Demonstration of Innovative Applications of Technology for Cost Reductions to the CT-121 FGD Process

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Volume 5 of 6: Environmental Monitoring Plan

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

1.0 INTRODUCTION

The purpose of the Innovative Clean Coal Technology demonstration project entitled "Demonstration of Innovative Applications of Technology for the CT-121 EGD Process," conducted at Plant Yates, was to demonstrate the use of the Chiyoda Thoroughbred-21 flue gas desulfurization process as a means of reducing SO_2 and particulate emissions from pulverized-coal utility boilers that use high-sulfur coal. The project was also designed to demonstrate the lower cost and higher reliability of the CT-121 process compared to conventional wet limestone FGD processes.

As the project sponsor, Southern Company Services, Inc., (SCS) was required to develop and implement an approved Environmental Monitoring Plan (EMP). The EMP for this project was prepared by Radian Corporation for SCS and submitted to the U.S. Department of Energy (DOE) on December 18, 1990. The EMP was subsequently revised and resubmitted on January 16, 1995.(1)

The EMP was developed to fulfill the following specific objectives:

- To provide monitoring data to fulfill environmental compliance requirements of local, state, and federal regulatory agencies;
- To define and describe supplemental monitoring activities;
- To ensure that emissions and environmental impacts were consistent with projections provided in documents prepared for this project as required by the National Environmental Policy Act of 1970 (NEPA); and
- To develop an environmental record that can be used for future replication of the subject technology.

This report presents and discusses the data obtained during the CT-121 demonstration project in fulfillment of the EMP objectives.

1.1 CT-121 Demonstration Facility Description

The CT-121 flue gas desulfurization project was conducted at Georgia Power Company's Plant Yates, an existing plant located approximately 40 miles south-southwest of Atlanta, Georgia. Plant Yates consists of seven steam turbine electric generating units providing a total nameplate capacity of 1,250 MW. Units 1 through 5, in service since the 1950s, are operated as intermediate load units and are located in one building that features a common 825-foot stack for venting emissions from all five units. Units 6 and 7, in service since 1974, are operated as base load units. A common 800-foot stack is used to vent emissions from these two units, which are housed in a separate building. All of Plant Yates' units are equipped with electrostatic precipitators (ESPs) for particulate control.

The CT-121 flue gas desulfurization project was constructed and operated to treat the entire flue gas stream from Unit 1(100 MW), approximately 12% of the total flue gas generated at Plant Yates. A new 258-foot stack was constructed to vent emissions from the CT-121 process.

A simplified process flow diagram of the CT-121 process is shown in Figure 1-1. Major process sampling locations are shown in that diagram. The following paragraphs describe key features of the process.

1.1.1 Limestone Feed System

Limestone is transported to Plant Yates by truck and delivered to a 30-day storage pile. From there it is loaded into an above-grade load hopper. A covered inclined conveyor system is used to deliver the limestone to a storage silo, from which it is conveyed to a wet ball mill. The mill product is pumped to hydroclones for size classification. The hydroclone overflow flows into a slurry feed tank, while the underflow is recycled to the ball mill. The limestone slurry is then pumped to the jet bubbling reactor.

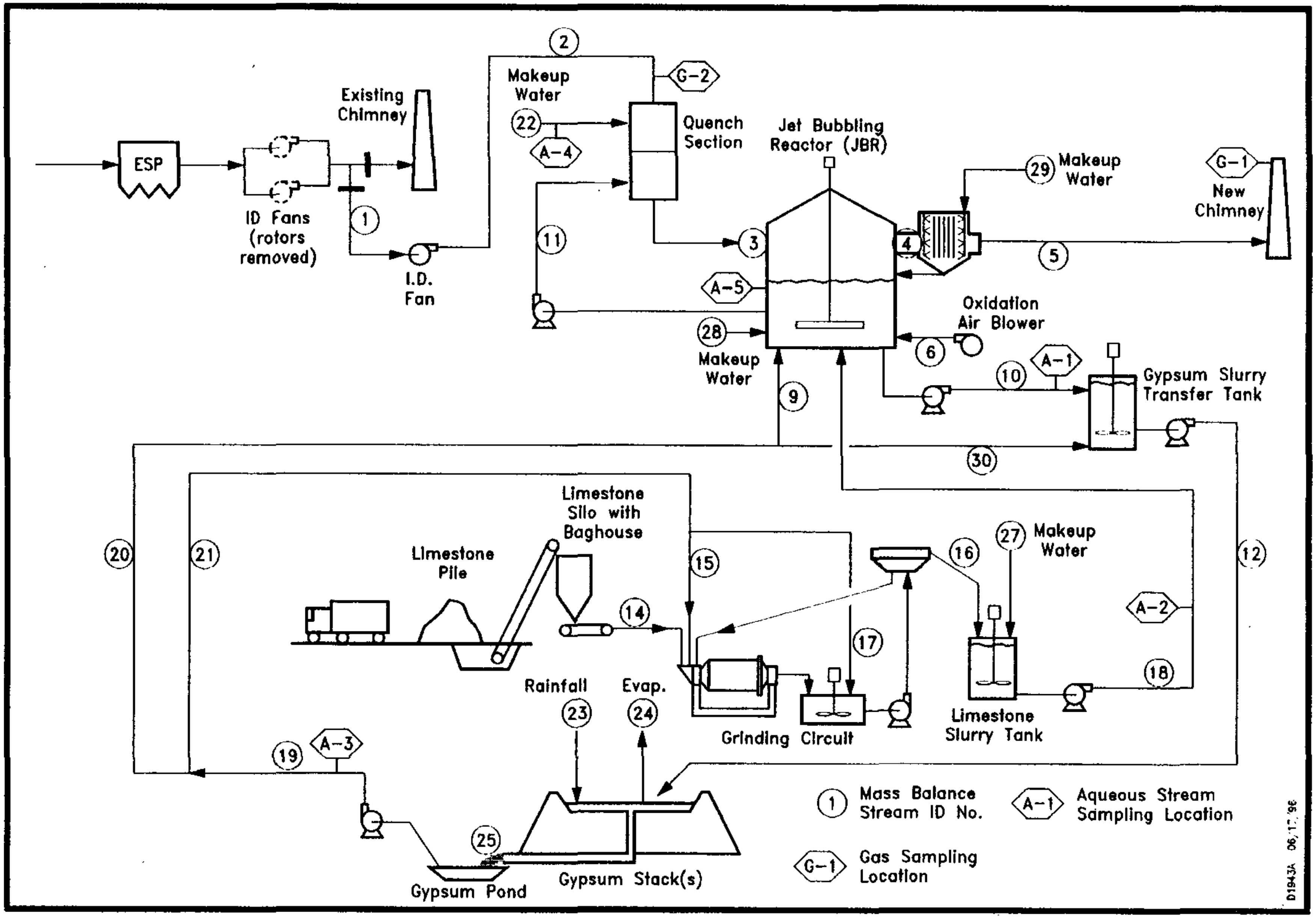

Figure 1-1. Simplified CT-121 Process Flow Diagram

1.1.2 Jet Bubbling Reactor

The jet bubbling reactor (JBR) is the key element of the CT-121 process. The demonstration project's JBR is approximately 40 feet tall by 40 feet in diameter and is constructed of fiberglass reinforced plastic (FRP). The JBR slurry is mixed using a single center-mounted agitator.

Pre-cooled flue gas from Unit 1 enters the JBR in a plenum chamber, from which it is forced into the froth zone of the JBR. Air is injected below the slurry surface to oxidize SO_2 absorbed from the flue gas, which reacts with the limestone slurry to form gypsum. The desulfurized flue gas flows upward through risers and into a second plenum, where most of the entrained liquid in the gas is disengaged, then through a mist eliminator to the dedicated stack.

1.1.3 Flue Gas Handling System

The flue gas handling system was designed to allow for several different modes of operation. Tests with low-particulate loading (with the ESP in service) and high-particulate loading (with the ESP either partially or completely out of service) were conducted as part of the demonstration project.

1.1.4 Solids Disposal

As the JBR slurry exceeds a prescribed density, the underflow is pumped approximately 2,540 feet via a pipeline to an eight-acre gypsum stacking area. The gypsum slurry is pumped to a central location in the stacking area. Supernatant liquor and accumulated rainfall are collected for reuse in the process. As the inner area of the stack is filled with solids, a dragline is used to stack the dewatered material and to raise the level of the perimeter dike.

1.2 Project Description

The CT- 121 demonstration project at Plant Yates consists of four distinct test periods including:

- Period 0: Site Preparation, Construction, and Startup of the Demonstration Project;
- Period 1: Baseline Testing at Low-Particulate Loading—With ESP in service;
- Period 2: Testing at High-Particulate Loading—ESP detuned or out of service; and
- Period 3: Post-Demonstration Groundwater Testing and Gypsum By-Product Evaluation.

Additional details about the environmental monitoring conducted during each of these four periods is provided in Section 2.

1.3 Report Organization

The remainder of this report is organized as follows:

- Section 2 discusses the technical approach used in performing environmental monitoring during the CT-121 demonstration project;
- Section 3 summarizes the environmental monitoring results for gaseous, aqueous, solid, and groundwater streams;
- Section 4 presents a summary of conclusions based on the results presented in the previous section;
- Section 5 provides a number of recommendations; and
- Section 6 is a list of references.

Tables and figures containing the detailed results for each of the streams monitored as part of the EMP are provided in the appendices.

2.0 TECHNICAL APPROACH

This section discusses the gaseous-, aqueous-, solid-, and groundwater-stream monitoring conducted under the EMP for the CT-121 demonstration project. It also summarizes the sampling and analytical methods that were used.

2.1 Environmental Monitoring Plan

The objectives of the EMP were addressed through an integrated monitoring approach. Monitoring efforts were divided into discrete areas:

- Gaseous stream monitoring, including internal process streams as well as discharges;
- Aqueous stream monitoring, including effluent streams and internal process streams;
- Solids monitoring, including solid waste and internal streams; and
- Monitoring of key process parameters that may be related to the environmental quality of pertinent streams.

A simplified process flow diagram of the CT-121 demonstration unit was shown earlier (Figure 1-1). EMP sampling and monitoring points are identified in this figure.

The CT-121 demonstration project at Plant Yates consisted of four distinct environmental test periods, including:

- Period 0: Site Preparation, Construction, and Startup of the Demonstration Project;
- Period 1: Baseline Testing at Low-Particulate Loading-with ESP in service;
- Period 2: Testing at High-Particulate Loading-ESP detuned or out of service; and

- Period 3: Post-Demonstration Groundwater Testing and Gypsum By-Product Evaluation.

The Low- and High-Particulate test periods each consisted of a number of short-term parametric and long-term load-following test blocks. These tests were conducted to determine how different operating conditions, such as jet bubbling reactor (JBR) pressure drop, scrubber slurry pH, gas flow (i.e., boiler load), coal sulfur content, limestone source, and ESP operating parameters affect emissions and CT-121 process performance. Tables 2-1 and 2-2 summarize the tests performed during the Low- and High-Particulate test periods, respectively. A more detailed discussion of the tests is provided in Volume 2 of the project's Final Report.(6)

The Low-Particulate loading test period consisted of the following test blocks, all of which were performed with the ESP fully energized:

- Parametric tests while using the baseline program coal (approximately 2.5% sulfur) and main program limestone;
- Long-term load-following tests while using the baseline program coal and limestone; and
- Auxiliary test blocks, consisting of high SO_2 removal, alternate limestone, and alternate coal (4.3% sulfur) tests.

During the High-Particulate loading test period, similar test blocks were performed, but with the ESP either partially or completely de-energized. The original plan called for all of the High-Particulate tests to be conducted with the ESP completely de-energized. However, severe sparger tube fouling was encountered during the High-Particulate Parametric Test block when the ESP was operated in this mode. In subsequent tests, the ESP was operated in a partially energized mode, to simulate operation with a marginally performing particulate collection device.

