1437	7.0	+-	0.5	758	678	557	333	2.636	3.081	3.687	0.2388		6

REACTOR F CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	INT NH3 corr. (ppmv)	NH3/NOx ratio actual	NOx corr. out (ppmv)	NOx pred. out (ppmv)	INT. NOx RED. %
1	213	242	300	210	5.2	0.700	157	94	68.3
4	223	246	315	346	21.6	1.098	31	-24	102.9
11	557	596	280	190	33.7	0.656		104	64.0
14	554	575	310	314	98.8	1.015	10	1	89.6
22	368	409	280	258	30.9	0.887	38	38	78.1
31	224	251	325	215	4.4	0.663	112	114	64.9
34	226	249	271	310	11.7	1.144	23	-33	110.1
41	554	581	199	195	28.1	0.980		8	83.9
44	555	605	289	309	75.9	1.068	0	-14	80.6
14	559	603	307	335	31.8	1.091	8	-21	
22	368	398	321	288	76.8	0.896	38	39	
22	377	409	305	266	0.7	0.872	81	44	

									LOAD unit #5 (MW)	SO2 plant inlet (ppmv)		SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	180	201	302	239		0.791	129	68	85.0	1978		2013	1902	6.9	3.2	-0.19
22	373	393	324	279		0.862	44	50	83.0	1874		1908	1811	7.5	7.9	0.02
31	224	237	311	210		0.674	162	108	86.0	2183		2202	2082	6.6	10.9	0.21
34	224	237	311	349		1.124	1	-32	86.0	2165		2177	2058	6.6	9.1	0.12
41	520	538	321	211		0.656	91	114	84.0	1800		1868	1807	7.2	9.1	0.10
44	519	538	325	356		1.094	5	-24	80.0	1763		1757	1696	8.4	6.7	-0.10

SECOND PARAMETRIC DATA SPREADSHEET KEY

Column Heading	Description
Parametric Operation Condition	Arbitrarily assigned number to particular, flow, temperature and NH_3/NO_x combination
Reactor Flow Rate	Nominal reactor flowrate in SCFM/1000 where T = 0 °F, P = 1.0 ATM
Reactor Inlet Temp.	Nominal parametric condition operating temperature °F
NH_3/NO_x Ratio	Nominal parametric condition NH_3 - to - NO_x ratio
Date	Date that sample was taken
Start time	Start time of three triplicate sample runs
End time	End time of three triplicate sample runs
Conc.	Constituent concentration, ppm by volume, based on wet phase gas (10% by volume moisture)
ρ	Standard deviation of measurement based on triplicate runs
TEMP gas in	Process gas temperature in °F measured at the reactor inlet
TEMP gas out	Process gas temperature in °F
Flow measured (scfm)	measured average flow from archive (0 °C 1 atm.)
NO_x inlet (ppmv)	measured average pilot plant inlet NO_x, wet, not O_2 corrected, from archive
O_2 inlet (%)	measured average plant inlet O_2 from archive, wet
O_2 rxr inlet (%)	measured reactor inlet O_2 (at verturi) wet, from archive
O_2 rxr outlet (%)	measured average reactor outlet O_2 wet, from archive
NH_3 actual (Kg/hr)	measured average NH_3 injection rate from mass flow controller, from archive
NO_x NOVA (ppmv)	NO_x measured by NOVA portable instrument at location of ammonia sample
NO_x out measured (ppmv)	measured average outlet NO_x concentration, wet, not O_2 corrected, from archive
FLOW corrected (scfm)	corrected reactor flow at inlet O_2 concentration (using post-test calibrations)
FLOW corrected out (scfm)	reactor flow corrected to outlet O_2 concentration (calculated outlet flow w/inleak)
NO_x corrected in (ppmv)	reactor inlet NOx corrected to inlet O_2 concentration
NH_3 actual (ppmv)	calculated actual NH_3 concentration corrected to inlet O_2 concentration, wet
NH_3/SO_3 concentration corrected	manual NH_3 concentration corrected to inlet O_2, measured at exit to catalyst layer #1, or at reactor exit for SO_3
NH_3 /NO_x ratio actual	actual NH_3/NO_x ratio using corrected NO_x and NH_3 values at reactor inlet O_2 concentration
NO_x out corrected (ppmv)	measured outlet NO_x corrected to inlet O_2
NO_x out pred (ppmv)	predicted outlet NO_x w/ 100% NH_3 reaction, corrected to inlet O_2 concentration
LOAD unit #5 (MW)	average unit load from archive
SO_2 plant inlet (ppmv)	average inlet SO_2 to pilot plant, wet, not O_2 corrected from archive
SO_2 corrected in (ppmv)	average reactor inlet SO_2 corrected to rxr inlet O_2
SO_2 corrected out (ppmv)	average reactor exit SO_2 calculated by corrected to rxr exit O_2
SO_3 predicted in (ppmv)	predicted reactor outlet SO_3 using correlation based on unit load
SO_3 corrected out (ppmv)	manual measured SO_3 out corrected to outlet O_2 concentration
SO_2 Ox rate (%)	oxidation rate of SO_2 based on corrected SO_2 and SO_3 outlet measured (as % of SO_2 oxidized)

SECOND PARAMETRIC TEST RESULTS

REACTOR A

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	19-Jan	0954	1053	16.9	+-	0.5	622	582	2999	294	1.522	2.451	3.0178	0.6078	86	78
11	7.5	620	0.8	18-Jan	1009	1124	28.8	+-	2.9	625	605	7161	267	1.168	2.240	2.338	1.31	132	94
12	7.5	620	0.8	18-Jan	1344	1445	40.8	+-	3.0	625	606	7179	286	1.683	2.808	3.0616	1.9308	85	45
14	7.5	620	1.0	19-Jan	1344	1446	47.4	+-	8.6	626	610	6998	328	2.668	3.633	4.4724	2.746	80	13
22	5	700	0.8	20-Jan	1004	1105	32.1	+-	3.3	705	679	4999	311	2.248	3.234	3.7125	1.4555	72	69
41	7.5	750	0.8	21-Jan	1002	1109	31.3	+-	2.1	751	725	6234	374	3.759	4.826	5.4723	1.6048	147	159
42	7.5	750	0.8	13-Jan	1340	1437	32.9	+-	0.4	747	719	6351	298	2.535	5.313	5.313	1.7598	104	47
Slip NH3																			
7	5	620	0.8	10-Jan	1005	1137	4.7	+-	0.7			7000	348	4.612	6.328	6.608		28	30
12	7.5	620	0.8	10-Jan	1339	1503	8.1	+-	1.3	625	608	6986	372	4.612	6.328	6.608	2.688	35	16
14	7.5	620	1.0	12-Jan	0951	1114	23.9	+-	3.1	626	608	7092	316	2.997	4.638	4.711	2.7846	5	4
22	5	700	0.8	7-Jan	0938	1105	2.3	+-	1.3	704	680	4997	323	3.982	5.631	5.837	1.5217	53	51
27	7.5	700	0.8	7-Jan	1338	1435	3.7	+-	0.2	704	682	6297	347	4.900	6.316	6.859	2.0575	53	52
42	7.5	750	0.8	11-Jan	1023	1154	2.5	+-	1.5	756	730	5991	360	4.328	6.154	6.310	2.1143	69	75
Outlet SO3 (Cat. Layer 4)																			
2	3	620	0.8	27-Jan	1331	1446	8.6	+-	0.7	624	600	3005	283	2.194	2.476	3.261	0.8	25	55
17	3	700	0.8	27-Jan	0944	1053	23.3	+-	0.8	705	668	3002	298	2.633	2.836	3.611	0.8442	55	53
22	5	700	0.8	26-Jan	0951	1118	9.7	+-	4.1	710	686	5001	278	1.414	2.426	2.666	1.3128	45	48
27	7.5	700	0.8	26-Jan	1345	1457	10.1	+-	0.6	704	685	6654	293	1.766	2.977	3.135	1.8434	42	61
32	3	750	0.8	25-Jan	0951	1116	25.2	+-	0.4	754	714	2999	295	2.396	3.389	3.984	0.8	39	58
37	5	750	0.8	25-Jan	1340	1453	29	+-	2.7	756	729	4997	305	2.269	3.399	3.770	1.438	60	81
42	7.5	750	0.8	28-Jan	0941	1057	16.6	+-	0.3	757	732	6166	277	2.145	2.988	3.221	1.6124	64	81

REACTOR A CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	2999	3094	280	157	17.4	0.561	89	80	126							
11	7161	7199	252	142	30.0	0.561	133	94	114							
12	7179	7280	269	208	41.2	0.773	86	46	65							
14	6998	7353	311	304	45.7	0.978	84	14	13							
22	4999	5138	295	225	31.7	0.765	74	71	74							
41	6234	6494	351	199	28.1	0.568	153	166	155							
42	6351	6351	253	215	28.7	0.847	104	47	43							
7	7000	7136	312	249	3.8	0.800	29	31	67							
12	6986	7122	333	298	6.6	0.895	36	16	41							
14	7092	7124	287	304	21.7	1.059	5	4	-11							
22	4997	5098	294	236	2.0	0.803	54	52	62							
27	6287	6539	316	253	3.0	0.799	55	54	68							
42	5991	6054	321	273	2.1	0.852	70	76	53							
2	3005	3138	279	206	8.7	0.739	26	57	77	85	1766	1817	1740	9.3	8.4	-0.05
17	3002	3136	295	218	23.5	0.739	57	55	81	84	1711	1727	1653	9.7	22.5	0.77
22	5001	5066	264	203	10.0	0.771	46	49	64	88	1832	1880	1866	8.0	9.9	0.10
27	6654	6713	275	215	10.1	0.781	42	62	64	88	1785	1787	1772	8.0	10.0	0.11
32	2999	3104	279	207	24.7	0.740	40	60	77	86	1728	1691	1634	9.3	23.8	0.89
37	4997	5105	287	223	28.2	0.777	61	83	68	86	1723	1685	1649	9.3	27.6	1.11
42	6166	6247	265	202	15.6	0.765	65	82	66	86	1724	1725	1703	9.3	15.4	0.36

SECOND PARAMETRIC TEST RESULTS

REACTOR B

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.8	20-Jan	1345	1505	6.2	+-	2.1	628	591	2998	378	3.901	4.965	5.8708	0.7734	140	192
11	7.5	620	0.8	17-Jan	1038	1141	55.4	+-	10.2	632	617	6690	286	2.281	3.323	3.459	1.3518	147	182
12	7.5	620	0.8	21-Jan	1334	1428	64.7	+-	9.1	623	608	7232	380	4.759	5.912	6.6307	2.59	126	39
14	7.5	620	1.0	18-Jan	1003	1122	81.6	+-	4.3	623	605	7271	268	1.156	1.914	1.742	2.0037	90	18
22	5	700	0.8	18-Jan	1338	1437	18.9	+-	2.8	706	675	4999	285	1.667	2.531	2.7208	1.3413	78	64
41	7.5	750	0.8	14-Jan	1012	1103	25.2	+-	2.5	755	724	6808	312	3.419	4.738	5.179	1.455	138	129
42	7.5	750	0.8	13-Jan	1014	1116	28.8	+-	0.5	757	729	6630	292	3.325	4.699	4.961	1.8253	93	69
Slip NH3																			
7	5	620	0.8	10-Jan	1016	1144	0.3	+-	0.1			7000	353	4.567	6.154	6.633		27	41
12	7.5	620	0.8	10-Jan	1342	1505	1.9	+-	0.8	628	609	7003	371	4.567	6.154	6.633	2.6936	53	25
14	7.5	620	1.0	12-Jan	1331	1443	5.9	+-	0.2	623	606	6948	365	4.456	5.809	6.147	3.051	22	22
22	5	700	0.8	7-Jan	0955	1131	0.5	+-	0.2	706	678	4992	320	3.982	5.066	5.461	1.509	57	60
27	7.5	700	0.8	7-Jan	1348	1513	0.7	+-	0.1	707	684	6599	348	4.920	6.341	6.779	2.158	64	44
42	7.5	750	0.8	11-Jan	1035	1159	0.7	+-	0.1	755	728	6503	362	4.328	5.895	6.392	2.312	53	74
Outlet SO3 (Cat. Layer 4)																			
2	3	620	0.8	17-Mar	1405	1519	3.8	+-	0.4	624	585	3006	287	2.708	2.254	2.397	0.848	51	44
17	3	700	0.8	17-Mar	1624	1734	20.7	+-	2.1	710	650	2999	259	1.953	1.924	2.013	0.765	40	34
22	5	700	0.8	18-Mar	1012	1118	7.0	+-	0.6	706	677	4999	310	2.576	2.332	2.435	1.524	46	46
27	7.5	700	0.8	21-Mar	1812	1912	4.7	+-	1.4	704	686	6427	299	3.046	2.865	2.949	1.928	62	66
32	3	750	0.8	21-Mar	1043	1150	18.2	+-	1.4			5000	298	2.538	2.378	2.365		56	
37	5	750	0.8	21-Mar	1407	1450	12.0	+-	1.8	753	722	4955	297	2.538	2.378	2.365	1.4563	70	56
42	7.5	750	0.8	21-Mar	1623	1721	14.3	+-	0.9	752	725	6804	316	3.240	3.060	3.128	2.0473	71	71

REACTOR B CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	2998	3175	354	200	5.5	0.564	148	204	159							
11	6690	6742	280	156	54.4	0.560	148	183	126							
12	7232	7594	353	277	54.2	0.786	132	41	81							
14	7271	7206	258	213	86.5	0.828	89	18	49							
22	4999	5051	272	208	19.4	0.763	79	65	69							
41	6808	6999	289	165	22.8	0.573	142	133	126							
42	6630	6738	269	213	26.1	0.792	95	60	60							
7	7000	7183	319	281	0.2	0.880	28	42	44							
12	7003	7186	335	298	1.6	0.889	54	26	43							
14	6948	7106	335	340	5.0	1.015	23	23	2							
22	4992	5119	300	234	0.4	0.781	58	51	70							
27	6599	6802	317	253	0.6	0.798	56	45	69							
42	6503	6724	328	275	0.6	0.839	55	77	58							
2	3006	3029	284	218	4.0	0.743	51	44	80	85	1849	1926	1911	9.3	3.9	-0.28
17	2999	3013	259	198	21.9	0.781	40	34	66	86	1997	2116	2107	8.9	21.8	0.62
22	4999	5027	314	236	7.3	0.752	46	46	83	85	1834	1902	1892	9.3	7.2	-0.11
27	6427	6457	302	232	4.7	0.769	62	66	74	83	1683	1696	1688	10.1	4.7	-0.32
32	5000	4997	301	231	18.8	0.770	56		74	85	1850	1914	1915	9.3	18.8	0.50
37	4955	4952	300	228	12.4	0.760	70	58	76	84	1754	1816	1818	9.7	12.4	0.15
42	6604	6629	319	240	14.3	0.752	71	71	84	84	1685	1679	1673	9.7	14.2	0.27

SECOND PARAMETRIC TEST RESULTS

REACTOR C

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	20-Jan	1000	1109	1.5	+-	0.2	625	586	2880	311	2.248	3.468	4.240	0.6335	125	124
11	7.5	620	0.8	19-Jan	1329	1433	20.2	+-	0.6	629	610	7447	320	2.401	3.584	4.444	2.213	126	79
12	7.5	620	0.8	21-Jan	1082	1105	26.9	+-	2.9	625	610	7487	375	4.683	5.167	5.925	2.864	120	113
14	7.5	620	1.0	13-Jan	1335	1434	53.0	+-	2.9	623	606	7428	298	3.466	4.975	5.661	2.659	80	29
22	5	700	0.8	20-Jan	1347	1453	14.0	+-	0.7	703	676	5003	377	3.827	5.059	5.847	2.22	83	82
41	7.5	750	0.6	17-Jan	1044	1149	13.0	+-	0.7	745	625	7001	294	2.164	3.227	3.845	1.409	147	146
Slip NH3																			
7	5	620	0.8	12-Jan	0956	1116	2.4	+-	0.4	623	600	5007	317	2.997	4.344	5.117	1.578	31	25
12	7.5	620	0.8	12-Jan	1330	1446	5.7		0.4	622	610	7441	363	4.455	5.911	6.477	2.549	102	91
14	7.5	620	1.0	13-Jan	1010	1117	11.6		1.3	624	608	7477	280	3.128	4.609	5.246	2.6128	102	30
22	5	700	0.8	5-Jan	1002	1148	1.2		0.1	704	674	4995	337	4.430	4.170	4.980	1.7298	62	54
27	7.5	700	0.8	5-Jan	1414	1540	2.6	+-	0.6	707	685	7408	357	5.167	4.814	5.663	2.731	91	65
42	7.5	750	0.8	11-Jan	1340	1500	3.6	+-	0.3	743	720	7202	332	4.672	6.191	6.741	2.329	73	74
Outlet SO3 (Cat. Layer 4)																			
2	3	620	0.8	26-Jan	0949	1117	7.5	+-	3.2	621	585	2999	278	1.414	2.417	3.060	0.7867	29	32
17	3	700	0.8	26-Jan	1340	1456	17.8	+-	16.6	709	660	3020	293	1.765	2.812	3.408	0.8374	51	36
22	5	700	0.8	27-Jan	0942	1053	20.6	+-	2.6	708	678	5002	298	2.633	3.190	3.671	1.4068	67	72
27	7.5	700	0.8	27-Jan	1328	1457	10.3	+-	1.1	704	684	7497	283	2.194	2.762	3.423	2	77	90
32	3	750	0.8	26-Jan	0958	1111	54.1	+-	2.0	756	710	3002	294	2.386	3.609	4.210	0.8318	59	59
37	5	750	0.8	26-Jan	1333	1438	42	+-	3.6	755	724	5000	305	2.269	3.356	3.877	1.437	65	82
42	7.5	750	0.8	24-Jan	1341	1456	27.8	+-	1.8	749	725	7299	291	1.872	2.904	3.579	1.9284	90	97

REACTOR C CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. out (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	2980	3128	291	164	1.5	0.564	131	130	130							
11	7447	7834	300	230	19.5	0.768	133	83	74							
12	7487	7863	364	295	23.7	0.811	126	119	75							
14	7428	7760	272	277	47.2	1.018	84	30	1							
22	5003	5195	350	344	12.4	0.982	86	85	13							
41	7001	7253	277	156	12.8	0.562	152	151	125							
7	5007	5251	293	244	2.2	0.832	33	26	54							
12	7441	7731	331	265	4.8	0.801	106	95	71							
14	7477	7779	266	271	10.6	1.017	106	31	1							
22	4995	5248	342	268	1.1	0.783	66	57	79							
27	7408	7818	385	285	2.3	0.782	96	69	85							
42	7202	7480	301	250	3.0	0.832	76	77	56							
2	2999	3106	264	203	7.7	0.770	30	33	66	88	1832	1891	1826	8.0	7.5	-0.03
17	3020	3122	277	215	18.0	0.776	53	37	67	88	1785	1804	1745	8.0	17.4	0.64
22	5002	5141	289	218	20.4	0.754	69	74	75	84	1711	1693	1647	9.7	19.8	0.62
27	7497	7783	275	207	10.4	0.752	80	93	72	85	1768	1790	1724	9.3	10.1	0.04
32	3002	3109	275	215	52.3	0.781	61	61	64	85	1728	1670	1612	9.3	50.5	2.55
37	5000	5152	287	223	40.9	0.775	67	84	69	85	1723	1689	1639	9.3	39.7	1.85
42	7299	7582	275	205	27.9	0.743	93	101	75	84	1881	1891	1820	9.7	28.9	0.95

SECOND PARAMETRIC TEST RESULTS

REACTOR D

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	22-Mar	1410	1525	23.1	+-	4.8	625	512	239	312	2.771	5.425	7.557	0.052	67	
11	7.5	620	0.8	22-Mar	1630	1733	83.8	+-	9.5	624	570	601	316	3.063	4.319	5.468	0.132	137	
12	7.5	620	0.8	23-Mar	1001	1106	96.6	+-	10.9	624	574	600	297	3.284	4.475	5.593	0.1708	128	36
14	7.5	620	1.0	23-Mar	1330	1430	160.0	+-	9.0	624	573	602	301	3.301	4.440	5.558	0.2188	148	22
22	5	700	0.8	24-Mar	1016	1123	59.7	+-	3.9	705	622	403	318	2.827	4.473	5.696	0.122	106	36
41	7.5	750	0.6	24-Mar	1340	1459	47.1	+-	14.1	753	687	598	314	2.974	4.094	5.229	0.1326	143	80
Slip NH3																			
7	5	620	0.8	8-Apr	1309	1410	1.2	+-	0.1	623	545	382	366	5.776	7.505	9.106	0.1377	148	164
12	7.5	620	0.8	14-Apr	0941	1048	29.6	+-	7.4	627	576	597	324	4.402	5.416	6.501	0.1898	46	38
14	7.5	620	1.0	14-Apr	1111	1215	54.8	+-	8.6	627	576	602	280	2.926	4.589	5.418	0.2103	34	26
22	5	700	0.8	15-Apr	1016	1137	3.2	+-	0.5	705	622	399	260	2.201	4.284	5.060	0.1004	36	30
27	7.5	700	0.8	15-Apr	1400	1510	8.9	+-	0.2	705	644	588	264	2.189	3.851	4.494	0.1416	48	36
42	7.5	750	0.8	18-Apr	1011	1129	12.7	+-	1.4	705	688	599	338	4.322	5.166	5.668	0.1932	67	38
Outlet SO3 (Cat. Layer 4)																			
2	3	620	0.8	3-Mar	1024	1146	2.6	+-	1.0	625	508	240	260	1.586	4.182	6.414	0.0575	14	12
17	3	700	0.8	23-Mar	1303	1410	21.0	+-	1.4	709	582	240	308	2.758	4.613	6.176	0.071	32	38
22	5	700	0.8	2-Feb	1342	1442	22.1	+-	3.9	705	611	400	302	3.074	4.892	5.901	0.1145	66	64
27	7.5	700	0.8	2-Mar	0958	1119	9.2	+-	1.9	704	647	600	279	2.720	4.343	5.090	0.159	59	47
32	3	750	0.8	2-Feb	1333	1447	26.4	+-	3.4	766	611	240	272	2.621	5.444	6.688	0.082	30	25
37	5	750	0.8	24-Feb	1356	1504	23.7	+-	1.2	763	680	400	302	2.435	4.778	5.079	0.1154	47	48
42	7.5	750	0.8	1-Mar	1005	1112	23.9	+-	1.6	746	680	600	284	2.349	4.019	4.708	0.1684	78	62

REACTOR D CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. out (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	239	277	267	206	20.0	0.771	78		65							
11	601	645	294	207	59.1	0.708	147		90							
12	600	644	277	253	88.7	0.915	137	39	29							
14	602	646	282	324	147.2	1.149	159	24	-36							
22	403	435	289	286	54.8	0.989	114	38	9							
41	598	641	294	209	44.2	0.711	153	86	89							
7	382	433	324	341	0.9	1.050	168	176	-9							
12	597	642	304	283	25.6	0.930	49	41	27							
14	602	634	263	314	50.0	1.192	36	26	-44							
22	399	418	231	238	3.0	1.028	38	31	-2							
27	588	611	232	218	8.6	0.941	50	36	18							
42	599	619	321	290	11.2	0.903	59	39	37							
2	240	277	217	226	2.4	1.045	16	14	-5	85	2029	1896	1644	9.3	2.1	-0.44
17	240	265	277	279	19.1	1.010	35	42	3	83	1914	1742	1576	10.1	17.3	0.46
22	400	427	271	270	19.8	0.996	70	68	6	84	1820	1629	1527	9.7	18.5	0.58
27	600	628	254	232	8.5	0.912	62	49	27	84	1887	1746	1668	9.7	8.1	-0.09
32	240	261	230	244	22.8	1.060	33	27	-9	83	1856	1604	1476	10.1	21.0	0.74
37	400	408	264	273	21.4	1.033	48	49	-3	85	2032	1831	1797	9.3	21.0	0.65
42	600	625	268	248	22.5	0.926	81	65	25	86	1934	1825	1761	8.9	21.6	0.73

SECOND PARAMETRIC TEST RESULTS

REACTOR E

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	25-Mar	1357	1511	7.1	+-	4.1	627	497	238	293	2.217	3.025	3.838	0.049	79	133
11	7.5	620	0.8	25-Mar	1037	1142	38.7	+-	13.0	623	555	600	315	2.689	2.332	3.273	0.1313	120	90
12	7.5	620	0.8	30-Mar	1335	1439	54.2	+-	8.5	627	562	599	365	5.583	5.278	5.857	0.2098	119	55
14	7.5	620	1.0	30-Mar	1015	1118	122.7	+-	5.0	625	562	600	367	4.951	4.723	4.993	0.2672	87	8
22	5	700	0.8	31-Mar	1951	1052	23.9	+-	1.1	703	600	400	358	6.978	6.832	7.577	0.137	42	25
41	7.5	750	0.6	31-Mar	1324	1420	25.5	+-	1.4	741	660	600	341	4.692	4.333	4.874	0.1473	146	98
Slip NH3																			
7	5	620	0.8	7-Apr	1344	1444	0.8	+-	0.2	625	529	400	334	3.150	3.446	4.344	0.1275	13	20
12	7.5	620	0.8	4-Apr	1002	1101	1.2	+-	0.2	626	566	599	314	2.836	3.384	3.511	0.1828	15	21
14	7.5	620	1.0	4-Apr	1350	1444	5.8	+-	1.4	627	564	597	314	2.718	2.750	3.430	0.228	5	6
22	5	700	0.8	5-Apr	1353	1444	1.0	+-	0.1	706	603	401	331	3.479	3.698	4.606	0.127	31	32
27	7.5	700	0.8	13-Apr	1115	1434	0.5	+-	0.1	704	633	600	282	2.957	2.698	3.197	0.162	54	60
42	7.5	750	0.8	6-Apr	1009	1104	1.0	+-	0.2	756	685	595	325	3.096	3.078	3.738	0.1845	41	39
Outlet SO3 (Cat. Layer 4)																			
2	3	620	0.8	17-Mar	1014	1214	11.3	+-	1.1	625	523	240	331	2.572	2.678	3.493	0.0766	96	92
17	3	700	0.8	14-Mar	1544	1653	16.6	+-	0.7	700	594	244	300	3.290	3.194	4.171	0.0703	110	102
22	5	700	0.8	14-Mar	1336	1441	21.9	+-	1.1	708	622	400	306	3.206	3.006	3.631	0.1168	104	94
27	7.5	700	0.8	17-Mar	1428	1541	19.2	+-	1.7	708	640	583	282	2.449	1.973	2.786	0.1688	81	72
32	3	750	0.8	16-Mar	1027	1138	30.2	+-	1.4	755	623	240	339	3.026	2.975	3.943	0.078	123	110
37	5	750	0.8	16-Mar	1324	1438	30.0	+-	1.1	755	650	389	323	3.093	2.678	3.436	0.1202	111	94
42	7.5	750	0.8	16-Mar	1543	1648	31.1	+-	1.7	756	685	601	310	3.262	2.689	3.374	0.1784	117	93

REACTOR E CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. out (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	238	249	280	159	7.1	0.569	83	139	124							
11	600	632	321	169	40.1	0.528	126	95	155							
12	599	622	372	271	47.3	0.729	124	67	106							
14	600	610	372	345	111.0	0.926	88	8	34							
22	400	422	362	265	18.8	0.733	44	26	102							
41	600	620	349	190	23.6	0.545	150	101	162							
7	400	422	328	247	0.8	0.751	14	21	86							
12	599	603	305	236	1.2	0.776	15	21	73							
14	597	620	313	298	5.9	0.943	5	6	24							
22	401	423	327	245	1.0	0.750	33	34	86							
27	600	620	288	209	0.5	0.727	56	62	83							
42	595	618	325	240	1.0	0.738	43	40	90							
2	240	251	329	247	11.5	0.751	100	98	87	85	1843	1876	1793	9.3	11.0	0.10
17	244	258	302	223	16.4	0.740	116	108	83	82	1713	1695	1602	10.5	15.5	0.31
22	400	414	309	226	21.9	0.731	108	97	88	83	1718	1717	1658	10.1	21.1	0.66
27	583	609	289	211	20.3	0.729	85	75	82	84	1831	1935	1853	9.7	19.4	0.53
32	240	264	340	252	30.2	0.740	130	116	93	83	1807	1810	1712	10.1	28.6	1.08
37	389	406	330	239	30.5	0.724	116	98	96	84	1864	1887	1809	9.7	29.3	1.08
42	601	624	320	230	31.6	0.718	122	97	95	84	1805	1836	1767	9.7	30.5	1.17

SECOND PARAMETRIC TEST RESULTS

REACTOR F

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
1	3	620	0.6	25-Mar	1035	1142	12.9	+-	0.2	622	600	245	313	2.721	2.880	5.092	0.0534	90	76
11	7.5	620	0.8	25-Mar	1403	1512	38.6	+-	2.6	626	558	594	293	2.234	2.266	3.262	0.121	119	94
12	7.5	620	0.8	30-Mar	1333	1434	82.7	+-	3.8	625	560	599	366	5.643	5.348	6.677	0.2104	175	85
14	7.5	620	1.0	30-Mar	1010	1125	105.8	+-	11.9	625	583	599	367	4.714	4.514	5.744	0.2672	151	20
22	5	700	0.8	24-Mar	1350	1502	38.3	+-	1.7	706	612	400	311	2.761	2.682	4.069	0.1205	106	81
41	7.5	750	0.8	31-Mar	0953	1057	46.8	+-	5.8	755	660	594	358	7.099	6.724	8.038	0.148	178	120
42	7.5	750	0.8	24-Mar	1028	1133	51.0	+-	8.1	754	677	600	316	2.800	2.704	3.553	0.1823	126	79
Slip NH3																			
7	5	620	0.8	8-Apr	1316	1421	0.9	+-	0.2	624	630	397	366	6.401	5.835	8.927	0.138	57	40
12	7.5	620	0.8	14-Apr	0915	1108	3.8	+-	0.1	626	560	600	325	4.672	3.991	6.668	0.1895	44	43
14	7.5	620	1.0	14-Apr	1328	1430	18.7	+-	3.4	625	561	597	276	2.557	2.212	4.880	0.2014	13	11
22	5	700	0.8	13-Apr	0955	1110	0.5	+-	1.0	708	592	400	338	4.500	3.455	6.932	0.1298	71	57
27	7.5	700	0.8	13-Apr	1414	1520	2.4	+-	0.8	705	622	601	275	2.560	1.837	4.739	0.1584	78	63
42	7.5	750	0.8	7-Apr	1348	1445	3.1	+-	0.8	708	657	594	329	3.150	2.730	5.378	0.1885	64	41
Outlet SO3 (Cat. Layer 4)																			
2	3	620	0.8	16-Mar	1012	1122	7.9	+-	0.7	623	606	240	339	3.020	2.655	3.828	0.0778	87	77
17	3	700	0.8	16-Mar	1340	1440	18.6	+-	0.3	708	555	240	323	3.093	2.456	3.640	0.0743	103	89
22	5	700	0.8	14-Mar	1332	1445	13.8	+-	0.7	706	610	400	306	3.197	2.951	3.631	0.1168	87	62
27	7.5	700	0.8	14-Mar	1538	1719	12.9	+-	0.6	704	638	605	299	3.209	2.925	3.408	0.1723	79	42
32	3	750	0.8	15-Mar	1650	1756	7.9	+-	0.8	755	620	246	267	2.425	2.162	2.928	0.062	85	87
37	5	750	0.8	15-Mar	1407	1531	9.8	+-	1.5	757	656	400	319	2.303	1.974	2.619	0.1016	80	73
42	7.5	750	0.8	15-Mar	1059	1222	10.9	+-	0.4	756	681	597	271	2.609	2.275	2.941	0.1543	72	74

REACTOR F CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. out (ppmv)	NOx pred. out (ppmv)
1	245	279	310	169	13.0	0.544	103	87	145
11	594	627	293	158	38.1	0.539	126	99	138
12	599	655	373	272	71.9	0.729	191	93	106
14	599	647	372	345	96.9	0.930	163	22	33
22	400	433	312	233	39.0	0.747	115	66	84
41	594	654	368	193	37.1	0.525	194	132	179
42	600	629	318	235	61.8	0.741	132	83	87
7	397	499	380	269	0.8	0.708	72	50	116
12	600	712	339	245	3.6	0.722	52	51	89
14	597	696	281	261	19.5	0.929	15	13	25
22	400	499	359	251	0.5	0.699	89	71	113
27	601	708	286	204	2.6	0.714	92	74	86
42	594	695	337	246	3.1	0.730	76	48	96
2	240	256	346	251	8.1	0.726	93	82	100
17	240	256	334	240	19.2	0.717	110	95	99
22	400	413	310	226	13.8	0.729	90	64	89
27	605	622	304	221	13.0	0.726	81	43	88
32	246	256	271	195	8.3	0.721	89	91	79
37	400	414	325	197	10.4	0.608	83	76	132
42	597	619	276	200	11.3	0.725	76	77	80

Parametric Operating Condition	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
2	83	1805	1840	1722	10.1	7.5	-0.15
17	84	1854	1910	1788	9.7	17.9	0.46
22	83	1718	1723	1667	10.1	13.4	0.20
27	83	1715	1722	1676	10.1	12.6	0.15
32	86	1766	1848	1773	8.9	7.9	-0.05
37	86	1748	1848	1785	8.9	10.0	0.06
42	86	1734	1804	1740	8.9	10.9	0.12

SECOND PARAMETRIC TEST RESULTS

REACTOR G

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
				Intermediate Level NH3															
1	3	620	0.6	31-Mar	1330	1430	5.7	+-	3.4	628	480	242	339	4.692	3.638	5.860	0.058	154	149
11	7.5	620	0.8	1-Apr	1035	1145	19.3	+-	0.1	625	546	600	355	3.679	2.728	3.724	0.1483	150	133
12	7.5	620	0.8	1-Apr	1340	1440	37.5	+-	3.7	628	548	600	343	3.665	2.724	3.863	0.1983	103	80
14	7.5	620	1.0	4-Apr	1002	1103	68.1	+-	3.8	676	655	402	309	2.838	1.928	3.158	0.1825	77	55
22	5	700	0.8	5-Apr	1010	1102	14.4	+-	1.0	705	598	401	325	3.098	2.023	3.410	0.124	63	60
41	7.5	750	0.6	5-Apr	1400	1452	19.2	+-	1.5	757	658	601	333	3.479	2.322	3.636	0.1395	133	139
				Slip NH3															
7	5	620	0.8	15-Apr	1022	1138	0.7	+-	0.4	625	529	400	261	2.214	1.404	4.496	0.1	66	65
12	7.5	620	0.8	15-Apr	1405	1505	1.0	+-	0.3	628	557	591	254	2.189	1.385	4.062	0.1415	74	70
14	7.5	620	1.0	19-Apr	0955	1045	15.4	+-	4.3	624	555	600	352	2.955	2.079	4.747	0.256	16	8
22	5	700	0.8	18-Apr	1450	1554	0.8	+-	0.6	704	600	400	322	2.958	2.438	5.915	0.117	102	91
27	7.5	700	0.8	19-Apr	1419	1522	2.0	+-	1.2	707	624	589	292	2.228	1.423	4.325	0.1665	61	103
42	7.5	750	0.8	18-Apr	1016	1128	2.1	+-	1.4	756	685	593	337	3.384	2.488	5.134	0.191	89	80
				Outlet SO3 (Cat. Layer 4)															
2	3	620	0.8	22-Mar	1017	1129	7.1	+-	1.4	624	493	241	308	2.884	2.268	3.439	0.0715	63	53
17	3	700	0.8	22-Mar	1311	1415	21.4	+-	2.0	707	538	240	303	2.925	2.130	3.314	0.0707	59	45
22	5	700	0.8	23-Mar	0923	1034	21.0	+-	1.3	704	599	400	302	3.289	2.616	3.196	0.1152	66	58
27	7.5	700	0.8	22-Mar	1535	1700	18.8	+-	0.8	707	626	590	314	2.855	2.223	2.706	0.177	79	65
32	3	750	0.8	21-Mar	1612	1716	32.1	+-	4.1	753	640	241	316	3.239	2.686	3.452	0.0735	77	125
37	5	750	0.8	21-Mar	1407	1525	22.5	+-	6.4	758	644	400	303	2.830	2.309	2.954	0.115	75	78
42	7.5	750	0.8	21-Mar	1050	1205	21.1	+-	1.3			600	298	2.855	2.223	2.889		65	

REACTOR G CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. out (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO2 corr. out (ppmv)	SO3 pred. in (ppmv)	SO3 corr. out (ppmv)	SO2 OX rate (%)
1	242	277	381	186	5.5	0.514	176	171	179							
11	600	635	374	191	19.6	0.511	159	141	187							
12	600	640	362	256	38.1	0.708	110	85	111							
14	402	430	324	352	72.2	1.083	82	69	-20							
22	401	433	344	239	15.2	0.695	68	65	110							
41	601	648	355	180	19.9	0.506	143	150	179							
7	400	475	272	194	0.8	0.711	78	77	82							
12	591	684	265	185	1.1	0.700	86	81	83							
14	600	698	369	330	16.2	0.895	19	9	45							
22	400	492	331	226	0.8	0.684	126	112	109							
27	589	692	304	219	2.2	0.719	72	121	90							
42	593	692	354	249	2.2	0.704	104	93	110							
2	241	257	319	230	7.4	0.721	67	67	93	85	1825	1899	1780	9.3	6.9	-0.13
17	240	256	316	228	22.4	0.721	63	48	93	85	1803	1880	1772	9.3	21.0	0.66
22	400	413	313	223	21.4	0.711	68	60	95	83	1812	1851	1792	10.1	20.8	0.59
27	590	606	325	232	19.6	0.715	81	67	97	85	1807	1885	1837	9.3	19.1	0.53
32	241	252	328	236	32.7	0.725	80	130	94	84	1664	1693	1622	9.7	31.3	1.33
37	400	414	312	223	23.4	0.714	78	81	93	84	1737	1804	1741	9.7	22.6	0.74
42	600	622	308	221	22.0	0.720	67		90	84	1700	1773	1710	9.7	21.2	0.67