In addition, a decision was made to continue to operate the scrubber during High-Particulate tests with the limestone used in the Low-Particulate Alternate Limestone test block; a third limestone

TABLE 2-1
SUMMARY OF LOW-PARTICULATE LOADING TESTS

Test Block	Test Numbers	Dates
Parametric Tests	P1-1 - P1-36	01/17/93 - 03/31/93
Long-Term Load-Following Tests	L1-1 – L1-3	04/01/93 - 09/10/93
Auxiliary Tests		
• High SO_2 Removal		
—Parametric	HR1-1 – HR1-3	09/14/93 - 09/16/93
—Load-Following	HR1-4	09/17/93 - 10/22/93
• Alternate Limestone		
—"Clean" JBR Parametric	P1B-1 – P1B-13	12/03/93 - 12/21/93
—Load-Following	AL1-1 – AL1-2	12/22/93 - 01/25/94
• Alternate Coal		
—Parametric	AC 1-1 - AC 1-12	01/26/94 - 02/21/94

TABLE 2-2
SUMMARY OF HIGH-PARTICULATE LOADING TESTS

Test Block	Test Numbers	Dates
Parametric Tests	P2-1 - P2-33R	03/14/94 - 03/28/94 04/19/94 - 05/28/94
Long-Term Load-Following Tests	L2-1 - L2-3	06/06/94 - 08/28/94
Auxiliary Tests		
• High SO_2 Removal		
—Parametric	HR2-1 - HR2-3	09/07/94 - 09/12/94
—Load-Following	HR2-4	09/13/94 - 10/03/94
• Alternate Coal		
—Parametric	AC2-1 - AC2-9	10/04/94 - 10/13/94
—Load-Following	AC2-10	10/14/94 - 10/28/94
• Alternate Limestone		
—Parametric	AL2-1-AL2-14	11/22/94 - 12/28/94

was used in the High-Particulate Alternate Limestone test block. A number of tests were also conducted using the plant's Phase 1 compliance coal (1.25% sulfur). The coal used in the High-Particulate Alternate Coal test block had a lower sulfur content than that used during the Low-Particulate Alternate Coal test block (3.4% sulfur versus 4.3%). In addition, the 2.5% sulfur baseline coal was unavailable during the latter part of the High-Particulate test block, resulting in some tests being conducted at lower SO_2 concentrations than were experienced during the Low-Particulate test block.

Another factor leading to a modification of the original test plan was the discovery during the High-Particulate Parametric tests that it was necessary to operate at lower slurry pH levels to avoid the formation of aluminum fluoride complexes that hindered limestone utilization.

For the reasons outlined above, it was not possible to make direct comparisons between many of the Low-Particulate and High-Particulate tests.

2.1.1 Gaseous Stream Monitoring

Gaseous stream monitoring as specified in the EMP is summarized in Table 2-3, and included two streams: the flue gas inlet to the JBR and the stack gas. Monitoring frequencies for each of the parameters included are shown in the table.

The only environmental compliance monitoring requirements were the continuous measurement of the JBR inlet flue gas opacity (for which a variance was obtained for the High-Particulate test blocks), and annual measurement of the particulate matter loading in the stack gas stream. All of the other parameters shown in Table 2-3 represented supplemental monitoring requirements.

SO_2 was monitored continuously in the JBR inlet flue gas and stack gas to determine SO_2 removal efficiency; oxygen was also monitored continuously so that all of the data could be normalized to a consistent basis (i.e., 3% O_2). SO_3 was measured to determine whether the scrubber removed this sulfuric acid mist precursor. Particulate matter loadings and particle size distributions were

TABLE 2-3
GASEOUS STREAMS: INTEGRATED MONITORING SCHEDULE FOR EACH TESTING PERIOD [a]

	Monitoring Schedule			
	Stack Gas Stream (G-1)		**Flue Gas Inlet to JBR (G-2)**	
Parameter	**Parametric**	**Long-Term**	**Parametric**	**Long-Term**
Opacity	None	None	C [comp.] [b]	C [comp.]
SO_2	C [supp.]	C [supp.]	C [supp.]	C [supp.]
O_2	C [supp.]	C [supp.]	C [supp.]	C [supp.]
Moisture Content	9 [supp.] [c]		9 [supp.]	
SO_3	36 [supp.]		36 [supp.]	
Particulate Matter				
Loading	9 [supp.] [d] A [comp.]		9 [supp.]	
Particle Size Distribution	9 [supp.]		9[supp.]	

Abbreviations:

A = Annual monitoring
C = Continuous monitoring
comp. = Compliance monitoring
supp. = Supplemental monitoring

Notes:

[a] Each of the two testing periods (Low-Particulate and High-Particulate) consisted of parametric and long-term tests.

[b] The opacity of the JBR inlet gas stream was measured using a continuous monitor.

[c] The numbers shown refer to the number of samples planned for EMP monitoring.

[d] Particulate loading measurements were to be made in triplicate for each of three load levels at three JBR liquid levels.

Stream identifiers G-1 and G-2 are shown in Figure 1-1.

measured to determine the ability of the scrubber to remove particulate matter present in the flue gas inlet to the JBR.

2.1.2 Aqueous Stream Monitoring

As shown in Table 2-4, aqueous stream monitoring included both compliance and supplemental monitoring. Of Plant Yates' permitted discharge streams, only two could have been affected by operation of the CT-121 scrubber demonstration: ash transport water and final plant discharge. The sampling frequency and parameters monitored were specified in the Georgia Department of Natural Resources, Environmental Protection Division (EPD) NPDES Permit No. GA0001473.

All of the remaining parameters included in the EMP represented supplemental monitoring and included parameters from several internal process streams, including JBR froth zone, JBR draw-off, limestone slurry feed, gypsum stack return, and makeup water. Both solid and liquid phase analyses were conducted for slurry streams. The parameters selected for monitoring were those needed to characterize the performance of the CT-121 process.

2.1.3 Solid Stream Monitoring

The only solid stream included in the scope of the EMP was the coal feed to the boiler supplying flue gas to the CT-121 scrubber. All of the other solids monitoring for process streams and gypsum byproduct were included as part of the aqueous stream monitoring, described in the previous section. As summarized in Table 2-5, the coal feed monitoring included proximate and ultimate analyses and trace elements.

2.1.4 Groundwater Monitoring

Groundwater monitoring was initiated during the preconstruction period (Period 0) and continued through the two-year post-demonstration period (Period 3). During the preconstruction period, five monitoring wells were installed in the vicinity of the proposed gypsum stacking area.

TABLE 2-4
AQUEOUS STREAMS: INTEGRATED MONITORING SCHEDULE FOR EACH TESTING PHASE

			JBR Froth Zone (A-5)		**JBR Draw-Off (A-1)**	
Parameter	**Ash Transport Water**	**Final Plant Discharge**	**Parametric**	**Long Term**	**Parametric**	**Long Term**
Liquid Phase						
pH		2/M [comp.]	7/M [supp.]	4/M [supp.]	7/M [supp.]	4/M [supp.]
Total Suspended Solids	2/M [comp.]					
Oil & Grease	2/M [comp.]					
Chloride			7/M [supp.]	4/M [supp.]		
Sulfite			7/M [supp.]	4/M [supp.]		
Sulfate			7/M [supp.]	4/M [supp.]		
Carbonate			7/M [supp.]	4/M [supp.]		
Trace Elements				1/M [supp.]		
Solid Phase						
Solids Content			7/M [supp.]	4/M [supp.]	7/M [supp.]	4/M [supp.]
Inert Content			7/M [supp.]	4/M [supp.]	7/M [supp.]	4/M [supp.]
Calcium			7/M [supp.]	4/M [supp.]	7/M [supp.]	4/M [supp.]
Magnesium					7/M [supp.]	4/M [supp.]
Sulfite					7/M [supp.]	4/M [supp.]
Sulfate			7/M [supp.]	4/M [supp.]	7/M [supp.]	4/M [supp.]
Carbonate			7/M [supp.]	4/M [supp.]	7/M [supp.]	4/M [supp.]
Trace Elements						1/M [supp.]
TCLP						1/P [supp.]

TABLE 2-4 (CONTINUED)

Parameter	Limestone Slurry Feed (A-2)		Gypsum Stack Return (A-3)		Makeup Water (A-4)	
	Parametric	Long-Term	Parametric	Long-Term	Parametric	Long-Term
Liquid Phase						
pH			7/M [supp.]	4/M [supp.]	1/M [supp.]	1/M [supp.]
Total Suspended Solids						
Oil & Grease						
Chloride			7/M [supp.]	4/M [supp.]	1/M [supp.]	1/M [supp.]
Sulfite					1/M [supp.]	1/M [supp.]
Sulfate			7/M [supp.]	4/M [supp.]	1/M [supp.]	1/M [supp.]
Carbonate			7/M [supp.]	4/M [supp.)	1/M [supp.]	1/M [supp.]
Trace Elements			1/M [supp.]	1/M [supp.]		
Solid Phase						
Solids Content	7/M [supp.]	4/M [supp]				
Inert Content	7/M [supp.]	4/M [supp.]				
Calcium	7/M [supp.]	4/M (supp.]				
Magnesium	7/M [supp.]	4/M [supp.]				
Sulfite						
Sulfate						
Carbonate	7/M [supp.]	4/M [supp.]				
Trace Elements						
TCLP						

Abbreviations:

n/M = n times per month
1/P = once per test period
comp. = compliance monitoring
supp. = supplemental monitoring

Notes:

1) Each of the two testing periods (Low-Particulate and High-Particulate) consisted of parametric and long-term tests.

2) Trace elements measured in these tests included the following:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Calcium
Cadmium
Copper
Chromium
Cobalt
Iron
Lead
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Phosphorus
Potassium
Selenium
Silicon
Sodium
Sulfur
Titanium
Uranium
Vanadium

2) Stream identifiers A-1, A-2, A-3, A-4, and A-5 are shown in Figure 2-1.

TABLE 2-5
SOLID STREAMS: INTEGRATED MONITORING SCHEDULE FOR EACH TESTING PERIOD

Parameter			**Monitoring Schedule Coal Feed**	
			Parametric	**Long Term**
Proximate Analysis, Sulfur, and HHV			1/D	1/D
Ultimate Analysis, Chlorine, and Fluorine			1/6M	1/6M
Trace Elements:			1/6M	1/6M
Aluminum	Cobalt	Phosphorus		
Antimony	Copper	Potassium		
Arsenic	Iron	Selenium		
Barium	Lead	Silicon		
Beryllium	Magnesium	Sodium		
Boron	Manganese	Sulfur		
Cadmium	Mercury	Titanium		
Calcium	Molybdenum	Uranium		
Chromium	Nickel	Vanadium		

Abbreviations:

1/D = Once per day
1/6M = Once every six months
HHV = Higher heating value

Notes:

1) All monitoring shown was supplemental.

2) The monitoring shown was in addition to the regulatory compliance requirement for weekly analysis of the coal feed for sulfur, moisture, heating value, and ash.

3) Each testing period consisted of parametric and long-term tests.

4) Gypsum solids were monitored and reported as part of the JBR draw-off (Stream A-1). See Table 2-4.

Monitoring was conducted every two months from September 1990 through July 1991 for the suite of parameters shown in Table 2-6.

Following the preconstruction period, and as a Georgia EPD permit requirement, two additional monitoring wells were installed in 1992. The locations of all seven monitoring wells are shown in Figure 2-1. Beginning in the third quarter of 1994, post-construction monitoring was performed quarterly. Monitoring was performed throughout both scrubber demonstration periods and continued for two additional years.

Groundwater monitoring parameters were selected to demonstrate that the gypsum stacking area can be operated in an environmentally benign and acceptable manner.

2.1.5 Modifications to the EMP

In the course of executing the environmental monitoring for the CT-121 demonstration project, a small number of changes and modifications were made to the EMP. These included the following:

- Several groundwater monitoring parameters were added as part of the permit requirements for the gypsum stacking area, including quarterly monitoring for total organic halides (TOX), and annual monitoring for volatile organic compounds (VOCs).
- Groundwater samples could not be obtained from all seven monitoring wells during each quarterly monitoring campaign. One of the downgradient wells was unproductive since groundwater monitoring began. The upgradient well was also unproductive from the fourth quarter of 1993 through the first quarter of 1995.
- Monitoring of the JBR froth zone solids was discontinued during the early part of the High-Particulate testing period. Previous monitoring demonstrated the similarity of the composition of these solids and the JBR draw-off solids, since the JBR was such a well-mixed vessel. Discontinuing the analysis of the JBR froth zone solids helped alleviate the large work load on the on-site laboratory without eliminating the gathering of unique information on the composition of the JBR solids.