THIRD PARAMETRIC DATA SPREADSHEET KEY

Column Heading	Description
Parametric Operation Condition	Arbitrarily assigned number to particular, flow, temperature and NH_3/NO_x combination
Reactor Flow Rate	Nominal reactor flowrate in SCFM/1000 where T = 0 °F, P = 1.0 ATM
Reactor Inlet Temp.	Nominal parametric condition operating temperature °F
NH_3/NO_x Ratio	Nominal parametric condition NH_3 - to - NO_x ratio
Date	Date that sample was taken
Start time	Start time of three triplicate sample runs
End time	End time of three triplicate sample runs
Conc.	Constituent concentration, ppm by volume, based on wet phase gas (10% by volume moisture)
ρ	Standard deviation of measurement based on triplicate runs
TEMP gas in	Process gas temperature in °F measured at the reactor inlet
TEMP gas out	Process gas temperature in °F
Flow measured (scfm)	measured average flow from archive (0 °C 1 atm.)
NO_x inlet (ppmv)	measured average pilot plant inlet NO_x, wet, not O_2 corrected, from archive
O_2 inlet (%)	measured average plant inlet O_2 from archive, wet
O_2 rxr inlet (%)	measured reactor inlet O_2 (at verturi) wet, from archive
O_2 rxr outlet (%)	measured average reactor outlet O_2 wet, from archive
NH_3 actual (Kg/hr)	measured average NH_3 injection rate from mass flow controller, from archive
NO_x NOVA (ppmv)	NO_x measured by NOVA portable instrument at location of ammonia sample
NO_x out measured (ppmv)	measured average outlet NO_x concentration, wet, not O_2 corrected, from archive
FLOW corrected (scfm)	corrected reactor flow at inlet O_2 concentration (using post-test calibrations)
FLOW corrected out (scfm)	reactor flow corrected to outlet O_2 concentration (calculated outlet flow w/inleak)
NO_x corrected in (ppmv)	reactor inlet NOx corrected to inlet O_2 concentration
NH_3 actual (ppmv)	calculated actual NH_3 concentration corrected to inlet O_2 concentration, wet
NH_3/SO_3 concentration corrected	manual NH_3 concentration corrected to inlet O_2, measured at exit to catalyst layer #1, or at reactor exit for SO_3
NH_3 /NO_x ratio actual	actual NH_3/NO_x ratio using corrected NO_x and NH_3 values at reactor inlet O_2 concentration
NO_x out corrected (ppmv)	measured outlet NO_x corrected to inlet O_2
NO_x out pred (ppmv)	predicted outlet NO_x w/ 100% NH_3 reaction, corrected to inlet O_2 concentration
LOAD unit #5 (MW)	average unit load from archive
SO_2 plant inlet (ppmv)	average inlet SO_2 to pilot plant, wet, not O_2 corrected from archive
SO_2 corrected in (ppmv)	average reactor inlet SO_2 corrected to rxr inlet O_2
SO_3 measured in (ppmv)	SO_3 concentration measured at the reactor inlet
ρ	standard deviation in inlet SO_3 concentration
SO_3 corrected in (ppmv)	SO_3 concentration corrected to reactor outlet O_2 concentrations
SO_2 Ox rate (%)	oxidation rate of SO_2 based on corrected SO_2 and SO_3 outlet measured (as % of SO_2 oxidized)

THIRD PARAMETRIC TEST RESULTS

REACTOR A

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	5	620	0.8	7/25/94	1014	1104	36.6	+-	2.3	646	620	5000	360	3.052	3.631	3.4208	1.7673	130	63
14	7.5	620	1.0	7/25/94	1352	1440	78.5	+-	2.7	650	630	6496	358	2.693	3.554	3.216	2.885	108	16
21	5	705	0.6	7/26/94	0950	1045	23.8	+-	5.4	705	680	4997	350	5.435	6.103	6.059	1.266	194	120
22	5	705	0.8	7/26/94	1328	1420	32.5	+-	2.9	707	680	5002	379	3.517	4.051	3.965	1.864	133	77
24	5	705	1.0	7/29/94	0950	1046	47.3	+-	8.5	708	682	4998	360	6.077	7.005	6.962	2.289	108	21
27	7.5	705	0.8	7/28/94	1310	1410	42.8	+-	1.7	704	680	6169	311	3.959	4.614	4.402	1.889	127	66
37	5	760	0.8	7/29/94	1322	1420	34.4	+-	3.0	756	685	4984	332	4.253	4.428	4.387	1.623	148	72
Slip NH3																			
2	3	620	0.8	6/27/94	0942	1114	2.1	+-	0.3	630	610	3000	383	4.341	5.133	4.932	1.07	89	
6	5	620	0.6	6/29/94	0950	1132	1.7	+-	0.3	630	610	5000	367	4.341	5.133	4.932	1.282	163	121
7	5	620	0.8	6/29/94	1226	1349	2.1	+-	0.7	631	611	5000	368	3.249	3.953	3.755	1.8096	96	56
9	5	620	1.0	8/8/94	1005	1122	4.1	+-	0.7	623	605	5003	295	4.609	5.532	5.712	1.824	36	7
14	7.5	620	1.0	8/8/94	1410	1523	4.9	+-	0.7	622	605	6105	215	4.682	5.611	5.549	1.627	27	5
21	5	705	0.6	6/24/94	0933	1102	1.4	+-	0.2	707	681	4996	331	2.304	3.265	3.028	1.199	147	0
22	5	705	0.8	6/27/94	1316	1614	2.3	+-	0.3	708	680	5010	360	3.223	3.879	3.243	1.772	99	0
24	5	705	1.0	8/10/94	1003	1117	2.0	+-	0.6	706	633	5007	296	6.321	6.573	6.442	1.834	78	33
26	7.5	705	0.6	6/28/94	0943	1120	1.9	+-	0.6	707	687	6087	365	3.526	4.409	4.084	1.565	164	0
27	7.5	705	0.8	1/6/00	1345	1517	2.5	+-	0.2	703	682	5165	336	1.920	3.090	2.784	1.984	95	0
29	7.5	705	1.0	8/10/94	1342	1504	2.8	+-	0.4	706	687	6063	330	2.283	3.342	2.928	2.483	61	35
36	5	760	0.6	8/9/94	1005	1113	1.9	+-	0.6	756	730	4991	399	4.945	4.863	5.102	1.44	219	169
37	5	760	0.8	8/9/94	1328	1439	1.8	+-	0.4	756	732	4999	386	3.798	4.265	4.376	1.902	139	90
39	5	760	1.0	8/11/94	0952	1108	2.1	+-	0.2	755	730	5011	302	4.821	5.496	5.219	1.867	60	26
Outlet SO3 (Cat. Layer 4)																			
32	5	700	0.8	9/14/94	1000	1120	16.5	+-	1.0	705	680	5011	317	2.023	2.621	2.509	1.594		95
37	5	760	0.8	9/14/94	1345	1500	30.3	+-	1.7	760	728	4996	313	2.230	2.884	2.729	1.766		105

REACTOR A CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)										
7	6000	4940	348	274	36.3	0.786	128	62	80										
14	6498	6373	341	344	76.1	1.008	106	16	4										
21	4997	4982	335	198	19.7	0.586	193	120	143										
22	5002	4977	367	289	30.6	0.785	132	77	85										
24	4998	4983	338	355	36.8	1.050	108	21	-10										
27	6169	6080	299	237	39.0	0.793	125	66	67										
37	4984	4972	329	252	31.7	0.767	148	72	81										
2	3000	2982	365	292	1.9	0.800	88		79	< ESTIMATED OPERATING DATA									
6	5000	4937	350	199	1.5	0.568	161	119	155										
7	5000	4943	353	280	2.0	0.793	95	55	79										
9	5003	5062	278	282	3.5	1.014	36	7	2										
14	6105	6120	204	206	4.2	1.011	27	5	2										
21	4998	4930	314	186	1.4	0.592	145	0	132										
22	5010	4831	347	274	2.2	0.790	95	0	78										
24	5007	4962	291	284	1.6	0.975	77	33	13										
26	6087	5970	337	199	1.8	0.591	161	0	142										
27	5165	5078	315	297	2.5	0.943	93	0	24										
29	6083	5924	311	317	2.7	1.019	60	34	0										
36	4991	5035	399	223	1.7	0.561	221	170	180										
37	4999	5035	376	295	1.7	0.784	140	91	87										
39	5011	4923	289	287	1.8	0.992	59	26	8										
					SO3 corr. out (ppmv)					LOAD unit #5 (MW)	SO2 plant inlet (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
32	5011	4981	307	246	17.0	0.802		94	66	87	1978		2020	0.2	+-	0.0	0.2	0.83	
37	4996	4954	302	274	30.8	0.906		104	34	87	1946		1959	0.2	+-	0.1	0.2	1.56	

THIRD PARAMETRIC TEST RESULTS

REACTOR B

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	6	620	0.8	7/26/94	0945	1035	58.2	+-	8.4	625	600	4998	350	5.435	6.124	6.274	1.721	86	25
14	7.5	620	1.0	7/26/94	1324	1423	138.8	+-	30.2	628	601	7429	380	3.663	3.955	3.665	3.495	139	0
21	6	705	0.6	7/25/94	1348	1445	18.4	+-	0.4	710	680	5002	358	2.837	3.330	3.062	1.285	106	127
22	6	705	0.8	7/25/94	1017	1105	41.9	+-	6.2	706	664	4999	359	3.052	3.512	3.237	1.765	52	53
24	6	705	1.0	8/1/94	1018	1113	98.4	+-	5.9	706	673	5006	394	5.622	2.994	6.018	2.446	66	0
27	7.5	705	0.8	7/28/94	1005	1059	81.5	+-	10.5	709	644	6780	373	6.381	6.498	6.88	2.49	148	48
37	6	750	0.8	8/1/94	1428	1528	48.2	+-	3.9	755	721	5002	371	2.577	3.107	2.822	1.776	86	80
Slip NH3																			
2	3	620	0.8	7/11/94	1026	1148	1.5	+-	1.3	624	592	3003	331	2.367	3.058	3.039	0.978	57	47
6	6	620	0.6	7/11/94	1309	1426	0.9	+-	0.2	625	600	5005	319	1.832	2.285	1.951	1.15	118	112
7	6	620	0.8	7/12/94	1308	1419	BDL	+-		626	591	5011	317	6.352	6.883	7.501	1.559	65	51
9	6	620	1.0	7/13/94	1007	1118	3.2	+-	0.3	623	602	4998	348	6.080	6.334	5.880	2.158	4	3
14	7.5	620	1.0	8/26/94	0943	1111	11.3	+-	1.4	625	610	6498	360	6.854	7.149	8.154	3.125	34	13
21	6	705	0.6	8/18/94	1302	1415	1.1	+-	0.3	704	680	5018	355	5.123	5.558	6.573	1.281	210	136
22	6	705	0.8	7/13/94	1412	1524	BDL	+-		700	664	4998	325	4.742	5.055	5.249	1.595	72	53
24	6	705	1.0	8/29/94	0945	1058	3.3	+-	0.0	704	679	5003	350	2.789	3.328	4.580	2.166	14	0
26	7.5	705	0.6	8/12/94	1325	1441	1.1	+-	0.2	708	672	6493	335	4.429	5.051	4.664	1.573	158	124
27	7.5	705	0.8	8/31/94	0934	1028	1.7	+-	0.2	707	680	6387	301	1.877	2.426	3.955	1.874	84	51
29	7.5	705	1.0	8/26/94	1412	1505	4.9	+-	0.6	705	682	6499	354	4.158	5.109	6.554	2.857	45	9
36	6	750	0.6	8/11/94	1256	1415	1.1	+-	0.1	757	723	4998	283	2.474	6.061	2.298	1.35	66	65
37	6	750	0.8	8/9/94	1004	1119	0.9	+-	0.1	757	721	5004	398	4.881	5.258	5.171	1.951	106	80
39	6	750	1.0	8/9/94	1329	1445	1.8	+-	0.6	756	725	5006	385	4.048	4.478	4.260	2.399	20	10
Outlet SO3 (Cat. Layer 4)																			
32	6	700	0.8	9/16/94	1006	1119	4.5	+-	0.5	704	678	5000	326	1.765	2.184	3.464	1.651		72
37	6	750	0.8	9/16/94	1333	1439	6.6	+-	0.4	755	725	4994	303	1.567	1.941	3.361	2.287		76

REACTOR B CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)	LOAD unit #6 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
7	4998	5049	335	267	46.4	0.797	86	25	73								
14	7429	7305	374	364	131.4	0.975	137	0	16								
21	5002	4927	348	200	18.1	0.576	104	125	152								
22	4999	4922	350	273	40.7	0.782	51	52	82								
24	5006	6016	461	378	98.4	0.820	79	0	90								
27	6780	6963	370	284	65.7	0.769	152	49	91								
37	5002	4924	360	276	47.9	0.763	85	59	91								
2	3003	3000	319	255	1.5	0.800	57	47	69								
6	5005	4917	311	178	0.9	0.571	114	110	137								
7	5011	5203	303	241		0.794	67	53	67								
9	4998	4848	342	334	2.6	0.977	4	3	14								
14	6498	7006	352	372	8.7	1.056	37	14	-13								
21	5018	5371	345	198	0.9	0.572	225	146	151								
22	4998	5060	319	247		0.775	73	54	76								
24	5003	5384	340	335	3.2	0.987	15	0	11								
26	6493	6339	322	188	1.0	0.582	154	121	139								
27	6367	6938	292	228	1.8	0.780	92	56	69								
29	6499	7149	334	340	4.3	1.019	60	10	0								
36	4998	3992	228	209	0.9	0.916	53	52	23								
37	5004	4976	389	302	0.8	0.777	105	80	93								
39	5006	4941	376	371	1.7	0.988	20	10	11								
32	5000	5365	319	256	4.4	0.802		77	68	89	2003	2094	0.1	+-	0.0	0.1	0.20
37	4994	5396	297	355	6.5	1.193		82	-50	88	2001	2119	0.2	+-	0.1	0.2	0.30

THIRD PARAMETRIC TEST RESULTS

REACTOR C

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	5	620	0.8	8/14/94	1000	1053	36.1	+-	4.7	625	603	5014	386	4.614	4.490	5.574	1.794	81	21
14	7.5	620	1.0	8/14/94	1338	1431	71.7	+-	9.0	652	637	7493	324	2.087	2.261	3.736	3.01	92	24
21	5	705	0.8	8/3/94	1008	1104	19.9	+-	1.6	706	678	5005	381	6.034	5.858	6.893	1.307	175	86
22	5	705	0.8	8/3/94	1322	1420	26.6	+-	0.6	709	680	4999	358	2.743	2.784	4.002	1.766	93	46
24	5	705	1.0	8/5/94	0953	1047	63.9	+-	7.1	708	680	5005	370	3.484	3.654	4.737	2.303	53	15
27	7.5	705	0.8	8/2/94	1003	1106	44.4	+-	6.1	707	687	7007	379	4.619	4.644	6.088	2.607	128	49
37	5	750	0.8	8/2/94	1358	1457	30.2	+-	1.7	753	717	4992	376	4.567	4.582	5.947	1.85	112	43
Slip NH3																			
2	3	620	0.8	8/28/94	0956	1128	0.9	+-	0.0	638	606	3003	349	3.308	3.757	4.366	1.036	10	3
6	5	620	0.6	8/28/94	1342	1514	1.3	+-	0.1	641	620	5010	339	1.920	2.689	2.684	1.228	98	2
7	5	620	0.8	8/29/94	1005	1139	2.8	+-	0.4	630	611	5005	365	4.470	4.665	5.011	1.751	43	24
9	5	620	1.0	8/29/94	1230	1354	23.2	+-	3.0	631	612	4998	365	3.240	3.801	3.881	2.274	5	2
14	7.5	620	1.0	7/15/94	1320	1433	24.3	+-	1.3	629	616	7404	376	7.690	7.395	7.939	3.449	26	14
21	5	705	0.6	8/24/94	0928	1109	1.1	+-	0.1	706	680	4990	332	2.486	2.831	3.203	1.199	114	0
22	5	705	0.8	7/12/94	1008	1120	3.3	+-	0.4	706	676	4998	378	6.698	6.357	6.928	1.764	65	29
24	5	705	1.0	7/12/94	1314	1427	17.1	+-	2.4	706	668	4995	315	6.352	6.466	7.120	1.95	0	0
26	7.5	705	0.6	7/13/94	1013	1127	4.1	+-	0.1	708	685	7021	348	6.069	6.058	5.985	1.772	149	80
27	7.5	705	0.8	7/13/94	1414	1530	7.9	+-	0.7	705	684	7073	326	4.742	5.037	5.390	2.25	68	33
29	7.5	705	1.0	6/27/94	0943	1122	17.5	+-	3.6	705	684	7050	383	4.742	5.037	5.390	3.425	31	
36	5	750	0.6	7/11/94	1026	1146	1.5	+-	0.0	758	723	4994	334	2.424	2.783	3.371	1.21	112	83
37	5	750	0.8	6/27/94	1318	1514	3.3	+-	0.8	758	727	4997	380	3.296	4.676	3.885	1.771	71	2
39	5	750	1.0	7/11/94	1318	1431	10.4	+-	1.7	757	725	5005	323	1.832	2.129	2.790	1.997	7	7
Outlet SO3 (Cat. Layer 4)																			
32	5	700	0.8	9/15/94	1010	1122	14.0	+-	1.7	704	678	4998	302	1.997	2.019	3.406	1.561		54
37	5	750	0.8	9/15/94	1333	1444	24.7	+-	2.3	754	720	4999	300	1.821	1.847	3.305	1.549		57

REACTOR C CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	5014	5366	367	277	33.1	0.756	87	22	95
14	7493	8133	321	311	74.6	0.969	100	26	16
21	5005	5372	365	202	16.7	0.554	188	92	167
22	4999	5357	357	272	26.9	0.761	100	49	91
24	5005	5338	366	356	61.6	0.972	57	16	17
27	7007	7686	378	288	40.3	0.761	138	54	96
37	4992	5445	376	287	27.5	0.764	122	47	94
2	3003	3113	340	272	0.8	0.800	10	3	73
6	5010	5009	325	190	1.3	0.583	98	2	139
7	5005	5113	361	271	2.5	0.751	44	25	95
9	4998	5021	353	352	22.2	0.997	5	2	8
14	7404	7712	384	361	18.4	0.938	27	15	31
21	4990	5094	326	186	1.1	0.571	116	0	143
22	4998	5201	387	272	2.7	0.702	68	30	121
24	4995	5231	313	302	13.8	0.967	0	0	16
26	7021	6987	348	195	3.4	0.561	148	80	157
27	7073	7233	319	246	7.0	0.772	70	34	78
29	7050	7209	376	376	15.5	1.000	32		7
36	4994	5161	328	188	1.5	0.573	116	86	144
37	4997	4766	332	274	3.0	0.827	68	2	63
39	5005	5187	318	309	10.9	0.972	7	7	15

< ESTIMATED OPERATING DATA

	SO3 corr. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
32	13.7	88	1997	2106	0.1	+-	0.0	0.1	0.64
37	24.3	88	1999	2127	0.2	+-	0.1	0.2	1.13

THIRD PARAMETRIC TEST RESULTS

REACTOR D

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	6	620	0.8	7/19/94	0929	1027	105.0	+-	17.1	626	551	394	326	4.345	7.014	6.616	0.124	122	14
14	7.5	620	1.0	7/19/94	1257	1402	155.0	+-	15.2	624	571	602	285	2.763	5.523	4.978	0.208	135	16
21	6	705	0.8	7/20/94	1002	1053	50.6	+-	6.0	705	620	399	325	1.806	5.747	5.119	0.09	141	35
22	6	705	0.8	7/20/94	1320	1410	78.1	+-	3.1	705	619	401	313	1.684	5.706	5.239	0.12	92	14
24	6	705	1.0	7/21/94	0947	1057	120.4	+-	7.7	707	622	400	300	1.788	5.606	4.935	0.146	70	4
27	7.5	705	0.8	7/22/94	1008	1105	112.7	+-	19.9	706	646	601	361	2.626	8.799	7.471	0.212	159	0
37	6	750	0.8	7/21/94	1312	1420	100.8	+-	11.5	756	656	402	324	3.469	6.212	5.701	0.154	98	4
Slip NH3																			
2	3	620	0.8	7/15/94	1324	1430	9.3	+-	0.9	622	525	240	364	4.349	8.839	8.787	0.083	3	16
6	6	620	0.6	8/26/94	1032	1145	4.4	+-	0.2	625	535	400	360	5.650	9.419	9.709	0.1005	127	34
7	6	620	0.8	8/25/94	1131	1227	13.8	+-	0.6	625	538	400	343	4.613	7.996	8.289	0.1187	39	11
9	6	620	1.0	8/29/94	0941	1058	66.5	+-	1.5	623	530	400	350	2.789	7.163	7.480	0.152	22	10
14	7.5	620	1.0	8/29/94	1349	1455	87.8	+-	2.8	625	563	601	340	2.585	6.147	6.265	0.224	59	19
21	6	705	0.6	8/19/94	1317	1436	2.4	+-	0.1	705	600	400	309	2.331	6.610	6.619	0.0863	73	30
22	6	705	0.8	8/10/94	1020	1120	8.1	+-	0.4	705	598	401	298	6.304	8.918	9.157	0.113	33	6
24	6	705	1.0	8/10/94	1358	1501	35.6	+-	0.3	705	593	400	326	2.329	6.626	6.646	0.159	13	6
26	7.5	705	0.6	8/19/94	0936	1038	6.8	+-	1.1	706	630	583	347	5.854	8.195	8.853	0.143	163	46
27	7.5	705	0.8	9/9/94	1019	1124	19.6	+-	0.3	707	630	599	352	2.350	3.007	4.234	0.2108	64	16
29	7.5	705	1.0	9/9/94	1324	1428	52.7	+-	5.8	706	630	600	348	2.305	2.955	4.294	0.259	45	10
36	6	750	0.6	9/12/94	0939	1051	1.7	+-	0.1	755	647	400	289	1.473	2.850	4.446	0.0836	139	45
37	6	750	0.8	9/12/94	1319	1429	3.2	+-	0.2	755	647	400	287	1.378	2.761	4.326	0.1095	88	36
39	6	750	1.0	9/13/94	1113	1212	13.6	+-	1.5	755	639	403	331	2.169	2.985	4.393	0.1637	28	7
REPEAT SLIPS																			
2	3	620	0.8	9/26/94	1020	1131	4.1	+-	0.8	621	517	239	363	3.992	5.024	4.606	0.0848	55	11
7	6	620	0.8	9/26/94	1328	1433	14.1	+-	1.8	624	553	400	332	5.807	6.018	7.038	0.136	75	20
22	6	705	0.8	9/27/94	0920	1031	4.3	+-	0.1	705	614	402	369	5.631	6.012	6.776	0.1487	71	36
Outlet SO3 (Cat. Layer 4)																			
32	6	700	0.8	9/19/94	1013	1129	8.2	+-	0.8	708	619	400	332	2.170	2.902	3.576	0.132		36
37	6	750	0.8	9/19/94	1333	1504	23.0	+-	4.4	756	661	405	308	2.604	3.258	3.916	0.123		24

REACTOR D CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	394	383	274	244	81.6	0.890	119	14	35
14	602	582	242	268	133.3	1.106	130	15	-20
21	399	383	258	175	42.9	0.678	135	34	87
22	401	389	248	232	66.4	0.935	89	14	21
24	400	383	240	283	103.0	1.176	67	4	-37
27	601	542	242	273	76.4	1.127	143	0	-25
37	402	389	273	287	82.8	1.085	95	4	-18
2	240	239	268	213	6.3	0.800	3	16	57
6	400	410	272	195	2.8	0.718	130	35	81
7	400	410	272	230	10.0	0.844	40	11	47
9	400	409	266	294	51.1	1.106	23	10	-23
14	601	606	274	289	55.9	1.052	59	19	-9
21	400	400	238	167	1.9	0.701	73	30	74
22	401	409	243	218	4.1	0.897	34	6	29
24	400	398	251	308	28.4	1.226	13	6	-51
26	583	615	293	190	4.8	0.647	172	48	107
27	599	643	340	272	19.6	0.802	69	17	72
29	600	648	334	334	52.8	1.001	49	11	6
36	400	439	269	162	1.7	0.602	152	49	110
37	400	438	267	212	3.2	0.795	98	39	59
39	403	438	317	315	13.6	0.992	30	8	9
2	239	231	341	273	3.6	0.800	63	11	74
7	400	429	327	263	11.7	0.804	80	21	69
22	402	424	360	286	3.6	0.798	75	38	79

	SO3 corr. out (ppmv)								LOAD unit #5 (MW)	SO2 plant inlet (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
32	7.9	0.801		37	69		86	1981		1972	0.4	+-	0.0	0.4	0.38			
37	21.8	0.792		26	67		85	1884		1857	0.5	+-	0.1	0.5	1.15			

THIRD PARAMETRIC TEST RESULTS

REACTOR E

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	6	620	0.8	7/19/94	1302	1358	175.0	+-	18.9	624	538	387	284	2.734	4.947	5.424	0.109	34	7
14	7.5	620	1.0	7/19/94	0925	1030	56.8	+-	5.1	626	566	603	326	3.924	5.268	5.841	0.237	80	5
21	6	705	0.6	8/2/94	1011	1112	9.9	+-	4.1	707	606	401	375	4.467	7.135	7.072	0.105	159	91
22	6	705	0.8	8/2/94	1407	1502	16.6	+-	1.3	704	585	400	371	4.503	7.673	7.369	0.143	64	24
24	6	705	1.0	8/3/94	1013	1104	58.1	+-	3.4	706	605	401	358	5.893	5.496	7.929	0.175	43	1
27	7.5	705	0.8	8/1/94	1032	1132	57.8	+-	4.3	706	638	600	394	5.515	7.996	7.274	0.226	113	34
37	6	760	0.8	8/1/94	1428	1526	15.5	+-	2.5	757	634	400	370	2.577	7.147	5.808	0.1423	87	33
Slip NH3																			
2	3	620	0.8	8/30/94	0941	1046	BDL	+-		625	499	243	316	2.433	10.244	8.072	0.0597	58	26
6	6	620	0.6	8/30/94	1235	1343	BDL	+-		625	532	400	313	2.205	7.493	6.181	0.0845	159	98
7	6	620	0.8	8/31/94	1023	1132	BDL	+-		623	537	401	312	1.988	7.752	5.737	0.087	83	68
9	6	620	1.0	8/31/94	1349	1458	BDL	+-		626	538	403	320	2.135	8.061	6.096	0.1215	50	35
14	7.5	620	1.0	9/2/94	1036	1145	24.6	+-	0.9	625	560	598	324	2.029	3.099	4.243	0.2365	24	6
21	6	705	0.6	8/24/94	1109	1217	BDL	+-		705	599	400	348	5.500	8.367	8.494	0.0879	167	
22	6	705	0.8	8/23/94	1020	1129	BDL	+-		705	599	403	337	5.500	8.367	8.494	0.1293	81	23
24	6	705	1.0	8/25/94	1410	1512	2.2	+-	0.2	704	601	398	293	1.914	8.251	6.639	0.1243	10	3
26	7.5	705	0.6	8/29/94	1104	1207	BDL	+-		704	625	602	347	2.691	6.180	5.240	0.1458	156	91
27	7.5	705	0.8	8/26/94	0920	1026	1.1	+-	0.1	702	622	602	359	6.796	9.402	9.019	0.206	59	26
29	7.5	705	1.0	8/25/94	1016	1124	10.5	+-	1.0	705	625	598	338	4.821	8.000	7.412	0.218	12	5
36	6	760	0.6	9/14/94	1002	1119	BDL	+-		755	648	400	320	2.032	2.447	3.277	0.0976	159	98
37	6	760	0.8	9/14/94	1353	1514	0.6	+-	0.2	755	648	401	310	2.219	2.620	3.385	0.1255	105	65
39	6	760	1.0	9/1/94	1107	1202	BDL	+-		755	648	400	338	2.368	7.180	5.946	0.1287	77	34
Outlet SO3 (Cat. Layer 4)																			
32	6	700	0.8	9/20/94	1009	1128	8.7	+-	1.2	708	591	400	340	1.985	2.386	3.924	0.1385		39
37	6	760	0.8	9/20/94	1331	1446	13.8	+-	0.6	755	630	398	331	1.829	2.188	3.763	0.1345		44

REACTOR E CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	387	399	250	218	166.1	0.874	35	7	38
14	603	626	300	304	49.6	1.013	83	5	2
21	401	399	314	203	7.6	0.645	158	91	116
22	400	391	300	277	12.3	0.924	63	23	28
24	401	476	367	338	50.0	0.920	51	1	38
27	600	668	331	292	41.8	0.881	107	32	45
37	400	365	278	276	11.9	0.990	61	30	8
2	243	202	183	146		0.800	48	22	39
6	400	365	225	125		0.555	145	89	103
7	401	348	217	168		0.774	72	59	52
9	403	350	219	233		1.064	43	30	-9
14	598	639	306	306	24.5	1.002	26	6	6
21	400	404	284	170		0.600	169		117
22	403	407	275	248		0.904	82	23	31
24	396	352	196	243	1.6	1.242	9	3	-43
26	602	566	281	188		0.668	147	86	97
27	602	583	293	265	0.7	0.904	57	25	33
29	598	572	272	282	7.6	1.039	11	5	-5
36	400	419	313	189		0.604	166	103	128
37	401	418	303	242	0.6	0.799	110	68	86
39	400	367	251	249		0.994	71	31	6
32	400	436	333	268	8.3	0.806		43	70
37	398	434	326	262	13.2	0.806		48	68

< ESTIMATED OPERATING DATA

	SO3 corr. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
32		88	2019	2088	1.7	+-	1.4	1.8	0.31
37		88	2032	2124	0.4	+-	0.1	0.4	0.60

THIRD PARAMETRIC TEST RESULTS

REACTOR F

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	5	620	0.8	7/22/94	1331	1429	100.5	+-	37.0	624	538	402	301	1.830	1.876	4.901	0.199	110	16
14	7.5	620	1.0	7/21/94	1313	1412	175.0	+-	8.7	627	584	580	324	2.661	2.468	4.339	0.227	136	
21	5	705	0.8	7/21/94	0948	1100	48.3	+-	2.3	706	601	399	321	1.788	1.883	4.046	0.084	111	
22	5	705	0.8	7/19/94	0939	1046	85.3	+-	1.2	706	602	401	318	3.489	3.673	5.653	0.1234	110	36
24	5	705	1.0	7/19/94	1310	1412	110.7	+-	13.0	712	608	399	286	2.769	2.686	4.613	0.138	87	2
27	7.5	705	0.8	7/20/94	1007	1056	111.9	+-	8.4	706	631	599	317	1.629	1.803	3.264	0.184	152	47
37	5	750	0.8	7/20/94	1322	1418	66.2	+-	7.3	757	640	400	313	1.684	1.968	4.278	0.12	104	39
Slip NH3																			
2	3	620	0.8	7/16/94	1259	1407	1.6	+-	0.6	623	505	241	365	4.349	4.321	7.060	0.084	31	34
6	5	620	0.8	9/2/94	0920	1030	0.8	+-	0.0	627	536	400	319	2.033	2.384	3.528	0.097	124	70
7	5	620	0.8	9/2/94	1409	1530	2.9	+-	0.4	627	540	402	335	2.650	2.994	4.117	0.1358	33	31
9	5	620	1.0	8/22/94	1333	1443	72.2	+-	26.4	624	534	400	323	2.597	4.507	6.030	0.16	4	4
14	7.5	620	1.0	8/23/94	0914	1015	82.7	+-	3.1	625	562	600	346	5.821	5.672	7.504	0.253	31	12
21	5	705	0.8	8/18/94	1007	1116	2.0	+-	0.8	704	601	402	362	7.108	7.205	8.955	0.101	114	62
22	5	705	0.8	9/1/94	0955	1101	0.9	+-	0.0	706	605	400	328	2.361	2.702	3.593	0.119	68	52
24	5	705	1.0	9/1/94	1355	1416	15.9	+-	2.4	706	607	402	351	2.638	2.886	3.777	0.1785	7	2
26	7.5	705	0.8	8/19/94	1310	1446	3.5	+-	1.4	705	628	596	306	2.203	3.669	4.519	0.1285	97	61
27	7.5	705	0.8	9/13/94	1009	1125	8.5	+-	0.3	705	636	592	334	2.241	2.333	2.988	0.2028	48	34
29	7.5	705	1.0	9/13/94	1342	1451	51.8	+-	3.6	705	640	600	330	2.082	2.264	2.768	0.254	16	10
36	5	750	0.8	8/18/94	1303	1407	2.8	+-	1.7	747	627	400	355	5.123	5.828	7.345	0.098	138	78
37	5	750	0.8	9/12/94	1009	1119	2.8	+-	1.3	753	638	400	260	5.071	4.688	6.974	0.0975	30	13
39	5	750	1.0	9/12/94	1334	1444	16.9	+-	1.4	755	630	400	337	4.455	4.115	6.144	0.1625	6	1
REPEAT SLIPS																			
2	3	620	0.8	8/24/94	0842	0942	37.7	+-	1.4	623	505	241	342	4.349	4.321	7.060	0.0787	1	
21	5	705	0.8	8/19/94	0923	1031	BDL	+-		704	603	400	358	6.250	6.530	8.214	0.0997	124	64
39	5	750	1.0	9/12/94	1100	1202	16.9	+-	1.4	756	651	400	292	1.453	2.235	1.467	0.144	13	2
Outlet SO3 (Cat. Layer 4)																			
32	5	700	0.8	9/21/94	1002	1115	1.6	+-	0.6	705	610	400	343	2.208	2.403	3.016	0.139		16
37	5	750	0.8	9/21/94	1328	1446	3.1	+-	1.1	756	651	399	314	2.189	2.306	2.891	0.13		13

REACTOR F CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	402	478	300	383	106.8	1.276	131	19	-76
14	580	645	327	303	180.2	0.926	151		30
21	399	450	319	163	51.3	0.510	125		160
22	401	455	316	238	82.6	0.763	125	41	83
24	399	448	289	268	113.2	0.927	98	2	28
27	599	648	314	238	119.3	0.757	165	51	81
37	400	455	308	232	70.0	0.753	118	44	81
2	241	288	366	292	1.5	0.800	37	41	79
6	400	427	313	188	0.8	0.599	132	75	129
7	402	429	329	262	2.9	0.796	35	33	72
9	400	441	289	310	66.2	1.070	4	4	-14
14	600	681	349	326	70.4	0.934	35	14	29
21	402	460	359	195	1.5	0.541	131	71	169
22	400	420	322	230	0.9	0.715	71	55	96
24	402	423	344	344	16.0	0.998	7	2	7
26	596	627	282	167	3.4	0.592	102	64	118
27	592	614	332	265	8.8	0.798	50	35	72
29	600	617	327	328	53.9	1.003	16	10	5
36	400	444	339	190	2.2	0.559	153	87	153
37	400	465	256	189	2.5	0.737	35	15	71
39	400	455	344	315	15.9	0.915	7	1	36
2	241	288	343	274	34.9	0.800	1		74
21	400	453	351	193		0.550	140	72	162
39	400	384	280	279	17.6	0.994	12	2	7

< ESTIMATED OPERATING DATA

	SO3 corr. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
32	1.6	87	1979	2045	0.3	+-	0.1	0.3	0.06
37	3.1	86	1803	1976	0.9	+-	1.1	0.9	0.11

THIRD PARAMETRIC TEST RESULTS

REACTOR G

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	6	620	0.8	8/8/94	1011	1128	56.1	+-	9.4	624	534	402	299	4.328	6.311	6.977	0.1123	72	9
14	7.5	620	1.0	8/8/94	1344	1502	100.0	+-	6.4	625	559	596	217	4.876	6.737	7.184	0.1635	63	2
21	6	705	0.6	8/5/94	1952	1048	21.3	+-	0.7	707	604	397	370	3.797	5.581	6.155	0.1043	131	93
22	6	705	0.8	8/3/94	1322	1416	36.9	+-	1.7	706	605	361	400	2.743	5.316	5.358	0.1367	81	28
24	6	705	1.0	8/5/94	1346	1447	77.7	+-	10.9	706	605	394	349	2.119	4.667	4.759	0.1618	61	0
27	7.5	705	0.8	8/4/94	1000	1053	75.3	+-	12.1	703	631	600	366	4.514	6.357	7.066	0.204	125	37
37	6	750	0.8	8/4/94	1333	1427	40.2	+-	2.8	755	651	403	324	2.087	5.617	5.438	0.1237	79	38
Slip NH3																			
2	3	620	0.8	8/23/94	0923	1029	BDL	+-		626	507	241	344	5.645	8.349	9.015	0.0793	34	16
6	6	620	0.6	8/23/94	1348	1501	BDL	+-		625	537	404	352	4.276	7.021	7.687	0.0968	120	85
7	6	620	0.8	8/24/94	0850	0949	2.0	+-	0.3	625	608	400	357	6.826	8.739	9.404	0.1357	28	21
9	6	620	1.0	9/8/94	1339	1502	86.3	+-	20.6	625	537	401	366	2.243	3.673	4.239	0.1764	11	1
14	7.5	620	1.0	9/14/94	1134	1255	40.2	+-	9.5	628	566	602	312	2.042	2.251	2.698	0.2313	35	36
21	6	705	0.6	9/9/94	1021	1125	0.7	+-	0.2	707	605	397	352	2.350	2.518	3.052	0.1078	97	77
22	6	705	0.8	9/9/94	1328	1437	2.0	+-	0.2	707	607	400	345	2.305	2.480	3.014	0.1416	31	21
24	6	705	1.0	9/19/94	0925	1040	52.6	+-	14.1	704	602	400	348	5.864	7.496	8.030	0.1718	8	0
26	7.5	705	0.6	9/12/94	0941	1111	1.2	+-	0.1	705	629	603	289	1.475	2.300	3.009	0.1296	144	106
27	7.5	705	0.8	9/12/94	1316	1423	2.8	+-	0.4	705	632	599	287	1.378	2.180	2.899	0.1683	87	64
29	7.5	705	1.0	8/19/94	1306	1428	38.2	+-	7.2	705	630	599	309	2.286	3.723	5.913	0.2276	13	3
36	6	750	0.6	9/13/94	0957	1103	1.2	+-	0.5	755	644	400	336	2.293	2.590	3.124	0.1022	132	102
37	6	750	0.8	9/13/94	1341	1449	2.0	+-	0.3	755	646	400	330	2.082	2.436	2.970	0.1343	61	89
39	6	750	1.0	8/22/94	1332	1444	30.0	+-	12.2	741	630	399	325	2.681	5.725	6.259	0.1595	2	0
														NOTE: O2 FOR RXR OUTLET ESTIMATED FROM HISTORICAL DATA					
Outlet SO3 (Cat. Layer 4)																			
32	6	700	0.8	9/22/94	1015	1127	2.0	+-	0.6	706	607	400	281	1.825	2.153	2.240	0.114		45
37	6	750	0.8	9/22/94	1320	1426	15.7	+-	3.0	756	650	399	292	2.203	2.612	2.699	0.12		55