TABLE 2-6
GROUNDWATER: INTEGRATED MONITORING SCHEDULE FOR EACH TESTING PERIOD

Parameter	Groundwater Preconstruction	Groundwater Post-Construction
pH	1/2M [supp.]	1/Q [supp.]
Specific Conductance	1/2M [supp.]	1/Q [supp.]
Temperature	1/2M [supp.]	1/Q [supp.]
Eh [a]	1/2M [supp.]	1/Q [supp.]
Alkalinity	1/2M [supp.]	1/Q [supp.]
Total Dissolved Solids	1/2M [supp.]	1/Q [supp.]
Bromide	1/2M [supp.]	1/Q [supp.]
Chloride	1/2M [supp.]	1/Q [supp.]
Total Organic Carbon	1/2M [supp.]	1/Q [supp.]
Fluoride	1/2M [supp.]	1/Q [supp.]
Nitrate	1/2M [supp.]	1/Q [supp.]
Sulfate	1/2M [supp.]	1/Q [supp.]
Radium 226 and 228	1/2M [supp.]	1/Q [supp.]
Gross Alpha	1/2M [supp.]	1/Q [supp.]
Gross Beta	1/2M [supp.]	1/Q [supp.]
Gross Gamma	1/2M [supp.]	1/Q [supp.]
Trace Elements	1/2M [supp.]	1/Q [supp.]

[a] Oxidation-reduction potential.

Abbreviations:

1/2M =	once every 2 months
1/Q =	once per quarter
supp. =	supplemental monitoring

Notes:

1) Trace elements that are measured in these tests are the following:

Aluminum
Antimony
Arsenic
Barium
Beryllium
Boron
Calcium
Cadmium
Copper
Chromium
Cobalt
Iron
Lead
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Phosphorus
Potassium
Selenium
Silicon
Sodium
Sulfur
Titanium
Uranium
Vanadium

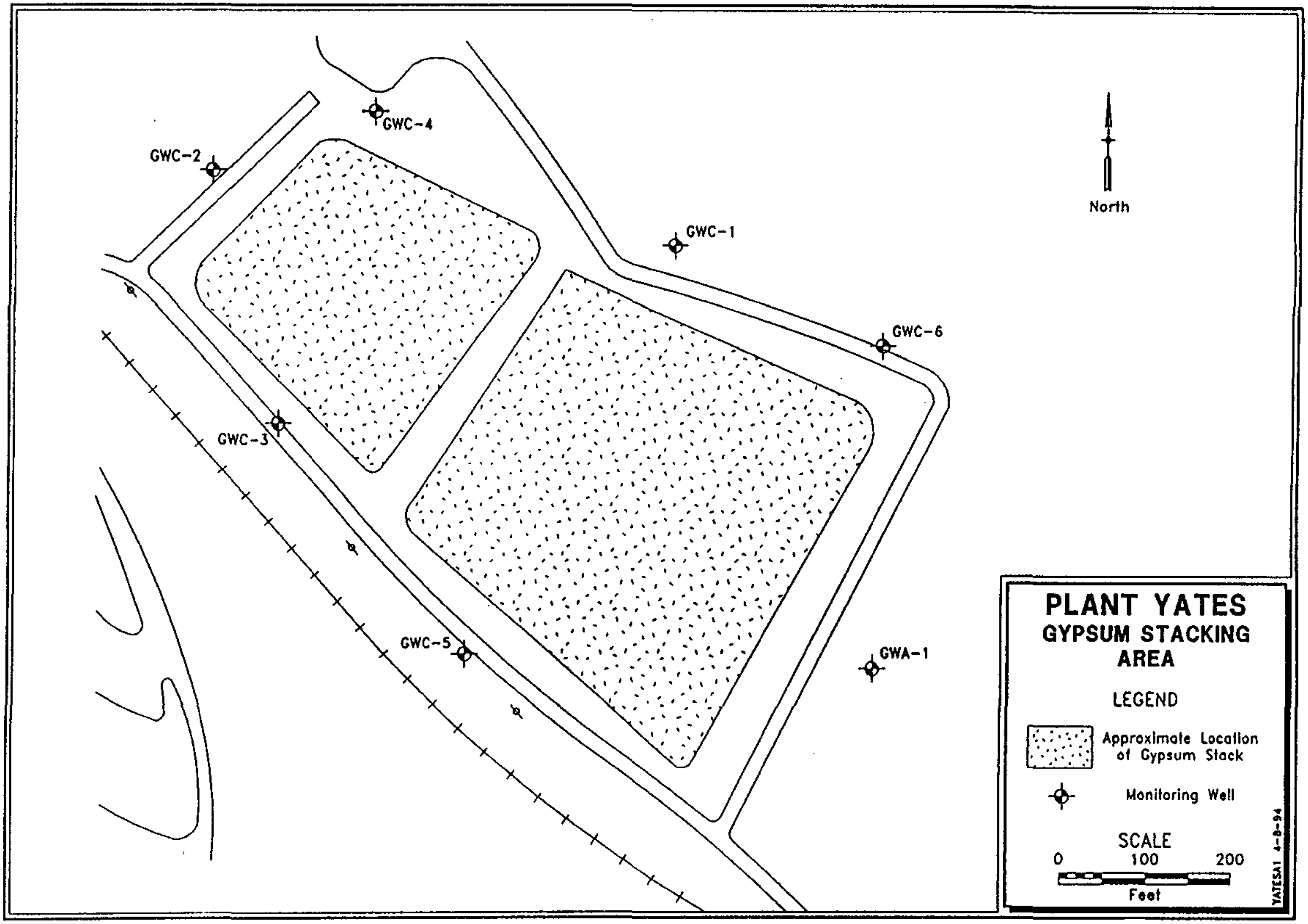

Figure 2-1. Locations of Monitoring Wells

- The EPA's Toxicity Characteristic Leaching Procedure (TCLP), scheduled to be performed on JBR draw-off solids once during each of the two scrubber operating periods, was not performed. A sample was obtained during the Low-Particulate test period but was not analyzed within the maximum allowable holding time; no sample was obtained during the High-Particulate test period due to a scheduling oversight.

2.2 Sampling and Analytical Methods

The EMP sampling and analytical methods are briefly summarized in this section. Additional details are provided in the Quality Assurance/Quality Control Plan appended to the project's EMP. Deviations from the EMP-specified methods are also discussed.

2.2.1 Summary of Gaseous Stream Methods

Table 2-7 shows the methods used to collect and analyze gaseous stream samples. Continuous emission monitors were used for opacity, sulfur dioxide, and oxygen measurements. EPA-approved sampling methods were followed to measure moisture (EPA Method 4) and particulate loading (EPA Method 5b). The size distribution of the particulate matter was determined using modified Brink cascade impactors that were operated at the average isokinetic flow rate at a given port.

The controlled condensation method was used for SO_3 sampling. In this method a gas sample is withdrawn from the stream at a temperature above the sulfuric acid dew point (400~600°F). The gas stream passes through a condenser where it is cooled to a temperature that is below the sulfuric acid dew point, but above the moisture dew point.

2.2.2 Summary of Aqueous Stream Methods

Grab samples were obtained from all monitored aqueous streams. Positive pressure filtration was used to remove solids from reactive slurry streams. The liquid phase samples were filtered directly

TABLE 2-7
SAMPLING AND ANALYTICAL METHODS: GASEOUS STREAMS

Parameter	Sampling Method	Analytical Method/Instrument	Streams Included [a]
Opacity	—	Continuous Opacity Monitor	G-2
SO_2	GAS [b]	UV Spectrophotometer	G-1,G-2
O_2	GAS [b]	O_2 Analyzer	G-1,G-2
Moisture	EPA Method 4	Gravimetric	G-1,G-2
SO_3	Controlled Condensation	Titration	G-1 ,G-2
Particulate Matter:			
Loading	EPA Method 5B	Gravimetric	G-1,G-2
Particle Size Distribution	Isokinetic, Cascade Impactor	Gravimetric	G-1,G-2

[a] Stream identification:

G-1 = treated stack gas stream; and
G-2 = flue gas inlet to JBR.

[b] GAS = Continuous extractive gas analysis system.

into sample containers containing appropriate preservatives. Vacuum filtration was used for separation of all other aqueous/slurry streams. Approved EPA, EPRI, and ASTM methods were used to analyze the aqueous stream samples, as shown in Table 2-8. Additional details are provided in the listed references.

2.2.3 Summary of Solid Stream Methods

Composited grab samples of coal feed were obtained and stored in plastic bags prior to analysis. The coal analyses followed the approved ASTM methods summarized in Table 2-9.

2.2.4 Summary of Groundwater Methods

Groundwater sampling and analytical methods are summarized in Table 2-10. The QED Well Wizard dedicated sampling system was used to purge the monitoring wells and collect samples. The Well Wizard system utilizes a dedicated Teflon® bladder pump and portable air compressor to extract groundwater samples. To ensure the collection of a representative sample, standing water was removed by purging a minimum of three wetted casing volumes.

Conductivity, pH, redox potential, and temperature were monitored and recorded during purging. Samples were collected after these indicator parameters stabilized. Approved EPA and ASTM methods were used for sample analysis, as summarized in Table 2-10.

2.2.5 Modifications to EMP-Specified Methods

For the most part, the methods specified in the EMP were followed. Deviations from these methods are briefly discussed below:

- For aqueous stream nitrates-nitrites, the colorimetric method (EPA 353.1) was used instead of the specified ion chromatographic method (EPA 300). The alternate method provides an improved detection limit as well as a longer sample holding time.

TABLE 2-8
SAMPLING AND ANALYTICAL METHODS: AQUEOUS STREAMS

Stream/Type & Parameter	Sampling Method	Analytical Method/Instrument [a,b]	Analytical Reference [c]	Streams Included [d]
Aqueous Discharge	Grab			
pH		Potentiometric [b]	EPA 150.1	f
Total Suspended Solids		Filtration/Drying/ Gravimetric [b]	EPA 160.2	a
Oil and Grease		Freon Extraction/ Gravimetric [b]	EPA 413.1	a
Process Streams - Liquid Phase	Positive Pressure Filtration [f] & Preservation			
pH [c]		Potentiometric	EPRI C1	A-1,A-3,A-4,A-5
Chloride		Ion Chromatography	EPRI I3	A-3,A-4,A-5
Sulfite		Indirect I_2 Titration	EPRI M2	A-4,A-5
Sulfate		Ion Chromatography	EPRI I3	A-3,A-4,A-5
Carbonate		Nondispersive IR	ASTM 2579	A-3,A-4,A-5
Trace Elements		AA and ICP-AES	EPA 200.2/200.7	A-3, A-5
Process Streams - Solid Phase	Positive Pressure Filtration			
Solids Content		Gravimetric	EPRI F1	A-1,A-2,A-5
Inerts		Acid Dissolution/ Gravimetric	—	A-1,A-2,A-5
Calcium		AA	EPRI H1	A-1,A-2,A-5
Magnesium		AA	EPRI H1	A-1,A-2
Sulfite		Indirect I_2 Titration	EPRI M2	A-1
Sulfate		Ion Chromatography	EPRI I3	A-1,A-5
Carbonate		Nondispersive IR or Acid-Base Titration	EPRI N2 or N3	A-1,A-2, A-5
Trace Metals		Dissolution/AA and ICP-AES	EPA 200.0/200.7	A-1
TCLP		Leaching/GC,AA	40 CFR 261; Appendices II and III	A-1

[a] Analytical methods: AA = atomic absorption; SIE = specific ion electrode; ICP-AES = inductively coupled plasma argon emission spectroscopy; and IR = infrared.

[b] All analytical methods for NPDES compliance were to follow 40 CFR 136 approved procedures.

[c] EPRI No: EPRI method number specified in "FGD Chemistry and Analytical Methods Handbook" (Ref 4). EPA No: EPA Methods for Chemical Analysis of Water and Wastes (Ref 7). SW No: Test Methods for Evaluation of Solid Wastes, EPA SW-846, 3rd ed. (November 1986).