REACTOR G CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
7	402	421	263	216	45.8	0.821	75	9	51								
14	596	615	192	199	79.2	1.039	65	2	-4								
21	397	412	332	203	18.2	0.613	136	97	132								
22	381	362	344	293	32.2	0.853	81	28	56								
24	394	396	302	318	70.5	1.053	61	0	-10								
27	600	631	325	263	61.3	0.810	131	39	67								
37	403	398	264	238	34.4	0.902	78	38	31								
2	241	254	283	227		0.800	36	17	61								
6	404	424	294	186		0.631	126	89	112								
7	400	423	309	263	1.4	0.851	30	22	51								
9	401	417	340	341	83.6	1.002	11	1	6								
14	602	617	309	298	41.9	0.964	36	37	17								
21	397	409	349	210	0.7	0.603	100	79	143								
22	400	412	342	274	2.1	0.801	32	22	73								
24	400	416	310	333	39.5	1.072	8	0	-16								
26	603	627	277	166	1.2	0.601	150	110	114								
27	599	622	276	218	2.9	0.791	90	67	82								
29	599	686	285	294	36.7	1.031	16	3	-3								
36	400	412	331	198	1.2	0.598	136	105	137								
37	400	412	324	260	2.1	0.803	63	92	69								
39	399	413	271	310	25.5	1.142	2	0	-32								
32	400	402	276	221	2.1	0.799		46	60	87	1919	2009	0.3	+-	0.1	0.3	0.09
37	399	401	286	233	16.0	0.815		56	57	88	1816	1855	0.4	+-	0.1	0.4	0.84

SO3 corr. out (ppmv)

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THIRD PARAMETRIC TEST RESULTS

REACTOR J

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx rxr inlet (ppmv)		O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	6	620	0.8	7/22/94	1013	1106	32.1	+-	1.2	625	582	403	280		4.427	5.341	0.1135	167	98
14	7.5	620	1.0	7/22/94	1332	1430	70.6	+-	6.8	628	584	597	283		3.917	4.611	0.212	166	78
21	6	705	0.6	9/2/94	0918	1009	16.0	+-	1.9	707	608	401	305		3.702	4.605	0.084	167	100
22	6	705	0.8	9/2/94	1040	1128	28.6	+-	1.4	708	608	404	309		3.686	4.578	0.128	115	51
24	6	705	1.0	9/2/94	1205	1254	41.5	+-	3.4	708	609	391	310		3.745	4.464	0.1593	78	13
27	7.5	705	0.8	9/2/94	1408	1458	43.8	+-	3.7	693	627	605	313		3.294	3.915	0.1945	150	57
Slip NH3																			
2	3	620	0.8	8/24/94	1244	1357	1.1	+-	0.2	623	561	240	307		5.534	6.410	0.1003	182	
6	6	620	0.6	8/25/94	1020	1123	1.7	+-	0.1	623	561	402	320		5.534	6.410	0.1003	223	143
7	6	620	0.8	8/25/94	1408	1514	2.8	+-	0.4	623	563	400	299		3.775	4.761	0.1183	142	107
9	6	620	1.0	8/26/94	0923	1027	4.7	+-	0.2	625	584	400	331		7.436	8.120	0.1607	142	86
14	7.5	620	1.0	8/26/94	1358	1501	20.0	+-	1.6	625	582	598	323		6.061	6.592	0.232	146	90
21	6	705	0.6	8/30/94	0936	1037	0.7	+-	0.0	707	609	375	301		3.835	5.209	0.0845	169	125
22	6	705	0.8	9/1/94	0952	1058	1.2	+-	0.0	708	613	401	308		3.039	5.108	0.095	154	112
24	6	705	1.0	9/1/94	1350	1459	3.8	+-	0.2	708	616	395	322		3.881	3.834	0.1645	31	15
26	7.5	705	0.6	8/30/94	1236	1344	1.8	+-	0.1	695	630	594	300		3.488	4.499	0.1243	166	123
27	7.5	705	0.8	8/31/94	1035	1142	3.6	+-	0.2	688	625	601	294		1.715	4.043	0.1688	103	75
29	7.5	705	1.0	8/31/94	1345	1455	10.0	+-	0.2	691	631	600	302		1.882	4.290	0.2178	46	33
														O2 plant inlet (%)					
Outlet SO3 (Cat. Layer 4)																			
32	6	700	0.8	9/23/94	1316	1427	8.3	+-	2.0	705	627	401	289	1.825	2.860	3.381	0.1195		77

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REACTOR J CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	403	427	290	218	29.6	0.752	177	102	76
14	597	619	283	275	67.0	0.972	171	79	13
21	401	423	305	182	16.4	0.595	176	108	127
22	404	426	309	245	25.6	0.794	121	54	68
24	391	408	310	315	39.8	1.018	79	14	1
27	605	627	313	249	43.1	0.795	155	59	69
2	240	254	307	246	0.9	0.800	172		66
6	402	426	320	193	1.5	0.604	236	162	131
7	400	424	299	228	2.7	0.766	151	113	74
9	400	421	331	311	3.5	0.940	150	91	26
14	596	618	323	301	16.6	0.933	151	93	28
21	376	408	301	174	0.7	0.580	184	136	130
22	401	453	308	183	1.2	0.598	174	127	128
24	395	394	322	322	3.6	1.001	31	15	6
26	594	630	300	192	1.8	0.640	176	131	141
27	601	684	294	217	3.9	0.740	117	85	81
29	600	686	302	281	10.6	0.931	53	38	26
32	401	413	289	231	8.1	0.798		79	83

< ESTIMATED OPERATING DATA

	SO3 corr. out (ppmv)	LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
		87	2082	2078	0.6	+-	0.2	0.6	0.36

FOURTH PARAMETRIC DATA SPREADSHEET KEY

Column Heading	Description
Parametric Operation Condition	Arbitrarily assigned number to particular, flow, temperature and NH_3/NO_x combination
Reactor Flow Rate	Nominal reactor flowrate in SCFM/1000 where T = 0 °F, P = 1.0 ATM
Reactor Inlet Temp.	Nominal parametric condition operating temperature °F
NH_3/NO_x Ratio	Nominal parametric condition NH_3 - to - NO_x ratio
Date	Date that sample was taken
Start time	Start time of three triplicate sample runs
End time	End time of three triplicate sample runs
Conc.	Constituent concentration, ppm by volume, based on wet phase gas (10% by volume moisture)
ρ	Standard deviation of measurement based on triplicate runs
TEMP gas in	Process gas temperature in °F measured at the reactor inlet
TEMP gas out	Process gas temperature in °F
Flow measured (scfm)	measured average flow from archive (0 °C 1 atm.)
NO_x inlet (ppmv)	measured average pilot plant inlet NO_x, wet, not O_2 corrected, from archive
O_2 inlet (%)	measured average plant inlet O_2 from archive, wet
O_2 rxr inlet (%)	measured reactor inlet O_2 (at verturi) wet, from archive
O_2 rxr outlet (%)	measured average reactor outlet O_2 wet, from archive
NH_3 actual (Kg/hr)	measured average NH_3 injection rate from mass flow controller, from archive
NO_x NOVA (ppmv)	NO_x measured by NOVA portable instrument at location of ammonia sample
NO_x out measured (ppmv)	measured average outlet NO_x concentration, wet, not O_2 corrected, from archive
FLOW corrected (scfm)	corrected reactor flow at inlet O_2 concentration (using post-test calibrations)
FLOW corrected out (scfm)	reactor flow corrected to outlet O_2 concentration (calculated outlet flow w/inleak)
NO_x corrected in (ppmv)	reactor inlet NOx corrected to inlet O_2 concentration
NH_3 actual (ppmv)	calculated actual NH_3 concentration corrected to inlet O_2 concentration, wet
NH_3/SO_3 concentration corrected	manual NH_3 concentration corrected to inlet O_2, measured at exit to catalyst layer #1, or at reactor exit for SO_3
NH_3 /NO_x ratio actual	actual NH_3/NO_x ratio using corrected NO_x and NH_3 values at reactor inlet O_2 concentration
NO_x corrected NOV (ppmv)	NOVA measurement corrected to inlet O_2 concentration
NO_x out corrected (ppmv)	measured outlet NO_x corrected to inlet O_2
NO_x out pred (ppmv)	predicted outlet NO_x w/ 100% NH_3 reaction, corrected to inlet O_2 concentration
LOAD unit #5 (MW)	average unit load from archive
SO_2 plant inlet (ppmv)	average inlet SO_2 to pilot plant, wet, not O_2 corrected from archive
SO_2 corrected in (ppmv)	average reactor inlet SO_2 corrected to rxr inlet O_2
SO_3 measured in (ppmv)	SO_3 concentration measured at the reactor inlet
ρ	standard deviation in inlet SO_3 concentration
SO_3 corrected in (ppmv)	SO_3 concentration corrected to reactor outlet O_2 concentrations
SO_2 Ox rate (%)	oxidation rate of SO_2 based on corrected SO_2 and SO_3 outlet measured (as % of SO_2 oxidized)

FOURTH PARAMETRIC TEST RESULTS

REACTOR A

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	6	620	0.8	21-Oct	0931	1028	35.2	+-	2.7	645	622	5008	281	2.465	3.036	2.93	1.407	188	61
14	7.5	620	1.0	21-Oct	1338	1432	74.8	+-	5.3	649	633	6590	265	2.640	2.18	3.306	2.180	161	32
21	6	705	0.6	20-Oct	0954	1047	20.3	+-	2.6	707	678	5000	266	2.195	2.767	2.733	1.000	206	125
22	6	705	0.8	19-Oct	0957	1057	23.6	+-	5.6	705	677	5001	313	2.333	3.416	3.362	1.347	193	81
24	6	705	1.0	20-Oct	1253	1409	35.3	+-	12.8	706	680	5007	261	3.293	3.465	3.436	1.648	129	36
27	7.5	705	0.8	9-Nov	0922	1023	49.4	+-	4.1	705	680	6100	359	2.323	2.966	2.801			
37	6	750	0.8	19-Oct	1338	1437	29.7	+-	5.0	754	724	4994	295	2.619	3.393	3.323	1.462	180	76
Slip NH3																			
2	3	620	0.8	25-Oct	1503	1615	1.9	+-	0.3	632	599	2995	284	2.159	2.769	2.884	0.855	105	46
6	6	620	0.6	27-Oct	0902	1015	2.8	+-	0.6	647	621	4999	377	2.924	3.683	3.381	1.407		71
7	6	620	0.8	27-Oct	1314	1431	4.5	+-	1.1	651	626	5004	363	2.403	3.077	2.953	1.801		21
9	6	620	1.0	1-Nov	0843	0954	22.9	+-	3.5	627	605	5009	374	4.516	4.731	4.679	2.389		0
14	7.5	620	1.0	25-Oct	1036	1150	6.6	+-	1.3	652	634	6516	309	2.072	2.946	2.801	2.479	118	32
21	6	705	0.6	28-Oct	1018	1142	2.6	+-	0.1	703	674	5004	378	2.815	3.523	3.280	1.408		70
22	6	705	0.8	24-Oct	0840	1010	3.0	+-	0.6	705	675	5004	266	2.418	2.894	2.870	1.339		64
24	6	705	1.0	28-Oct	1438	1604	2.6	+-	0.4	703	674	5000	361	2.769	3.443	3.171	1.351		61
26	7.5	705	0.6	26-Oct	0904	1028	3.0	+-	0.2	705	680	6206	342	2.136	3.014	2.752	1.572	259	101
27	7.5	705	0.8	24-Oct	1337	1500	2.8	+-	1.4	705	681	6998	263	2.323	2.966	2.801	1.579		63
29	7.5	705	1.0	26-Oct	1330	1440	1.4	+-	1.0	704	682	6289	319	1.776	2.475	2.637	2.331	81	4
36	6	750	0.6	31-Oct	0856	1013	1.9	+-	0.3	756	725	4997	337	2.243	3.767	3.618	1.260		89
37	6	750	0.8	31-Oct	1258	1412	2.8	+-	0.5	753	726	5001	311	2.155	2.823	2.664	1.548		34
39	6	750	1.0	2-Nov	0848	1003	7.6	+-	2.6	756	727	4998	337	2.157	2.761	2.714	2.111		12
Outlet SO3 (Cat. Layer 4)																			
22	6	700	0.8	1-Dec	0920	1033	18.3	+-	0.9	702	674	4993	350	3.131	4.397	4.808	1.773		20
27	7.5	700	0.8	12-Jan	0926	1029	15.2	+-	2.2	708	680	6465	334	2.813	4.019	4.421	1.963		69
37	6	750	0.8	1-Dec	1500	1603	41.6	+-	2.0	758	720	4951	333	2.887	4.083	4.487	1.661		56

REACTOR A CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)										
7	5008	4977	272	218	35.1	0.799	187	81	59										
14	6590	7009	272	256	78.2	0.943	171	34	21										
21	5000	4991	258	155	20.6	0.600	206	125	106										
22	5001	4986	295	209	23.1	0.707	192	81	90										
24	5007	4999	258	255	34.4	0.988	129	35	9										
27	6100	6045	347	347	49.5	1.000			7	<	ESTIMATED DATA								
37	4994	4974	283	227	29.1	0.802	179	76	60										
2	2995	3014	275	221	2.0	0.804	106	46	58										
6	4999	4942	363	218	2.7	0.600		70	150										
7	5004	4970	350	279	4.5	0.797		21	77										
9	5009	4993	369	369	20.7	1.000		0	7										
14	6516	6394	295	295	6.6	0.999	116	31	6										
21	5004	4935	363	218	2.5	0.600		69	150										
22	5004	4997	259	207	3.0	0.799		64	56										
24	5000	4924	348	209	2.5	0.602		60	143										
26	6206	6117	326	196	3.0	0.601	255	100	134										
27	5998	5944	254	204	2.8	0.803		62	54										
29	6289	6344	307	287	1.4	0.934	82	4	26										
36	4997	4954	310	196	1.8	0.631		88	118										
37	5001	4958	300	240	2.8	0.799		34	65										
39	4998	4986	326	327	7.7	1.003		12	6										
					SO3 corr. out (ppmv)						LOAD unit #5 (MW)	SO2 plant inlet (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	4983	5109	325	276	16.5	0.847		21	55		84	1755		1619	9.2	+-	0.8	8.5	0.49
27	6465	6622	312	235	14.0	0.754		71	81		84	1704		1608	4.6	+-	1.5	4.3	0.60
37	4951	5072	311	260	38.2	0.836		57	56		84	1738		1633	9.7	+-	0.7	9.1	1.78

FOURTH PARAMETRIC TEST RESULTS

REACTOR B

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Intermediate Level NH3 Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
7	6	620	0.8	21-Oct	1350	1446	35.9		4	632	604	4991	268	2.612	4.478	3.605	1.308	181	107
14	7.5	620	1.0	21-Oct	936	1031	77.8		9.2	652	627	6910	281	2.48	2.96	4.221	2.436	202	65
21	6	705	0.6	20-Oct	1002	1058	20.6		2	706	670	5007	266	2.185	2.704	3.721	1.005	233	131
22	6	705	0.8	19-Oct	1522	1621	24.2		3.6	704	665	4999	294	2.526	3.111	4.154	1.469	160	96
24	6	705	1.0	20-Oct	1300	1357	32.4		6.6	706	672	4997	260	3.293	3.764	4.691	1.631	139	49
27	7.5	705	0.8	24-Oct	837	939	42.8		2.5	706	680	6805	265	2.315	2.731	4.178	1.831	218	74
37	6	750	0.8	19-Oct	1105	1209	19.4		1.7	756	718	5001	309	2.333	3.359	4.549	1.336	207	125
2	3	620	0.8	25-Oct	1336	1456	1.01		0.28	630	583	3005	297	2.099	2.75	3.5134	0.892	101	59
6	6	620	0.8	26-Oct	1040	1205	0.64	<		651	617	4990	330	1.778	2.28	3.253	1.249	293	101
7	6	620	0.8	27-Oct	1023	1136	1.47		0	660	615	5005	369	2.629	2.976	3.977	1.863		20
9	6	620	1.0	27-Oct	1540	1645	10.6		0.83	656	620	4992	357	2.614	2.983	4.029	2.258		3
14	7.5	620	1.0	1-Nov	1000	1051	23.8		2.4	636	612	7331	384	4.298	4.668	5.865	3.561		9
21	6	705	0.6	3-Nov	1004	1130	1	<		704	675	4997	334	5.167	5.397	6.202	1.273		105
22	6	705	0.8	26-Oct	1545	1645	1.1		0.28	708	667	4983	306	1.911	2.333	3.427	1.547	136	42
24	6	705	1.0	28-Oct	1304	1424	10.3		1.7	705	667	4995	373	2.742	3.214	4.376	2.346		0
26	7.5	705	0.6	28-Oct	848	1009	1.4		0.09	706	668	6597	373	2.786	3.261	4.687	1.849		97
27	7.5	705	0.8	24-Oct	1017	1133	2.1		0.18	705	678	6794	265	2.462	2.885	4.337	1.820		79
29	7.5	705	1.0	31-Oct	1021	1134	6.2		0.18	706	678	6596	338	2.48	2.857	4.201	2.821		6
36	6	750	0.6	31-Oct	1419	1609	1.01		0.28	757	715	4997	325	3.267	3.157	4.299	1.229		108
37	6	750	0.8	2-Nov	848	1005	1.1		0.09	756	715	5004	338	2.157	2.677	3.885	1.697		40
39	6	750	1.0	2-Nov	1302	1416	2.1		5.5	756	726	4992	325	2.324	2.709	3.935	2.056		5
22	6	700	0.8	30-Nov	939	1051	4.2		1.12	704	673	5007	279	4.039	4.361	5.365	1.430		84
27	7.5	700	0.8	12-Jan	1319	1425	2.66		0.65	705	683	6441	345	2.653	3.112	4.706	2.233		51
37	6	750	0.8	30-Nov	1459	1606	17.3		1.76	756	717	5000	265	2.589	2.989	4.167	1.339		86

REACTOR B CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	4991	4741	241	203	33.0	0.843	172	102	42
14	6910	7429	274	273	78.0	0.997	217	70	6
21	5007	5302	269	155	20.9	0.601	247	139	108
22	4999	5309	285	228	24.1	0.799	170	102	62
24	4997	5281	263	263	31.0	0.999	147	52	5
27	6805	7380	259	208	43.4	0.804	237	80	55
37	5001	5383	292	207	19.0	0.708	222	134	89
2	3005	3136	287	230	1.0	0.801	105	62	61
6	4990	5264	321	194	0.7	0.603	309	107	131
7	5005	5299	362	288	1.5	0.796		21	79
9	4992	5300	350	350	10.6	1.001		3	6
14	7331	7911	375	376	21.6	1.002		10	7
21	4997	5269	329	197	0.9	0.599		111	138
22	4983	5293	299	240	1.1	0.803	143	45	64
24	4995	5344	363	364	10.2	1.001		0	7
26	6597	7174	363	217	1.4	0.597		105	151
27	6794	7386	269	207	2.1	0.801		86	56
29	6586	7124	331	331	6.2	1.000		6	6
36	4997	5339	327	190	1.0	0.582		113	140
37	5004	5367	329	263	1.1	0.799		43	71
39	4992	5351	318	319	2.1	1.002		6	6

					SO3 corr. out (ppmv)					LOAD unit #6 (MW)	SO2 meas. in (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	5007	5328	274	221	3.6	0.808		89	57	89	1982	1832	6.1	+-	5.0	5.6	-0.11
27	6441	7071	336	268	2.4	0.798		56	73	88	1671	1661	1.8	+-	0.1	1.8	0.04
37	5000	5350	259	207	16.2	0.800		92	56	87	1774	1775	8.9	+-	0.8	8.9	0.41

FOURTH PARAMETRIC TEST RESULTS

REACTOR C

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	6	620	0.8	15-Nov	0954	1100	6.2	+-	1.0	627	608	4915	381	5.232	4.998	6.79	1.936	75	7
14	7.5	620	1.0	9-Nov	1040	1145	109.6	+-	2.1	627	610	6500	369	5.375	4.681	5.638			
21	6	700	0.6	15-Nov	1300	1405	23.6	+-	0.8	704	675	5000	377	5.140	4.889	5.797	1.486	149	75
22	6	700	0.8	16-Nov	1013	1127	31.0	+-	4.6	707	682	5000	334	5.103	4.944	5.828	1.746	78	23
24	6	700	1.0	16-Nov	1323	1433	63.4	+-	11.1	708	683	4998	337	5.085	4.908	5.795	2.196	60	3
27	7.5	700	0.8	9-Nov	1525	1620	50.4	+-	7.8	705	685	6396	358	2.601	2.678	3.801	2.365		0
37	6	750	0.8	17-Nov	1014	1109	38.4	+-	2.5	757	729	5001	351	4.748	4.539	5.614	1.841	118	38
Slip NH3																			
2	3	620	0.8	28-Oct	0849	1010	2.5	+-	0.5	638	598	3004	373	2.786	2.984	4.221	1.143		3
6	6	620	0.6	28-Oct	1304	1416	2.6	+-	0.0	652	626	4995	375	2.742	2.733	3.818	1.461		60
7	6	620	0.8	31-Oct	0948	1003	6.5	+-	0.8	649	623	5003	349	2.388	3.048	4.167	1.817		15
9	6	620	1.0	31-Oct	1407	1607	38.8	+-	3.3	647	622	4998	325	2.776	2.737	3.781	2.101		6
14	7.5	620	1.0	9-Nov	0845	1005	41.9	+-	6.8	627	610	6500	361	5.375	4.681	5.638			
21	6	700	0.6	1-Nov	0839	1000	3.0	+-	1.1	708	677	5008	374	4.491	4.419	5.372	1.469		95
22	6	700	0.8	2-Nov	1012	1121	5.2	+-	0.3	708	677	4992	342	2.336	2.365	3.560	1.762		45
24	6	700	1.0	2-Nov	1455	1600	15.6	+-	0.2	705	678	4997	315	2.179	2.205	3.364	2.033		6
26	7.5	700	0.6	3-Nov	0853	1007	4.7	+-	0.2	704	680	6479	336	5.375	5.219	6.310	1.705		113
27	7.5	700	0.8	3-Nov	1255	1408	8.6	+-	0.6	704	682	6428	328	4.800	4.681	5.638	2.201		36
29	7.5	700	1.0	8-Nov	0900	1027	20.2	+-	0.7	706	684	6303	373	2.257	3.012	4.426	2.915		0
36	6	750	0.6	8-Nov	1312	1446	2.6	+-	0.3	756	723	4997	368	2.162	2.873	4.316	1.376		0
37	6	750	0.8	4-Nov	0838	0944	4.4	+-	0.2	755	724	4998	316	4.464	4.361	5.421	1.648		4
39	6	750	1.0	4-Nov	1250	1407	16.2	+-	0.6	757	729	4997	330	4.656	4.542	5.598	2.158		0
Outlet SO3 (Cat. Layer 4)																			
22	6	700	0.8	28-Nov	1255	1412	12.9	+-	0.0	702	681	4999	303	1.980	2.145	3.193	1.557		56
27	7.5	700	0.8	16-Jan	1008	1127	2.5	+-	0.3	704	682	6428	328	4.800	4.681	5.638	2.201		
37	6	750	0.8	28-Nov	0925	1039	37.5	+-	3.5	756	729	4998	338	2.793	2.913	4.122	1.737		62

REACTOR C CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)									
7	4916	5171	387	305	5.5	0.789	79	7	88									
14	6500	6860	385	385	99.4	1.000			8	<	ESTIMATED DATA							
21	5000	5289	383	230	21.1	0.601	158	79	157									
22	5000	5291	337	270	27.7	0.802	83	24	72									
24	4996	5287	341	340	56.7	0.999	64	3	7									
27	6396	6814	357	286	51.3	0.803		0	76									
37	5001	5350	355	285	35.1	0.802	126	41	76									
2	3004	3225	369	295	2.5	0.799		3	80									
6	4995	5310	375	225	2.6	0.600		64	155									
7	5003	5336	337	281	6.5	0.835		16	61									
9	4998	5301	328	325	39.4	0.999		6	7									
14	6500	6860	377	377	38.0	1.000			7	<	ESTIMATED DATA							
21	5008	5313	378	226	2.8	0.601		101	154									
22	4992	5334	341	273	5.4	0.800		48	74									
24	4997	5325	316	316	16.3	1.001		6	6									
26	6479	6860	339	204	4.1	0.600		121	140									
27	6428	6784	330	265	7.8	0.802		38	70									
29	6303	6841	358	358	20.2	1.000		0	7									
36	4997	5429	354	213	2.6	0.602		0	146									
37	4998	5338	318	255	4.1	0.803		4	67									
39	4997	5340	332	334	14.8	1.006		0	4									
					SO3 * corr. out (ppmv)						LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	4999	5293	300	241	12.8	0.803		59	64		88	1927		2019	8.8	+-	0.7	9.2	0.18
27	6428	6784	330	265	2.1	0.802			70		88	1710		1650	5.5	+-	1.0	5.0	-0.18
37	4998	5354	338	269	35.2	0.802		66	72		87	1951		1960	10.9	+-	1.8	11.0	1.23

FOURTH PARAMETRIC TEST RESULTS

REACTOR D

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	4	620	0.8	14-Nov	0957	1052	168.0	+-	15.7	623	551	400	367	4.604	5.088	5.765	0.148		41
14	6	620	1.0	14-Nov	1300	1410	263.8	+-	18.2	625	572	598	403	4.438	5.407	5.298	0.306		60
21	4	700	0.6	15-Nov	1510	1611	78.4	+-	2.0	704	616	399	385	5.360	5.741	6.484	0.117	171	72
22	4	700	0.8	16-Nov	0902	1005	111.0	+-	9.3	705	615	399	344	5.058	5.712	6.409	0.136	135	12
24	4	700	1.0	16-Nov	1525	1631	154.6	+-	14.3	703	614	400	342	5.176	5.780	6.604	0.170	129	9
27	6	700	0.8	17-Nov	1021	1114	123.4	+-	23.9	705	643	600	351	4.746	5.152	5.764	0.213	218	63
37	4	750	0.8	11-Nov	1455	1553	94.1	+-	5.7	756	663	400	376	3.008	3.848	4.580	0.149	161	27
Slip NH3																			
2	2.4	620	0.8	4-Jan	0948	1113	5.3	+-	1.0	625	502	240	381	2.487	4.185	4.699	0.081		17
6	4	620	0.6	4-Jan	1304	1421	7.8	+-	1.0	625	542	400	348	2.436	3.526	3.955	0.102		60
7	4	620	0.8	4-Jan	1532	1656	22.4	+-	2.7	626	545	400	359	2.537	3.602	3.991	0.140		40
9	4	620	1.0	11-Jan	1225	1332	72.3	+-	6.8	624	549	399	357	3.406	4.527	4.989	0.174		25
14	6	620	1.0	11-Jan	1514	1623	86.3	+-	1.2	625	572	603	389	2.872	3.633	4.051	0.289		55
21	4	700	0.6	5-Jan	0932	1041	2.0	+-	0.2	706	605	400	346	2.633	3.746	4.061	0.101		172
22	4	700	0.8	5-Jan	1300	1412	6.9	+-	0.5	704	610	400	345	6.103	6.585	6.950	0.138		72
24	4	700	1.0	5-Jan	1530	1642	28.0	+-	1.7	703	614	400	338	5.176	5.780	6.604			9
26	6	700	0.6	9-Jan	0958	1110	2.9	+-	0.4	704	615	402	344	2.581	3.774	4.282	0.100		59
27	6	700	0.8	9-Jan	1233	1345	9.5	+-	0.6	705	617	400	346	2.362	3.570	3.984	0.134		18
29	6	700	1.0	9-Jan	1613	1618	36.8	+-	3.9	703	616	404	347	2.444	3.644	4.221	0.170		9
36	4	750	0.6	10-Jan	0929	1041	2.7	+-	0.3	754	654	400	357	3.217	4.383	4.856	0.104		64
37	4	750	0.8	10-Jan	1228	1340	6.6	+-	0.3	754	658	400	356	2.987	4.141	4.580	0.138		26
39	4	750	1.0	10-Jan	1528	1650	27.4	+-	2.8	754	658	391	355	2.948	4.102	4.579	0.171		7
Outlet SO3 (Cat. Layer 4)																			
22	4	700	0.8	5-Dec	0921	1042	13.4	+-	0.4	704	617	400	309	3.358	4.179	4.830	0.122		19
27	6	700	0.8	17-Jan	1010	1117	0.2	+-	0.0	705	617	400	346	2.362	3.570	3.984	0.134		
37	4	750	0.8	6-Dec	0833	0947	11.0	+-	2.4	755	657	399	304	2.490	3.417	4.012	0.120		12

REACTOR D CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)										
7	400	418	356	286	148.5	0.802		43	76										
14	598	594	379	396	228.5	1.044		60	-9										
21	399	419	376	228	66.5	0.606	180	76	152										
22	399	418	330	265	94.3	0.802	141	13	71										
24	400	423	329	329	130.7	1.000	136	10	6										
27	600	624	342	275	108.6	0.803	227	66	73										
37	400	418	358	288	89.7	0.805	168	28	76										
2	240	248	328	261	5.0	0.797		18	72										
6	400	410	328	197	7.6	0.603		62	134										
7	400	409	338	270	21.7	0.799		41	73										
9	399	411	334	337	66.2	1.008		26	4										
14	603	618	373	370	83.3	0.994		56	9										
21	400	407	324	196	1.9	0.605		175	132										
22	400	410	334	267	5.5	0.800		74	72										
24	400	423	325	325	23.7	1.000		10	6	<	ESTIMATED DATA								
26	402	414	322	193	2.8	0.599		61	133										
27	400	410	324	260	9.2	0.803		18	69										
29	404	418	325	326	35.5	1.004		9	5										
36	400	412	334	200	2.5	0.601		66	137										
37	400	411	333	267	6.2	0.802		27	71										
39	391	402	332	339	25.7	1.019		7	0										
					SO3 corr. out (ppmv)						LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	400	416	295	236	12.0	0.800		20	63		86	1663		1654	4.5	+-	5.4	4.2	0.50
27	400	410	324	260	0.2	0.803		0	69		85	1652		1600	0.7	+-	0.1	0.7	-0.03
37	399	0413	289	233	10.4	0.806		12	60		87	1678		1639	1.1	+-	0.0	1.1	0.57

FOURTH PARAMETRIC TEST RESULTS

REACTOR E

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	4	620	0.8	21-Nov	1404	1500	44.8	+-	1.6	644	573	400	395	1.918	2.377	3.06	0.159	88	19
14	6	620	1.0	15-Nov	0853	0947	167.9	+-	17.1	625	565	600	387	5.434	5.589	6.141	0.297	. 148	7
21	4	700	0.6	17-Nov	0924	1014	16.6	+-	0.3	706	607	400	354	4.819	5.059	5.653	0.108	196	80
22	4	700	0.8	17-Nov	1339	1429	23.3	+-	1.0	708	612	400	346	4.611	4.848	5.428	0.141	139	30
24	4	700	1.0	18-Nov	1003	1055	44.1	+-	3.6	705	609	401	331	3.438	3.752	4.346	0.168	92	7
27	6	700	0.8	18-Nov	1324	1513	54.6	+-	1.7	708	635	602	328	3.356	3.549	4.3	0.202	139	45
37	4	750	0.8	21-Nov	1034	1127	25.0	+-	3.1	755	650	391	340	2.155	2.587	3.382	0.136	120	42
Slip NH3																			
2	2.4	620	0.8	14-Nov	1249	1356	0.8	<		625	521	250	401	4.373	4.892	5.707	0.099		53
6	4	620	0.6	4-Nov	1246	1350	0.7	<		625	538	399	340	4.668	4.879	5.669	0.102		166
7	4	620	0.8	4-Nov	0940	1100	0.7	<		624	536	400	322	4.424	4.736	5.235	0.131		34
9	4	620	1.0	15-Nov	1505	1608	12.4	+-	1.6	624	547	400	387	5.360	5.633	6.467	0.197		3
14	6	620	1.0	15-Nov	0858	1105	56.8	+-	5.1	625	565	601	382	5.203	5.381	6.055	0.293		34
21	4	700	0.6	11-Nov	0847	1003	0.7	<		706	606	400	364	2.619	2.936	3.658	0.110		52
22	4	700	0.8	11-Nov	1253	1403	0.7	<		708	610	400	371	2.888	3.272	4.008	0.151		29
24	4	700	1.0	10-Nov	1031	1148	1.5	+-	0.4	706	612	398	364	2.637	3.055	3.718	0.184		3
26	6	700	0.6	10-Nov	1309	1420	1.0	+-	0.2	710	630	599	352	2.111	2.417	2.979	0.161		162
27	6	700	0.8	8-Nov	1016	1132	1.7	+-	0.3	704	632	599	372	2.179	3.394	4.101	0.217		28
29	6	700	1.0	8-Nov	1308	1423	5.6	+-	0.4	705	633	595	370	2.162	3.359	4.099	0.288		8
36	4	750	0.6	16-Nov	0853	1003	0.8	<		753	646	401	344	5.085	5.294	6.005	0.105		61
37	4	750	0.8	9-Nov	1010	1122	0.7	<		753	646	400	342	2.155	2.587	3.382			28
39	4	750	1.0	9-Nov	1334	1443	0.7	<		753	646	400	364	2.155	2.587	3.382			3
2	2.4	620	0.8	14-Nov	0945	1052	0.8	<		625	544	400	367	4.619	4.953	5.615	0.112		73
Outlet SO3 (Cat. Layer 4)																			
22	6	700	0.8	6-Dec	1434	1540	9.3	+-	1.9	704	620	399	311	2.640	2.898	3.283	0.126		23
27	7.5	700	0.8	17-Jan	1350	1457	8.1	+-	1.4	704	632	599	372	2.179	3.394	4.101	0.217		
37	6	750	0.8	6-Dec	1055	1208	10.7	+-	5.7	749	640	399	302	2.590	2.964	3.377	0.123		30

REACTOR E CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)										
7	400	415	385	307	48.4	0.797	91	20	84										
14	600	622	383	383	143.8	0.999	153	7	8										
21	400	415	349	209	14.7	0.599	204	83	144										
22	400	415	341	272	20.9	0.798	144	31	74										
24	401	415	325	324	42.3	0.998	95	7	7										
27	602	629	322	260	52.9	0.805	145	47	68										
37	391	409	332	269	25.6	0.809	125	44	69										
2	250	263	388	306	0.7	0.788		68	88										
6	398	420	334	198	0.7	0.593		175	140										
7	400	413	316	254	0.7	0.804		36	67										
9	400	423	380	381	10.6	1.003		3	6										
14	601	628	378	378	49.3	1.000		38	7										
21	400	417	358	214	0.7	0.600		54	148										
22	400	417	363	293	0.7	0.807		30	76										
24	398	413	356	357	1.5	1.004		3	6										
26	599	618	346	209	1.0	0.602		167	142										
27	599	624	348	280	1.7	0.804		29	74										
29	595	621	346	348	5.5	1.005		8	5										
36	401	420	339	203	0.7	0.598		64	140										
37	400	418	334	267	0.7	0.800		29	72	<	ESTIMATED DATA								
39	400	418	356	356	0.7	1.000		3	7	<	ESTIMATED DATA								
2	400	417	360	216	0.7	0.600		76	148										
					SO3 corr. out (ppmv)						LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	399	408	305	245	9.2	0.802		23	65		88	1741		1761	2.8	±	0.2	2.8	0.36
27	599	624	348	280	5.7	0.804		0	74		88	1716		1678	0.3	±	0.0	0.3	0.32
37	399	408	296	239	10.5	0.807		31	62		87	1717		1720	1.2	±	0.7	1.2	0.64