TABLE 2-8 (CONTINUED)

[d] Stream identification:

a = Ash transport water
f = Final plant discharge
A-l = JBR draw-off
A-2 = Limestone slurry feed
A-3 = Gypsum stack return
A-4 = Makeup water
A-S = JBR froth zone

[e] Slurry pH was measured prior to sample filtration.

[f] Positive pressure filtration was to be used to collect samples of all reactive slurry streams. Vacuum filtration was to be used for sampling and separation of all other aqueous/slurry streams. The liquid phase of reactive slurries was to be preserved to prevent loss of reactive compounds.

TABLE 2-9
SAMPLING AND ANALYTICAL METHODS: SOLID STREAM (COAL FEED)

Parameter	Sampling Method	Analytical Method [a]	Analytical Reference [b]
Ultimate Analysis	Grab/Composite	—	ASTM D3176
Proximate Analysis	Grab/Composite	Thermogravimetric	ASTM D3 172
Higher Heating Value	Grab/Composite	Calorimetry	ASTM D2015
Total Chlorine	Grab/Composite	Fusion/IC or Titration	ASTM D2361/4208
Total Fluorine	Grab/Composite	Fusion Combustion/SIE	ASTM D376 1
Trace Elements	Grab/Composite	Fusion and/or Dissolution/AA	ASTM D3682, D3683, D3684

[a] Analytical methods: AA = atomic absorption; SIE = specific ion electrode; and IC = ion chromatography.
[b] Analytical reference: ASTM Number = American Society for Testing and Materials Method Number.

TABLE 2-10
SAMPLING AND ANALYTICAL METHODS: GROUNDWATER

Stream/Type & Parameter	Sampling Method	Analytical Method/Instrument [a]	Analytical Reference [b]
Groundwater Wells	Well Pumps		
pH		Potentiometric	EPA 150.1
Specific Conductance		Conductivity Meter	EPA 120.1
Temperature		Temperature Probe	EPA 170.1
Eh		Electrometry	ASTM D1498
Alkalinity		Colorimetry or Titration	EPA 310.1/310.2
Bromide		Ion Chromatography	EPA 300.0
Chloride		Ion Chromatography	EPA 300.0
Total Organic Carbon		Combustion/IR	EPA 415.1
Fluoride		Distillation/SIE	EPA 340.2
Nitrate-Nitrite (as N)		Colorimetry	EPA 353.1
Sulfate		Ion Chromatography	EPA 300.0
Total Dissolved Solids		Filtration/Evaporation Gravimetric	EPA 160.2
Mercury		Cold Vapor AA	SW 7470
Trace Elements		AA and ICP-AES	Note c
Radium 226 and 228		Proportional Counter	ASTM D2460
Gross Alpha		Proportional Counter	ASTM D1943
Gross Beta		Proportional Counter	ASTM D1890
Gross Gamma		Gamma Ray Spectrometer	ASTM D2459

[a] Analytical methods: AA = atomic absorption; ICP-AES = inductively coupled plasma argon emission spectroscopy; and IR = infrared.

[b] EPA No: EPA Methods for Chemical Analysis of Water and Wastes. SW No: Test Methods for Evaluation of Solid Wastes, EPA SW-846, 3rd ed. (November 1986).

[c] Methods for groundwater trace elements include SW 6010 (metals by ICP-AES); SW 7041 (Sb); SW 7060 (As); SW 7421 (Pb); SW 7740 (Se); and SW 7841 (Tl).

- Rather than determining coal trace elements using inductively coupled argon plasma emission spectroscopy (ICP-AES; EPA 200.7), Georgia Power Company used ASTM methods based on atomic absorption spectrophotometry, which give improved detection limits (i.e., ASTM D3682, D3683, and D3684).

3.0 MONITORING RESULTS

This section presents a summary of the environmental monitoring program results, primarily in graphical and tabular form. Tables containing the complete results for all EMP parameters are provided in Appendix A. The results for gaseous streams, aqueous streams, solid streams, and groundwater are presented in separate subsections.

3.1 Gaseous Stream Monitoring Results

Two gaseous streams were monitored as specified in the EMP: the flue gas inlet to the JBR and the stack gas. Table 3-1 summarizes the actual and planned gaseous stream monitoring for the Low- and High-Particulate test periods. Essentially all of the planned EMP monitoring was performed during both periods. Monitoring the opacity of the flue gas inlet to the JBR was not conducted during the High-Particulate test period. A variance to Plant Yates' operating permit was obtained for this period because the intentionally high concentrations of particulate matter in this stream led to high opacity values that did not represent the opacity of the stack gas emitted to the atmosphere. Although the results are not presented in this report, continuous monitoring of the oxygen content of the two gas streams was performed as planned. This was done so that the measured SO_2 concentrations could be normalized to a consistent basis (i.e., 3% O_2).

Supplemental and compliance monitoring results are discussed separately below.

3.1.1 Supplemental Monitoring

This section presents a summary of the results of EMP monitoring for sulfur dioxide, particulate matter loading and size distribution, sulfur trioxide, and water vapor.

TABLE 3-1
GASEOUS STREAMS: ACTUAL AND PLANNED MONITORING [a]

Parameter	Stack Gas		Flue Gas Inlet to JBR	
	Low-Particulate	**High-Particulate**	**Low-Particulate**	**High-Particulate**
Opacity	0/0	0/0	C/C[b]	Note c
SO_2	C/C	C/C	C/C	C/C
O_3	C/C	C/C	C/C	C/C
Moisture Content	9/9	9/9	9/9	9/9
SO_3	34/36	34/36	33/36	35/36
Particulate Loading	9/9	9/9	9/9	9/9
Particle Size Distribution	9/9	9/9	9/9	9/9

[a] 9/9 = 9 actual/9 planned.

[b] C = Continuous monitoring.

[c] Opacity monitoring was not conducted during the High-Particulate test period since the particulate loading in this stream led to opacity levels that were not representative of stack gas conditions. A variance to Plant Yates' operating permit was obtained to allow this emission.

3.1.1.1 Sulfur Dioxide

Defining the impacts of CT-121 scrubber operating variables on sulfur dioxide removal efficiency was one of the major areas of emphasis in this demonstration project. SO_2 concentrations in the JBR inlet gas and stack gas streams were monitored continuously during all comparison of results. This section discusses the results from the Low- and High-Particulate Parametric, Long-Term, and Auxiliary test blocks of the Low- and High-Particulate test periods. The measured SO_2 concentrations in both streams were normalized to 3% O_2 to allow direct computation of the scrubber removal efficiency.

Parametric Tests. The purpose of the Parametric Tests was to determine the impact of several scrubber operating variables (including scrubber slurry pH, boiler load, and JBR deck pressure drop) on SO_2 removal efficiency. The results were regressed to develop equations predicting SO_2 removal as a function of scrubber operating parameters. The details of the data regression are beyond the scope of this EMP volume, but they are provided in Volume 2 of the project's Final Report.(6) A full set of Parametric Tests was performed during both the Low- and High-Particulate test periods.

The operating variables and the ranges studied during the Low-Particulate Parametric tests included pH (4.0,4.5, and 5.0), boiler operating load (50, 75, and 100 MWe), and JBR deck pressure drop (8, 12, and 16 inches of water column - in. WC). The results obtained during this test block are shown graphically in Figures 3-1 through 3-7. In Figures 3-1 through 3-6, the measured SO_2 removal efficiencies were normalized to 2,200 ppmv SO_2 inlet concentration, using the predictive operations described above to facilitate comparisons.

Figures 3-1 through 3-3 present the SO_2 removal efficiency data plotted against pressure drop and pH for loads of 100, 75, and 50 MWe, respectively. These figures show that, in general, SO_2 removal increased with increasing JBR deck pressure drop and slurry pH. However, the incremental increase in SO_2 removal obtained when the slurry pH increased from 4.5 to 5.0 was typically small, indicating that there is little incentive to operate at the higher pH level. Very high pH operation (i.e., pH>5.2) was also found to be undesirable because of operating problems such as scaling and diminished limestone utilization. Achieving SO_2 removal efficiencies above 90% generally required a JBR deck pressure drop of 12 in. WC or more.

Figures 3-4 through 3-6 show the impact of boiler load and JBR deck pressure drop on SO_2 removal efficiency at slurry pH levels of 4.0, 4.5, and 5.0. In general, SO_2 removal tended to decrease with increasing boiler load, although the impact was greatest at low pressure drop and became insignificant at the highest pressure drop of 16 in. WC for pH values of 4.5 and 5.0.

Because of natural variations in the coal sulfur content during these tests, it was possible to determine the impact of this variable on SO_2 removal efficiency at two inlet SO_2 concentrations: 2170 ppmv and 2430 ppmv (corrected to 3% oxygen). As shown in Figure

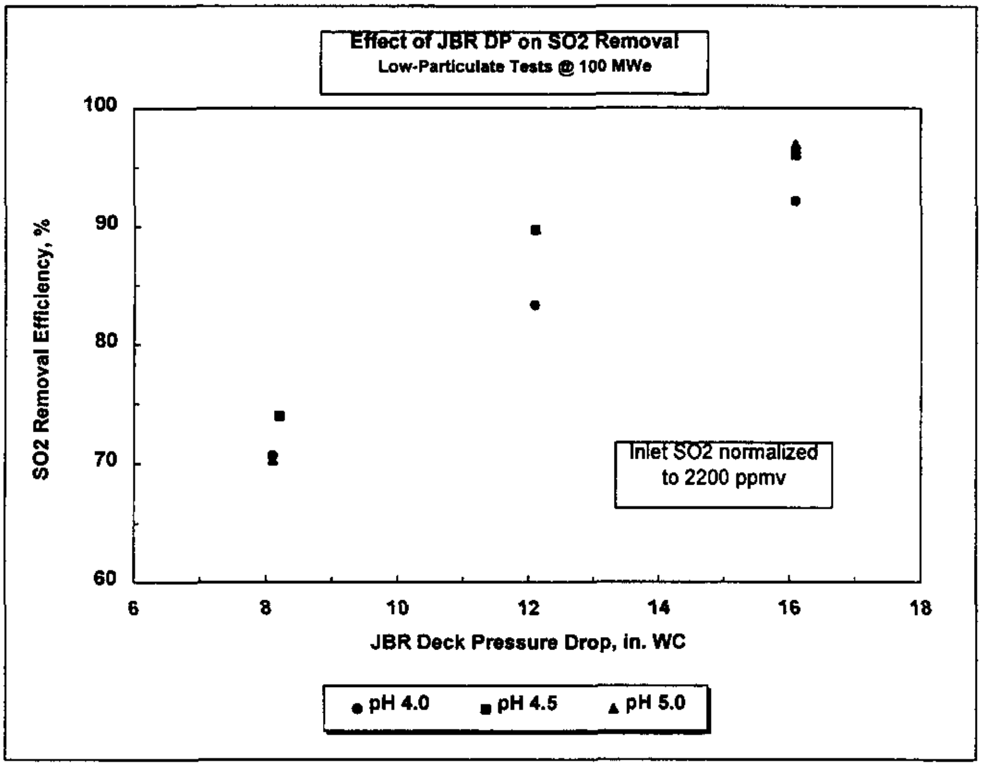

Figure 3-1. Low-Particulate Parametric Test Results at 100 MWe

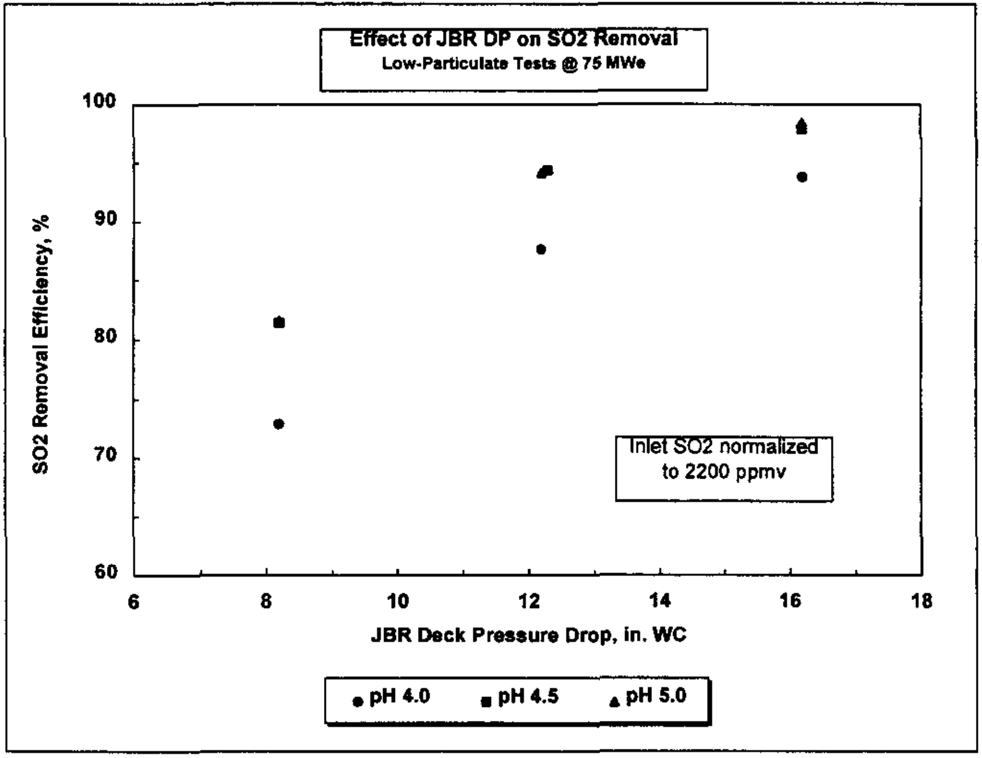

Figure 3-2. Low-Particulate Parametric Test Results at 75 MWe

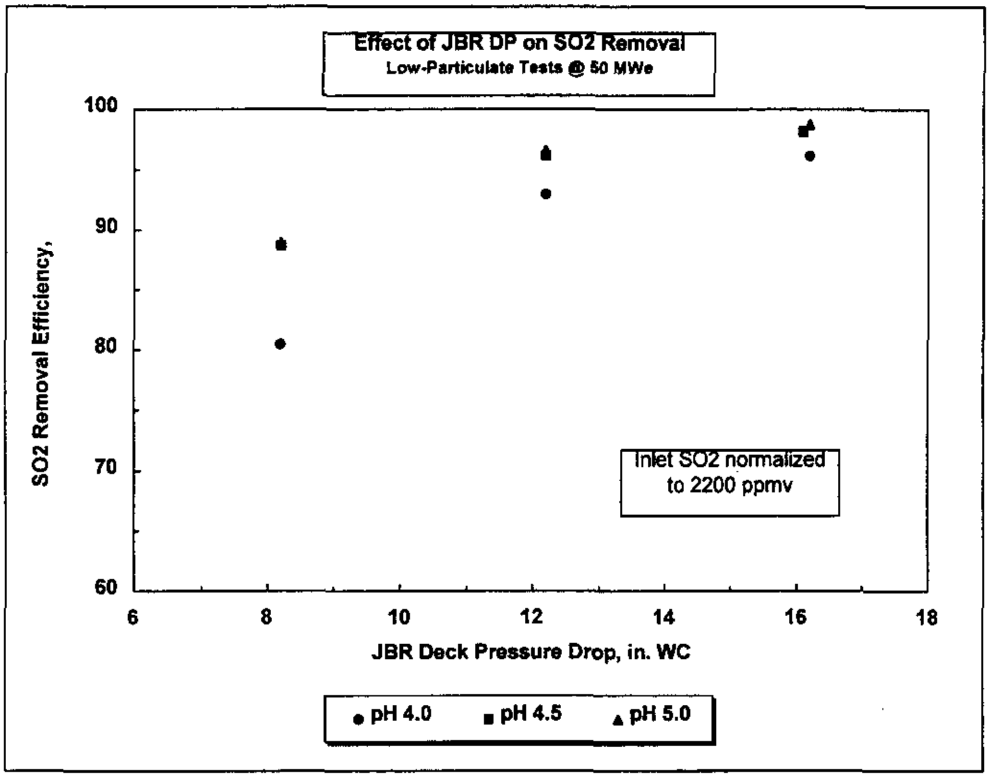

Figure 3-3. Low-Particulate Parametric Test Results at 50 MWe

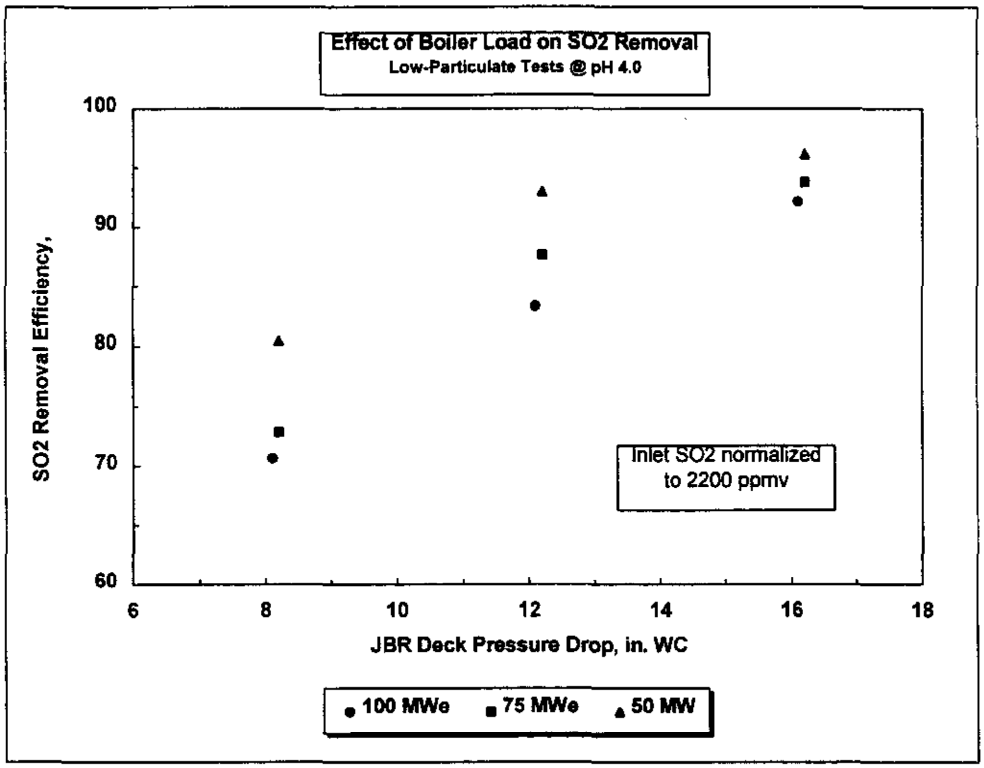

Figure 3-4. Low-Particulate Parametric Tests: Effect of Load and JBR ΔP on SO_2 Removal Efficiency at pH = 4.0

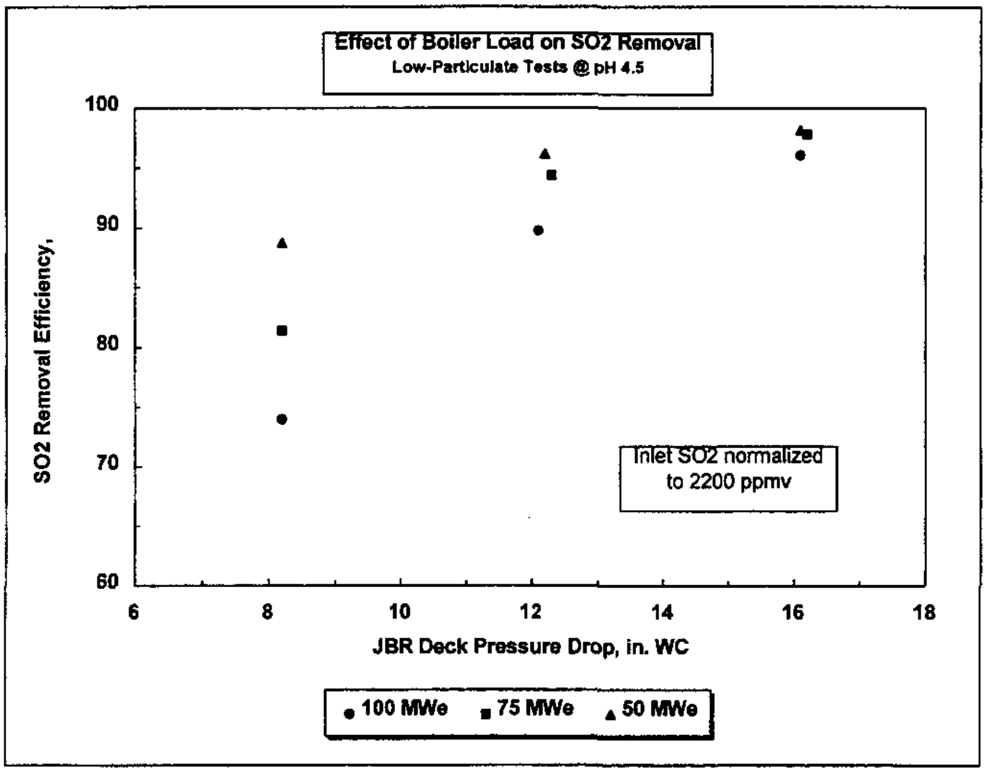

Figure 3-5. Low-Particulate Parametric Tests: Effect of Load and JBR ΔP on SO_2 Removal Efficiency at pH = 4.5

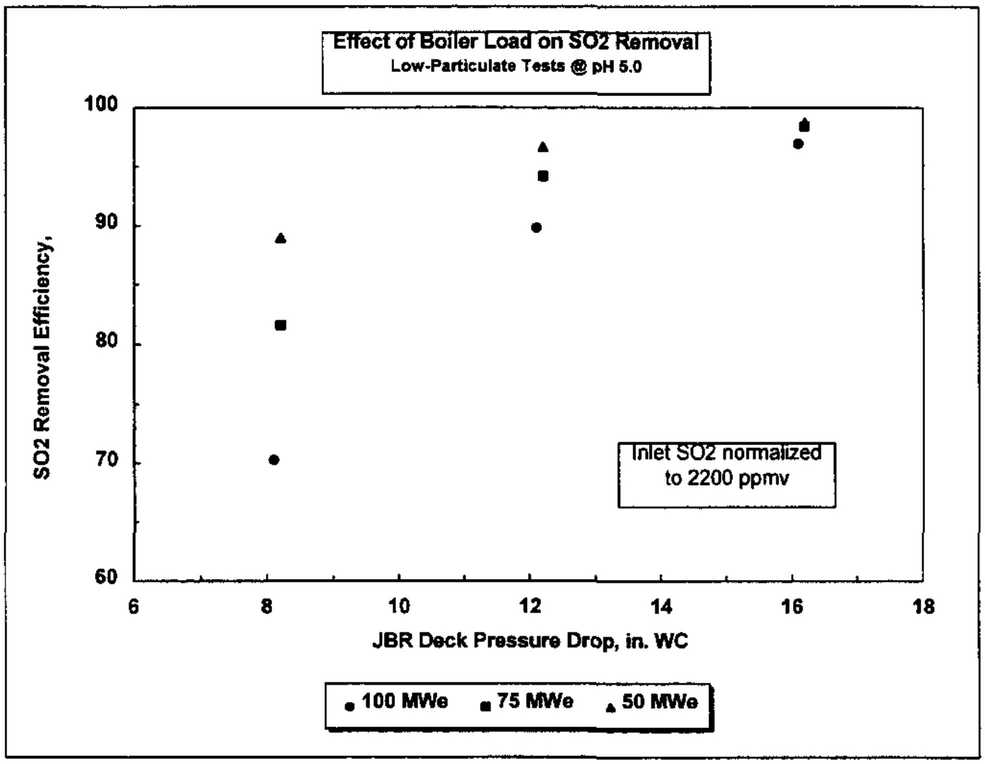

Figure 3-6. Low-Particulate Parametric Tests: Effect of Load and JBR ΔP on SO_2 Removal Efficiency at pH = 5.0

3-7, an increase in inlet SO_2 concentration led to a decrease in removal efficiency at a given set of scrubber operating conditions.