FOURTH PARAMETRIC TEST RESULTS

REACTOR F

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	4	620	0.8	18-Nov	1315	1507	84.4	+-	10.0	625	546	400	328	3.342	3.437	4.42	0.135	156	37
14	6	620	1.0	18-Nov	0957	1047	169.7	+-	5.9	640	582	599	331	3.419	3.403	4.130	0.258	183	13
21	4	700	0.6	17-Nov	0918	1007	64.7	+-	3.5	707	608	400	353	4.830	4.696	5.656	0.110	197	72
22	4	700	0.8	17-Nov	1328	1419	74.7	+-	3.7	707	612	400	344	4.627	4.514	5.503	0.143	156	39
24	4	700	1.0	21-Nov	1029	1120	92.5	+-	7.9	705	614	402	340	2.138	2.289	3.406	0.174	119	21
27	6	700	0.8	21-Nov	1400	1453	128.7	+-	6.9	704	642	600	395	1.915	1.974	2.761	0.240	147	27
37	4	750	0.8	9-Nov	1346	1446	88.8	+-	5.5	755	651	400	374	2.570	3.119	4.953	0.145	124	70
Slip NH3																			
2	2.4	620	0.8	15-Nov	0843	0954	0.8	<		625	505	240	385	5.422	5.499	7.374	0.095		19
6	4	620	0.6	14-Nov	0836	0940	1.2	+-	0.1	625	543	402	380	4.759	4.758	6.191	0.119		76
7	4	620	0.8	14-Nov	1403	1559	2.8	+-	0.3	625	544	400	401	4.426	4.333	6.144	0.168		33
9	4	620	1.0	15-Nov	1247	1408	11.2	+-	0.2	624	540	400	379	5.140	5.044	6.486	0.197		9
14	6	620	1.0	3-Nov	1502	1608	30.1	+-	2.3	626	571	595	324	4.605	4.782	6.553	0.246		20
21	4	700	0.6	8-Nov	0856	1010	0.7	<		704	609	400	369	2.263	3.754	4.795	0.105		93
22	4	700	0.8	8-Nov	1501	1610	0.9	+-	0.3	705	611	400	358	2.249	3.696	4.704	0.137		66
24	4	700	1.0	10-Nov	1425	1623	11.5	+-	2.5	708	612	400	345	2.007	2.635	4.449	0.173		9
26	6	700	0.6	4-Nov	0832	0940	2.7	+-	0.2	706	637	600	318	4.454	4.660	5.536	0.148		82
27	6	700	0.8	4-Nov	1405	1516	4.2	+-	0.4	705	638	600	335	4.607	4.811	5.616	0.203		55
29	6	700	1.0	16-Nov	1007	1136	22.5	+-	0.5	707	640	595	335	5.107	4.976	6.325	0.263		31
36	4	750	0.6	11-Nov	1007	1115	1.0	+-	0.1	756	648	400	360	2.473	2.979	4.361	0.109		76
37	4	750	0.8	9-Nov	1518	1636	0.9	+-	0.1	755	651	399	359	2.570	3.119	4.953	0.145		63
39	4	750	1.0	16-Nov	1315	1416	2.6	+-	0.6	756	644	399	338	5.086	5.053	6.280	0.179		3
26	6	700	0.6	10-Nov	0918	1026	3.1	+-	0.3	706	638	600	383	2.544	2.903	3.866	0.166		100
Outlet SO3 (Cat. Layer 4)																			
22	5	700	0.8	7-Dec	1009	1117	1.0	+-	0.1	706	603	400	354	2.898	2.906	4.236	0.147		23
27	7.5	700	0.8	18-Jan	0938	1043	0.2	+-	0.1	705	638	600	335	4.607	4.811	5.616			
37	5	750	0.8	7-Dec	1444	1611	0.7	+-	0.1	758	641	400	340	2.696	2.694	3.994	0.141		30

REACTOR F CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)										
7	400	424	328	282	82.4	0.803	165	39	69										
14	599	625	331	333	156.1	1.005	191		5										
21	400	425	356	213	58.6	0.598	209		147										
22	400	426	346	277	68.4	0.799	166	41	75										
24	402	428	337	335	96.2	0.994	127	22	9										
27	600	626	394	310	136.0	0.788	153	28	90										
37	400	446	363	280	68.3	0.800	138		78	<	ESTIMATED DATA								
2	240	273	383	306	0.7	0.800		22	83										
6	402	441	380	229	1.1	0.603		83	155										
7	400	449	403	321	2.6	0.797		37	88										
9	400	440	381	382	9.9	1.002		10	7										
14	595	625	321	321	27.1	1.000		21	6										
21	400	428	340	203	0.7	0.597		99	141										
22	400	425	330	264	0.9	0.800		70	71										
24	400	444	334	334	11.7	1.003		10	6										
26	600	634	312	191	2.5	0.611		87	125										
27	600	631	331	261	3.8	0.790		68	75										
29	595	650	338	342	20.0	1.013		34	2										
36	400	433	350	212	1.0	0.604		81	143										
37	399	445	348	281	0.9	0.808		70	72										
39	399	432	339	347	2.3	1.024		3	-1										
26	600	634	356	214	3.1	0.602		106	146										
					SO3 corr. out (ppmv)						LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	400	432	354	285	0.9	0.804		25	75		87	1775		1784	0.7	+-	0.1	0.7	0.01
27	600	631	331	265	0.2	0.800		0	71		86	1728		1554	1.3	+-	1.1	1.2	-0.07
37	400	431	340	273	0.7	0.804		32	72		86	1749		1779	0.6	+-	1.1	0.7	0.00

FOURTH PARAMETRIC TEST RESULTS

REACTOR G

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	4	620	0.8	24-Oct	0951	1059	55.5	+-	4.1	626	533	397	269	2.662	3.702	5.633	0.104	218	14
14	6	620	1.0	24-Oct	1348	1504	111.9	+-	1.6	624	571	601	264	2.323	3.164	5.867	0.196	234	42
21	4	700	0.6	19-Oct	0951	1100	32.2	+-	2.2	705	612	391	313	2.333	3.384	5.869	0.082	243	119
22	4	700	0.8	19-Oct	1140	1250	48.7	+-	2.2	705	613	400	300	2.523	3.270	5.653	0.118	204	67
24	4	700	1.0	10-Nov	1334	1434	121.6	+-	9.7	704	617	406	346	2.085	2.468	5.777	0.181	187	17
27	6	700	0.8	10-Nov	1040	1149	107.4	+-	3.0	703	641	601	365	2.637	2.908	7.258	0.222	246	64
37	4	750	0.8	11-Nov	0959	1105	86.0	+-	4.3	756	663	400	363	2.477	2.840	6.216	0.148	266	67
Slip NH3																			
2	2.4	620	0.8	25-Oct	1023	1141	0.7	<		622	513	219	308	2.072	4.040		0.087	136	60
6	4	620	0.6	25-Oct	1334	1446	0.6	<		622	545	404	298	2.099	3.303	5.234	0.087	178	105
7	4	620	0.8	26-Oct	1036	1158	2.9	+-	0.7	625	547	403	330	1.859	3.152	5.083	0.127	193	60
9	4	620	1.0	26-Oct	1323	1434	17.8	+-	1.4	625	547	400	318	1.776	3.035	4.866	0.154	81	9
14	6	620	1.0	24-Oct	1529	1639	11.9	+-	2.8	624	568	601	266	2.290	3.079	5.792	0.196	85	37
21	4	700	0.6	2-Nov	1300	1416	0.8	+-	0.1	701	622	400	326	2.324	3.553	6.138	0.095		90
22	4	700	0.8	3-Nov	0902	1018	1.8	+-	0.1	706	620	400	336	5.375	6.198	8.783	0.137		36
24	4	700	1.0	3-Nov	1259	1416	9.7	+-	1.1	706	622	401	328	4.726	5.683	8.268	0.155		19
26	6	700	0.6	27-Oct	1017	1131	3.3	+-	0.3	706	638	600	371	2.645	3.670	8.020	0.164		99
27	6	700	0.8	27-Oct	1310	1427	5.5	+-	0.4	706	639	601	363	2.403	3.418	7.768	0.212		59
29	6	700	1.0	8-Nov	1034	1149	15.0	+-	2.3	705	643	600	372	2.180	3.381	7.731	0.271		37
36	4	750	0.6	4-Nov	0952	1101	1.3	+-	0.2	756	662	400	322	4.424	4.747	8.123	0.099		105
37	4	750	0.8	4-Nov	1413	1525	2.9	+-	0.6	756	665	400	328	4.596	4.923	8.299	0.134		69
39	4	750	1.0	28-Oct	1016	1144	8.3	+-	0.3	755	662	400	377	2.809	4.033	7.409	0.182		13
Outlet SO3 (Cat. Layer 4)																			
22	6	700	0.8	8-Dec	1304	1420	3.5	+-	0.8	705	633	400	331	2.802	3.061	5.646	0.135		40
27	7.5	700	0.8	16-Jan	1601	1604	3.9	+-	2.5	705	640	600	340	2.403	3.418	7.768			
37	6	750	0.8	8-Dec	0959	1107	13.6	+-	2.2	757	664	399	342	3.059	3.346	6.722	0.140		47

FOURTH PARAMETRIC TEST RESULTS

REACTOR G

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	4	620	0.8	24-Oct	0951	1059	55.5	+-	4.1	626	533	397	269	2.562	3.702	5.633	0.104	218	14
14	6	620	1.0	24-Oct	1348	1504	111.9	+-	1.6	624	571	601	264	2.323	3.154	5.867	0.196	234	42
21	4	700	0.6	19-Oct	0951	1100	32.2	+-	2.2	705	612	391	313	2.333	3.384	5.969	0.082	243	119
22	4	700	0.8	19-Oct	1140	1250	48.7	+-	2.2	705	613	400	300	2.523	3.270	5.653	0.118	204	67
24	4	700	1.0	10-Nov	1334	1434	121.6	+-	9.7	704	617	406	346	2.085	2.458	5.777	0.181	187	17
27	6	700	0.8	10-Nov	1040	1149	107.4	+-	3.0	703	641	601	365	2.637	2.808	7.268	0.222	246	64
37	4	750	0.8	11-Nov	0959	1105	86.0	+-	4.3	756	663	400	363	2.477	2.840	6.216	0.148	266	57
Slip NH3																			
2	2.4	620	0.8	25-Oct	1023	1141	0.7	<		622	513	219	308	2.072	4.040		0.067	136	60
6	4	620	0.8	25-Oct	1334	1446	0.6	<		622	545	404	298	2.099	3.303	5.234	0.087	178	105
7	4	620	0.8	26-Oct	1036	1158	2.9	+-	0.7	625	547	403	330	1.859	3.152	5.083	0.127	193	60
9	4	620	1.0	26-Oct	1323	1434	17.8	+-	1.4	625	547	400	318	1.775	3.035	4.966	0.164	81	9
14	6	620	1.0	24-Oct	1529	1639	11.9	+-	2.8	624	568	601	266	2.280	3.079	5.792	0.196	85	37
21	4	700	0.6	2-Nov	1300	1416	0.8	+-	0.1	701	622	400	325	2.324	3.553	6.138	0.095		90
22	4	700	0.8	3-Nov	0902	1018	1.8	+-	0.1	706	620	400	336	5.375	6.198	8.783	0.137		36
24	4	700	1.0	3-Nov	1259	1416	9.7	+-	1.1	706	622	401	328	4.726	5.883	8.268	0.155		19
26	6	700	0.6	27-Oct	1017	1131	3.3	+-	0.3	706	638	600	371	2.645	3.670	8.020	0.164		99
27	6	700	0.8	27-Oct	1310	1427	5.5	+-	0.4	706	639	601	363	2.403	3.418	7.768	0.212		59
29	6	700	1.0	8-Nov	1034	1149	15.0	+-	2.3	705	643	600	372	2.180	3.381	7.731	0.271		37
36	4	750	0.6	4-Nov	0952	1101	1.3	+-	0.2	756	662	400	322	4.424	4.747	8.123	0.099		105
37	4	750	0.8	4-Nov	1413	1525	2.9	+-	0.6	756	665	400	328	4.596	4.923	8.299	0.134		69
39	4	750	1.0	28-Oct	1016	1144	8.3	+-	0.3	755	662	400	377	2.809	4.033	7.409	0.182		13
Outlet SO3 (Cat. Layer 4)																			
22	5	700	0.8	8-Dec	1304	1420	3.5	+-	0.8	705	633	400	331	2.802	3.061	5.646	0.135		40
27	7.5	700	0.8	16-Jan	1501	1604	3.9	+-	2.5	705	640	600	340	2.403	3.418	7.768			
37	5	750	0.8	8-Dec	0959	1107	13.6	+-	2.2	757	664	399	342	3.059	3.346	6.722	0.140		47

FOURTH PARAMETRIC TEST RESULTS

REACTOR J

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx rxr inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																			
7	4	620	0.8	14-Nov	0855	0948	19.3	+-	0.3	624	529	400	332		5.470	6.784	0.138		53
14	6	620	1.0	14-Nov	1422	1555	123.6	+-	7.4	625	557	594	342		5.194	6.508	0.265		26
21	4	700	0.6	11-Nov	0854	0952	4.5	+-	0.3	707	588	400	330		3.663	5.49	0.102	247	119
22	4	700	0.8	11-Nov	1301	1400	9.9	+-	0.2	707	586	400	335		4.022	6.154	0.139	97	56
24	4	700	1.0	10-Nov	0928	1026	26.2	+-	0.3	708	596	404	333		3.736	5.602	0.174	50	7
27	6	700	0.8	10-Nov	1443	1623	28.0	+-	0.3	703	622	600	319		3.213	5.336	0.199	144	48
37	4	750	0.8	11-Jan	1509	1600	46.2	+-	4.7	756	619	403	257		6.328	10.19	0.108		24
Slip NH3																			
2	2.4	620	0.8	26-Oct	1633	1641	1.1	+-	0.2	625	543	239	289		3.490	5.354	0.073	218	85
6	4	620	0.8	26-Oct	0901	1025	0.7	+-	0.1	625	507	400	310		3.306	4.828	0.097	280	132
7	4	620	0.8	27-Oct	0856	1010	1.7	+-	0.3	625	531	402	332		3.954	5.630	0.137		53
9	4	620	1.0	27-Oct	1536	1641	7.2	+-	0.5	625	536	403	320		4.036	5.613	0.168		13
14	6	620	1.0	25-Oct	1453	1604	18.6	+-	0.4	624	570	601	310		3.250	4.890	0.242	87	47
21	4	700	0.6	2-Nov	1014	1130	0.6	+-	0.1	646	575	399	330		7.202	7.709	0.136		79
22	4	700	0.8	2-Nov	1457	1612	1.0	+-	0.1	666	591	399	320		6.783	7.395	0.132		84
24	4	700	1.0	3-Nov	1026	1139	1.9	+-	1.4	705	595	400	305		5.236	6.278	0.134		20
26	6	700	0.6	3-Nov	1505	1616	1.4	+-	0.1	686	611	601	299		4.609	5.818	0.140		106
27	6	700	0.8	31-Oct	1011	1119	4.4	+-	0.3	674	602	599	320		3.324	4.821	0.195		63
29	6	700	1.0	31-Oct	1250	1400	22.4	+-	0.4	676	607	599	302		3.267	4.828	0.232		21
36	4	750	0.6	9-Jan	1001	1113	2.6	+-	0.9	756	625	401	224		5.993	9.392	0.070		62
37	4	750	0.8	11-Jan	1222	1331	4.2	+-	0.5	758	629	401	257		6.328	10.187	0.108		24
39	4	750	1.0	9-Jan	1247	1401	10.2	+-	2.5	754	623	397	226		6.272	9.487	0.116		8
Outlet SO3 (Cat. Layer 4)																			
22	5	700	0.8	9-Dec	0953	1113	3.4	+-	0.6	704	568	400	229		4.399	7.678	0.096		45
27	6	700	0.8	12-Dec	1042	1153	7.0	+-	0.7	703	625	599	274		5.062	7.575	0.166		36
37	4	750	0.8	9-Dec	1511	1628	11.7	+-	0.4	756	609	401	243		4.686	7.751	0.101		66

REACTOR J CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOVA (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	400	437	332	266	16.7	0.802		58	71
14	594	648	342	345	108.5	1.010		28	3
21	400	447	330	197	4.3	0.597	276	133	137
22	400	457	335	270	9.3	0.805	111	64	71
24	404	453	333	333	25.1	1.000	56	8	7
27	600	681	319	256	27.7	0.804	164	55	68
37	403	547	257	208	37.7	0.810		33	53
2	239	287	289	236	1.1	0.815	244	95	58
6	400	438	310	187	0.7	0.603	306	144	127
7	402	443	332	264	1.6	0.796		58	73
9	403	441	320	319	6.8	0.995		14	8
14	601	662	310	311	18.3	1.004	96	52	5
21	399	414	330	264	0.5	0.799		82	72
22	399	417	320	256	0.8	0.799		88	69
24	400	428	305	260	1.7	0.852		21	50
26	601	653	299	180	1.3	0.602		115	122
27	599	654	320	252	4.3	0.788		69	73
29	599	657	302	300	22.1	0.994		23	8
36	401	518	224	135	2.2	0.603		80	91
37	401	544	257	209	3.4	0.811		33	53
39	397	508	226	226	8.3	1.001		10	4

Parametric Operating Condition	LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
				SO3 corr. out (ppmv)					
22	87	1865		1720	0.6	+-	0.0	0.6	0.11
27	87	1881		1866	1.5	+-	0.3	1.3	0.23
37	87	1952		1769	0.9	+-	0.1	0.8	0.44

FIFTH PARAMETRIC DATA SPREADSHEET KEY

Column Heading	Description
Parametric Operation Condition	Arbitrarily assigned number to particular, flow, temperature and NH_3/NO_x combination
Reactor Flow Rate	Nominal reactor flowrate in SCFM/1000 where T = 0 °F, P = 1.0 ATM
Reactor Inlet Temp.	Nominal parametric condition operating temperature °F
NH_3/NO_x Ratio	Nominal parametric condition NH_3 - to - NO_x ratio
Date	Date that sample was taken
Start time	Start time of three triplicate sample runs
End time	End time of three triplicate sample runs
Conc.	Constituent concentration, ppm by volume, based on wet phase gas (10% by volume moisture)
ρ	Standard deviation of measurement based on triplicate runs
TEMP gas in	Process gas temperature in °F measured at the reactor inlet
TEMP gas out	Process gas temperature in °F
Flow measured (scfm)	measured average flow from archive (0 °C 1 atm.)
NO_x inlet (ppmv)	measured average pilot plant inlet NO_x, wet, not O_2 corrected, from archive
O_2 inlet (%)	measured average plant inlet O_2 from archive, wet
O_2 rxr inlet (%)	measured reactor inlet O_2 (at verturi) wet, from archive
O_2 rxr outlet (%)	measured average reactor outlet O_2 wet, from archive
NH_3 actual (Kg/hr)	measured average NH_3 injection rate from mass flow controller, from archive
NH_3 corrected kg/hr	corrected NH_3 feed rate accounting for drift in calibrations
NO_x NOVA (ppmv)	NO_x measured by NOVA portable instrument at location of ammonia sample
NO_x out measured (ppmv)	measured average outlet NO_x concentration, wet, not O_2 corrected, from archive
FLOW corrected (scfm)	corrected reactor flow at inlet O_2 concentration (using post-test calibrations)
FLOW corrected out (scfm)	reactor flow corrected to outlet O_2 concentration (calculated outlet flow w/inleak)
NO_x corrected in (ppmv)	reactor inlet NOx corrected to inlet O_2 concentration
NH_3 actual (ppmv)	calculated actual NH_3 concentration corrected to inlet O_2 concentration, wet
NH_3/SO_3 concentration corrected	manual NH_3 concentration corrected to inlet O_2, measured at exit to catalyst layer #1, or at reactor exit for SO_3
NH_3 /NO_x ratio actual	actual NH_3/NO_x ratio using corrected NO_x and NH_3 values at reactor inlet O_2 concentration
NO_x corrected NOV (ppmv)	NOVA measurement corrected to inlet O_2 concentration
NO_x out corrected (ppmv)	measured outlet NO_x corrected to inlet O_2
NO_x out pred (ppmv)	predicted outlet NO_x w/ 100% NH_3 reaction, corrected to inlet O_2 concentration
LOAD unit #5 (MW)	average unit load from archive
SO_2 plant inlet (ppmv)	average inlet SO_2 to pilot plant, wet, not O_2 corrected from archive
SO_2 corrected in (ppmv)	average reactor inlet SO_2 corrected to rxr inlet O_2
SO_3 measured in (ppmv)	SO_3 concentration measured at the reactor inlet
ρ	standard deviation in inlet SO_3 concentration
SO_3 corrected in (ppmv)	SO_3 concentration corrected to reactor outlet O_2 concentrations
SO_2 Ox rate (%)	oxidation rate of SO_2 based on corrected SO_2 and SO_3 outlet measured (as % of SO_2 oxidized)

FIFTH PARAMETRIC TEST RESULTS

REACTOR A

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Intermediate Level NH3 Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
7	5	620	0.8	28-Jun	0910	1009	21.7	+-	1.7	637	611	4983	314	3.093	4.673	3.774	1.472	1.561	105	67
17	7.5	620	1.0	29-Jun	1525	1618	3.9	+-	0.1	704	663	2982	313	3.192	4.353	4.013	0.805	0.960	110	78
21	5	700	0.8	30-Jun	0926	1015	9.3	+-	0.6	708	674	4998	311	3.346	4.537	3.975	1.121	1.191	169	120
22	5	700	0.8	17-Jun	1032	1125	15.2	+-	0.3	706	673	4998	318	3.264	5.668	4.271	1.417	1.474	125	50
24	5	700	1.0	28-Jun	0917	1005	43.4	+-	1.9	706	676	4984	368	4.309	5.651	4.84	2.181	2.309	71	24
27	7.5	700	0.8	28-Jun	1455	1548	32.2	+-	1.6	706	678	6060	355	4.127	5.651	4.84	2.007	2.125	123	74
37	5	750	0.8	24-Jun	0815	0907	16.4	+-	0.2	757	724	4984	320	3.752	4.986	4.457	1.533	1.613	110	67
Slip NH3																				
2	3	620	0.8	8-Jun	1058	1210	0.7	<		623	593	2993	348	3.784	4.932	4.516	1.005	1.030		92
6	5	620	0.6	7-Jun	0932	1044	0.7	<		624	603	5002	369	3.708	5.646	4.505	1.268	1.298		125
7	5	620	0.8	7-Jun	1338	1500	0.6	<		626	606	4999	360	3.553	5.395	4.175	1.657	1.696		60
9	5	620	1.0	5-Jul	0939	1100	1.5	+-	0.5	637	613	5017	338	3.380	4.8	3.914	2.007	2.149		19
14	7.5	620	1.0	7-Jul	0914	1023	2.5	+-	0.4	629	609	5984	339	3.831	5.601	4.412	2.340	2.513		56
21	5	700	0.6	5-Jun	1050	1209	0.8	<		705	673	5007	337	4.377	6.108	4.961	1.174	1.198		117
22	5	700	0.8	4-Jun	0905	1022	3.9	+-	0.2	702	675	4992	356	5.303	6.118	5.753	1.741	1.773		52
24	5	700	1.0	6-Jul	0918	1030	0.8	<		706	680	4984	338	3.972	4.931	4.451	2.045	2.193		18
26	7.5	700	0.6	6-Jun	0923	1050	0.6	<		709	684	5813	330	2.693	4.987	3.677	1.300	1.328		134
27	7.5	700	0.8	5-Jun	1328	1448	0.7	<		703	675	5737	252	4.488	5.939	4.989	1.016	1.037		84
29	7.5	700	1.0	10-Jul	1118	1228	1.5	+-	1.1	705	675	5251	338	4.552	5.924	4.970	2.101	2.256		45
36	5	750	0.6	14-Jun	0858	1009	0.7	<		757	723	4983	385	5.838	8.803	6.146	1.135	1.175		152
37	5	750	0.8	14-Jun	1115	1224	0.8	<		757	724	4998	369	6.183	9.239	6.497	1.523	1.577		99
39	5	750	1.0	6-Jul	1421	1535	1.5	+-	0.1	756	726	5006	323	3.669	4.873	4.231	1.942	2.082		39
Outlet SO3 (Cat. Layer 4)																				
22	5	700	0.8	1-Jun	0950	1133	7.1	+-	1.0	705	673	5004	336	3.328	5.32	4.037	1.538	1.559		65

REACTOR A CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)									
7	6671	6375	286	213	19.6	0.744	100	64	77									
17	3394	3326	293	219	3.6	0.748	108	76	78									
21	6705	6517	280	182	8.6	0.667	163	116	132									
22	6462	6006	275	209	13.0	0.761	115	46	70									
24	6654	6371	338	316	37.0	0.934	67	23	28									
27	6875	6530	323	239	27.5	0.741	117	70	88									
37	6580	6401	297	224	14.6	0.753	106	65	78									
2	3172	3092	325	252	0.7	0.774		90	78									
6	6282	4917	328	190	0.6	0.681		116	141									
7	6279	4896	322	249	0.6	0.773		56	78									
9	6823	6521	311	286	1.3	0.919		18	31									
14	6989	6488	304	278	2.1	0.916		52	31									
21	5250	4874	302	177	0.7	0.585		109	129									
22	6216	6091	338	263	3.3	0.780		61	79									
24	6803	6636	317	293	0.7	0.923		17	30									
26	6117	5655	289	168	0.6	0.583		124	124									
27	6016	6668	230	133	0.6	0.580		79	99									
29	6193	6824	310	282	1.2	0.911		42	33									
36	5392	4428	294	169	0.5	0.575		125	128									
37	5409	4386	293	226	0.5	0.771		80	72									
39	6828	6606	301	277	1.3	0.920		38	29									
					SO3 corr. out (ppmv)						LOAD unit #5 (MW)	SO2 plant inlet (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	5172	4781	297	233	6.2	0.785		60	68		90	1223	1065	0.9	+-	0.5	0.8	0.50

FIFTH PARAMETRIC TEST RESULTS

REACTOR B

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Intermediate Level NH3 Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
7	6	625	0.8	28-Jun	1047	1137	51.74	+-	0.917	627	607	5000	359	4.209	4.687	4.866	1.805	1.864	121	39
17	7.5	625	1.0	28-Jun	1312	1400	12.2	+-	0.734	707	664	3006	360	4.255	4.851	5.54	1.076	1.111	106	57
21	6	705	0.6	30-Jun	1121	1216	19.91	+-	0.826	706	678	4998	317	3.266	3.761	4.138	1.193	1.234	157	99
22	6	705	0.8	23-Jun	1505	1559	34.31	+-	0.642	703	676	4991	314	3.541	4.04	4.378	1.575	1.619	106	54
24	6	705	1.0	29-Jun	1054	1147	47.06	+-	4.123	707	683	5008	312	3.134	3.678	3.832	1.951	2.017	82	6
27	7.5	705	0.8	29-Jun	1335	1432	42.02	+-	3.67	707	681	6495	313	3.195	3.718	3.779	2.038	2.107	128	57
37	6	755	0.8	23-Jun	903	954	32.02	+-	0.183	753	722	4999	338	4.178	6.275	6.284	1.687	1.734	122	56
2	3	625	0.8	6-Jun	1057	1212	0.826	<		621	591	3001	347	2.959	4.88	5.24	0.960	0.972		48
6	6	625	0.6	7-Jun	1050	1203	0.734	<		626	605	4988	362	3.52	3.918	3.965	1.367	1.386		110
7	6	625	0.8	7-Jun	1504	1615	0.734	<		625	605	5005	355	3.505	3.898	3.878	1.788	1.812		60
9	6	625	1.0	7-Jul	1113	1220	2.2	+-	0.09	626	606	5002	340	3.807	4.239	4.33	2.140	2.228		2
14	7.5	625	1.0	7-Jul	1349	1455	5.41	+-	1.1	629	612	6205	344	3.656	4.035	4.046	2.693	2.804		6
21	6	705	0.6	5-Jun	1458	1603	0.826	<		705	676	4999	256	5.02	6.158	6.16	0.913	0.923		60
22	6	705	0.8	4-Jun	1032	1148	0.826	<		704	678	5010	355	5.312	6.097	6.833	1.726	1.744		45
24	6	705	1.0	6-Jul	1114	1220	1.193	+-	0.183	708	682	5002	337	3.715	4.129	4.213	2.123	2.208		2
26	7.5	705	0.6	6-Jun	1409	1539	0.734	<		709	680	6058	347	2.796	3.795	4.046	1.538	1.557		117
27	7.5	705	0.8	5-Jun	928	1043	0.826	<		709	684	6050	342	4.232	5.297	5.637	2.002	2.024		65
29	7.5	705	1.0	8-Jul	847	958	2.39	+-	0.09	707	682	6005	351	4.04	4.448	4.339	2.651	2.783		28
36	6	755	0.6	9-Jun	1422	1530	0.55	<		756	726	5006	352	3.654	4.091	4.239	1.329	1.349		123
37	6	755	0.8	14-Jun	1349	1455	0.734	<		757	727	5002	368	5.553	5.723	5.914	1.872	1.909		61
39	6	755	1.0	6-Jul	1257	1408	1.468	+-	0.469	756	732	5000	327	2.797	3.325	3.377	2.047	2.137		7
22		700	0.8	1-Jun	1341	1525	0.55	+-	0.37	706	676	5003	318	3.553	4.959	5.39	1.510	1.521		36

REACTOR B CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 meas. in (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)	σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
7	5191	5249	349	278	46.9	0.797	122	39	76							
17	3121	3260	347	276	10.9	0.794	111	60	77							
21	5200	5316	308	184	19.1	0.596	161	101	128							
22	5165	5260	305	243	32.3	0.797	108	56	67							
24	5205	5251	302	300	45.3	0.992	83	6	8							
27	6750	6774	304	242	40.3	0.795	128	57	67							
37	5164	4838	296	260	26.2	0.879	114	52	41							
2	3046	3115	310	247	0.7	0.797		49	68							
6	6067	6081	354	212	0.7	0.598		110	146							
7	6086	6079	347	276	0.7	0.795		60	76							
9	5241	5269	331	329	2.0	0.993		2	9							
14	6501	6505	336	334	5.1	0.992		6	9							
21	5068	5066	238	141	0.7	0.593		60	99							
22	5074	5337	337	268	0.7	0.789		47	76							
24	5230	5257	329	327	1.1	0.994		2	8							
26	6148	6239	328	196	0.7	0.598		119	136							
27	6133	6269	320	256	0.7	0.798		66	70							
29	6288	6257	343	340	2.2	0.991		28	10							
36	5086	5141	343	205	0.5	0.597		124	142							
37	6121	5185	364	289	0.6	0.793		62	81							
39	5228	5244	318	316	1.4	0.997		7	7							
22	5051	5190	292	233	0.5	0.798		37	64	89	1174	1046	0.4	0.0	0.3	0.02

FIFTH PARAMETRIC TEST RESULTS

REACTOR C

Parametric Operating Condition	Reactor Flow Rate kWSCFM	Reactor Inlet Temp. deg F	NH3/NOx ratio	Intermediate Level NH3 Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
7	6	625	0.8	28-Jun	0917	1005	45.8	+-	4.3	632	611	4993	369	4.261	4.582	6.056	1.864	1.740	99	43
17	7.5	625	1.0	28-Jun	1450	1539	18.3	+-	4.6	703	663	3000	355	4.127	4.578	6.013	1.071	1.000	92	56
21	6	705	0.6	29-Jun	1043	1138	17.8	+-	1.9	708	680	5001	312	3.134	3.518	5.264	1.183	1.100	151	72
22	6	705	0.8	17-Jun	0941	1025	32.8	+-	0.6	708	678	5001	316	3.210	3.727	5.97	1.585	1.538	104	48
24	6	705	1.0	29-Jun	1329	1425	58.3	+-	6.8	707	678	5013	313	3.195	3.573	5.33	1.980	1.842	84	1
27	7.5	705	0.8	30-Jun	1345	1434	64.1	+-	3.1	708	684	6500	329	3.282	3.522	5.506	2.186	2.026	97	24
37	6	755	0.8	24-Jun	0955	1053	38.7	+-	2.8	758	727	5001	314	3.628	4.081	5.702	1.579	1.495	107	42
Slip NH3																				
2	3	625	0.8	14-Jun	0803	1024	0.8	<		624	591	3001	365	5.822	6.160	6.923	1.107	1.081		46
6	6	625	0.8	12-Jun	1043	1202	3.1	+-	0.1	627	603	5003	386	3.485	3.681	5.367	1.478	1.458		73
7	6	625	0.8	12-Jun	1344	1458	12.4	+-	1.8	626	605	4995	384	3.428	3.617	5.355	1.958	1.932		16
9	6	625	1.0	12-Jul	1026	1138	42.6	+-	4.6	631	609	4998	327	3.924	4.224	5.545	2.076	1.882		4
14	7.5	625	1.0	12-Jul	1358	1510	43.0	+-	2.8	623	606	4990	345	3.936	4.240	5.549	2.182	1.979		6
21	6	705	0.6	10-Jun	1048	1155	2.2	+-	0.1	707	678	5002	338	3.378	3.556	5.479	1.273	1.265		105
22	6	705	0.8	10-Jun	0857	1000	5.1	+-	0.2	707	678	5008	337	3.128	3.294	5.671	1.724	1.713		43
24	6	705	1.0	13-Jul	1124	1225	26.0	+-	1.3	707	680	4998	333	3.428	3.594	5.470	2.127	1.929		4
26	7.5	705	0.6	10-Jun	1334	1459	6.0	+-	0.4	707	684	6847	344	4.107	4.223	6.818	1.811	1.789		101
27	7.5	705	0.8	13-Jun	1335	1441	12.8	+-	0.3	705	685	6797	383	4.617	4.706	7.123	2.674	2.629		43
29	7.5	705	1.0	8-Jul	1102	1230	31.8	+-	2.5	708	677	5004	348	3.788	4.074	6.486	1.789	1.804		8
36	6	755	0.6	13-Jun	0851	1001	2.9	+-	0.2	756	724	5003	387	4.539	4.675	7.069	1.485	1.460		113
37	6	755	0.8	13-Jun	1045	1153	5.9	+-	0.2	756	725	5003	388	4.340	4.463	6.862	1.988	1.955		67
39	6	755	1.0	11-Jul	1056	1202	10.0	+-	0.6	756	726	5002	318	3.943	4.272	6.138	2.009	1.822		15
Outlet SO3 (Cat. Layer 4)																				
22	6	700	0.8	1-Jul	1424	1545	8.1	+-	0.9	705	678	5004	319	3.358	3.706	5.240	1.614	1.491		28

REACTOR C CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)	LOAD unit #5 (MW)	SO2 meas. in (ppmv)	SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
7	5392	5924	362	250	41.8	0.690	109	47	117								
17	3240	3550	346	239	16.7	0.692	101	61	111								
21	5421	6023	305	157	17.3	0.515	168	80	151								
22	5181	5954	307	230	31.4	0.749	120	66	82								
24	5434	6043	306	262	56.4	0.857	71	1	49								
27	7072	7978	326	222	62.6	0.683	109	27	107								
37	5321	5885	306	218	34.5	0.712	118	48	92								
2	3073	3242	357	272	0.7	0.763		49	90								
6	5083	5631	382	222	3.0	0.582		81	164								
7	5075	5638	380	295	12.0	0.776		17	91								
9	5677	6163	321	257	39.7	0.799		4	70								
14	5668	6149	339	270	40.1	0.798		7	74								
21	5042	5667	335	194	2.1	0.580		118	144								
22	5048	5831	334	263	5.0	0.787		60	76								
24	5698	6386	330	262	24.1	0.795		4	73								
26	6902	8164	342	202	5.6	0.591		119	144								
27	6933	8141	381	294	11.6	0.771		60	93								
29	5604	6536	342	222	29.9	0.648		7	125								
36	5103	5980	384	222	2.7	0.577		132	167								
37	5103	5969	385	297	5.4	0.770		67	94								
39	5662	6373	312	249	9.3	0.799		17	68								
22	5464	5998	313	211	7.8	0.676		31	108		85	1089		1027	1.1	+- 0.1	1.1	0.65

FIFTH PARAMETRIC TEST RESULTS

REACTOR D

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																				
7	4	625	0.8	19-Jun	0914	1002	103.0	+-	5.5	625	550	394	341	3.603	4.714	6.091	0.129	0.114	226	68
17	6	625	1.0	19-Jun	1600	1656	65.8	+-	3.6	700	571	243	317	3.393	5.379	6.757	0.070	0.062	122	26
21	4	705	0.6	22-Jun	0828	0918	57.8	+-	5.0	704	613	400	343	6.219	6.903	7.608	0.101	0.088	274	109
22	4	705	0.8	16-Jun	0916	1010	68.2	+-	7.6	704	592	401	348	2.870	4.287	6.07	0.132	0.119	183	42
24	4	705	1.0	22-Jun	1349	1442	97.5	+-	4.9	698	609	402	348	3.797	4.885	6.052	0.168	0.147	198	60
27	6	705	0.8	26-Jun	0922	1014	93.4	+-	1.8	708	643	644	330	5.195	5.701	6.683	0.179	0.163	251	122
37	4	755	0.8	27-Jun	1517	1605	81.4	+-	4.1	756	651	400	360	3.645	4.623	5.815	0.140	0.119	214	67
Slip NH3																				
2	2.4	625	0.8	6-Jun	0928	1103	0.9	+-	0.2	624	482	237	333	2.758	4.528	6.764	0.074	0.070		12
6	4	625	0.6	7-Jun	0935	1051	1.8	+-	0.4	625	535	400	368	3.689	4.751	6.395	0.107	0.101		73
7	4	625	0.8	6-Jun	1410	1548	5.1	+-	0.6	626	534	394	348	2.779	3.881	5.445	0.135	0.128		51
9	4	625	1.0	5-Jul	0933	1055	12.1	+-	0.9	624	556	400	338	3.448	4.274	5.066	0.165	0.134		46
14	6	625	1.0	7-Jul	0908	1015	32.8	+-	0.4	625	583	601	340	4.080	4.699	5.424	0.255	0.205		77
21	4	705	0.6	5-Jun	1331	1454	1.6	+-	0.2	708	606	401	247	4.060	5.141	6.656	0.073	0.069		48
22	4	705	0.8	4-Jun	0913	1028	3.1	+-	0.8	706	609	402	356	5.268	6.020	7.489	0.140	0.134		46
24	4	705	1.0	6-Jul	0908	1027	4.4	+-	1.1	703	627	400	335	4.240	5.060	5.801	0.165	0.133		34
26	6	705	0.6	7-Jun	1537	1645	4.1	+-	0.3	708	626	636	363	3.415	4.185	5.578	0.140	0.132		87
27	6	705	0.8	8-Jun	1425	1541	8.9	+-	0.8	705	636	602	362	3.667	4.490	5.777	0.208	0.194		73
29	6	705	1.0	8-Jul	0843	0950	17.7	+-	0.8	705	653	593	361	4.040	4.673	5.318	0.258	0.207		56
36	4	755	0.6	13-Jun	0905	1016	1.5	+-	0.2	755	635	400	387	4.579	5.648	7.116	0.113	0.103		89
37	4	755	0.8	13-Jun	1051	1204	2.5	+-	0.2	755	635	397	388	4.336	5.303	7.017	0.151	0.138		62
39	4	755	1.0	8-Jul	1416	1524	4.3	+-	0.7	757	672	401	324	3.679	4.565	5.288	0.168	0.128		41
Outlet SO3 (Cat. Layer 4)																				
22	4	700	0.8	2-Jun	0954	1209	1.2	+-	0.7	707	629	400	215	7.022	6.787	7.330	0.085	0.082		24

REACTOR D CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	352	384	319	252	93.2	0.788	247	74	73
17	217	238	281	221	48.4	0.787	134	29	64
21	352	376	327	194	45.3	0.593	293	116	137
22	363	407	321	253	83.3	0.789	205	47	73
24	354	381	324	321	87.3	0.990	211	65	10
27	469	501	319	252	79.4	0.790	268	130	72
37	343	370	340	268	74.1	0.790	231	72	77
2	225	260	301	241	0.8	0.801		14	64
6	378	420	345	208	1.7	0.597		81	143
7	374	411	327	264	4.8	0.809		56	68
9	330	346	322	315	11.3	0.979		48	13
14	490	513	328	324	29.7	0.989		81	10
21	382	422	231	141	1.4	0.608		53	93
22	385	427	339	269	2.6	0.793		51	75
24	328	344	319	315	3.9	0.989		36	10
26	508	552	338	202	3.9	0.597		95	140
27	563	611	335	266	8.2	0.795		79	74
29	481	501	338	334	16.1	0.988		58	11
36	367	409	364	218	1.3	0.597		99	151
37	365	409	365	293	2.2	0.801		70	78
39	329	344	307	301	3.9	0.979		43	12

	SO3 corr. out (ppmv)					LOAD unit #6 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	0.9	0.751		25	58	64	1064		840	3.9	+-	2.1	3.0	-0.25

FIFTH PARAMETRIC TEST RESULTS

REACTOR E

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																				
7	4	625	0.8	19-Jun	1324	1413	14.9	+-	1.6	621	548	400	327	3.379	4.357	5.965	0.127	0.114	182	9
17	6	625	1.0	19-Jun	1110	1204	5.1	+-	0.6	706	569	241	333	3.531	4.673	6.541	0.077	0.069	187	75
21	4	705	0.6	22-Jun	1212	1305	11.2	+-	0.4	706	612	400	343	3.873	4.570	6.82	0.102	0.090	267	59
22	4	705	0.8	16-Jun	1127	1217	12.8	+-	0.3	705	607	391	357	3.085	3.982	5.93	0.139	0.126	186	62
24	4	705	1.0	27-Jun	1053	1143	23.0	+-	0.4	705	614	400	381	4.276	4.818	6.471	0.180	0.159	142	93
27	6	705	0.8	27-Jun	1346	1437	33.3	+-	2.1	704	633	555	382	3.896	4.404	6.065	0.201	0.178	204	103
37	4	755	0.8	26-Jun	1048	1143	13.1	+-	1.5	756	656	396	335	5.051	5.514	7.51	0.134	0.116	184	119
Slip NH3																				
2	2.4	625	0.8	8-Jun	1108	1230	0.6	<		624	549	243	348	3.786	4.619	6.102	0.082	0.077		117
6	4	625	0.6	7-Jun	1058	1213	0.7	<		626	543	401	357	3.635	4.200	5.605	0.109	0.103		149
7	4	625	0.8	7-Jun	1351	1508	0.7	<		625	544	400	360	3.528	4.110	5.522	0.143	0.135		118
9	4	625	1.0	7-Jul	1105	1212	0.8	+-	0.2	627	544	401	400	3.804	4.367	5.433	0.169	0.139		84
14	6	625	1.0	7-Jul	1341	1445	3.3	+-	0.3	627	570	587	344	3.660	4.116	5.176	0.258	0.212		56
21	4	705	0.6	5-Jun	1504	1624	0.6	<		704	604	400	266	4.949	5.386	7.571	0.077	0.073		122
22	4	705	0.8	4-Jun	1035	1148	0.9	+-	0.3	702	609	393	355	5.132	5.651	7.974	0.140	0.134		108
24	4	705	1.0	8-Jul	1106	1208	0.7	<		706	613	399	337	3.712	4.286	5.770	0.168	0.139		57
26	6	705	0.6	6-Jun	1135	1254	0.7	+-	0.2	705	631	550	349	2.949	3.461	4.130	0.144	0.137		157
27	6	705	0.8	5-Jun	0935	1049	0.9	+-	0.3	704	626	545	343	4.282	4.727	6.936	0.188	0.179		103
29	6	705	1.0	8-Jul	1055	1210	2.4	+-	0.6	706	632	542	353	3.942	4.385	5.736	0.241	0.197		66
36	4	755	0.6	15-Jun	0923	1045	0.6	<		756	653	401	379	3.936	4.493	6.424	0.114	0.092		121
37	4	755	0.8	15-Jun	1126	1240	0.6	<		756	656	400	389	3.819	4.384	6.344	0.155	0.125		63
39	4	755	1.0	5-Jul	1249	1356	0.6	<		756	659	401	326	2.794	3.402	4.887	0.163	0.135		73
Outlet SO3 (Cat. Layer 4)																				
22		700	0.8	2-Jun	1420	1630	5.0	+-	0.7	706	606	404	207	6.635	6.940	9.422	0.085	0.082		60

REACTOR E CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	429	476	309	205	13.7	0.665	201	10	108
17	259	292	311	207	4.6	0.664	211	85	109
21	433	502	329	161	10.2	0.490	309	68	171
22	416	470	339	235	12.1	0.693	210	70	109
24	439	489	349	281	20.7	0.804	158	104	74
27	609	676	351	226	30.7	0.643	227	114	130
37	433	497	325	208	11.3	0.638	211	137	122
2	253	278	331	236	0.6	0.714		129	99
6	416	464	345	192	0.7	0.555		183	157
7	415	463	348	252	0.7	0.725		129	101
9	462	483	387	238	0.8	0.615		90	154
14	672	718	335	244	3.1	0.728		60	96
21	413	480	249	138	0.6	0.553		142	114
22	405	477	343	257	0.8	0.748		127	92
24	448	492	326	240	0.7	0.735		83	91
26	569	592	339	186	0.7	0.549		183	157
27	563	651	334	247	0.8	0.740		119	92
29	612	666	344	249	2.2	0.725		72	100
36	426	482	367	168	0.6	0.457		137	202
37	425	482	376	229	0.6	0.608		71	152
39	449	491	315	233	0.6	0.740		80	87

	SO3 corr. out (ppmv)						LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	413	502	203	154	3.9	0.760		73	62	46	1087		849	4.5	+-	0.5	3.5	0.04

FIFTH PARAMETRIC TEST RESULTS

REACTOR F

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																				
7	4	625	0.8	27-Jun	0907	0958	81.8	+-	2.2	624	535	401	351	4.188	6.137	8.224	0.127	0.097	212	77
17	6	625	1.0	27-Jun	1527	1611	32.8	+-	0.9	704	546	247	360	2.421	6.776	9.476	0.074	0.057	152	58
21	4	705	0.6	29-Jun	0908	0958	33.9	+-	1.4	705	597	400	313	3.100	5.219	7.328	0.085	0.064	228	78
22	4	705	0.8	16-Jun	1350	1450	47.7	+-	3.1	706	594	401	348	2.990	3.686	6.233	0.139	0.117	221	112
24	4	705	1.0	28-Jun	1308	1355	64.2	+-	15.1	708	600	405	360	4.265	6.324	8.445	0.164	0.124	213	79
27	6	705	0.8	28-Jun	1044	1133	93.6	+-	2.8	706	627	599	359	4.228	5.755	7.553	0.202	0.153	258	80
37	4	755	0.8	29-Jun	1519	1611	43.9	+-	3.7	754	636	401	313	3.192	5.219	7.089	0.114	0.086	194	78
Slip NH3																				
2	2.4	625	0.8	15-Jun	1428	1541	0.6	<		626	487	243	386	3.724	4.230	6.857	0.094	0.080		15
6	4	625	0.6	8-Jun	0907	1025	0.8	+-	0.2	623	533	400	349	3.642	3.932	5.982	0.106	0.095		117
7	4	625	0.8	8-Jun	1410	1523	1.5	+-	0.2	626	531	400	349	3.571	3.907	5.921	0.142	0.128		85
9	4	625	1.0	12-Jul	1019	1128	1.8	+-	0.2	628	539	400	329	3.928	6.570	8.916	0.144	0.101		69
14	6	625	1.0	10-Jul	0850	1006	11.4	+-	1.0	624	559	600	331	4.423	5.729	7.175	0.235	0.165		65
21	4	705	0.6	12-Jun	1351	1512	1.2	+	0.1	704	587	401	386	3.423	3.752	6.132	0.117	0.102		116
22	4	705	0.8	4-Jun	1239	1354	1.5	+-	0.2	708	600	400	356	5.994	6.130	7.945	0.144	0.134		66
24	4	705	1.0	11-Jul	0841	0952	1.1	+-	0.2	705	602	401	311	4.044	5.814	7.384	0.144	0.101		72
26	6	705	0.6	10-Jun	0856	1009	2.6	+-	0.2	706	623	601	338	3.137	3.404	5.260	0.154	0.137		132
27	6	705	0.8	10-Jun	1052	1211	4.2	+-	0.8	706	623	601	339	3.685	3.926	5.736	0.206	0.183		103
29	6	705	1.0	11-Jul	1408	1517	4.8	+-	1.7	709	618	594	321	3.915	5.228	7.152	0.230	0.161		77
36	4	755	0.6	9-Jun	0906	1022	1.2	+-	0.6	754	634	400	332	3.784	4.053	6.033	0.103	0.092		127
37	4	755	0.8	9-Jun	1100	1208	1.4	+-	0.5	755	637	400	347	3.689	3.998	5.900	0.141	0.126		103
39	4	755	1.0	10-Jul	1438	1549	1.7	+-	0.1	756	639	401	336	4.375	5.952	7.519	0.293	0.206		68
Outlet SO3 (Cat. Layer 4)																				
22		700	0.8	3-Jun	0917	1120	1.1	+-	0.6	706	614	400	241	6.995	6.927	7.702	0.100	0.094		49

REACTOR F CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)
7	394	459	310	191	67.6	0.616	247	80	123
17	243	300	276	181	26.0	0.656	188	72	98
21	393	453	276	126	29.8	0.456	263	90	152
22	396	465	335	229	45.9	0.685	259	131	110
24	398	465	316	242	52.4	0.767	249	92	78
27	689	667	326	202	79.3	0.618	292	102	129
37	394	446	277	168	38.4	0.607	220	88	112
2	240	285	375	258	0.6	0.688		18	122
6	397	451	343	186	0.8	0.542		133	161
7	397	450	342	249	1.4	0.729		96	98
9	390	466	278	201	1.5	0.721		82	81
14	686	647	305	218	9.7	0.715		72	91
21	397	461	378	199	1.1	0.526		135	183
22	398	453	353	260	1.2	0.738		74	98
24	391	437	279	200	0.9	0.718		80	82
26	596	666	331	177	2.5	0.536		148	157
27	596	667	334	237	4.0	0.710		115	102
29	680	660	298	218	4.2	0.728		88	85
36	397	449	327	180	1.1	0.549		144	151
37	397	447	341	246	1.3	0.721		116	100
39	392	437	303	407	1.4	1.341		76	-96

	SO3 corr. out (ppmv)				LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	0.9	0.762		62	64		64	1086		833	4.4	+-	3.9	3.4	-0.31

FIFTH PARAMETRIC TEST RESULTS

REACTOR G

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Intermediate Level NH3 Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx plant inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
7	4	625	0.8	19-Jun	0916	1008	78.5	+-	7.0	624	534	400	340	3.665	4.581	6.189	0.133	0.111	261	88
17	6	625	1.0	19-Jun	1332	1425	25.1	+-	0.3	707	569	248	331	3.377	4.496	6.364	0.077	0.064	174	85
21	4	705	0.6	22-Jun	0837	0931	33.2	+-	1.4	703	603	400	344	6.218	6.710	8.96	0.103	0.084	303	123
22	4	705	0.8	17-Jun	0848	0935	42.4	+-	2.8	708	602	400	316	3.305	4.286	6.244	0.123	0.104	218	68
24	4	705	1.0	22-Jun	1355	1450	64.1	+-	1.8	686	601	401	345	3.797	4.442	6.095	0.172	0.140	218	86
27	6	705	0.8	26-Jun	1058	1148	51.7	+-	1.2	711	612	605	329	4.657	5.271	6.932	0.164	0.129	246	91
37	4	755	0.8	27-Jun	1348	1445	45.9	+-	0.7	753	621	401	382	3.883	4.764	6.76	0.142	0.111	245	93
															-					
															estimated					
				Slip NH3											data					
2	2.4	625	0.8	13-Jun	1340	1453	0.6	<		624	607	240	382	4.600	5.210	6.693	0.092	0.080		105
6	4	625	0.6	9-Jun	0902	1009	0.6	<		624	549	400	334	3.794	4.256	5.661	0.101	0.091		150
7	4	625	0.8	9-Jun	1054	1156	0.7	+-	0.0	625	547	402	347	3.700	4.168	5.580	0.140	0.126		114
9	4	625	1.0	10-Jul	1123	1233	2.4	+-	0.3	623	557	394	338	4.552	5.218	6.294	0.168	0.121		83
14	6	625	1.0	10-Jul	0904	1010	6.2	+-	0.3	629	571	506	333	4.453	5.075	6.135	0.207	0.149		80
21	4	705	0.6	8-Jun	1402	1516	0.6	<		704	612	397	348	3.600	4.165	6.350	0.105	0.095		157
22	4	705	0.8	8-Jun	0905	1018	0.7	+-	0.2	705	614	398	349	3.575	4.168	6.481	0.139	0.126		128
24	4	705	1.0	12-Jul	1351	1508	2.2	+-	0.2	709	618	400	344	3.944	4.903	6.387	0.165	0.119		123
26	6	705	0.6	12-Jun	0841	1006	2.4	+-	0.5	708	636	571	373	3.384	3.987	4.636	0.157	0.135		151
27	6	705	0.8	12-Jun	1052	1210	5.4	+-	0.3	706	637	576	386	3.478	4.059	6.268	0.221	0.195		112
29	6	705	1.0	13-Jul	0858	1005	6.0	+-	0.6	708	646	497	343	3.588	4.451	5.802	0.211	0.152		73
36	4	755	0.6	14-Jun	1123	1234	0.6	<		740	642	403	370	6.231	6.626	8.567	0.111	0.096		164
37	4	755	0.8	14-Jun	1355	1507	0.9	+-	0.2	754	657	399	367	5.565	6.028	7.988	0.147	0.127		127
39	4	755	1.0	11-Jul	1050	1157	3.0	+-	0.8	756	669	403	318	3.957	4.849	6.334	0.165	0.112		100
															-					
															estimated					
				Outlet SO3 (Cat. Layer 4)											data					
22		700	0.8	3-Jun	1314	1521	0.3	+-	0.0	708	616	400	233	7.267	7.544	10.026	0.093	0.087		79

REACTOR G CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)									
7	470	621	322	183	71.6	0.568	289	98	143									
17	291	328	310	171	23.0	0.551	196	96	143									
21	478	687	333	136	26.4	0.409	360	146	199									
22	464	526	298	174	39.3	0.582	247	66	128									
24	479	532	332	226	59.0	0.682	242	96	110									
27	617	689	317	162	45.2	0.512	276	102	158									
37	492	681	343	174	41.4	0.508	279	106	172									
2	272	300	368	229	0.6	0.622		116	144									
6	443	483	325	159	0.6	0.489		164	169									
7	445	486	338	219	0.7	0.660		124	123									
9	518	556	324	181	2.1	0.558		89	147									
14	665	713	320	174	5.5	0.542		86	160									
21	437	502	337	169	0.5	0.501		180	171									
22	438	508	337	223	0.7	0.661		148	119									
24	531	585	325	173	2.0	0.534		135	155									
26	644	670	361	163	2.3	0.451		157	201									
27	649	747	372	232	5.1	0.623		129	145									
29	663	722	326	178	5.5	0.546		79	152									
36	460	531	360	162	0.5	0.450		189	201									
37	455	524	356	217	0.8	0.609		146	143									
39	533	587	301	162	2.7	0.539		110	142									
					SO3 corr. out (ppmv)						LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
22	427	523	228	159	0.2	0.695		97	73		64	1082		794	5.6	+-	0.4	4.2	-0.50

FIFTH PARAMETRIC TEST RESULTS

REACTOR J

Parametric Operating Condition	Reactor Flow Rate SCFM/100	Reactor Inlet Temp. deg F	NH3/NOx ratio	Date 1994/95	Start Time	End Time	Conc. ppm(v) wet, @ 3% O2		σ	TEMP gas in F	TEMP gas out F	FLOW meas. (scfm)	NOx rxr inlet (ppmv)	O2 plant inlet (%)	O2 rxr inlet (%)	O2 rxr outlet (%)	NH3 actual (Kg/hr)	NH3 corrected (Kg/hr)	NOx NOVA (ppmv)	NOx out meas. (ppmv)
Intermediate Level NH3																				
7	4	625	0.8	19-Jun	1507	1602	9.5	+-	0.5	624	544	402	220	3.393	7.823	8.591	0.093	0.071	201	67
17	6	625	1.0	19-Jun	1118	1210	4.7	+-	0.6	706	568	246	192	3.527	9.672	11.122	0.048	0.037	227	84
21	4	705	0.8	22-Jun	1216	1308	8.0	+-	1.0	706	589	412	232	3.873	7.852	9.249	0.074	0.054	278	131
22	4	705	0.8	23-Jun	1335	1423	8.5	+-	0.5	706	621	401	226	4.088	8.243	9.291	0.094	0.068	199	107
24	4	705	1.0	27-Jun	1101	1150	14.7	+-	0.7	704	616	400	243	4.306	8.096	9.191	0.123	0.085	204	99
27	6	705	0.8	27-Jun	0858	0945	16.7	+-	1.0	704	634	532	234	3.987	7.075	8.865	0.126	0.087	230	108
37	4	755	0.8	23-Jun	1000	1055	9.1	+-	0.7	754	659	401	223	4.165	8.124	9.799	0.092	0.067	228	108
Slip NH3																				
2	2.4	625	0.8	15-Jun	1422	1527	0.8	+-	0.0	624	508	235	211	3.749	9.982	11.010	0.052	0.042		99
6	4	625	0.8	15-Jun	0939	1047	0.9	+-	0.2	625	544	401	229	4.018	8.285	9.516	0.070	0.056		133
7	4	625	0.8	15-Jun	1119	1225	1.2	+-	0.0	624	545	401	234	3.851	8.309	9.470	0.094	0.075		106
9	4	625	1.0	10-Jul	1440	1544	2.0	+-	0.7	622	545	400	255	4.382	7.649	9.103	0.093	0.056		107
14	6	625	1.0	11-Jul	0851	0959	4.7	+-	1.3	625	561	500	233	4.048	6.623	7.900	0.149	0.090		67
21	4	705	0.8	16-Jun	0907	1012	0.7	<		706	612	400	223	2.874	7.671	9.426	0.069	0.055		114
22	4	705	0.8	16-Jun	1118	1219	0.7	+-	0.1	707	612	399	225	3.049	7.677	9.436	0.093	0.074		110
24	4	705	1.0	13-Jul	0907	1014	2.3	+-	0.1	707	618	401	238	3.502	6.929	8.171	0.124	0.075		72
26	6	705	0.8	16-Jun	1404	1505	1.0	+-	0.0	705	629	547	231	2.991	7.673	9.429	0.097	0.077		123
27	6	705	0.8	17-Jun	1251	1357	1.3	+-	0.1	753	669	530	224	3.272	7.667	9.424	0.122	0.096		100
29	6	705	1.0	11-Jul	1417	1525	3.3	+-	0.6	706	628	492	235	3.901	5.925	8.132	0.149	0.090		62
36	4	755	0.6	17-Jun	0839	0948	0.7	<		756	659	402	208	3.305	7.667	9.421	0.064	0.050		118
37	4	755	0.8	17-Jun	1022	1130	0.8	+-	0.1	753	654	400	211	3.254	7.665	9.420	0.085	0.067		107
39	4	755	1.0	13-Jul	1145	1250	2.3	+-	0.6	756	655	400	308	3.449	6.378	8.297	0.119	0.072		74
Outlet SO3 (Cat. Layer 4)																				
22	4	700	0.8	1-Jul	1034	1203	10.3	+-	1.2	708	585	384	243	3.593	7.132	9.920	0.095	0.062		97

REACTOR J CALCULATED RESULTS

Parametric Operating Condition	FLOW corr. in (scfm)	FLOW corr. out (scfm)	NOx corr. in (ppmv)	NH3 actual in (ppmv)	NH3|SO3 conc.corr. (ppmv)	NH3/NOx ratio actual	NOx corr. NOV (ppmv)	NOx corr. GAS (ppmv)	NOx pred. out (ppmv)										
7	411	436	220	134	7.0	0.609	213	71	89										
17	262	288	192	113	2.9	0.588	260	108	81										
21	427	478	232	99	4.4	0.426	311	147	135										
22	417	464	225	127	6.0	0.564	217	117	101										
24	423	463	243	155	10.5	0.638	223	108	91										
27	583	646	234	119	12.9	0.510	264	124	117										
37	417	480	223	124	6.5	0.557	262	124	101										
2	236	260	211	137	0.5	0.648		109	77										
6	403	446	229	108	0.6	0.471		147	123										
7	403	443	234	145	0.8	0.619		117	92										
9	447	501	265	97	1.5	0.382		120	160										
14	561	615	233	124	3.7	0.534		83	111										
21	404	465	223	105	0.5	0.470		131	120										
22	403	464	225	142	0.5	0.630		127	86										
24	463	497	238	128	1.8	0.538		79	113										
26	552	636	231	108	0.7	0.467		142	125										
27	537	619	224	138	0.9	0.615		115	89										
29	552	646	235	126	2.8	0.538		73	111										
36	407	469	208	95	0.5	0.458		136	115										
37	405	467	211	127	0.6	0.603		123	86										
39	452	520	308	123	1.9	0.400		85	187		LOAD unit #5 (MW)	SO2 meas. in (ppmv)		SO2 corr. in (ppmv)	SO3 meas. in (ppmv)		σ (ppmv)	SO3 corr. in (ppmv)	SO2 OX rate (%)
					SO3 corr. out (ppmv)														
22	413	517	243	116	7.9	0.477		121	129		86	1173		904	6.1	+-	0.3	4.7	0.36

TESTING AND ANALYTICAL SERVICES FOR THE INNOVATIVE CLEAN COAL TECHNOLOGY DEMONSTRATION OF SELECTIVE CATALYTIC REDUCTION (SCR) TECHNOLOGY FOR THE CONTROL OF NITROGEN OXIDE (NO_x) EMISSIONS FROM HIGH SULFUR COAL

Final Report for Task 4

Air Heater Tests
Reactors A, B, C
First Parametric Series

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Section 1

INTRODUCTION

This is the fifth in a series of reports describing the results of testing and analytical services for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the control of nitrogen oxide (NO_x) emissions from high-sulfur, coal-fired boilers. The test results for the initial set of air heater tests are summarized in this report. The air heater tests were conducted during the last week of April and the first two weeks of May, 1994, following the completion of the first sequence of parametric testing under Task 4: Long-Term Parametric Tests.

The SCR test facility is located at Gulf Power Company's Plant Crist Unit 5 in Pensacola, Florida. The test facility includes three large SCR reactors, each designed to treat 5000 wscfm of flue gas, and six small reactors, each processing 400 wscfm of flue gas. An air heater capable of removing sufficient heat to reduce the flue gas temperature from a range of 600 to 750 °F down to 300 °F was included in the design of each of the three large reactors. The three large reactors are designated as reactors A, B, and C. Reactors A and B incorporate Ljungstrom-type air heaters and Reactor C's air heater incorporates a heat pipe design.

The original design of the SCR test facility also included bypass heat exchangers on each of the three large reactors. These units were intended for use during parametric testing of the reactors (Task 4: Long Term Parametric Tests) so that flue gas containing higher concentrations of slip ammonia could be diverted around the air heaters. However, the bypass heat exchangers did not function as planned and the practice of bypassing the air heaters on Reactors A, B and C during parametric testing was abandoned. Thus, the air heater test data presented in this report include the effects of day-long periods of exposure to ammonia concentrations normally ranging from a few parts per million by volume ppm(v) to 20 ppm(v), although brief excursions approached 100 ppm(v).

The air heater testing included the determinations of particulate mass concentration and measurements of the concentrations of sulfur dioxide, sulfur trioxide, hydrogen chloride and ammonia. All tests were conducted with manual sampling methods. Ammonia samples were segregated into solid and gas-phase fractions to characterize the gas/solid phase partitioning of ammonia across the air heaters. In general, simultaneous tests were performed at the inlet and outlet of each of the three air heaters (except for mass concentration measurements at the outlet of the Reactor C air heater). The fly ash (particulate) catches from the mass concentration measurements were further analyzed in the laboratory to determine particle size distributions, ash mineralogy, and ash resistivity.

This report is divided into several sections. Section 2 describes the test methods used for the air heater testing. Section 3 reviews all of the test results. The test data are briefly summarized in Section 4. Tables containing original data summaries that were produced for the air heater testing are contained in Appendix A.

Section 2

TEST METHODS

A variety of test methods were used to characterize air heater performance. The following subsections briefly describe the test methods for ammonia (NH_3), sulfur dioxide (SO_2), sulfur trioxide (SO_3), hydrogen chloride (HCl), and particulate mass concentration, particle size, ash mineralogy, and ash resistivity. Figure 2-1 shows a sketch of a large reactor and its air heater (not to scale). The test port locations for air heater inlet and outlet measurements are indicated on the diagram. Test ports (three horizontal ports) upstream of catalyst layer 4 (the normal reactor outlet test location) were used to measure concentrations of air heater inlet particulate and gas constituents. Three test ports (horizontal) were installed in a transition piece in the outlet ducting of the Reactor A and B air heaters that were suitable for particulate and gas phase flue gas constituent testing. Test ports at this same location in the Reactor C air heater outlet were not installed. However, a single test port (horizontal) in a section of ducting at the inlet transition to the cyclone on Reactor C (downstream of the reactor bypass duct) was suitable for testing gas phase flue gas constituents. Turbulent flow at this location precluded mass concentration tests.

Air heater tests were performed with the reactors operating at Test Condition 22, the normal baseline or long-term operating condition. These operating conditions included a flue gas temperature of 700 °F, an NH_3/NO_x ratio of 0.8, and a flue gas flow rate of 5000 wscfm. During measurements of air heater inlet and outlet ammonia concentrations only, additional tests were performed at Test Condition 24 (except Reactor A). The operating parameters for these tests were a flue gas temperature of 700 °F, an NH_3/NO_x ratio of 1.0, and a flue gas flow rate of 5000 wscfm.

AMMONIA

Ammonia concentrations were measured simultaneously at the air heater inlet (upstream of catalyst layer 4) and at the air heater outlet on each of the large reactors. At each site and at each test condition, three independent tests were performed to determine an average ammonia concentration. Sampling ports located upstream of catalyst layer 4 were used to measure air heater inlet ammonia concentration. Flue gas was sampled at three equidistant points in each of the three test ports (a total of nine traverse points) to determine an average inlet ammonia concentration for each test. At the air heater outlet sampling location on Reactors A and B the probe also sampled at three equidistant points in each of the three test ports (a total of nine traverse points). At the single Reactor C outlet test port, the ammonia probe traversed three, equally-spaced, points (front to rear) during each test.

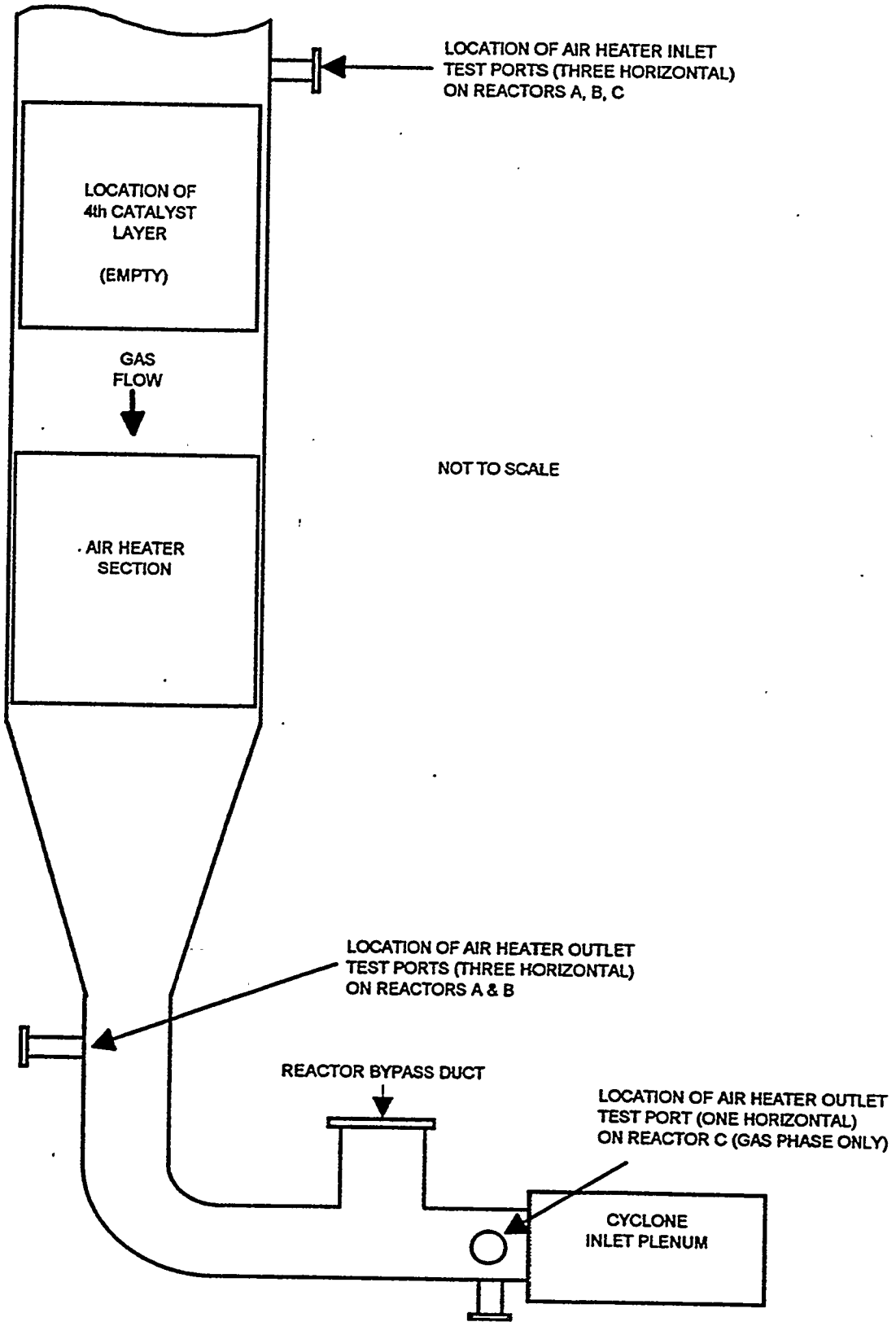

Figure 2-1. Schematic drawing of SCR reactor and air heater cross section (side view).

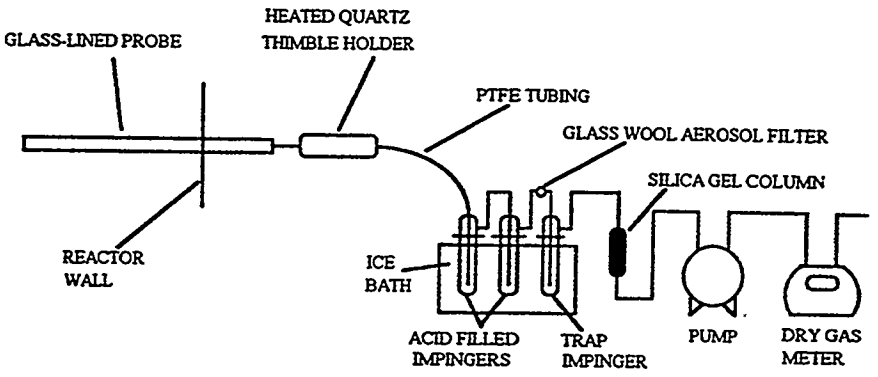

Figure 2-2. Schematic diagram of the ammonia sampling train.

A schematic drawing of the ammonia sampling train is shown in Figure 2-2. The flue gas sample is drawn through a glass-lined probe and a heated filter to remove particulate. The filter is maintained at the nominal flue gas temperature. The gas sample passes through a length of PTFE tubing to a set of three impingers in an ice bath. The first two impingers contain a 0.1 normal solution of sulfuric acid. The third impinger serves as a trap to prevent the solutions from accidentally being drawn into the pump. A second glass wool plug is placed in the line between the last two impingers to collect any ammonia aerosols that may escape the second impinger. The remainder of the train consists of a silica gel column to remove the last traces of water from the flue gas sample, a leak-free pump, and a dry gas meter to measure the volume of the sample.

The samples were segregated during sample collection into a solid-phase sample and a gas-phase sample. The solid-phase sample consisted of the heated filter, all of the collected particulate, and the probe-wash liquid. The gas-phase sample consisted of the impinger liquids and the wash and rinse liquids. The two samples were analyzed separately to characterize the ammonia partitioning between the gas and solid phases.

At the outset of the Task 4 parametric testing, modified Greenberg-Smith type impingers were used for ammonia sampling. However, 100 mL gas sampling impingers, each containing about 50 mL of solution, were used for the air heater ammonia testing to reduce the detection limit to less than 1 ppm(v) for a reasonable sample volume, about 3 ft^3 of gas. The lower detection limit was needed for much of the air heater ammonia testing because ammonia concentrations are very low at the reactor exit when operating at the reactor design condition with an NH_3/NO_x ratio of 0.8.

The impinger solutions are made alkaline in the laboratory (converting the NH_4^+ ion to free NH_3 in solution). The concentration of ammonia is then determined with an ammonia ion specific electrode, Orion Model 920A. As mentioned above, three individual measurements of ammonia concentration are made for each test condition. Two independent determinations of the ammonia concentration are then conducted on each sample.

SULFUR DIOXIDE AND SULFUR TRIOXIDE

During the air heater evaluation, SO_2 and SO_3 concentrations were measured simultaneously at the reactor outlet upstream of catalyst layer 4 (air heater inlet) and the air heater outlet. Sulfur dioxide (SO_2) and sulfur trioxide (SO_3) were collected in a controlled condensation sampling train. All

tests were conducted using single-point sampling in either the right-hand port (air heater inlet test location) or middle port (air heater outlet test location).

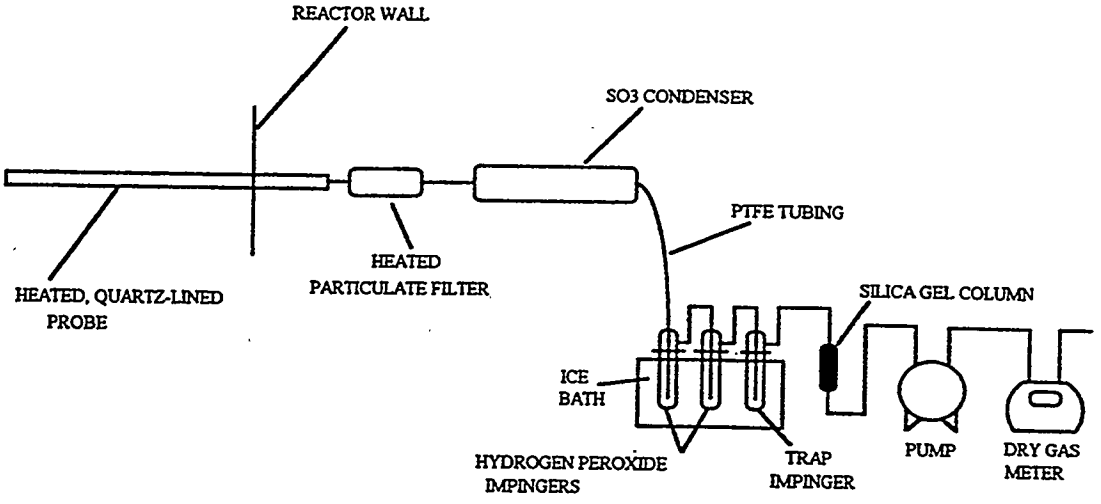

Figure 2-3. Schematic diagram of the controlled condensation sampling train for SO_2 and SO_3.

A schematic drawing of the SO_2/SO_3 sampling train is shown in Figure 2-3. The flue gas sample is drawn through a heated, quartz-lined probe maintained above 550 °F. The sample then passes through a quartz filter housed in a heated quartz filter holder, also maintained at 550 °F. The next element in the train is the SO_3 condenser. The condenser is a length of quartz tubing packed with quartz wool and maintained between 120 °F and 130 °F in a heated water bath. The sample next passes through a length of PTFE tubing to a set of three impingers in an ice bath. The first two impingers contain a 3% solution of hydrogen peroxide to oxidize SO_2. The third impinger serves as a trap to prevent the solutions from accidentally being drawn into the pump. The remainder of the train consists of a silica gel column to remove the last traces of water from the sample, a leak-free pump, and a dry gas meter to measure the volume of the sample.

The SO_3 is collected in the condensing element and the SO_2 is collected in the bubblers by oxidation with the hydrogen peroxide, converting it to H_2SO_4 in solution. In the condenser the SO_3 present begins a hydration reaction with the water vapor present making H_2SO_4. The excess water vapor also condenses to produce a condensate of concentrated aqueous H_2SO_4. Thus, two solutions of H_2SO_4 are collected; one a very concentrated solution of limited amount containing the original SO_3 and the other a relatively weak solution in far greater amount containing the original SO_2. The concentrations of the sulfate ion are determined by ion chromatography using a DIONEX Model DX-100 Ion Chromatograph.

HYDROGEN CHLORIDE

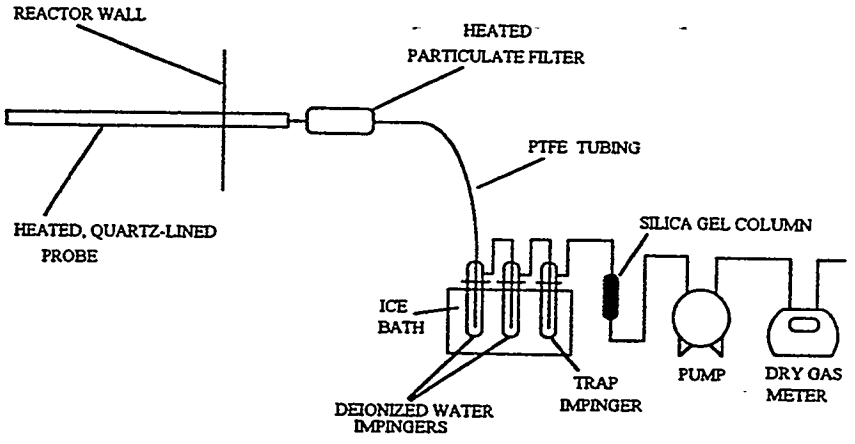

Figure 2-4. Schematic diagram of the chloride sampling train.