The test plan for the High-Particulate Parametric Test block did not cover exactly the same ranges of operating parameters as those used during the Low-Particulate Test block.

Although the majority of the tests were conducted with the ESP completely de-energized, a cautious approach was taken to determine the operability of the scrubber at reduced ESP efficiencies (i.e., target particulate removal efficiencies of 90% and 50%) prior to conducting the tests with the ESP completely de-energized. The range of JBR deck pressure drops was altered to evaluate only those in the more typical operating range (10, 13, and 16 in. WC). The pH range was modified (3.5, 3.75, and 4.0) when inhibited limestone dissolution was detected, as a result of the high ash loading. Figures 3-8 through 3-13 present the results from this Parametric Test block. As before, the measured SO_2 removal efficiencies were normalized to an SO_2 inlet concentration of 2,200 ppmv to facilitate direct comparisons between tests.

Figures 3-8 through 3-10 show the impact of JBR deck pressure drop and pH for boiler loads of 100, 75, and 50 MWe, respectively. The increase in SO_2 removal efficiency with increasing JBR deck pressure drop was similar to that seen during the Low-Particulate Parametric Test block. The impact of pH is not clear from these data, primarily because of the scaling in the JBR that occurred over the period of time that this test block was conducted.

Figures 3-11 through 3-13 show the impacts of boiler load and JBR deck pressure drop on SO_2 removal efficiency at slurry pH levels of 3.5, 3.75, and 4.0, respectively. The expected increase in SO_2 removal efficiency with increasing JBR deck pressure drop was observed, but the impact of load was confounded because of progressive scaling in the JBR. Project personnel were able to construct a model to predict the decrease in SO_2 removal efficiency with time due to the buildup of fouling deposits; this is discussed in the project's High-

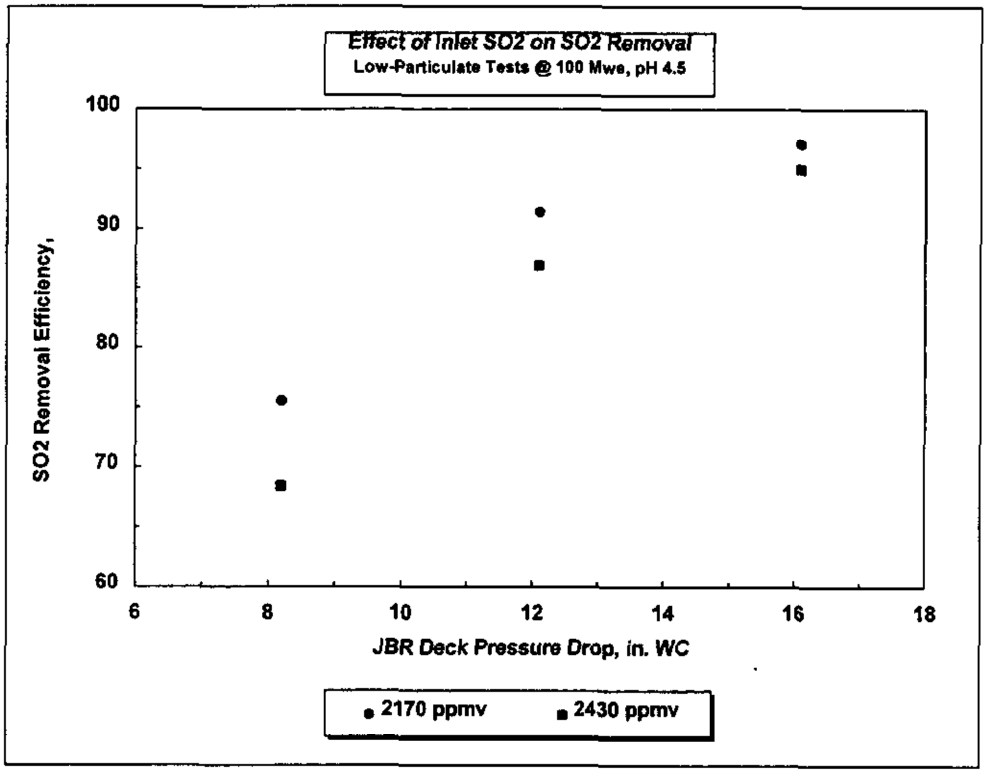

Figure 3-7. Low-Particulate Parametric Tests: Effect of JBR Inlet Gas SO_2 Concentration on SO_2 Removal Efficiency

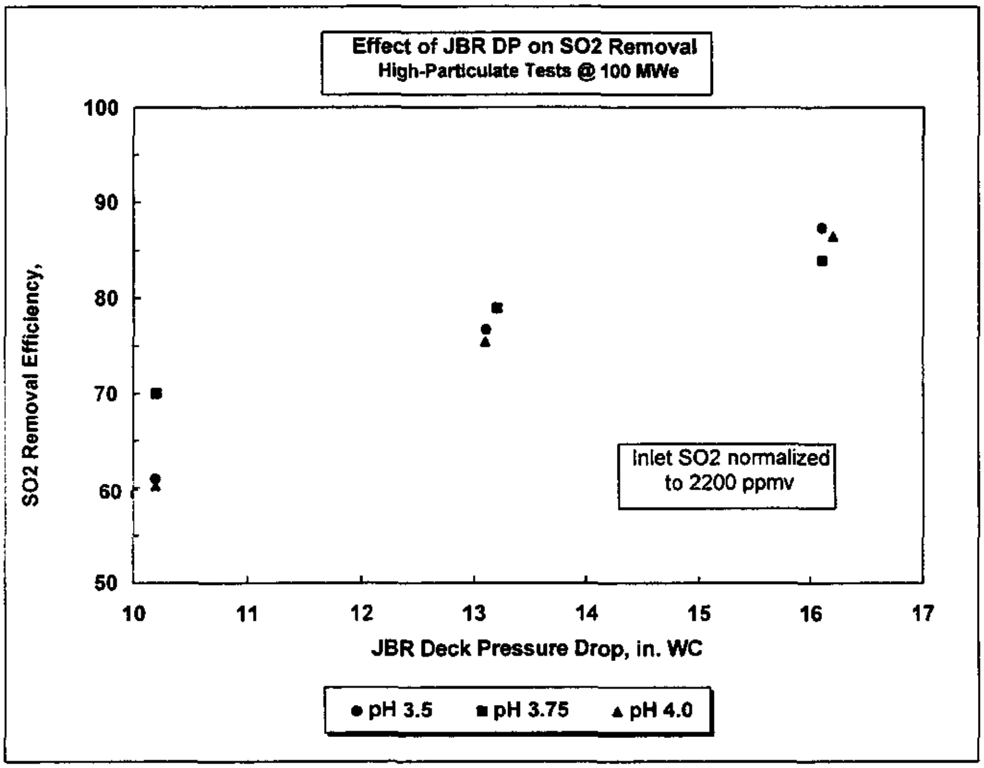

Figure 3-8. High-Particulate Parametric Test Results at 100 MWe

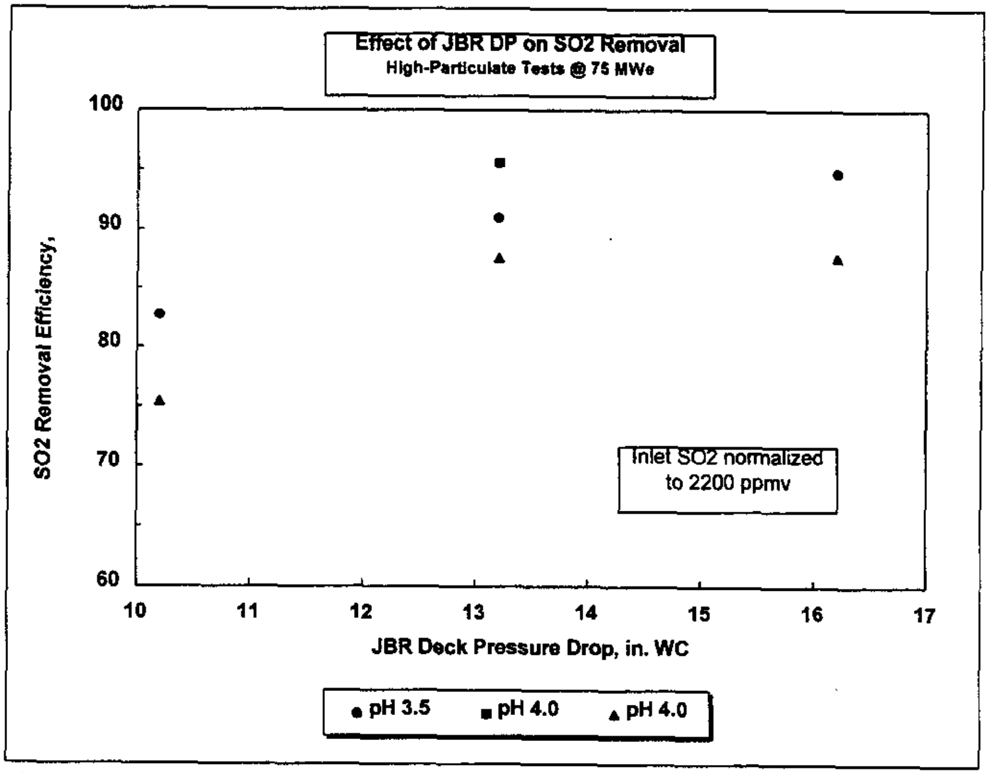

Figure 3-9. High-Particulate Parametric Test Results at 75 MWe

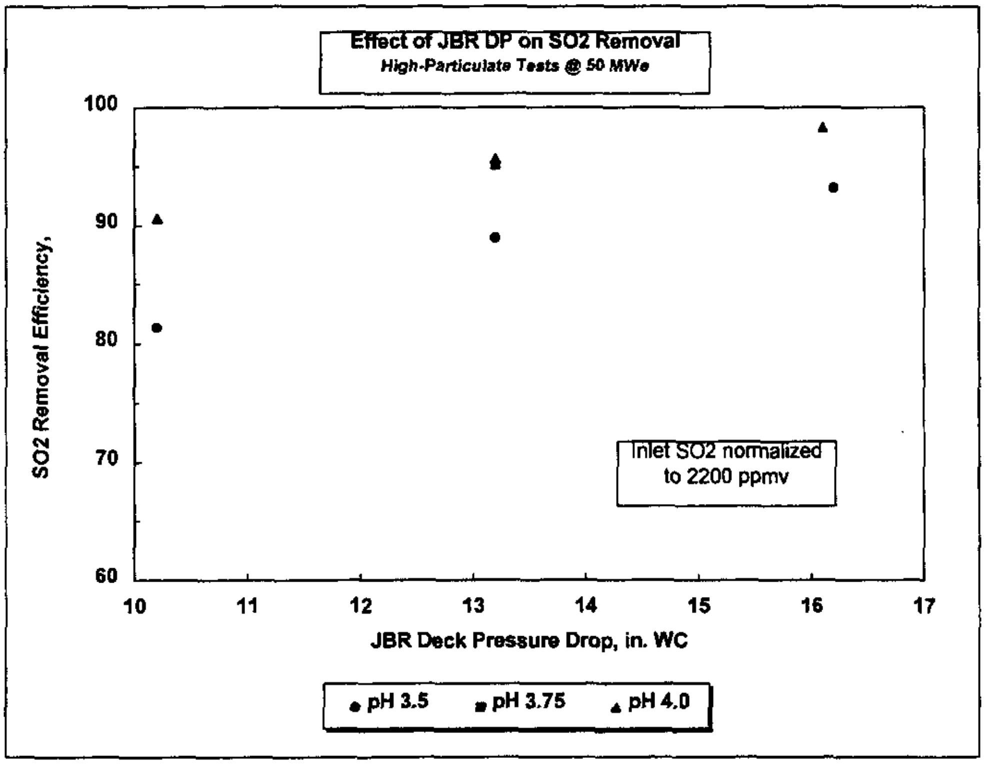

Figure 3-10. High-Particulate Parametric Test Results at 50 MWe

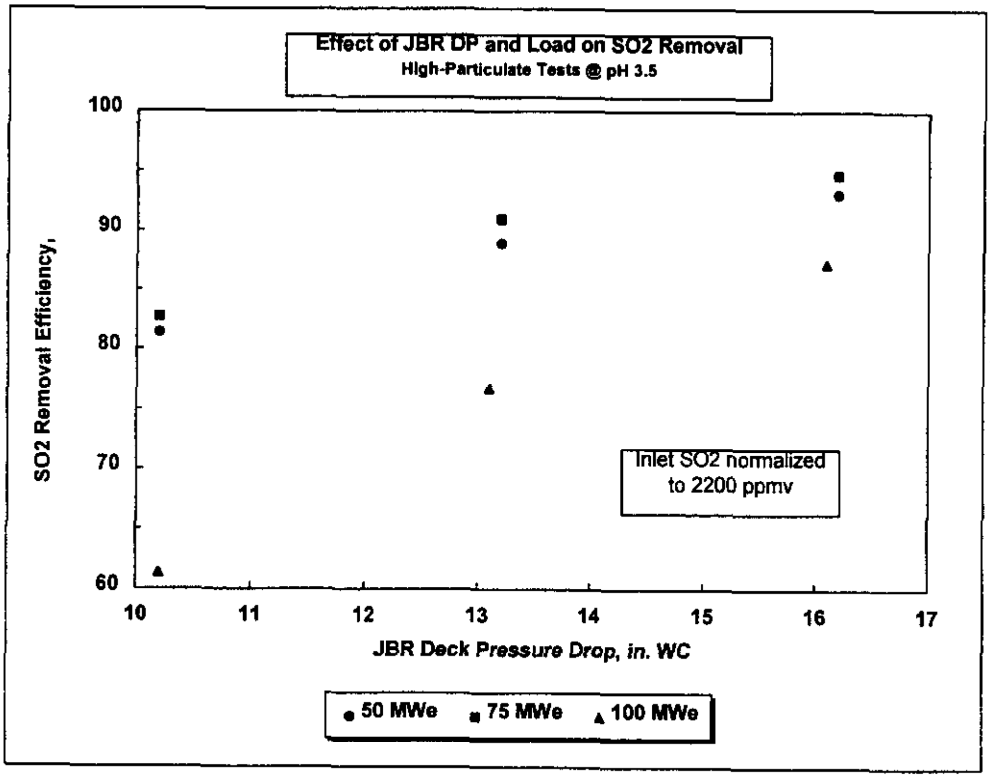

Figure 3-11. High-Particulate Parametric Tests: Effect of Load and JBR ΔP on SO_2 Removal Efficiency at pH = 3.5

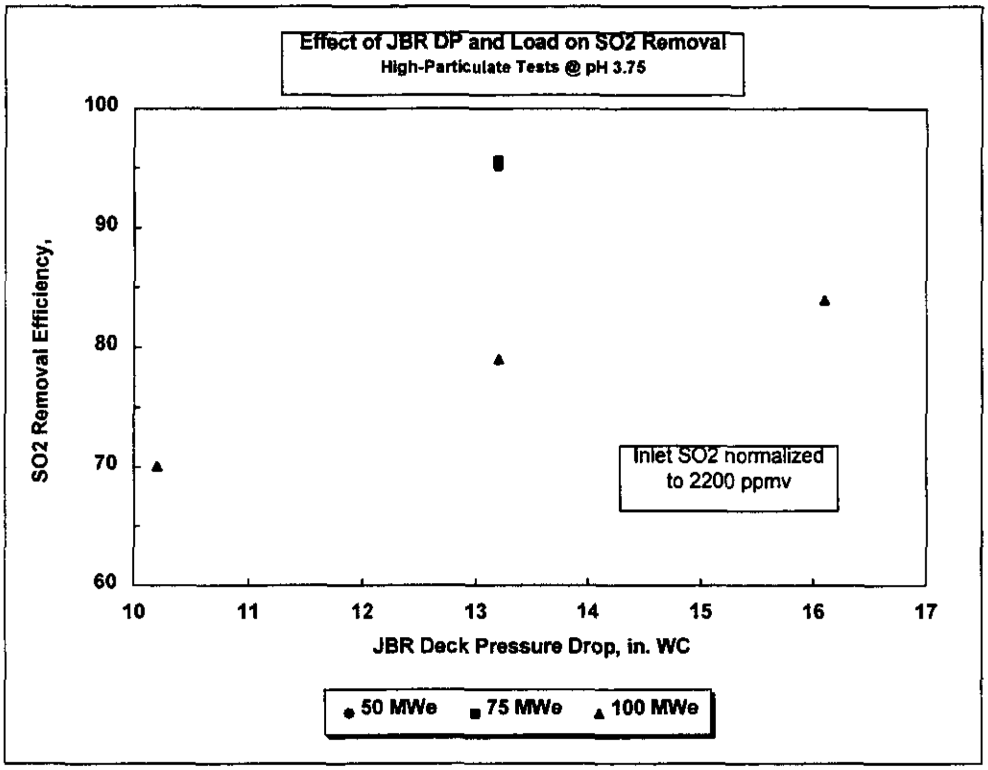

Figure 3-12. High-Particulate Parametric Tests: Effect of Load and JBR ΔP on SO_2 Removal Efficiency at pH = 3.75

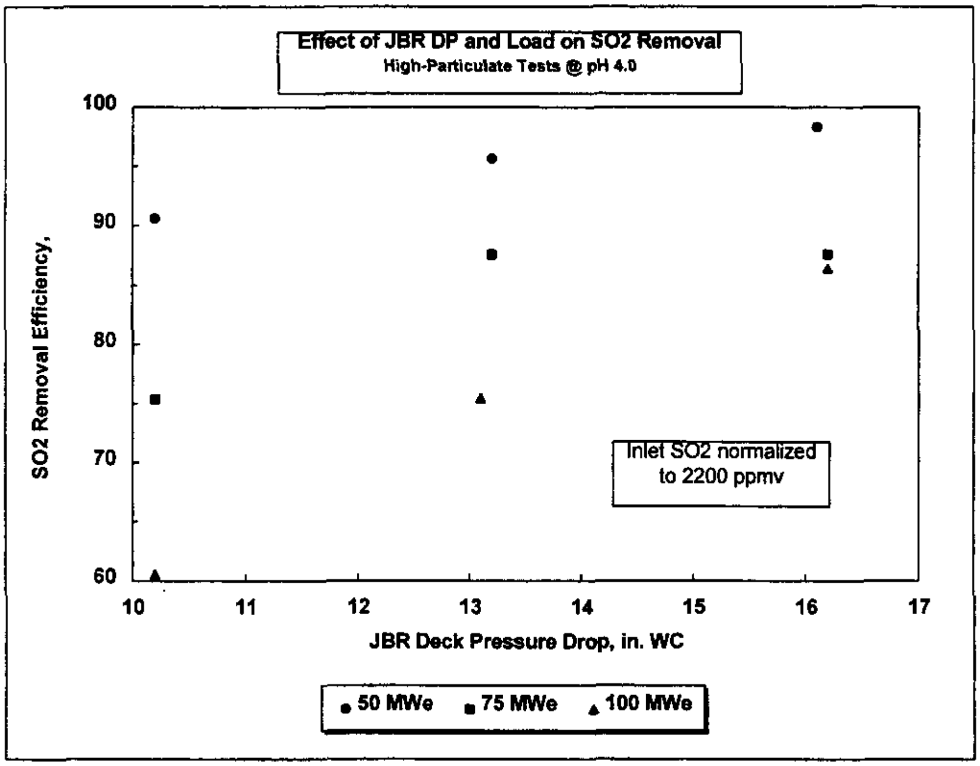

Figure 3-13. High-Particulate Parametric Tests: Effect of Load and JBR ΔP on SO_2 Removal Efficiency at pH = 4.0

Particulate Auxiliary Test Block Report (28 April 1995)(2) and in Volume 2 of the project's Final Report.(6)

Because of the differences in operating parameters, direct comparisons between the Low- and High-Particulate Parametric test blocks are somewhat limited. The results of comparable tests conducted at a pH of 4.0 at boiler loads of 100, 75, and 50 MWe are shown in Figures 3-14 through 3-16, respectively. The SO_2 removal efficiencies obtained during the 50 MWe and most of the 75 MWe tests were very similar for the two test blocks. Significantly higher SO_2 removal efficiencies were obtained at 100 MWe during the Low-Particulate test block than during the High-Particulate test block. The lower removal efficiency at the high particulate loadings is most likely due, however, to the buildup of scaling deposits over time during the High-Particulate tests.

Long-Term Tests. Long-Term tests were conducted over extended periods of time during the Low- and High-Particulate test periods, throughout which the Unit 1 boiler load was allowed to vary in response to system power demand. Figures 3-17 and 3-18 present the daily average SO_2 concentrations in the JBR inlet gas and stack gas streams, and the SO_2 removal efficiency over the same periods, respectively.

During the first week of the Low-Particulate Long-Term test period, the results of the data regression of the Low-Particulate Parametric tests were not yet available, so the test was started with a preliminary set of process conditions pH = 4.0, JBR ΔP = 12 in. WC) that were expected to give approximately 95% SO_2 removal efficiency. By the second week of testing, long-term conditions were finalized pH = 5.0, JBR ΔP = 14 in. WC) based on the analysis of the Low-Particulate Parametric test data. Further evaluation of the parametric test data led to a final revision of the long-term operating parameters.

The operating pH was lowered to 4.5 to avoid the pH range (pH>5.2) that was known to result in a drop in limestone utilization. At these conditions, the average long-term SO_2 removal was nearly 94 percent. Compared to model predictions, the removal during this

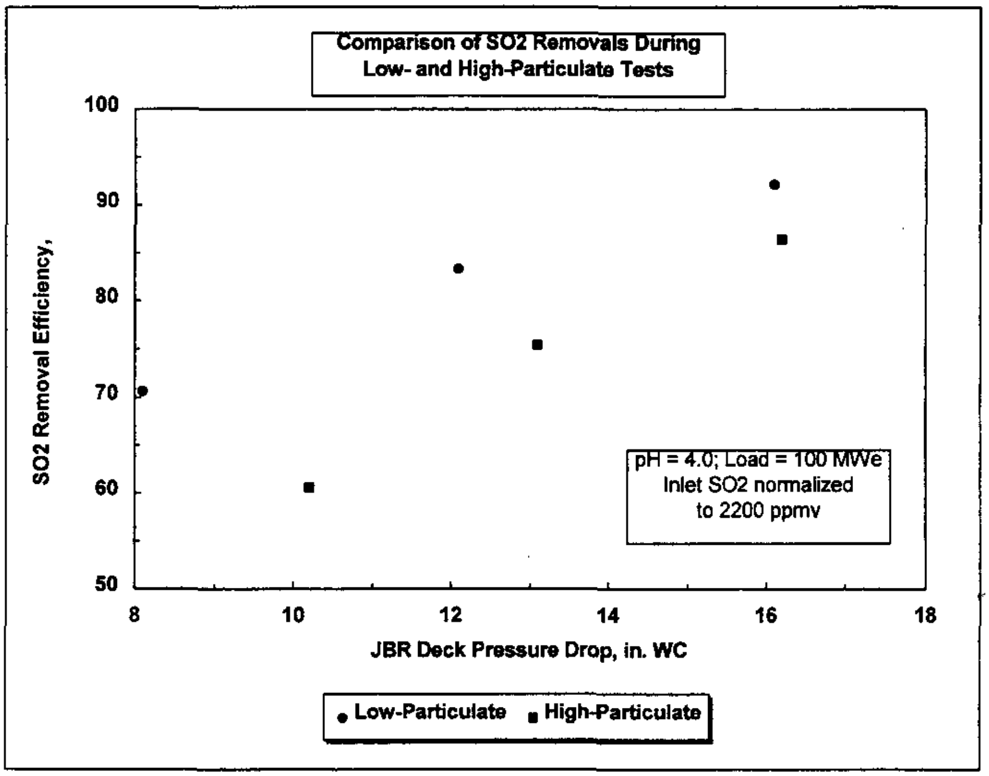

Figure 3-14. Comparison of SO_2 Removal Efficiency During Low- and High-Particulate Parametric Tests at pH = 4.0, Load = 100 MWe