A schematic sketch of the chloride sampling train is shown in Figure 2-4. The flue gas sample is drawn through a heated, quartz-lined probe maintained above 550 °F. The sample then passes through a quartz filter housed in a heated quartz filter holder, also maintained at 550 °F. The sample next passes through a length of PTFE tubing to a set of three impingers in an ice bath. The first two impingers contain type 1 de-ionized water for removal of HCl vapor. The third impinger serves as a trap to prevent the solutions from accidentally being drawn into the pump. The remainder of the train consists of a silica gel column to remove the last traces of water from the sample, a leak-free pump, and a dry gas meter to measure the volume of the sample.

The chloride ion concentration is determined by ion chromatography using a DIONEX Model DX-100 Ion Chromatograph. Hydrogen chloride concentrations were determined by single-point sampling (at the mid-point of the duct) at the air heater inlet (upstream of the 4th catalyst layer, right-hand port) and at the air heater outlet (middle port). Inlet and outlet tests were conducted simultaneously.

MASS CONCENTRATION

Mass concentration was measured using a sampling train similar to that defined in the EPA Reference Test Method 17. A schematic drawing of the train used for mass concentration sampling is shown below in Figure 2-5.

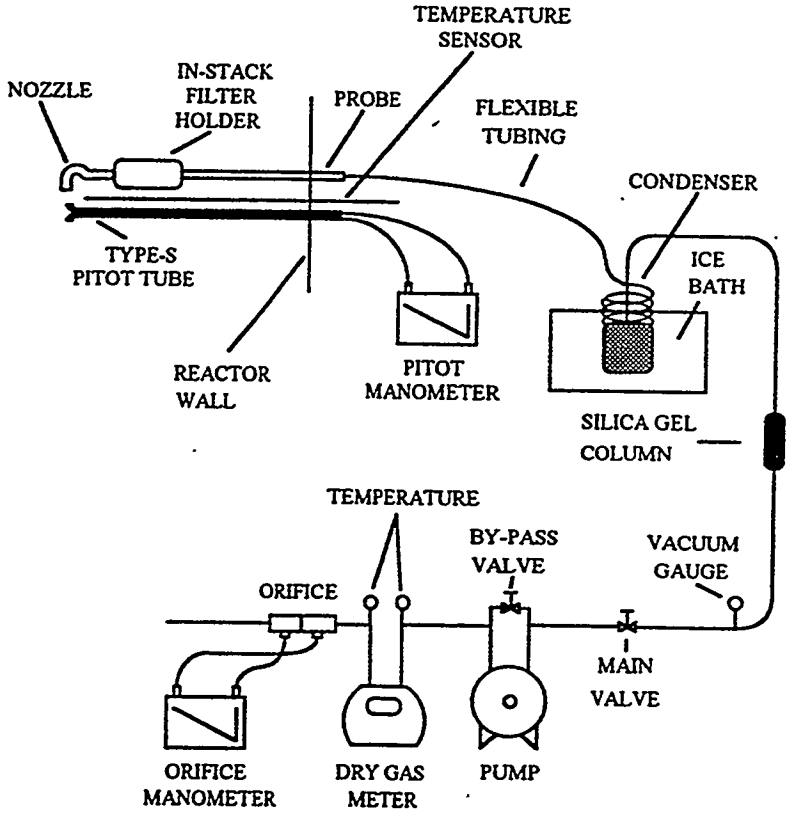

Figure 2-5. Schematic drawing of the mass concentration sampling train.

This train consists of a filter holder and nozzle that is designed to operate in the flue gas stream, followed by a heated sampling probe, a condenser, a drying column, a gas meter, a pump, and finally a flow control mechanism, usually a calibrated orifice. An S-type pitot and thermocouple located near the nozzle provide a means for sampling isokinetically during each test. The glass fiber thimbles are desiccated before and after sampling and then weighed on an electronic microbalance.

Particulate mass concentrations were measured simultaneously upstream of catalyst layer 4 (air heater inlet) and at each air heater outlet (except Reactor C). At the air heater inlet, the three sample ports immediately above the access door at the fourth catalyst layer were used to obtain the sample. During each test particulate was sampled at three, equally-spaced, positions within the three test ports (a total of nine traverse points). At the air heater outlets on reactors A and B, three ports are available for mass sampling. During each test particulate was sampled at

three, equally-spaced, positions within the three test ports (a total of nine traverse points). Three runs were made at each test site to give a meaningful statistical average.

ASH MINERALOGY, PARTICLE SIZE, ASH RESISTIVITY

After the particulate catches were weighed, they were transported to SRI's Birmingham laboratories where particle size distributions, ash mineralogy and ash resistivity were determined. The instrument used to determine particle size distribution of the fly ash was a Shimadzu Model SA-CP4 Centrifugal Particle Size Analyzer. It is able to size the particles into approximately 25 size intervals between 0.056 and 56.2 micrometers physical diameter (or Stokes diameter, based on assumed spherical shape and true, or actual, particle density). Ash resistivity was determined using the IEEE 548 (1984) ash resistivity test method, commonly referred to as a descending temperature method. The humidity of the atmosphere surrounding the resistivity test cell was controlled to a moisture content of 8.7%, approximately the same as that measured in the flue gases at the Plant Crist SCR Test Facility.

SAMPLING QUALITY ASSURANCE

The measures adopted to ensure that meaningful results were obtained during the various testing procedures can be divided into three categories; equipment maintenance and calibrations, operating techniques, and analytical techniques. New equipment was obtained for use in the SCR testing program and preventive maintenance and calibrations are performed at regular intervals. Due to the dynamic nature of the process, each measurement requires three replicate samples. The replicates are averaged to yield a representative value. Variability gives a means to discern any anomalies not revealed by other quality control checks.

The sample trains are leak-checked by drawing a vacuum of 15 in. Hg before and after each sampling run. No in-leakage is tolerated. If any loss of pressure is observed within one minute, the source of the leakage is found and eliminated prior to testing. During each run the oxygen level of the gas exiting the dry gas meter is measured to detect air in-leakage that could dilute the samples.

Ammonia samples are analyzed with an ion-specific electrode. The instrument is calibrated using 0.1 μg/mL, 0.5 μg/mL, 1.0 μg/mL, 5.0 μg/mL and 10 μg/mL standards. At the conclusion of each analytical session, a sample spiked with a known amount of ammonia is analyzed and the result compared with the predicted concentration. A blank sample is analyzed to detect zero drift and a mid-range standard is also analyzed to detect calibration drift.

Both the sulfate (SO_2 & SO_3) samples and the chloride (HCl) samples are analyzed by means of ion chromatography. This instrument is calibrated using a minimum of three points on the calibration curve. As with the ammonia analysis, spiked samples, blanks, and standards are analyzed to ensure that calibration drift has not occurred.

While gas-phase flue gas constituents are being sampled, both field blanks and sample blanks are run as quality control checks. The field blank consists of a container of type 1 de-ionized water that is exposed to ambient air at the sampling site. Sample blanks are obtained by passing ambient

air through the probe and through the impingers filled with the appropriate solution. These blanks would detect sample contamination should it occur.

Section 3

AIR HEATER TEST RESULTS

AMMONIA CONCENTRATIONS

Concentrations of ammonia were measured simultaneously at each of the three air heater inlet and outlet test locations. The tests were conducted so as to differentiate between gas-phase and solid-phase ammonia. All three air heaters were tested with the reactors operating at Test Condition 22, the baseline operating condition. The Reactor B and C air heaters were also tested at Test Condition 24 ($NH_3/NO_x = 1.0$), however, the Reactor A air heater was not tested at this condition because of concern that the air heater might become plugged during operation with the higher inlet ammonia concentration.

The test data are summarized in Table 3-1. Table 3-1 also gives estimated solid-phase ammonia concentrations on a mass of ammonia per mass of ash basis. The values shown in the table were derived both from solid-phase ammonia measurements made at the same time the gas-phase measurements were made and mass concentration measurements made earlier at the same location. The ammonia partitioning between the gas and solid phases shown in the table are similar for the air heaters on reactors B and C. These data show that ammonia partitioning at the inlet to the air heater is roughly equal (on a flue gas volumetric basis or ammonia mass basis) between the gas and solid phases on reactors B and C. On both reactors the partitioning shifts toward the solid phase at the air heater outlet. As expected, a significant increase in total ammonia concentration was measured during operation at the higher NH_3/NO_x ratio at Test Condition 24 for both the air heater inlet and air heater outlet on Reactors B and C. The test run on the Reactor A air heater at Test Condition 22 indicated a higher total ammonia concentration at the air heater inlet than at the air heater outlet with the ammonia strongly partitioned to the solid phase. The total ammonia measured at the Reactor A air heater outlet was less than one-half of the total ammonia measured at the air heater inlet with the ammonia more evenly partitioned between the gas and solid phases. The lack of ammonia mass balance closure suggests an error in the measurement so that this result should be disregarded until further testing is done. The original data summaries for these tests can be found in Table A-1 in Appendix A.

SO_2 and SO_3 CONCENTRATIONS

Concentrations of sulfur dioxide and sulfur trioxide were measured simultaneously at the air heater inlet and outlet test locations of Reactors A, B, and C during operation at Test Condition 22. The test data are summarized in Table 3-2.

SO_3 inlet concentrations ranged from 8 to 19 ppm(v) dry @ 3% O_2, while SO_3 concentrations at the reactor outlets ranged from 5 to 11 ppm(v) dry @ 3% O_2. Reductions in SO_3 concentration across the air heaters ranged from 37.5% on Reactor B to 42.1% on Reactor A. Within the tolerance of the standard deviations given for average SO_2 concentrations in Table 3-2, there was no measurable change in SO_2 concentration across any of the three air heaters. Air heater inlet SO_2 concentrations averaged 2044 ± 41 ppm(v) dry @ 3% O_2, while the air heater outlet SO_2 concentrations averaged 2095 ± 34 ppm(v) dry @ 3% O_2. Since the standard deviations of the mean concentrations at the inlet and outlet overlap, it can be concluded that no measurable

Table 3-1. SCR Reactor Air Heater Tests: Ammonia Concentrations

Reactor	Date	$\frac{NH_3}{NO_x}$	Air Preheater Location	Gas-Phase NH_3, ppm(v), @ 3% O_2, dry	Solid-Phase NH_3, Equivalent ppm(v), @ 3% O_2, dry	Estimated Solid-Phase NH_3, µg/g	Estimated Upper Limit Solid-Phase NH_3, µg/g	Estimated Lower Limit Solid-Phase NH_3, µg/g
A	11-May-94	0.8	Inlet	0.6 ± 0.1	3.3 ± 0.2	307	372	256
			Outlet	0.6 ± 0.1	1.0 ± 0.2	108	139	84
A	Not Tested	1.0	Inlet					
			Outlet					
B	10-May-94	0.8	Inlet	< 0.4	0.2 ± 0.01	22	24	20
			Outlet	<0.3	0.5 ± 0.01	65	70	61
B	10-May-94	1.0	Inlet	1.8 ± 0.4	1.9 ± 0.5	186	239	137
			Outlet	< 0.4	1.3 ± 0.2	162	189	137
C	6-May-94	0.8	Inlet	0.7 ± 0.1	0.6 ± 0.1	56	68	45
			Outlet	< 0.3	1.0 ± 0.1	116	137	99
C	9-May-94	1.0	Inlet	3.3 ± 0.3	3.8 ± 0.5	332	390	280
			Outlet	< 0.3	6.7 ± 1.6	746	1003	525

Table 3-2. SCR Reactor Air Heater Tests: SO_2 and SO_3 Concentrations

Reactor	SO_3		SO_2	
	Inlet	Outlet	Inlet	Outlet
	ppm(v), dry @ 3% O_2	ppm(v), dry @ 3% O_2	ppm(v), dry @ 3% O_2	ppm(v), dry @ 3% O_2
A	19 ± 1.4	11 ± 1.2	2040 ± 23	2073 ± 19
B	8.0 ± 1.5	5.0 ± 0.4	2087 ± 17	2078 ± 15
C	17 ± 0.5	10 ± 3.2	2005 ± 50	2134 ± 144

difference in SO_2 concentration was observed. Table A-2 in Appendix A contains the original data summaries for these tests.

HCl CONCENTRATION

Measurements of the concentration of hydrogen chloride were conducted simultaneously at the inlet and outlet of each of the three large reactor air heaters. Three independent tests were performed at each test location. Single point sampling was used. The test results are presented in Table 3-3 as the average concentration and the standard deviation. All HCl concentrations fell within the range of 221 to 233 ppm(v) dry @ 3% O_2. There was no measurable change in HCl concentration across any of the three air heaters. The original data summaries for these HCl tests are presented in Table A-3 in Appendix A.

PARTICULATE MASS CONCENTRATION

Particulate mass concentrations were measured simultaneously at the inlet and outlet of the air heaters on Reactors A and B. Particulate mass concentration was measured only at the inlet to the heat pipe air heater on Reactor C. No outlet measurement was possible on the Reactor C air heater because sampling ports in a location suitable for mass concentration measurements could not be installed on that reactor.

Table 3-4 presents the mass concentration data for the air heater tests. The average air heater inlet mass concentration ranged from 3.42 ± 0.12 (Reactor B) to 3.84 ± 0.17 gr/dscf (Reactor C). The Reactor A inlet and outlet average mass concentration values were within one standard deviation of each other, while the Reactor B average outlet mass concentration was 19% lower than the Reactor B average inlet mass concentration. The original data summaries for the mass concentration tests can be found in Table A-4 in Appendix A.

PARTICLE SIZE DISTRIBUTIONS

The particulate collected during the air heater inlet and outlet particulate mass concentration tests was analyzed using a Shimadzu Model SA-CP4 Centrifugal Particle Size Analyzer to determine particle size distribution. Table 3-5 presents the mass median diameter (MMD) as the Stokes' diameter (micrometers) for each of the ash samples. The Stokes' or physical diameter is based on the assumption of spherical particles and the true, or actual, particle density. The mass median diameters ranged from 9.9 to 10.4 micrometers at the air heater inlets, and were 10.5 and 11.2 micrometers at the outlet of the Reactor A and B air heaters, respectively. No significant change in MMD across the air heaters was evident from these data. Figures A-1 through A-5 in Appendix A show the particle size distributions graphically on both a cumulative per cent mass basis and a differential mass basis. The figures visually demonstrate the similarity between the particle size distributions among the various ash samples.

ASH MINERALOGY

Fly ash samples collected during mass concentration tests at the air heater inlet and outlet test locations were submitted for ash mineralogy tests. Fly ash samples were available for air heater

Table 3-3. SCR Reactor Air Heater Tests: HCl Concentration

Reactor	HCl	
	Inlet	Outlet
	ppm(v), dry @ 3% O_2	ppm(v), dry @ 3% O_2
A	233 ± 9.8	227 ± 11
B	222 ± 5.7	221 ± 7.2
C	233 ± 2.8	221 ± 8.5

Table 3-4. SCR Reactor Air Heater Tests: Inlet and Outlet Mass Concentrations

Reactor	Air Heater Inlet	Air Heater Outlet
	gr/dscf	gr/dscf
A	3.52 ± 0.44	3.21 ± 0.32
B	3.42 ± 0.12	2.76 ± 0.14
C	3.84 ± 0.17	Not Tested

Table 3-5. SCR Reactor Air Heater Tests: Fly Ash Particle Size

Reactor	Air Heater Inlet	Air Heater Outlet
	Stokes' MMD, micrometers	Stokes' MMD, micrometers
A	9.9	11.2
B	10.4	10.5
C	10.0	Not Tested

inlets on Reactors A, B and C and for the air heater outlets on Reactors A and B. No fly ash samples were collected at the outlet of the Reactor C air heater. The test results are presented in Table 3-6. There were no significant differences in the chemical constituents of the fly ash between the air heater inlets and outlets or among the three air heaters.

ASH RESISTIVITY

Laboratory measurements of ash resistivity were conducted on fly ash samples collected at the inlet and outlet of the three large reactor air heaters, except the outlet of the Reactor C air heater. The test data (pages A-33 to A-38) are summarized in Figure 3-1. The resistivity/temperature relationships for the five ash samples are very similar. For all of the ash samples the peak in the resistivity ranging from 4.5×10^{11} to 1×10^{12} ohm-cm, occurs at about 300 °F. The ash resistivity measured during the Task 1 baseline testing at the location of the SCR test facility inlet scoop was 3.9×10^{11} ohm-cm @ 293 °F. Based on these two measurements, the SCR process appears to have little or no effect on fly ash resistivity.

Table 3-6. SCR Reactor Air Heater Tests: Ash Mineralogy

Chemical Constituent	Reactor A Inlet % weight	Reactor A Outlet % weight	Reactor B Inlet % weight	Reactor B Outlet % weight	Reactor C Inlet % weight
Li_2O	0.03	0.03	0.03	0.03	0.04
Na_2O	0.97	0.91	1.2	1.1	0.91
K_2O	2.4	2.2	2.4	2.5	2.5
MgO	0.98	0.97	1.0	0.97	1.0
CaO	3.5	3.7	2.9	2.9	3.3
Fe_2O_3	18.7	20.3	18.5	18.2	18.5
Al_2O_3	22.2	22.0	22.3	21.7	21.9
SiO_2	48.0	47.4	49.3	49.3	49.0
TiO_2	1.1	1.1	1.1	0.91	0.91
P_2O_5	0.14	0.14	0.14	0.15	0.14
SO_3	1.1	1.0	0.78	0.27	0.78
Loss on Ignition	14.7	16.5	16.3	16.9	16.3

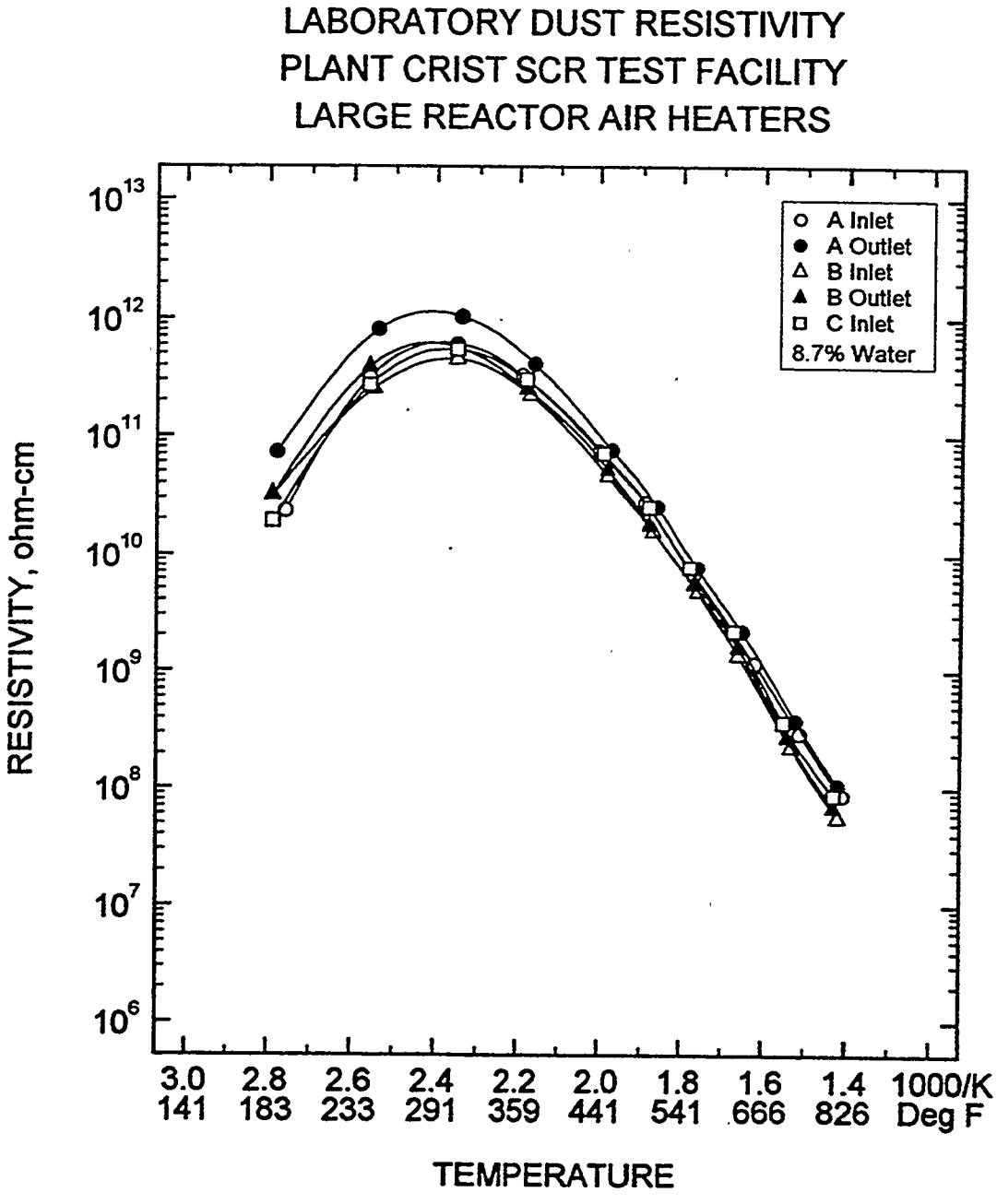

Figure 3-1. Resistivity/temperature relationship for air heater inlet and outlet fly ashes.

Section 4

SUMMARY

This report describes the initial air heater performance characterization tests for the Innovative Clean Coal Technology Demonstration of Selective Catalytic Reduction (SCR) Technology for the control of nitrogen oxide (NO_x) emissions from high-sulfur, coal-fired boilers. The SCR test facility is located at Gulf Power Company's Plant Crist Unit 5 in Pensacola, Florida. The air heater evaluations were conducted during the last week of April and the first two weeks of May, 1994, following the completion of the first sequence of parametric testing under Task 4: Long-Term Parametric Tests.

The SCR test facility at the Plant Crist test site includes three large SCR reactors, each designed to treat 5000 wscfm of flue gas, and six small reactors, each processing 400 wscfm of flue gas. An air heater capable of removing sufficient heat to reduce the flue gas temperature from a range of 600 to 750 ^{o}F down to 300 ^{o}F was included in the design of each of the three large reactors. The three large reactors are designated as reactors A, B, and C. Reactors A and B incorporate Ljungstrom-type air heaters and Reactor C incorporates a heat pipe design.

The air heater testing included the determinations of particulate mass concentration and measurements of the concentrations of sulfur dioxide, sulfur trioxide, hydrogen chloride and ammonia with manual sampling methods. Ammonia samples were segregated into solid and gas-phase fractions to characterize the gas/solid phase partitioning of ammonia across the air heaters. Tests were performed at the inlet and outlet of each of the three air heaters (except for mass concentration measurements at the outlet of the Reactor C air heater). The fly ash (particulate) catches from the mass concentration measurements were further analyzed in the laboratory to determine particle size distributions, ash mineralogy, and ash resistivity.

AMMONIA CONCENTRATIONS

Concentrations of ammonia were measured simultaneously at each of the three air heater inlet and outlet test locations. The tests were conducted so as to differentiate between gas-phase and solid-phase ammonia. The majority of the ammonia was found in the solid phase. Most of the gas phase ammonia concentrations were below the detection limit, especially at the air heater outlets. A measurable increase in ammonia concentration in the solid phase was detected during operation at the higher NH_3/NO_x ratio during operation at Test Condition 24 (1.8 to 6.7 ppm(v) dry @ 3% O_2 at Test Condition 24 versus 0.2 to 1.0 ppm(v) dry @ 3% O_2 at Test Condition 22 on Reactors B and C).

SO_2 and SO_3 CONCENTRATIONS

Concentrations of sulfur dioxide and sulfur trioxide were measured simultaneously at the air heater inlet and outlet test locations of Reactors A, B, and C during operation at Test Condition 22. SO_3 inlet concentrations ranged from 8 to 19 ppm(v) dry @ 3% O_2, while SO_3 concentrations at the reactor outlets ranged from 5 to 11 ppm(v) dry @ 3% O_2. Reductions in SO_3 concentration across the air heaters ranged from 37.5% on Reactor B to 42.1% on Reactor A. Within the

tolerance of the standard deviations for the average SO_2 concentrations, there was no measurable change in SO_2 concentration across any of the three air heaters. Air heater inlet SO_2 concentrations averaged 2044 ± 41 ppm(v) dry @ 3% O_2, while the air heater outlet SO_2 concentrations averaged 2095 ± 34 ppm(v) dry @ 3% O_2.

HCl CONCENTRATION

Measurements of the concentration of hydrogen chloride were conducted simultaneously at the inlet and outlet of each of the three large reactor air heaters. All HCl concentrations fell within the range of 221 to 233 ppm(v) dry @ 3% O_2. There was no measurable change in HCl concentration across any of the three air heaters.

MASS CONCENTRATION

Mass concentration was measured simultaneously at the inlet and outlet of the air heaters on Reactors A and B. Mass concentration was measured only at the inlet to the heat pipe air heater on Reactor C.

The average air heater inlet mass concentrations ranged from 3.42 ± 0.12 (Reactor B) to 3.84 ± 0.17 gr/dscf (Reactor C). The Reactor A inlet and outlet average mass concentration values were within one standard deviation of each other, while the Reactor B average outlet mass concentration was 19% lower than the Reactor B average inlet mass concentration.

PARTICLE SIZE DISTRIBUTIONS

The particulate collected in the Method 17 thimbles during the reactor inlet and outlet mass concentration tests was analyzed using a Shimadzu Model SA-CP4 Centrifugal Particle Size Analyzer to determine particle size distribution. The mass median diameters (Stokes' diameters) of the fly ashes ranged from 9.9 to 11.2 micrometers. The Stokes' or physical diameter is based on the assumption of spherical particles and the true, or actual, particle density. No significant change in MMD across the air heaters was evident in these data.

ASH MINERALOGY

Fly ash samples collected during mass concentration tests at the air heater inlet and outlet test locations were submitted for ash mineralogy tests. Fly ash samples were available for air heater inlets on Reactors A, B and C and for the air heater outlets on Reactors A and B. No fly ash samples were collected at the outlet of the Reactor C air heater. There were no significant differences in the chemical constituents of the fly ash between the air heater inlets and outlets or among the three air heaters.

ASH RESISTIVITY

Laboratory measurements of ash resistivity were conducted on fly ash samples collected at the inlet and outlet of the three large reactor air heaters, except the outlet of the Reactor C air heater. The

resistivity/temperature relationships for the five ash samples are very similar. For all of the ash samples the peak in the resistivity, ranging from 4.5×10^{11} to 1×10^{12} ohm-cm, occurs at about 300 °F. These ash resistivities are similar to those measured during Task 1 on ashes collected from the Unit 5 ESP inlet duct.

APPENDIX A

ORIGINAL DATA SUMMARIES

Table A-1 (Reference Table 3-1)

Week	Site	Case	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average		σ	Reactor Conditions: Condition Number	Flow, lscfm	Temp., deg F	NH_3 / NO_x	H_2O, %	Unit 5 Load, MW	Sample O2, %	Analytical: NH_3, mg/l	Df	Vol., ml	NH_3, µM	NH_3, ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total, STD L, wet	Temp, Avg., deg K	Barometric Pressure, in. Hg	Temp, Begin, deg F	Temp, End, deg F	Volume, Begin, ft3	Volume, End, ft3	Meter I.D	Corr. Factor
071	AAI	NHx	01	0930	0941	11-May	<0.7	±	BDL	Air							0.100	1	343	2	0.70	77.92	302	30.13	83	86	425.100	428.100	Stack 1	1.0080
										Blank							0.100			2	0.70									
071	AAI	NHO	02	0950	1033	11-May	0.56	±	0.03	22	5	700	0.8	9	82	3.8	0.156	1	351	4	0.54	169.38	306	30.13	86	95	428.200	434.200	Stack 1	1.0080
																	0.168			4	0.58									
071	AAI	NHO	03	1050	1133	11-May	0.51	±	0.02	22	5	700	0.8	9	82	3.6	0.151		349	4	0.52	168.15	308	30.13	94	95	434.400	440.400	Stack 1	1.0080
																	0.143			4	0.49									
071	AAI	NHO	04	1146	1233	11-May	0.73	±	0.00	22	5	700	0.8	9	83	4.3	0.223		319	5	0.73	168.31	307	30.13	95	93	440.600	446.600	Stack 1	1.0080
																	0.224			5	0.73									
																3.8														
							0.6	±	0.12							0.4														
071	AAI	NHS	02	0950	1033	11-May	3.12	±	0.06	22	5	700	0.8	9	82	3.6	1.430	1	220	22	3.07	169.38	306	30.13	86	95	428.200	434.200	Stack 1	1.0080
																	1.470			23	3.16									
~~071~~	~~AAI~~	~~NHS~~	~~03~~	~~1050~~	~~1133~~	~~11-May~~	~~0.50~~	~~±~~	~~0.01~~	~~22~~	~~5~~	~~700~~	~~0.8~~	~~9~~	~~82~~	~~3.6~~	~~0.210~~		~~225~~	~~4~~	~~0.40~~	~~168.15~~	~~308~~	~~30.13~~	~~94~~	~~95~~	~~434.400~~	~~440.400~~	~~Stack 1~~	~~1.0080~~
																	~~0.228~~			~~4~~	~~0.51~~									
071	AAI	NHS	04	1146	1233	11-May	3.39	±	0.08	22	5	700	0.8	9	83	4.3	1.830		178	23	3.34	168.31	307	30.13	95	93	440.600	446.600	Stack 1	1.0080
																	1.890			24	3.45									
																3.8														
							3.3	±	0.20							0.4														
071	AAO	NHx	01	0925	0941	11-May	<0.4	±	BDL	Air							0.100	1	204	1	0.43	76.01	306	30.13	90	93	653.500	656.500	Stack 2	0.9960
										Blank							0.100			1	0.43									
071	AAO	NHO	02	1000	1040	11-May	0.29	±	0.00	22	5	700	0.8	9	82	7.5	0.100	1	227	2	0.29	166.30	307	30.13	92	96	656.700	662.700	Stack 2	0.9960
																	0.100			2	0.29									
071	AAO	NHO	03	1100	1137	11-May	0.28	±	0.00	22	5	700	0.8	9	82	7.4	0.100		218	2	0.28	165.55	309	30.13	95	98	662.900	668.900	Stack 2	0.9960
																	0.100			2	0.28									
071	AAO	NHO	04	1155	1235	11-May	0.36	±	0.00	22	5	700	0.8	9	83	7.8	0.100		273	2	0.36	165.70	309	30.13	97	95	669.000	675.000	Stack 2	0.9960
																	0.100			2	0.36									
																7.6														
							<0.3	±	BDL							0.2														
071	AAO	NHS	02	1000	1040	11-May	1.15	±	0.04	22	5	700	0.8	9	82	7.5	0.520	1	168	6	1.12	166.30	307	30.13	92	96	656.700	662.700	Stack 2	0.9960
																	0.544			7	1.17									
071	AAO	NHS	03	1100	1137	11-May	1.13	±	0.03	22	5	700	0.8	9	82	7.4	0.705		123	6	1.11	165.55	309	30.13	95	98	662.900	668.900	Stack 2	0.9960
																	0.732			6	1.15									
071	AAO	NHS	04	1155	1235	11-May	0.86	±	0.02	22	5	700	0.8	9	83	7.8	0.466		138	5	0.85	165.70	309	30.13	97	95	669.000	675.000	Stack 2	0.9960
																	0.483			5	0.88									
																7.6														
							1.0	±	0.16							0.2														

Table A-1, continued (Reference Table 3-1)

Week	Site	Gas	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average	±	σ	Reactor Conditions: Condition Number	Flow kscfm	Temp. deg F	NH_3, NO_x %	H_2O %	Unit 5 Load, MW	Sample O2 %	Analytical: NH_3 mg/l	Df	Vol. ml	NH_3 µM	NH_3 ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total STD L, wet	Temp, Avg. deg K	Barometric Pressure in. Hg	Temp, Begin deg F	Temp, End deg F	Volume, Begin ft3	Volume, End ft3	Meter I.D	Corr. Factor
071	BAI	NHx	01	0914	0926	10-May	<0.56	±	0.00	Air							0.100	1	277	2.0	0.56	79.12	297	30.09	76	75	365.700	368.700	Stack 1	1.0080
										Blank							0.100			2.0	0.56									
071	BAI	NHO	02	0941	1030	10-May	0.31	±	0.00	22	5	700	0.8	9	77	4.7	0.100	1	307	2.2	0.31	173.41	298	30.09	76	78	369 000	375.000	Stack 1	1 0080
																	0.100			2.2	0.31									
071	BAI	NHO	03	1054	1142	10-May	0.36	±	0.00	22	5	700	0.8	9	83	2.8	0.100		390	2.8	0.36	172.44	300	30.09	79	81	375 200	381.200	Stack 1	1.0080
																	0.100			2.8	0.36									
071	BAI	NHO	04	1200	1248	10-May	0.42	±	0.00	22	5	700	0.8	9	80	3.5	0.124		356	3.2	0.42	172.28	300	30.09	80	81	381.400	387.400	Stack 1	1.0080
																	0.124			3.2	0.42									
																3.7														
							<0.4	±	0.05							1.0					0.1									
071	BAI	NHS	02	0941	1030	10-May	0.24	±	0.01	22	5	700	0.8	9	77	4.7	0.110	1	217	1.7	0.24	173.41	298	30 09	76	78	369.000	375.000	Stack 1	1.0080
																	0.104			1.6	0.23									
071	BAI	NHS	03	1054	1142	10-May	0.23	±	0.00	22	5	700	0.8	9	83	2.8	0.105		238	1.8	0.23	172.44	300	30 09	79	81	375.200	381.200	Stack 1	1.0080
																	0.104			1.8	0.23									
071	BAI	NHS	04	1200	1248	10-May	0.21	±	0.01	22	5	700	0.8	9	80	3.5	0.101		226	1.6	0.22	172.28	300	30.09	80	81	381.400	387.400	Stack 1	1.0080
																	0.097			1.6	0.21									
																3.7														
							0.2	±	0.01							1.0					0.0									
071	BAO	NHx	01	0913	0926	10-May	<0.3	±	0.00	Air							0.100	1	158	1.1	0.33	77.53	300	30.09	80	80	612.700	615.700	Stack 2	0.9960
										Blank							0.100			1.1	0.33									
071	BAO	NHO	02	0950	1025	10-May	0.28	±	0.00	22	5	700	0.8	9	77	7.5	0.100	1	219	1.6	0.28	169.92	301	30 09	80	83	615.900	621.900	Stack 2	0 9960
																	0.100			1.6	0.28									
071	BAO	NHO	03	1105	1137	10-May	0.31	±	0.00	22	5	700	0.8	9	82	7.2	0.100		248	1.8	0.31	169.29	302	30.09	84	83	622.100	628.100	Stack 2	0 9960
																	0.100			1.8	0.31									
071	BAO	NHO	04	1207	1240	10-May	0.31	±	0.00	22	5	700	0.8	9	80	7.5	0.100		244	1.7	0.31	169.45	301	30.09	82	84	628.300	634.300	Stack 2	0.9960
																	0.100			1.7	0.31									
																7.4														
							<0.3	±	0.02							0.2					0.0									
071	BAO	NHS	02	0950	1025	10-May	0.55	±	0.02	22	5	700	0.8	9	77	7.5	0.267	1	160	3.1	0.54	169.92	301	30.09	80	83	615.900	621.900	Stack 2	0.9960
																	0.281			3.2	0.57									
071	BAO	NHS	03	1105	1137	10-May	0.53	±	0.01	22	5	700	0.8	9	82	7.2	0.211		201	3.0	0.52	169.29	302	30.09	84	83	622.100	628.100	Stack 2	0.9960
																	0.216			3.1	0.54									
071	BAO	NHS	04	1207	1240	10-May	0.54	±	0.00	22	5	700	0.8	9	80	7.5	0.272		157	3.1	0.54	169.45	301	30.09	82	84	628.300	634.300	Stack 2	0.9960
																	0.273			3.1	0.54									
																7.4														
							0.5	±	0.01							0.2					0.0									

Table A-1, continued (Reference Table 3-1)

Week	Site	Occ	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average	±	σ	Condition Number	Reactor Conditions Flow kscfm	Temp. deg F	NH_3, NO_x	H_2O %	Unit 5 Load, MW	Sample O2 %	Analytical NH3 mg/l	Df	Vol. ml	NH3 µM	NH3 ppm, wet, @ 3% O2	Dry Gas Meter Volume, Total STD L, wet	Temp, Avg. deg K	Barometric Pressure In. Hg	Temp, Begin deg F	Temp, End deg F	Volume, Begin ft3	Volume, End ft3	Meter I.D	Corr. Factor
071	BAI	NHx	01	0914	0926	10-May	<0.56	±	0.00	Air Blank																				
071	BAI	NHO	05	1435	1520	10-May	1.35	±	0.00	24	5	700	1	9	81	3.6	0.358	1	391	10.0	1.36	170.86	302	30.09	83	87	388.000	394.000	Stack 1	1.0080
																	0.357			10.0	1.35									
071	BAI	NHO	06	1543	1627	10-May	2.24	±	0.05	24	5	700	1	9	83	4.0	0.622		368	16.3	2.28	170.23	304	30.09	87	87	394.200	400.200	Stack 1	1.0080
																	0.603			15.9	2.21									
071	BAI	NHO	07	1644	1731	10-May	1.80	±	0.08	24	5	700	1	9	83	3.3	0.444		410	13.0	1.75	169.46	305	30.09	88	91	400.400	406.400	Stack 1	1.0080
																	0.472			13.8	1.86									
																3.6														
							1.8	±	0.44							0.4					0.4									
071	BAI	NHS	05	1442	1516	10-May	1.40	±	0.01	24	5	700	1	9	79	7.5	0.496	1	222	7.9	1.40	168.21	304	30.09	86	88	634.700	640.700	Stack 2	0.9960
																	0.500			7.9	1.41									
071	BAI	NHS	06	1547	1621	10-May	2.08	±	0.03	24	5	700	1	9	82	7.2	0.758		218	11.8	2.06	167.59	305	30.09	88	90	640.900	646.900	Stack 2	0.9960
																	0.773			12.0	2.10									
071	BAI	NHS	07	1653	1728	10-May	2.27	±	0.05	24	5	700	1	9	83	7.0	1.010		180	13.0	2.24	167.14	306	30.09	90	91	647.200	653.200	Stack 2	0.9960
																	1.040			13.4	2.31									
																7.2														
							1.9	±	0.46							0.3					0.5									
071	BAO	NHx	01	0913	0926	10-May	<0.3	±	0.00	Air Blank																				
070	BAO	NHO	05	1442	1516	10-May	0.30	±	0.00	24	5	700	1	9	79	7.5	0.100	1	240	1.7	0.30	168.21	304	30.09	86	88	634.700	640.700	Stack 2	0.9960
																	0.100			1.7	0.30									
070	BAO	NHO	06	1547	1621	10-May	0.33	±	0.00	24	5	700	1	9	82	7.2	0.100		266	1.9	0.33	167.59	305	30.09	88	90	640.900	646.900	Stack 2	0.9960
																	0.100			1.9	0.33									
070	BAO	NHO	07	1653	1728	10-May	0.43	±	0.00	24	5	700	1	9	83	7.0	0.100		349	2.5	0.43	167.14	306	30.09	90	91	647.200	653.200	Stack 2	0.9960
																	0.100			2.5	0.43									
																7.2														
							<0.4	±	0.1							0.3					0.1									
070	BAO	NHS	05	1442	1516	10-May	1.18	±	0.05	24	5	700	1	9	79	7.5	0.536	1	167	6.4	1.14	168.21	304	30.09	86	88	634.700	640.700	Stack 2	0.9960
																	0.572			6.8	1.21									
070	BAO	NHS	06	1547	1621	10-May	1.47	±	0.00	24	5	700	1	9	82	7.2	1.180		99.6	8.4	1.47	167.59	305	30.09	88	90	640.900	646.900	Stack 2	0.9960
																	1.179			8.4	1.46									
070	BAO	NHS	07	1653	1728	10-May	1.39	±	0.02	24	5	700	1	9	83	7.0	0.744		150	8.0	1.38	167.14	306	30.09	90	91	647.200	653.200	Stack 2	0.9960
																	0.761			8.2	1.41									
																7.2														
							1.3	±	0.2							0.3					0.2									

Table A-1, continued (Reference Table 3-1)

Week	Site	Org	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average	±	σ	Reactor Conditions: Condition Number	Flow, kscfm	Temp, deg F	NH_3/NO_x	H_2O, %	Unit 5 Load, MW	Sample O2, %	Analytical: NH_3, mg/l	Df	Vol, ml	NH_3, µM	NH_3, ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total STD L, wet	Temp, Avg, deg K	Barometric Pressure, in. Hg	Temp, Begin, deg F	Temp, End, deg F	Volume, Begin, ft3	Volume, End, ft3	Meter I.D	Corr. Factor
070	CAI	NHx	01	1005	1020	6-May	<0.3	±	0.00	Air							0.100	1	188	1	0.30	99.04	302	30.18	82	85	302.500	306.300	Stack 1	1.0080
										Blank							0.100			1	0.30									
070	CAI	NHG	02	1104	1155	6-May	0.77	±	0.00	22	5	700	0.8	9	84	3.1	0.259	1	313	6	0.77	170.12	305	30.18	86	92	306.500	312.500	Stack 1	1.0080
																	0.261			6	0.77									
070	CAI	NHG	03	1341	1428	6-May	0.76	±	0.01	22	5	700	0.8	9	85	2.9	0.254		317	6	0.76	169.35	306	30.18	90	93	312.700	318.700	Stack 1	1.0080
																	0.257			6	0.77									
070	CAI	NHG	04	1455	1543	6-May	0.66	±	0.01	22	5	700	0.8	9	85	3.5	0.193		354	5	0.67	168.74	307	30.18	93	94	319.000	325.000	Stack 1	1.0080
																	0.189			5	0.65									
																3.2														
							0.7	±	0.06							0.3					0.1									
070	CAI	NHS	02	1104	1155	6-May	0.77	±	0.01	22	5	700	0.8	9	84	3.1	0.341	1	236	6	0.76	170.12	305	30.18	86	92	306.500	312.500	Stack 1	1.0080
																	0.347			6	0.77									
070	CAI	NHS	03	1341	1428	6-May	0.56	±	0.00	22	5	700	0.8	9	85	2.9	0.291		206	4	0.56	169.35	306	30.18	90	93	312.700	318.700	Stack 1	1.0080
																	0.292			4	0.57									
070	CAI	NHS	04	1455	1543	6-May	0.61	±	0.00	22	5	700	0.8	9	85	3.5	0.277		224	4	0.61	168.74	307	30.18	93	94	319.000	325.000	Stack 1	1.0080
																	0.279			4	0.61									
																3.2														
							0.6	±	0.11							0.3					0.1									
070	CAO	NHx	01	1024	1037	6-May	<0.4	±	0.00	Air							0.100	1	181	1	0.38	77.05	302	30.18	84	86	568.400	571.400	Stack 2	0.9960
										Blank							0.100			1	0.38									
070	CAO	NHG	02	1118	1155	6-May	0.29	±	0.00	22	5	700	0.8	9	84	6.0	0.100	1	255	2	0.29	168.40	304	30.18	86	90	572.000	578.000	Stack 2	0.9960
																	0.100			2	0.29									
070	CAO	NHG	03	1350	1423	6-May	0.29	±	0.00	22	5	700	0.8	9	85	5.9	0.100		251	2	0.29	167.94	305	30.18	88	91	578.200	584.200	Stack 2	0.9960
																	0.100			2	0.29									
070	CAO	NHG	04	1509	1541	6-May	0.24	±	0.00	22	5	700	0.8	9	85	5.6	0.100		229	2	0.24	178.49	306	30.18	91	92	584.400	590.800	Stack 2	0.9960
																	0.100			2	0.24									
																5.8														
							<0.3	±	0.03							0.2					0.0									
070	CAO	NHS	02	1118	1155	6-May	1.14	±	0.01	22	5	700	0.8	9	84	6.0	0.403	1	247	7	1.14	168.40	304	30.18	86	90	572.000	578.000	Stack 2	0.9960
																	0.406			7	1.14									
070	CAO	NHS	03	1350	1423	6-May	1.03	±	0.02	22	5	700	0.8	9	85	5.9	0.418		215	6	1.02	167.94	305	30.18	88	91	578.200	584.200	Stack 2	0.9960
																	0.428			7	1.05									
070	CAO	NHS	04	1509	1541	6-May	0.96	±	0.00	22	5	700	0.8	9	85	5.6	0.514		178	7	0.96	178.49	306	30.18	91	92	584.400	590.800	Stack 2	0.9960
																	0.514			7	0.96									
																5.8														
							1.0	±	0.09							0.2					0.1									

Table A-1, continued (Reference Table 3-1)

Week	Site	Case	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average	±	σ	Reactor Conditions: Condition Number	Flow kscfm	Temp. deg F	NH_3/NO_x	H_2O %	Unit 5 Load, MW	Sample O2 %	Analytical: NH3 mg/l	Df	Vol. ml	NH3 µM	NH3 ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total STD L, wet	Temp, Avg. deg K	Barometric Pressure in. Hg	Temp, Begin deg F	Temp, End deg F	Volume, Begin ft3	Volume, End ft3	Meter I.D	Corr. Factor
071	CAI	NHx	01	1000	1014	9-May	<.4	±	0.00	Air							0.100	1	206	1	0.43	77.23	304	30.03	88	87	336.300	339.300	Stack 1	1.0080
										Blank							0.100			1	0.43									
071	CAI	NHG	02	1031	1121	9-May	3.09	±	0.00	24	5	700	1	9	86	2.3	1.050	1	323	24	3.09	169.12	305	30.03	88	91	339.600	345.600	Stack 1	1.0080
																	1.051			24	3.09									
071	CAI	NHG	03	1303	1353	9-May	3.57	±	0.02	24	5	700	1	9	86	2.6	1.160		331	27	3.55	169.12	305	30.03	94	85	345.800	351.800	Stack 1	1.0080
																	1.170			28	3.58									
071	CAI	NHG	04	1410	1458	9-May	3.15	±	0.05	24	5	700	1	9	85	3.1	0.915		357	23	3.11	168.97	305	30.03	86	94	352.100	358.100	Stack 1	1.0080
																	0.937			24	3.19									
																2.7														
							3.3	±	0.26							0.4					0.3									
071	CAI	NHS	02	1031	1121	9-May	4.27	±	0.04	24	5	700	1	9	86	2.3	2.070	1	225	33	4.24	169.12	305	30.03	88	91	339.600	345.600	Stack 1	1.0080
																	2.100			34	4.30									
071	CAI	NHS	03	1303	1353	9-May	3.90	±	0.04	24	5	700	1	9	86	2.6	1.890		221	30	3.87	169.12	305	30.03	94	85	345.800	351.800	Stack 1	1.0080
																	1.920			30	3.93									
071	CAI	NHS	04	1410	1458	9-May	3.36	±	0.05	24	5	700	1	9	85	3.1	1.920		182	25	3.33	168.97	305	30.03	86	94	352.100	358.100	Stack 1	1.0080
																	1.960			25	3.40									
																2.7														
							3.8	±	0.46							0.4					0.5									
071	CAO	NHx	01	0957	1010	9-May	<0.3	±	0.00	Air							0.100	1	144	1	0.30	77.09	301	30.03	82	82	591.000	594.000	Stack 2	0.9960
										Blank							0.100			1	0.30									
071	CAO	NHG	02	1045	1115	9-May	0.24	±	0.00	24	5	700	1	9	86	3.6	0.100	1	246	2	0.24	168.49	302	30.03	83	87	594.300	600.300	Stack 2	0.9960
																	0.100			2	0.24									
071	CAO	NHG	03	1316	1351	9-May	0.28	±	0.00	24	5	700	1	9	86	4.5	0.100		264	2	0.28	166.50	306	30.03	90	93	600.200	606.200	Stack 2	0.9960
																	0.100			2	0.28									
071	CAO	NHG	04	1415	1450	9-May	0.24	±	0.00	24	5	700	1	9	85	4.6	0.100		222	2	0.24	165.75	307	30.03	93	95	606.400	612.400	Stack 2	0.9960
																	0.100			2	0.24									
																4.2														
							<0.3	±	0.02							0.6					0.0									
070	CAO	NHS	02	1045	1115	9-May	8.47	±	0.11	24	5	700	1	9	86	3.6	4.770	1	179	61	8.39	168.49	302	30.03	83	87	594.300	600.300	Stack 2	0.9960
																	4.860			62	8.55									
070	CAO	NHS	03	1316	1351	9-May	6.39	±	0.09	24	5	700	1	9	86	4.5	3.350		180	43	6.32	166.50	306	30.03	90	93	600.200	606.200	Stack 2	0.9960
																	3.420			44	6.46									
070	CAO	NHS	04	1415	1450	9-May	5.26	±	0.05	24	5	700	1	9	85	4.6	2.770		178	35	5.23	165.75	307	30.03	93	95	606.400	612.400	Stack 2	0.9960
																	2.810			36	5.30									
																4.2														
							6.7	±	1.63							0.6					1.6									

Table A-2 (Reference Table 3-2)

Week	Site	Origin	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average	±	σ	Reactor Conditions: Condition Number	Flow, kscfm	Temp, deg F	NH3/NOx	H2O, %	Unit 5 Boiler Load, MW	Sample O2, %	Analytical: SO4, ppm	Dil	Vol, ml	SO4, µM	SO2, or SO3, ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total, STD L, wet	Temp, Avg, deg K	Barometric Pressure, in. Hg	Temp, Begin, deg F	Temp, End, deg F	Volume, Begin, ft3	Volume, End, ft3	Meter I.D	Corr. Factor
070	AAI	SO3	01	1050	1105	3-May	17.4	±	0.03	22	5	700	0.8	9	84	2.3	9.180	12.5	58.7	70	17.3	87.21	297	30.01	78	74	235.000	238.020	Stack 1	1.0080
																	9.200			70	17.4									
070	AAI	SO3	02	1143	1157	3-May	19.3	±	0.04	22	5	700	0.8	9	84	2.3	9.705		61.9	78	19.3	87.53	294	30.01	71	70	238.400	241.400	Stack 1	1.0080
																	9.730			78	19.3									
070	AAI	SO3	03	1212	1226	3-May	20.2	±	0.11	22	5	700	0.8	9	84	3.1	6.953		85.8	78	20.1	87.04	296	30.01	72	75	241.800	244.800	Stack 1	1.0080
																	7.005			78	20.3									
																2.6														
							19	±	1.4							0.5														
070	AAI	SO2	01				2031	±	4								6.894	200	573	8230	2034.2									
																	6.874			8206	2028.3									
070	AAI	SO2	02				2022	±	11								6.413		617	8243	2030.1									
																	6.365			8182	2014.9									
070	AAI	SO2	03				2067	±	4								5.644		680	7996	2069.2									
																	5.630			7976	2064.1									
							2040	±	23																					
070	AAO	SO3	01	1050	1104	3-May	10.5	±	0.04	22	5	700	0.8	9	84	5.7	3.616	12.5	70.9	33	10.5	83.73	304	30.01	89	87	507.100	510.100	Stack 2	0.9960
																	3.597			33	10.5									
070	AAO	SO3	02	1142	1155	3-May	4.8	±	0.05	22	5	700	0.8	9	84	6.3	1.564		71.3	15	4.7	84.58	301	30.01	84	81	510.600	513.600	Stack 2	0.9960
																	1.589			15	4.8									
070	AAO	SO3	03	1211	1222	3-May	12.2	±	0.03	22	5	700	0.8	9	84	6.5	3.329		85.7	37	12.2	84.81	300	30.01	81	81	513.900	516.900	Stack 2	0.9960
																	3.317			37	12.2									
																6.2														
							11	±	1.2							0.4														
070	AAO	SO2	01	1050	1104	3-May	2074	±	2								5.299	200	596	6580	2072.9									
																	5.307			6590	2076.0									
070	AAO	SO2	02	1142	1155	3-May	2091	±	27								5.421		565	6381	2071.9									
																	5.522			6500	2110.5									
070	AAO	SO2	03	1211	1222	3-May	2054	±	7								4.245		709	6270	2058.5									
																	4.225			6241	2048.8									
							2073	±	19																					

Table A-2, continued (Reference Table 3-2)

Week	Site	Run	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average	±	σ	Reactor Conditions: Condition Number	Flow kscfm	Temp. deg F	NH3/NOx	H2O %	Unit 5 Boiler Load, MW	Sample O2 %	Analytical: SO4 ppm	Dil	Vol. ml	SO4 µM	SO2, or SO3 ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total STD L, wet	Temp, Avg. deg K	Barometric Pressure in. Hg	Temp, Begin deg F	Temp, End deg F	Volume, Begin ft3	Volume, End ft3	Meter I.D	Corr. Factor
070	BAI	SO3	01	1025	1034	4-May	9.5	±	0.10	22	5	700	0.8	9	84	3.5	4.281	12.5	65.7	37	9.6	87.95	293	30.01	67	69	258.000	261.000	Stack 1	1.0080
																	4.217			36	9.5									
070	BAI	SO3	02	1053	1107	4-May	7.7	±	0.01	22	5	700	0.8	9	84	3.6	3.802		59.5	29	7.7	88.28	294	30.01	69	70	261.500	264.520	Stack 1	1.0080
																	3.796			29	7.7									
070	BAI	SO3	03	1155	1209	4-May	6.6	±	0.02	22	5	700	0.8	9	84	3.6	3.057		62.9	25	6.6	87.29	295	30.01	71	73	265.000	268.000	Stack 1	1.0080
																	3.047			25	6.6									
																3.6														
							8.0	±	1.5							0.1														
070	BAI	SO2	01	1025	1034	4-May	2076	±	6								6.218	200	613	7941	2080.6									
																	6.193			7909	2072.2									
070	BAI	SO2	02	1053	1107	4-May	2078	±	4								6.218		612	7928	2081.2									
																	6.201			7906	2075.6									
070	BAI	SO2	03	1155	1209	4-May	2107	±	16								6.052		626	7893	2095.7									
																	6.116			7976	2117.9									
							2087	±	17																					
070	BAO	SO3	01	1025	1038	4-May	4.6	±	0.09	22	5	700	0.8	9	84	6.9	1.155	12.5	93.9	14	4.7	86.09	296	30.01	72	74	528.000	531.000	Stack 2	0.9960
																	1.125			14	4.6									
070	BAO	SO3	02	1053	1106	4-May	5.3	±	0.00	22	5	700	0.8	9	84	6.9	1.382		88.1	16	5.3	85.92	296	30.01	74	74	531.400	534.400	Stack 2	0.9960
																	1.383			16	5.3									
070	BAO	SO3	03	1154	1207	4-May	5.2	±	0.01	22	5	700	0.8	9	84	7.9	1.255		89.2	15	5.2	86.01	296	30.01	73	74	534.700	537.700	Stack 2	0.9960
																	1.258			15	5.2									
																7.2														
							5.1	±	0.4							0.6														
070	BAO	SO2	01	1025	1038	4-May	2088	±	1								5.114	200	589	6275	2087.7									
																	5.117			6279	2088.9									
070	BAO	SO2	02	1053	1106	4-May	2067	±	1								4.818		618	6203	2067.6									
																	4.814			6198	2065.9									
070	BAO	SO2	03	1156	1207	4-May	2345	±	26								4.093		738	6306	3225.6									
																	4.164			6315	3264.8									
							2078	±	15																					

Table A-2, continued (Reference Table 3-2)

Week	Site	Case	Run Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O2 Average	±	σ	Reactor Conditions: Condition Number	Flow, kscfm	Temp, deg F	NHU/NOx	H2O, %	Unit 5 Boiler Load, MW	Sample O2, %	Analytical: SO4, ppm	DB	Vol, ml	SO4, µM	SO2, or SO3, ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total, STD L, wet	Temp, Avg, deg K	Barometric Pressure, in. Hg	Temp, Begin, deg F	Temp, End, deg F	Volume, Begin, ft3	Volume, End, ft3	Meter I.D	Corr. Factor
070	CAI	SO3	01	1047	1101	5-May	16.8	±	0.07	22	5	700	0.8	9	84	4.3	6.924	12.5	67.7	61	16.7	88.08	294	30.14	69	70	281.600	284.600	Stack 1	1.0080
																	6.966			61	16.8									
070	CAI	SO3	02	1116	1130	5-May	17.2	±	0.04	22	5	700	0.8	9	84	4.0	8.074		62.7	66	17.2	90.88	295	30.14	72	72	285.000	288.110	Stack 1	1.0080
																	8.045			66	17.1									
070	CAI	SO3	03	1142	1155	5-May	17.7	±	0.04	22	5	700	0.8	9	84	3.8	8.123		63.1	67	17.7	88.29	296	30.14	73	74	288.500	291.530	Stack 1	1.0080
																	8.099			67	17.7									
																4.0														
							17.2	±	0.5							0.3														
070	CAI	SO2	01	1047	1101	5-May	2062	±	6								5.916	200	609	7506	2058.3									
																	5.939			7535	2066.3									
070	CAI	SO2	01	1116	1130	5-May	1973	±	9								5.900		613	7535	1967.0									
																	5.938			7583	1979.7									
070	CAI	SO2	01	1142	1155	5-May	1979	±	9								5.373		668	7477	1985.7									
																	5.339			7430	1973.2									
							2005	±	50																					
070	CAO	SO3	01	1048	1102	5-May	10.6	±	0.03	22	5	700	0.8	9	84	4.5	3.057	12.5	93.7	37	10.6	86.22	297	30.14	74	75	548.000	551.000	Stack 2	0.9960
																	3.045			37	10.5									
070	CAO	SO3	02	1115	1129	5-May	13.1	±	0.02	22	5	700	0.8	9	84	6.1	3.438		92.5	41	13.0	85.97	297	30.14	75	77	551.700	554.700	Stack 2	0.9960
																	3.444			41	13.1									
070	CAO	SO3	03	1142	1156	5-May	6.7	±	0.05	22	5	700	0.8	9	84	6.1	1.826		88.8	21	6.7	85.73	298	30.14	76	79	555.000	558.000	Stack 2	0.9960
																	1.845			21	6.7									
																5.6														
							10.1	±	3.2							0.9														
070	CAO	SO2	01	1048	1102	5-May	1968.9	±	2.0								4.876	200	684	6948	1970.3									
																	4.869			6938	1967.5									
070	CAO	SO2	02	1115	1129	5-May	2233.0	±	15.0								5.399		633	7120	2243.6									
																	5.348			7053	2222.4									
070	CAO	SO2	03	1142	1156	5-May	2200.9	±	1.3								4.687		713	6962	2200.0									
																	4.691			6968	2201.9									
							2134.3	±	144.1																					

Table A-3 (Reference Table 3-3)

Week	Site	Case	Run Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O_2 Average	±	σ	Reactor Conditions: Condition Number	Flow kscfm	Temp. deg F	NH_3/ NO_x	H_2O %	Unit 5 Load, MW	Sample O_2 %	Analytical: CT ppm	DR	Vol. ml	CT µM	HCl ppm, wet, @ 3% O2	Dry Gas Meter: Volume, Total STD L, wet	Temp, Avg. deg K	Barometric Pressure in. Hg	Temp, Begin deg F	Temp, End deg F	Volume, Begin ft3	Volume, End ft3	Meter I.D	Corr. Factor
070	AAI	HCl	01	1422	1436	3-May	235	±	2.6	22	5	700	0.8	9	84	2.5	4.985	12.5	522	918	233.4	85.68	301	30.01	80	84	245.200	248.200	Stack 1	1.0080
																	5.069			933	237.3									
070	AAI	HCl	02	1448	1503	3-May	241	±	4.0	22	5	700	0.8	9	84	2.5	4.073	12.5	650	934	238.1	85.44	302	30.01	82	85	248.800	251.800	Stack 1	1.0080
																	4.169			956	243.7									
070	AAI	HCl	03	1513	1527	3-May	222	±	0.7	22	5	700	0.8	9	84	2.4	3.565	12.5	702	882	221.4	86.37	301	30.01	82	84	252.300	255.330	Stack 1	1.0080
																	3.580			886	222.4									
															AVG	2.5														
							233	±	9.6						σ	0.1														
070	AAO	HCl	01	1422	1435	3-May	238	±	0.1	22	5	700	0.8	9	84	6.8	1.460	25	688	708	238.2	84.58	301	30.01	82	83	517.460	520.460	Stack 2	0.996
																	1.461			709	238.3									
070	AAO	HCl	02	1449	1502	3-May	217	±	0.6	22	5	700	0.8	9	84	6.0	1.547	25	622	679	216.7	84.27	302	30.01	84	85	521.100	524.100	Stack 2	0.996
																	1.553			681	217.5									
070	AAO	HCl	03	1512	1525	3-May	225	±	0.1	22	5	700	0.8	9	84	6.3	1.678	25	582	689	224.7	84.19	302	30.01	84	86	524.400	527.400	Stack 2	0.996
																	1.679			689	224.8									
																6.4														
							227	±	10.7							0.4														

Table A-3, continued (Reference Table 3-3)

Week	Site	Gas	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O_2 Average	±	σ	Reactor Conditions: Condition Number	Flow	Temp.	NOx/NO$_x$	H_2O	Unit 5 Load,	Sample O_2	Analytical: CT	Dil	Vol.	CT	HCl	Dry Gas Meter: Volume, Total	Temp, Avg.	Barometric Pressure	Temp, Begin	Temp, End	Volume, Begin	Volume, End	Meter I.D	Corr. Factor
											kscfm	deg F		%	MW	%	ppm		ml	µM	ppm, wet, @ 3% O2	STD L, wet	deg K	in. Hg	deg F	deg F	ft3	ft3		
070	BAI	HCl	01	1347	1400	4-May	226	±	3.1	22	5	700	0.8	9	84	3.4	1.817	25	677	867	228.6	86.96	296	30.01	74	74	268.500	271.500	Stack 1	1.0080
																	1.782			851	224.2									
070	BAI	HCl	02	1411	1424	4-May	215	±	0.2	22	5	700	0.8	9	84	3.4	1.872	25	619	817	215.5	86.88	297	30.01	74	75	272.000	275.000	Stack 1	1.0080
																	1.870			816	215.3									
070	BAI	HCl	03	1435	1449	4-May	223	±	0.7	22	5	700	0.8	9	84	3.7	1.921	25	615	833	223.8	86.80	297	30.01	75	75	275.500	278.500	Stack 1	1.0080
																	1.913			830	222.8									
																3.5														
							222	±	5.7							0.2														
070	BAO	HCl	01	1347	1404	4-May	225	±	1.0	22	5	700	0.8	9	84	7.7	1.337	25	673	635	226.0	85.29	299	30.01	77	79	538.000	541.000	Stack 2	0.9960
																	1.329			631	224.7									
070	BAO	HCl	02	1410	1427	4-May	225	±	1.6	22	5	700	0.8	9	84	7.4	1.357	25	672	643	224.0	85.29	299	30.01	78	78	541.400	544.400	Stack 2	0.9960
																	1.372			650	226.4									
070	BAO	HCl	03	1434	1447	4-May	213	±	4.3	22	5	700	0.8	9	84	7.6	1.347	25	616	585	209.8	85.36	298	30.01	77	78	544.800	547.800	Stack 2	0.9960
																	1.386			602	215.9									
																7.6														
							221	±	7.2							0.2														

Table A-3, continued (Reference Table 3-3)

Week	Site	Gas	Number	Time, Begin	Time, End	Date	Concentration ppm (v), wet, @ 3% O_2 Average		σ	Reactor Conditions Condition Number	Flow kscfm	Temp. deg F	NH_3/NO_x	H_2O %	Unit 5 Load, MW	Sample O_2 %	Analytical CT ppm	DII	Vol. ml	CT µM	HCl ppm, wet, @ 3% O2	Dry Gas Meter Volume, Total STD L, wet	Temp, Avg. deg K	Barometric Pressure in. Hg	Temp, Begin deg F	Temp, End deg F	Volume, Begin ft3	Volume, End ft3	Meter I.D	Corr. Factor
070	CAI	HCl	01	1355	1408	5-May	234	±	0.6	22	5	700	0.8	9	84	4.7	1.777	25	653	818	233.4	86.77	298	30.14	77	78	292.000	295.000	Stack 1	1.0080
																	1.783			821	234.2									
070	CAI	HCl	02	1419	1432	5-May	235	±	0.1	22	5	700	0.8	9	84	4.7	1.909	25	610	821	234.9	86.53	299	30.14	79	79	295.500	298.500	Stack 1	1.0080
																	1.910			822	235.0									
070	CAI	HCl	03	1443	1457	5-May	230	±	0.8	22	5	700	0.8	9	84	3.8	2.014	25	596	847	229.1	86.65	300	30.14	79	81	299.000	302.010	Stack 1	1.0080
																	2.024			851	230.2									
																4.4														
							233	±	2.8							0.5														
070	CAO	HCl	01	1354	1410	5-May	225	±	0.3	22	5	700	0.8	9	84	5.3	1.499	25	703	743	224.9	84.94	301	30.14	82	83	558.300	561.300	Stack 2	0.9960
																	1.502			745	225.3									
070	CAO	HCl	02	1418	1435	5-May	211	±	0.2	22	5	700	0.8	9	84	4.8	1.683	25	605	718	211.1	84.71	302	30.14	83	85	561.700	564.700	Stack 2	0.9960
																	1.681			717	210.9									
070	CAO	HCl	03	1443	1500	5-May	226	±	0.9	22	5	700	0.8	9	84	5.5	1.695	25	612	732	225.5	84.48	303	30.14	85	86	565.100	568.100	Stack 2	0.9960
																	1.705			736	226.8									
																5.2														
							221	±	8.5							0.4														

Table A-4 (Reference Table 3-4)

INPUT DATA

DATE: 4/25/94
RUN ID: 69-AAI-M17-01

Flue gas O_2	5.5 % wet	Nozzle diameter	0.469 in.
Flue gas CO_2	13 % wet	Gas meter corr.	1.055
Flue gas N_2	73.66 % wet	Pitot corr. (C_p)	0.821
Flue gas H_2O	7.84 % wet	Duct Area	15.47 ft^2
Ambient Pressure	30.01 in. Hg		
Stack Pressure	-11 in. H_2O		
Stack Temp	683.78 °F		
Volume water	32.1 ml	Meter volume	17.434 ft^3
Particle mass	4437.8 mg	SQRT DP pitot	0.1789
Run time	45 min	AVG DH orifice	0.54 in. H_2O
Meter Temp	88.94 °F		

FINAL CALCULATED DATA

% WATER	7.84%	gr/ACF :	1.5996 wet
% ISOKINETIC	91.08%	gr/SCF :	3.9134 dry
STACK VEL.	14.49 ft/s	mg/ACM :	3660.59 wet
		mg/SCM :	8955.45 dry
STACK FLOW	13450 ACFM (wet)		
STACK FLOW	5482 SCFM (dry)	LB/MBTU	7.3157

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 4/25/94
RUN ID: 69-AAI-M17-02

Flue gas O2	5.5 % wet	Nozzle diameter	0.469 inches
Flue gas CO2	13 % wet	Gas meter corr.	1.055
Flue gas N2	71.68 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	9.82 % wet	Duct Area	15.47 ft2
Ambient Pressure	30.01 in Hg		
Stack Pressure	-11 in H2O		
Stack Temp	683.78 °F		
Volume water	41.4 ml	Meter volume	17.61 ft3
Particle mass	4122.8 mg	SQRT DP pitot	0.1789
Run time	45 min	AVG DH orifice	0.54 in H2O
Meter Temp	89.889 °F		

FINAL CALCULATED DATA

% WATER	9.82%	gr/ACF :	1.4422 wet
% ISOKINETIC	93.54%	gr/SCF :	3.6055 dry
STACK VEL.	14.54 ft/s	mg/ACM :	3300.37 wet
		mg/SCM :	8250.88 dry
STACK FLOW	13495 ACFM (wet)		
STACK FLOW	5382 SCFM (dry)	LB/MBTU	6.7401

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 4/25/94
RUN ID: 69-AAI-M17-03

Flue gas O2	5.5 % wet	Nozzle diameter	0.469 inches
Flue gas CO2	13 % wet	Gas meter corr.	1.055
Flue gas N2	72.28 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	9.22 % wet	Duct Area	15.47 ft2
Ambient Pressure	30.01 in Hg		
Stack Pressure	-11 in H2O		
Stack Temp	696 °F		
Volume water	39 ml	Meter volume	17.927 ft3
Particle mass	3505.1 mg	SQRT DP pitot	0.1789
Run time	45 min	AVG DH orifice	0.54 in H2O
Meter Temp	94.7 °F		

FINAL CALCULATED DATA

% WATER	9.22%	gr/ACF :	1.2101 wet
% ISOKINETIC	94.37%	gr/SCF :	3.0375 dry
STACK VEL.	14.60 ft/s	mg/ACM :	2769.09 wet
		mg/SCM :	6950.98 dry
STACK FLOW	13554 ACFM (wet)		
STACK FLOW	5383 SCFM (dry)	LB/MBTU	5.6783

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 4/25/94
RUN ID: 69-AAO-M17-01

Flue gas O2	5.5 % wet	Nozzle diameter	0.219 inches
Flue gas CO2	13 % wet	Gas meter corr.	1.002
Flue gas N2	73.55 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	7.95 % wet	Duct Area	3.36 ft2
Ambient Pressure	30.01 in Hg		
Stack Pressure	-22.5 in H2O		
Stack Temp	318.44 °F		
Volume water	40.4 ml	Meter volume	22.585 ft3
Particle mass	4856.6 mg	SQRT DP pitot	0.7984
Run time	45 min	AVG DH orifice	0.9522 in H2O
Meter Temp	85.11 °F		

FINAL CALCULATED DATA

% WATER	7.95%	gr/ACF :	2.0117 wet
% ISOKINETIC	97.17%	gr/SCF :	3.4530 dry
STACK VEL.	54.15 ft/s	mg/ACM :	4603.66 wet
		mg/SCM :	7901.93 dry
STACK FLOW	10916 ACFM (wet)		
STACK FLOW	6341 SCFM (dry)	LB/MBTU	6.4551

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 4/25/94
RUN ID: 69-AAO-M17-02

Flue gas O2	5.5 % wet	Nozzle diameter	0.219 inches
Flue gas CO2	13 % wet	Gas meter corr.	1.002
Flue gas N2	72.19 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	9.31 % wet	Duct Area	3.36 ft2
Ambient Pressure	30.01 in Hg		
Stack Pressure	-22.5 in H2O		
Stack Temp	317.2 °F		
Volume water	52.4 ml	Meter volume	24.92 ft3
Particle mass	5096.7 mg	SQRT DP pitot	0.8626
Run time	45 min	AVG DH orifice	1.11 in H2O
Meter Temp	91.28 °F		

FINAL CALCULATED DATA

% WATER	9.31%	gr/ACF :	1.9088 wet
% ISOKINETIC	99.29%	gr/SCF :	3.3201 dry
STACK VEL.	58.59 ft/s	mg/ACM :	4368.12 wet
		mg/SCM :	7597.76 dry
STACK FLOW	11812 ACFM (wet)		
STACK FLOW	6771 SCFM (dry)	LB/MBTU	6.2066

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 4/25/94
RUN ID: 69-AAO-M17-03

Flue gas O2	5.5 % wet	Nozzle diameter	0.219 inches
Flue gas CO2	13 % wet	Gas meter corr.	1.002
Flue gas N2	72.56 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	8.94 % wet	Duct Area	3.36 ft2
Ambient Pressure	30.01 in Hg		
Stack Pressure	-22.5 in H2O		
Stack Temp	316.44 °F		
Volume water	50.8 ml	Meter volume	25.36 ft3
Particle mass	4427.7 mg	SQRT DP pitot	0.8577
Run time	45 min	AVG DH orifice	1.096 in H2O
Meter Temp	93.83 °F		

FINAL CALCULATED DATA

% WATER	8.94%	**gr/ACF :**	**1.6453** wet
% ISOKINETIC	100.76%	**gr/SCF :**	**2.8475** dry
STACK VEL.	58.19 ft/s	**mg/ACM :**	**3765.00** wet
		mg/SCM :	**6516.19** dry
STACK FLOW	11732 ACFM (wet)		
STACK FLOW	6758 SCFM (dry)	**LB/MBTU**	**5.3231**

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 5/2/94
RUN ID: 70-BAI-M17-01

Flue gas O2	3.5 % wet	Nozzle diameter	0.469 inches
Flue gas CO2	15 % wet	Gas meter corr.	1.055
Flue gas N2	72.2 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	9.3 % wet	Duct Area	15.47 ft2
Ambient Pressure	30.1 in Hg		
Stack Pressure	-14 in H2O		
Stack Temp	689.89 °F		
Volume water	33.9 ml	Meter volume	14.683 ft3
Particle mass	3422 mg	SQRT DP pitot	0.1549
Run time	45 min	AVG DH orifice	0.38 in H2O
Meter Temp	68.89 °F		

FINAL CALCULATED DATA

% WATER	9.30%	gr/ACF :	1.3716 wet
% ISOKINETIC	94.18%	gr/SCF :	3.4431 dry
STACK VEL.	12.61 ft/s	mg/ACM :	3138.76 wet
		mg/SCM :	7879.23 dry
STACK FLOW	11703 ACFM (wet)		
STACK FLOW	4634 SCFM (dry)	LB/MBTU	5.6967

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 5/2/94
RUN ID: 70-BAI-M17-02

Flue gas O2	3.5 % wet	Nozzle diameter	0.469 inches
Flue gas CO2	15 % wet	Gas meter corr.	1.055
Flue gas N2	71.83 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	9.67 % wet	Duct Area	15.47 ft2
Ambient Pressure	30.1 in Hg		
Stack Pressure	-14 in H2O		
Stack Temp	687.33 °F		
Volume water	35.1 ml	Meter volume	14.846 ft3
Particle mass	3240.8 mg	SQRT DP pitot	0.1549
Run time	45 min	AVG DH orifice	0.38 in H2O
Meter Temp	79.17 °F		

FINAL CALCULATED DATA

% WATER	9.67%	gr/ACF :	1.3073 wet
% ISOKINETIC	93.62%	gr/SCF :	3.2877 dry
STACK VEL.	12.60 ft/s	mg/ACM :	2991.57 wet
		mg/SCM :	7523.62 dry
STACK FLOW	11697 ACFM (wet)		
STACK FLOW	4623 SCFM (dry)	LB/MBTU	5.4396

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 5/2/94
RUN ID: 70-BAI-M17-03

Flue gas O2	3.5 % wet	Nozzle diameter	0.469 inches
Flue gas CO2	15 % wet	Gas meter corr.	1.055
Flue gas N2	70.35 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	11.15 % wet	Duct Area	15.47 ft2
Ambient Pressure	30.1 in Hg		
Stack Pressure	-14 in H2O		
Stack Temp	689.11 °F		
Volume water	41.1 ml	Meter volume	14.983 ft3
Particle mass	3479.2 mg	SQRT DP pitot	0.1549
Run time	45 min	AVG DH orifice	0.38 in H2O
Meter Temp	84.83 °F		

FINAL CALCULATED DATA

% WATER	11.15%	gr/ACF :	1.3800 wet
% ISOKINETIC	94.90%	gr/SCF :	3.5340 dry
STACK VEL.	12.64 ft/s	mg/ACM :	3158.06 wet
		mg/SCM :	8087.28 dry
STACK FLOW	11735 ACFM (wet)		
STACK FLOW	4555 SCFM (dry)	LB/MBTU	5.8471

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 5/2/94
RUN ID: 70-BAO-M17-01

Flue gas O2	3.5 % wet	Nozzle diameter	0.219 inches
Flue gas CO2	15 % wet	Gas meter corr.	1.002
Flue gas N2	72.59 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	8.91 % wet	Duct Area	3.36 ft2
Ambient Pressure	30.1 in Hg		
Stack Pressure	-20 in H2O		
Stack Temp	317.33 °F		
Volume water	46.7 ml	Meter volume	22.585 ft3
Particle mass	3837.4 mg	SQRT DP pitot	0.7703
Run time	45 min	AVG DH orifice	0.904 in H2O
Meter Temp	75.61 °F		

FINAL CALCULATED DATA

% WATER	8.91%	gr/ACF :	1.5582 wet
% ISOKINETIC	103.41%	gr/SCF :	2.6731 dry
STACK VEL.	51.91 ft/s	mg/ACM :	3565.87 wet
		mg/SCM :	6117.18 dry
STACK FLOW	10465 ACFM (wet)		
STACK FLOW	6064 SCFM (dry)	LB/MBTU	4.4227

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 5/2/94
RUN ID: 70-BAO-M17-02

Flue gas O2	3.5 % wet	Nozzle diameter	0.219 inches
Flue gas CO2	15 % wet	Gas meter corr.	1.002
Flue gas N2	72.14 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	9.36 % wet	Duct Area	3.36 ft2
Ambient Pressure	30.1 in Hg		
Stack Pressure	-20 in H2O		
Stack Temp	315.78 °F		
Volume water	50.1 ml	Meter volume	23.343 ft3
Particle mass	3911.2 mg	SQRT DP pitot	0.7898
Run time	45 min	AVG DH orifice	0.9489 in H2O
Meter Temp	85.11 °F		

FINAL CALCULATED DATA

% WATER	9.36%	gr/ACF :	1.5590 wet
% ISOKINETIC	102.76%	gr/SCF :	2.6826 dry
STACK VEL.	53.21 ft/s	mg/ACM :	3567.71 wet
		mg/SCM :	6138.76 dry
STACK FLOW	10728 ACFM (wet)		
STACK FLOW	6198 SCFM (dry)	LB/MBTU	4.4383

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 5/2/94
RUN ID: 70-BAO-M17-03

Flue gas O2	3.5 % wet	Nozzle diameter	0.219 inches
Flue gas CO2	15 % wet	Gas meter corr.	1.002
Flue gas N2	71.73 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	9.77 % wet	Duct Area	3.36 ft2
Ambient Pressure	30.1 in Hg		
Stack Pressure	-20 in H2O		
Stack Temp	315.22 °F		
Volume water	52.4 ml	Meter volume	23.527 ft3
Particle mass	4242.7 mg	SQRT DP pitot	0.7948
Run time	45 min	AVG DH orifice	0.962 in H2O
Meter Temp	90.78 °F		

FINAL CALCULATED DATA

% WATER	9.77%	gr/ACF :	1.6889 wet
% ISOKINETIC	102.21%	gr/SCF :	2.9171 dry
STACK VEL.	53.57 ft/s	mg/ACM :	3864.93 wet
		mg/SCM :	6675.53 dry
STACK FLOW	10799 ACFM (wet)		
STACK FLOW	6215 SCFM (dry)	LB/MBTU	4.8264

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE:	**4/26/94**				
RUN ID:	**69-CAI-M17-01**				
Flue gas O2	4	% wet	Nozzle diameter	0.469	inches
Flue gas CO2	13	% wet	Gas meter corr.	1.055	
Flue gas N2	71.88	% wet	Pitot corr. (Cp)	0.821	
Flue gas H2O	11.12	% wet	Duct Area	15.47	ft2
Ambient Pressure	30.02	in Hg			
Stack Pressure	-11	in H2O			
Stack Temp	686.1	°F			
Volume water	47.5	ml	Meter volume	17.597	ft3
Particle mass	4154.9	mg	SQRT DP pitot	0.1789	
Run time	45	min	AVG DH orifice	0.54	in H2O
Meter Temp	90.67	°F			

FINAL CALCULATED DATA

% WATER	11.12%	**gr/ACF :**	**1.4326**	wet
% ISOKINETIC	94.49%	**gr/SCF :**	**3.6402**	dry
STACK VEL.	14.60 ft/s	**mg/ACM :**	**3278.45**	wet
		mg/SCM :	**8330.32**	dry
STACK FLOW	13553 ACFM (wet)			
STACK FLOW	5316 SCFM (dry)	**LB/MBTU**	**6.2010**	

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE: 4/26/94
RUN ID: 69-CAI-M17-02

Flue gas O2	4 % wet	Nozzle diameter	0.469 inches
Flue gas CO2	13 % wet	Gas meter corr.	1.055
Flue gas N2	72.41 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	10.59 % wet	Duct Area	15.47 ft2
Ambient Pressure	30.02 in Hg		
Stack Pressure	-11 in H2O		
Stack Temp	682 °F		
Volume water	45.4 ml	Meter volume	17.843 ft3
Particle mass	4480.1 mg	SQRT DP pitot	0.1789
Run time	45 min	AVG DH orifice	0.54 in H2O
Meter Temp	93.11 °F		

FINAL CALCULATED DATA

% WATER	10.59%	**gr/ACF :**	**1.5449** wet
% ISOKINETIC	94.74%	**gr/SCF :**	**3.8882** dry
STACK VEL.	14.56 ft/s	**mg/ACM :**	**3535.26** wet
		mg/SCM :	**8897.76** dry
STACK FLOW	13516 ACFM (wet)		
STACK FLOW	5353 SCFM (dry)	**LB/MBTU**	**6.6234**

Table A-4, continued (Reference Table 3-4)

INPUT DATA

DATE:	**4/26/94**		
RUN ID:	**69-CAI-M17-03**		
Flue gas O2	4 % wet	Nozzle diameter	0.469 inches
Flue gas CO2	13 % wet	Gas meter corr.	1.055
Flue gas N2	70.38 % wet	Pitot corr. (Cp)	0.821
Flue gas H2O	12.62 % wet	Duct Area	15.47 ft2
Ambient Pressure	30.02 in Hg		
Stack Pressure	-11 in H2O		
Stack Temp	683.67 °F		
Volume water	54.8 ml	Meter volume	17.869 ft3
Particle mass	4537.9 mg	SQRT DP pitot	0.1789
Run time	45 min	AVG DH orifice	0.54 in H2O
Meter Temp	99.44 °F		

FINAL CALCULATED DATA

% WATER	12.62%	**gr/ACF :**	**1.5423** wet
% ISOKINETIC	95.72%	**gr/SCF :**	**3.9777** dry
STACK VEL.	14.62 ft/s	**mg/ACM :**	**3529.43** wet
		mg/SCM :	**9102.50** dry
STACK FLOW	13573 ACFM (wet)		
STACK FLOW	5246 SCFM (dry)	**LB/MBTU**	**6.7758**

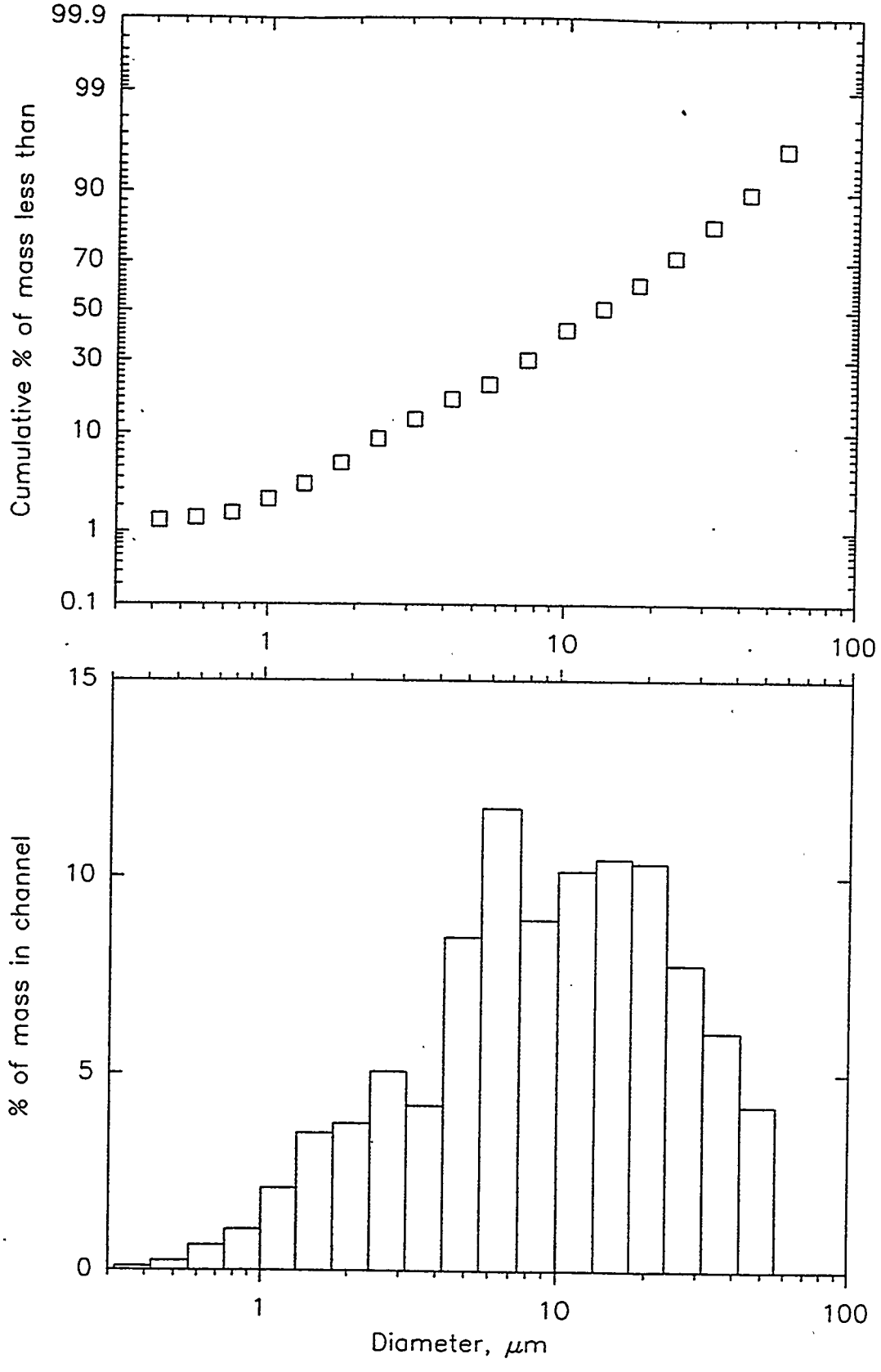

Figure A-1. Particle size distributions (cumulative % mass, top; differential % mass, bottom) of fly ash collected at the Reactor A air heater inlet.

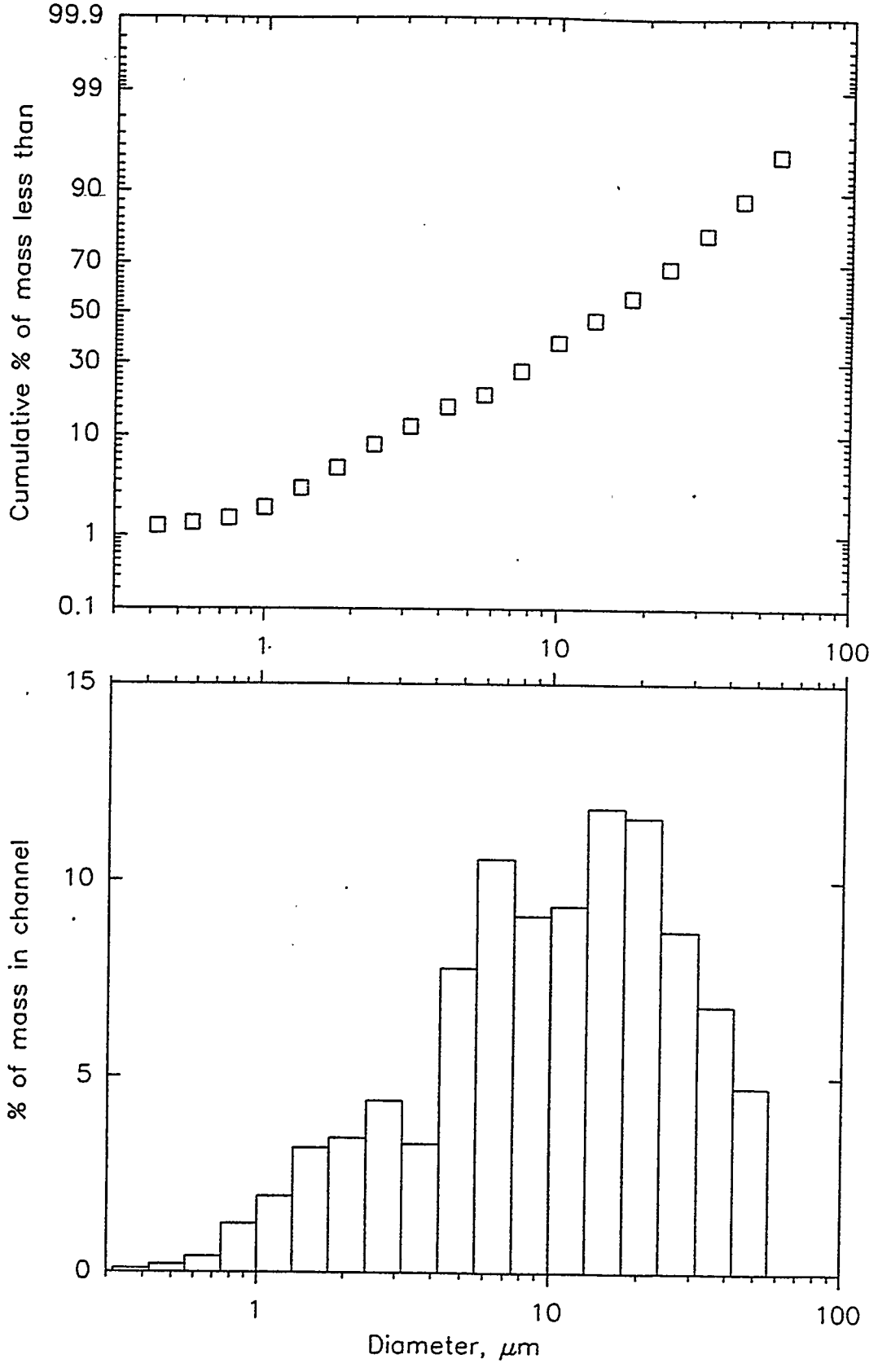

Figure A-2. Particle size distributions (cumulative % mass, top; differential % mass, bottom) of fly ash collected at the Reactor A air heater outlet.

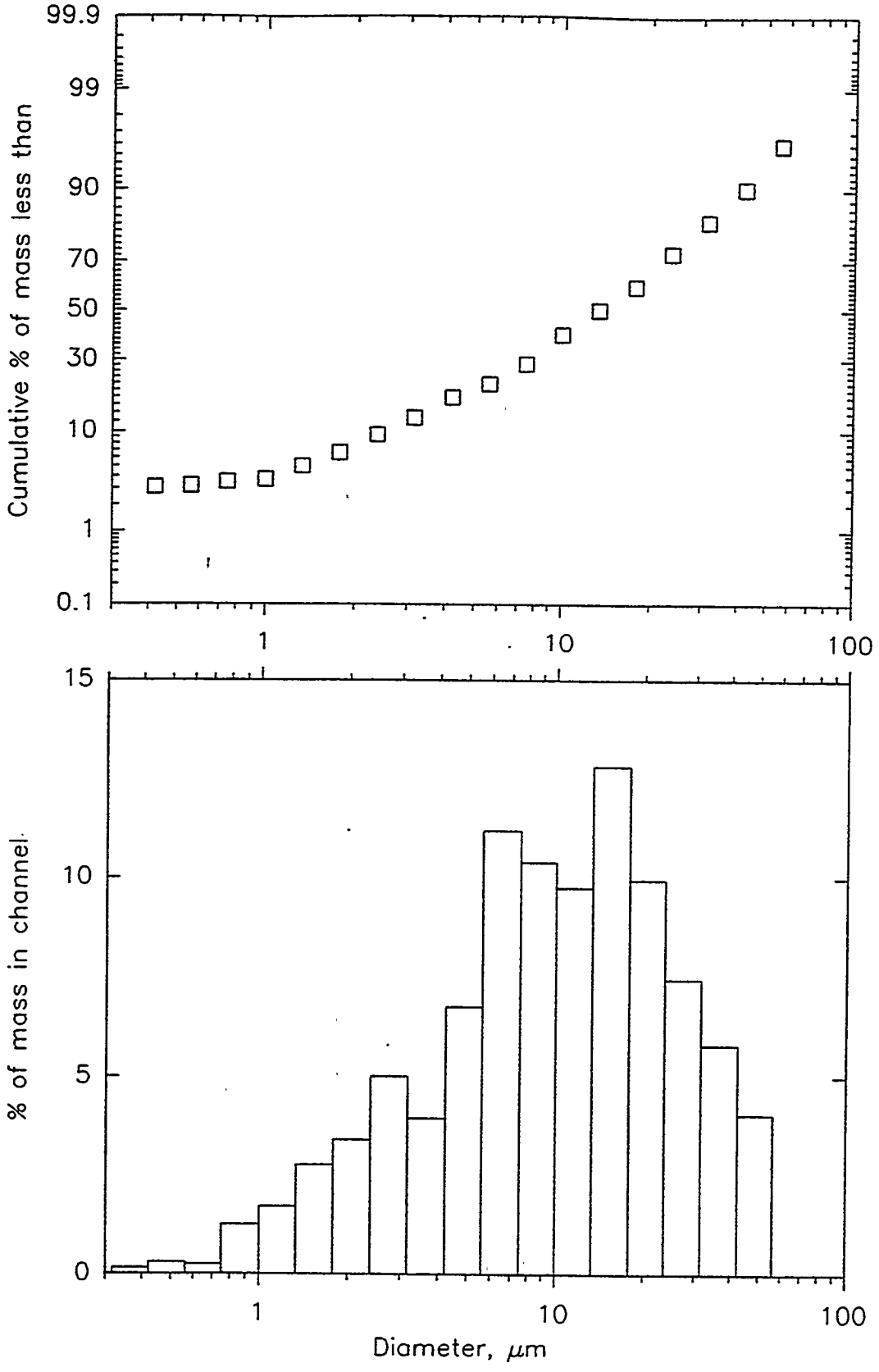

Figure A-3. Particle size distributions (cumulative % mass, top; differential % mass, bottom) of fly ash collected at the Reactor B air heater inlet.

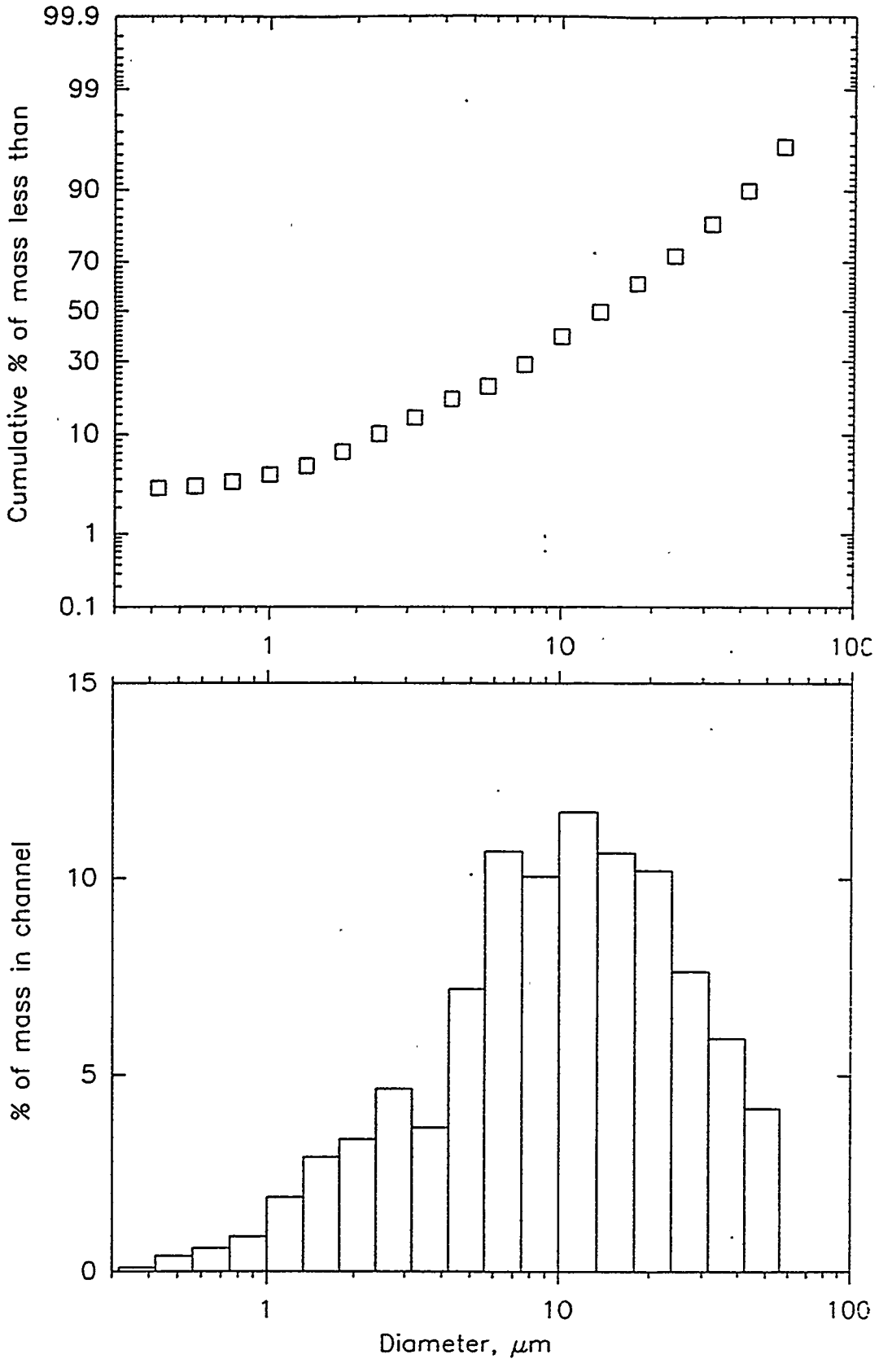

Figure A-4. Particle size distributions (cumulative % mass, top; differential % mass, bottom) of fly ash collected at the Reactor B air heater outlet.

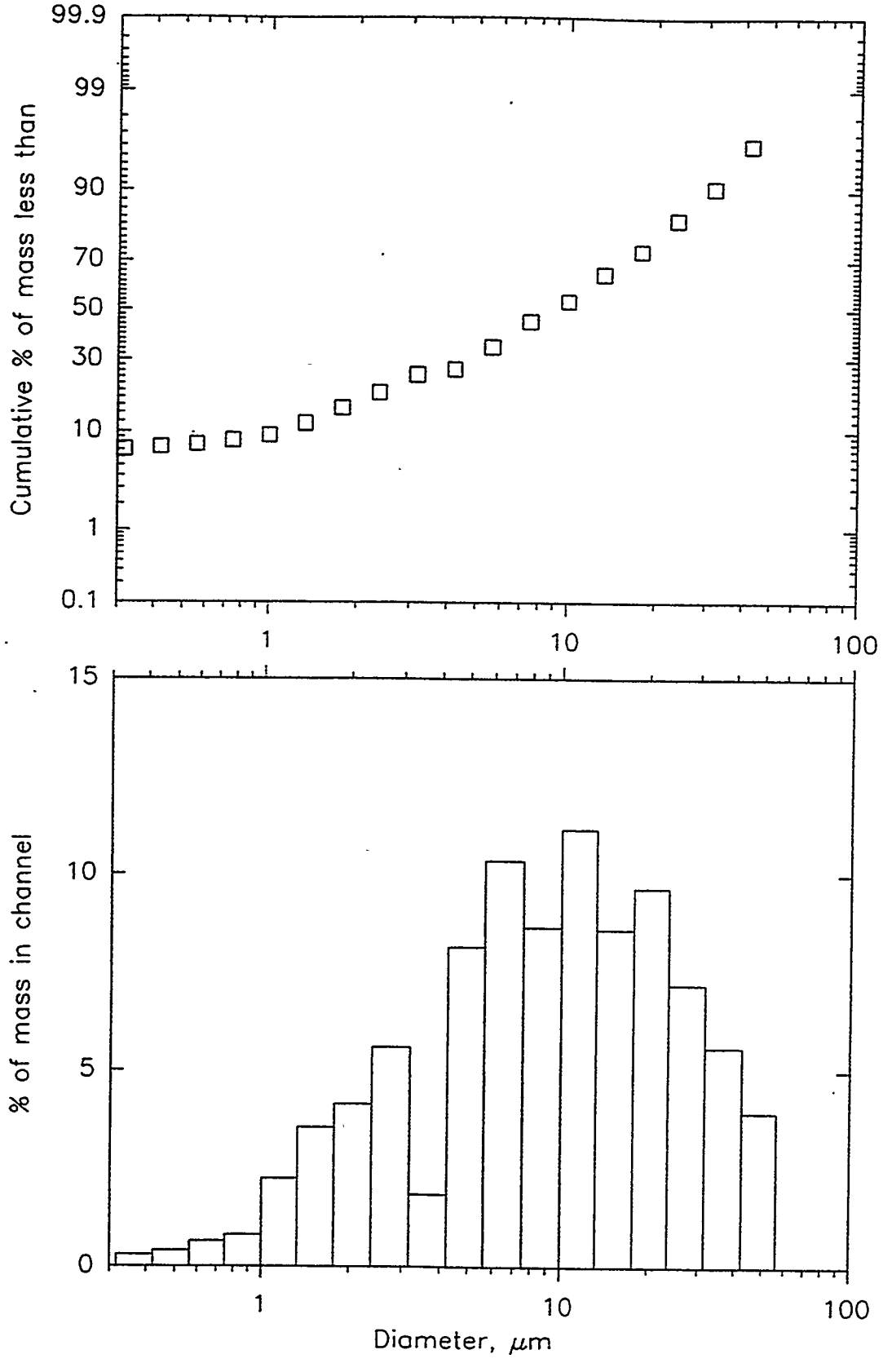

Figure A-5. Particle size distributions (cumulative % mass, top; differential % mass, bottom) of fly ash collected at the Reactor C air heater inlet.

RESISTIVITY TEST DATA

START DATE 23 SEPT 94 APPARATUS NO. 2 TEST TYPE:
PROJECT NO. 7613.07.01 DESCENDING ✓455°C
TEST NO. ASCENDING
PLANT/COMPANY PLANT CRIST UNIT 5 ACID

Position	Cell No.	Cell Volume	Weight Full	Weight Empty	Weight Ash	Ash Density	Ash Volume	%P
1	1							
2	2							
3	3							
4	4							

Position	Ash I.D.	Thickness	Sink	A/(T-S)	Mesh Size
1	060-E4-M17-01,02			8.00	-60
2	060-F4-M17-01,02	.495cm	.2cm	13.15	"
3	046-G4-M17-01, 2, 3			7.92	"
4	No. 4090 A INLET			7.84	"

Thermocouple Readings in °C

Time												
1				5				9				
2				6				10				
3				7				11				
4				8				12				

Gas Composition:

Water Bath Temperature: 44.5

Acid Bath Temperature:

Volume % Water:

Weight Wet:

Weight Dry:

Weight Water:

$$\frac{(\quad)(1.244) \times 100}{(\quad)(1.244) + [\quad \cdot 0.8 \cdot (460/\quad)]} = 8.7\%$$

RESISTIVITY TEST DATA

START DATE 23 SEPT 94 APPARATUS NO. 2 PAGE NO. 1
PROJECT NO. 7613-07.01
TEST SAMPLE I.D. PLANT CRIST UNIT 5

Date/Time	Temperature °C	Temperature 1000/°K	D.C. Volts	D.C. Amperes	A/L	Resistivity Ohm-cm	Comments
23SEPT/0833	440/442	1.40	-2000	.10 x10^{-3}	8.00	1.60 x10^{8}	0750 - H_2O ON
	434/438	1.41	-200 ★	.10 x10^{-4}	13.15	2.63 x10^{8}	0821 - OVEN OFF
	431/436	"	-2000	.10 x10^{-3}	7.92	1.58 x10^{8}	★P.S TRIPS @ -2KV
	428/434	"	"	.18 x10^{-3}	7.84	7.71 x10^{7}	
0856	384/398	1.49	-2000	.28 x10^{-4}		5.71 x10^{8}	
	380/394	1.50	-200	.36 x10^{-5}		7.31 x10^{8}	
	377/391	1.51	-2000	.29 x10^{-4}		5.4[illegible] x10^{8}	
	374/388	"	"	.53 x10^{-4}		2.96 x10^{8}	
0914	342/357	1.59	-2000	.22 x10^{-5}		[illegible] x10^{9}	
	338/355	"	-200	.15 x10^{-5}		1.75 x10^{9}	
	330/347	1.61	-2000	.76 x10^{-5}		2.08 x10^{9}	
	327/344	1.62	"	.135 x10^{-4}		1.16 x10^{9}	
0942	283/301	1.74	-2000	.14 x10^{-5}		1.14 x10^{10}	
	280/298	1.75	-200	.34 x10^{-6}		7.74 x10^{9}	
	277/295	1.76	-2000	.13 x10^{-5}		1.22 x10^{10}	
	275/293	1.77	"	.24 x10^{-5}		6.53 x10^{9}	
1006	243/261	1.87	-2000	.35 x10^{-6}		4.57 x10^{10}	
	241/259	1.88	-200	.11 x10^{-6}		2.39 x10^{10}	
	239/257	1.89	-2000	.33 x10^{-6}		4.80 x10^{10}	
	237/255	"	"	.57 x10^{-6}		2.75 x10^{10}	
1025	215/233	1.98	-2000	.14 x10^{-6}		1.14 x10^{11}	
	214/231	"	-200	~.68 x10^{-7} ★★		3.87 x10^{10}	★★ SLIGHTLY ERRATIC
	212/229	1.99	-2000	.13 x10^{-6}		1.22 x10^{11}	
	211/228	2.00	"	.21 x10^{-6}		7.47 x10^{10}	
1104	172/188	2.17	-2000	.38 x10^{-7}		4.21 x10^{11}	
	171/187	"	-200	.19 x10^{-7}		1.38 x10^{11}	
	169/185	2.18	-2000	.39 x10^{-7}		4.06 x10^{11}	
	168/184	2.19	"	.48 x10^{-7}		3.27 x10^{11}	
				x10^{-}		x10	
				x10^{-}		x10	

RESISTIVITY TEST DATA

START DATE 23 SEPT 94 APPARATUS NO. 2 PAGE NO. 2
PROJECT NO. 7613.[illegible].01
TEST SAMPLE I.D. PLANT CRIST UNIT 5

Date/Time	Temperature °C	Temperature 1000/°K	D.C. Volts	D.C. Amperes	A/L	Resistivity Ohm-cm	Comments
1140	142/156	2.33	-2000	.24 x 10⁻⁷	8.00	6.67 x10 ¹¹	
	141/155	2.34	-200	.24 x 10⁻⁷	13.15	1.10 x10 ¹¹	
	140/154	"	-2000	.28 x 10⁻⁷	7.92	5.66 x10 ¹¹	
	139/153	2.35	"	.26 x 10⁻⁷	7.84	6.03 x10 ¹¹	
1238	108/119	2.55	-2000	.49 x 10⁻⁷		3.27 x10 ¹¹	
	106/117	2.56	-200	.87 x 10⁻⁷		3.02 x10 ¹⁰	
	107/118	"	-2000	.66 x 10⁻⁷		2.40 x10 ¹¹	
	106/117	"	"	.50 x 10⁻⁷		3.14 x10 ¹¹	
1353	81/90	2.75	-2000	.63 x 10⁻⁶		2.54 x10 ¹⁰	
	80/89	2.76	-200	.28 x 10⁻⁶		9.39 x10 ⁹	HIGHEST CARBON CONTENT AFTER
	80/89	"	-2000	.97 x 10⁻⁶		1.63 x10 ¹⁰	TEST. ALSO [illegible]
	80/89	"	"	.67 x 10⁻⁶		2.34 x10 ¹⁰	[illegible]
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	

RESISTIVITY TEST DATA

START DATE 27 SEPT 94 APPARATUS NO. 2 TEST TYPE:
PROJECT NO. 7613.07.01 DESCENDING ✓ 455°C
TEST NO. ASCENDING
PLANT/COMPANY PLANT CRIST UNIT 5 ACID

Position	Cell No.	Cell Volume	Weight Full	Weight Empty	Weight Ash	Ash Density	Ash Volume	%P
1	1							
2	2							
3	3							
4	4							

Position	Ash I.D.	Thickness	Sink	A/(T-S)	Mesh Size
1	No. 4091 A OUTLET			8.00	-60
2	4092 B INLET			7.84	"
3	4093 B OUTLET			7.92	"
4	4094 C INLET			7.84	"

Thermocouple Readings in °C

Time												
1				5				9				
2				6				10				
3				7				11				
4				8				12				

Gas Composition: _____

Water Bath Temperature: _____

Acid Bath Temperature: _____

Volume % Water:

Weight Wet: _____

Weight Dry: _____

Weight Water: _____

$$\frac{(\quad)(1.244) \times 100}{(\quad)(1.244) + [\quad \cdot 0.8 \cdot (460/\quad)]} = \quad \%$$

RESISTIVITY TEST DATA

START DATE 27 SEPT 94 APPARATUS NO. 2 PAGE NO. 1
PROJECT NO. 7613.07.01
TEST SAMPLE I.D. PLANT CRIST UNIT 5

Date/Time	Temperature °C	Temperature 1000/°K	D.C. Volts	D.C. Amperes	A/L	Resistivity Ohm-cm	Comments
27SEPT/0831	443/444	1.39	-200	.12 x 10^{-4}	8.00	x10	0750 - 4200 Ω
	441/442	1.40	"	.21 x 10^{-4}	7.74	x10	
	439/440	"	"	.19 x 10^{-4}	7.92	x10	
	436/437	1.41	"	.14 x 10^{-4}	7.84	x10	
0835	433/433	1.42	-2000	.15 x 10^{-3}		1.07 x 10^{8}	
	431/432	"	"	.28 x 10^{-3}		5.60 x 10^{7}	
	427/428	1.43	"	.23 x 10^{-3}		6.89 x 10^{7}	
	425/426	"	"	.18 x 10^{-3}		8.71 x 10^{7}	
0858	377/383	1.52	"	.42 x 10^{-4}		3.81 x 10^{8}	
	374/375	1.53	"	.70 x 10^{-4}		2.24 x 10^{8}	
	371/377	1.54	"	.57 x 10^{-4}		2.73 x 10^{8}	
	367/374	1.55	"	.43 x 10^{-4}		3.65 x 10^{8}	
0925	315/332	1.65	"	.74 x 10^{-5}		2.16 x 10^{9}	
	313/330	1.66	"	.115 x 10^{-4}		1.36 x 10^{9}	
	311/328	"	"	.10 x 10^{-4}		1.58 x 10^{9}	
	303/325	1.67	"	.73 x 10^{-5}		2.15 x 10^{9}	
0944	278/296	1.76	"	.21 x 10^{-5}		7.62 x 10^{9}	
	276/294	"	"	.33 x 10^{-5}		4.75 x 10^{9}	
	274/292	1.77	"	.29 x 10^{-5}		5.46 x 10^{9}	
	272/290	1.78	"	.215 x 10^{-5}		7.65 x 10^{9}	
1003	246/267	1.86	"	.63 x 10^{-6}		2.54 x 10^{10}	
	244/262	1.87	"	.16 x 10^{-5}		1.57 x 10^{10}	
	242/260	1.88	"	.89 x 10^{-6}		1.78 x 10^{10}	
	240/258	"	"	.63 x 10^{-6}		2.49 x 10^{10}	
1023	217/234	1.97	"	.21 x 10^{-6}		7.62 x 10^{10}	
	215/232	1.98	"	.34 x 10^{-6}		4.61 x 10^{10}	
	215/232	"	"	.30 x 10^{-6}		5.28 x 10^{10}	
	213/230	1.99	"	.22 x 10^{-6}		7.13 x 10^{10}	
				x 10^{-}		x10	
				x 10^{-}		x10	

RESISTIVITY TEST DATA

START DATE 27 SEPT 94 APPARATUS NO. 2 PAGE NO. 2
PROJECT NO. 7613.07.01
TEST SAMPLE I.D. PLANT CRIST UNIT 5

Date/Time	Temperature °C	Temperature 1000/°K	D.C. Volts	D.C. Amperes	A/L	Resistivity Ohm-cm	Comments
1102	173/189	2.16	−2000	.39 x 10⁻⁷	8.00	4.10 x10 ¹¹	
	172/188	2.17		.70 x 10⁻⁷	7.84	2.24 x10 ¹¹	
	171/186	2.18		.63 x 10⁻⁷	7.92	2.51 x10 ¹¹	
	170/185	"		.52 x 10⁻⁷	7.84	3.02 x10 ¹¹	
1142	140/154	2.34		.155 x 10⁻⁷		1.03 x10 ¹²	
	139/153	2.35		.35 x 10⁻⁷		4.48 x10 ¹¹	
	138/152	"		.28 x 10⁻⁷		5.66 x10 ¹¹	
	138/153	"		.29 x 10⁻⁷		5.41 x10 ¹¹	
1236	109/120	2.54		.20 x 10⁻⁷		7.01 x10 ¹¹	
	108/119	2.55		.62 x 10⁻⁷		2.53 x10 ¹¹	
	107/118	2.56		.41 x 10⁻⁷		3.86 x10 ¹¹	
	107/118	"		.57 x 10⁻⁷		2.70 x10 ¹¹	
1350	82/87	2.78		.22 x 10⁻⁶		2.37 x10 ¹⁰	
	81/86	2.79		.83 x 10⁻⁶		1.29 x10 ¹⁰	
	81/86	"		.50 x 10⁻⁶		3.17 x10 ¹⁰	
	81/86	"		.82 x 10⁻⁶		1.91 x10 ¹⁰	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	
				x 10⁻		x10	

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