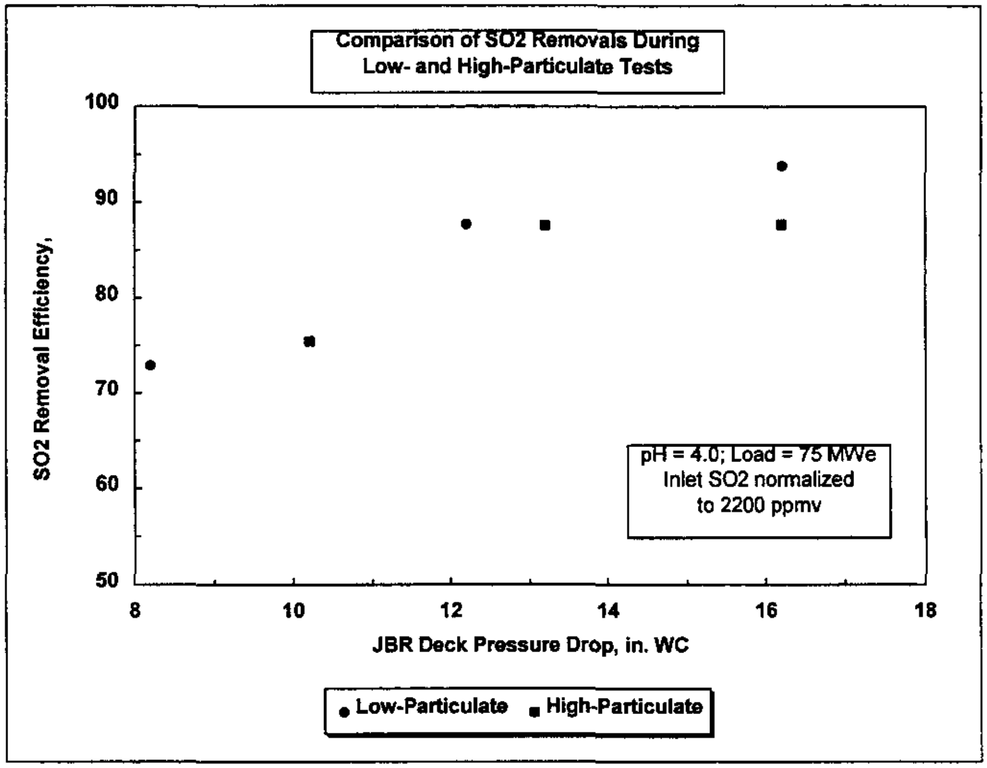

Figure 3-15. Comparison of SO_2 Removal Efficiency During Low- and High-Particulate Parametric Tests at pH = 4.0, Load = 75 MWe

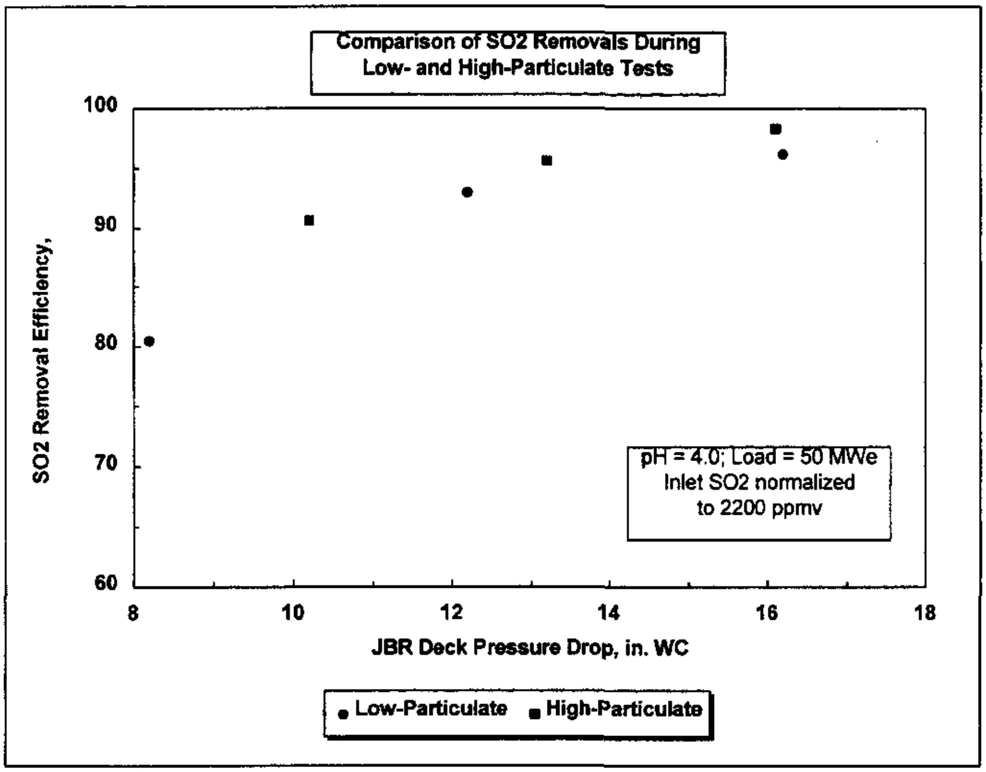

Figure 3-16. Comparison of SO_2 Removal Efficiency During Low- and High-Particulate Parametric Tests at pH = 4.0, Load = 50 MWe

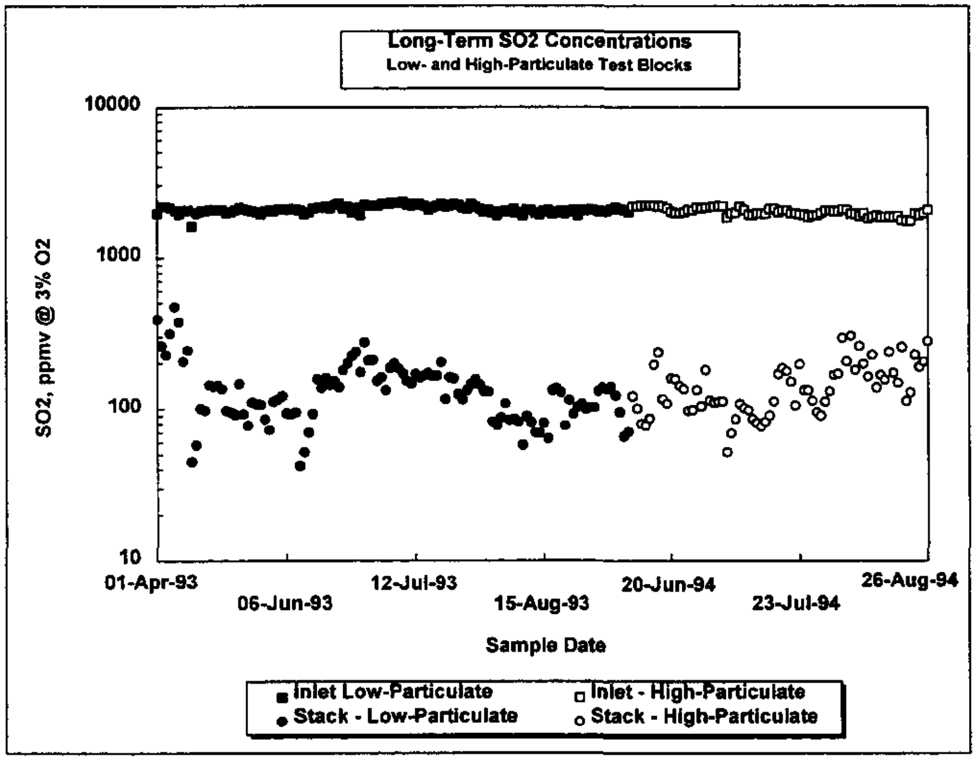

Figure 3-17. Daily Average SO_2 Concentrations During Low- and High-Particulate Long-Term Test Blocks

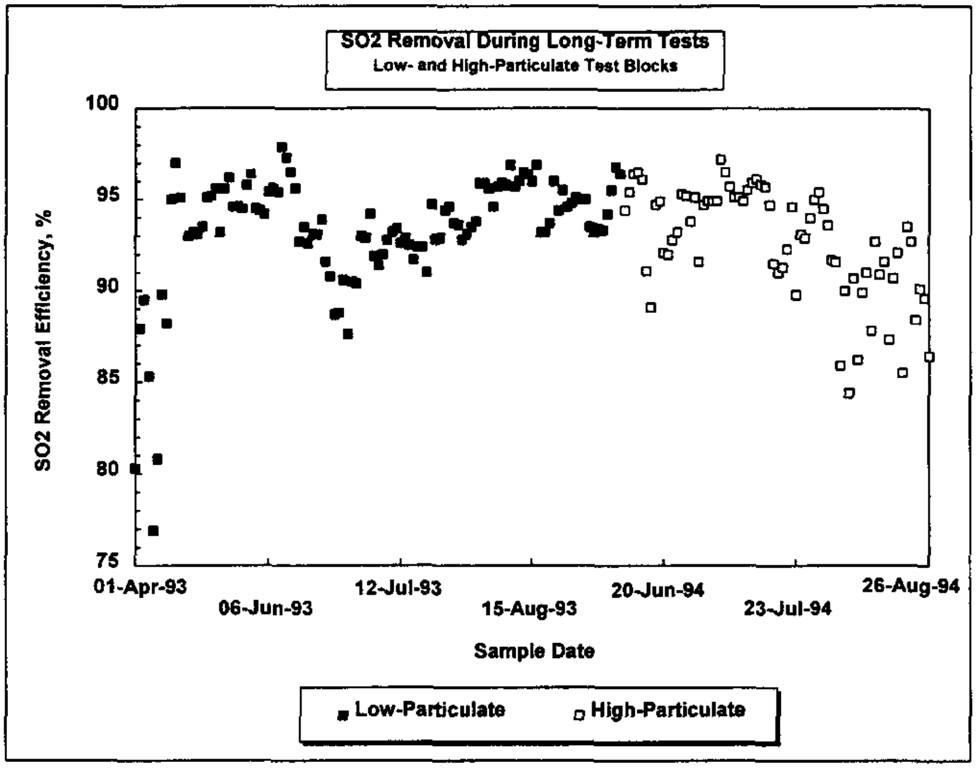

Figure 3-18. Daily Average SO_2 Removal Efficiency During Low- and High-Particulate Long-Term Test Blocks

test block was slightly low, possibly due to fouling of the JBR lower deck and sparger tubes, flue gas bypass through broken sparger tube(s), and/or erosion damage to the inlet plenum.

During the High-Particulate Long-Term test block, the ESP was detuned to achieve approximately 90% particulate removal, and the initial scrubber operating conditions were the same as those during the Low-Particulate test block (pH =4.5, JBR ΔP = 14 in. WC). Because of the elevated ash content in the slurry, aluminum fluoride blinding was observed soon after the test block was initiated. In response, the pH setpoint was lowered to 4.0, and this setpoint was maintained for the majority of the test block. The average SO_2 removal efficiency during the High-Particulate Long-Term test block was 93.1%, which compared well with the predicted efficiency. The average relative difference between the measured and predicted removals was lower than expected based on the Low-Particulate Long-Term test results, largely due to an uncharacteristically low boiler load during the High-Particulate Long-Term test block (i.e., 59 MWe). At higher operating loads the measured scrubber performance was typically much lower than predicted. Some effects of ash buildup over time were also observed at moderate ash loading.

<u>Auxiliary Tests</u>. The Auxiliary Test blocks for both testing periods included High Removal, Alternate Limestone, and Alternate Coal tests.

The High Removal tests were conducted at the maximum practical pH and JBR pressure drop levels to evaluate system performance under conditions that would yield maximum SO_2 removal while maintaining safe and reliable scrubber operation.

The Low-Particulate High Removal tests were conducted at a scrubber pH of 4.8 and a JBR ΔP of 18 in. WC. Short-term parametric tests were conducted at boiler loads of 50, 75, and 88 MWe, followed by a load-following test while Unit 1 load was controlled by system dispatch (the average boiler load during this period was 90.6 MWe). Figure 3-19 presents the results of these tests. There was no statistically significant variation in SO_2

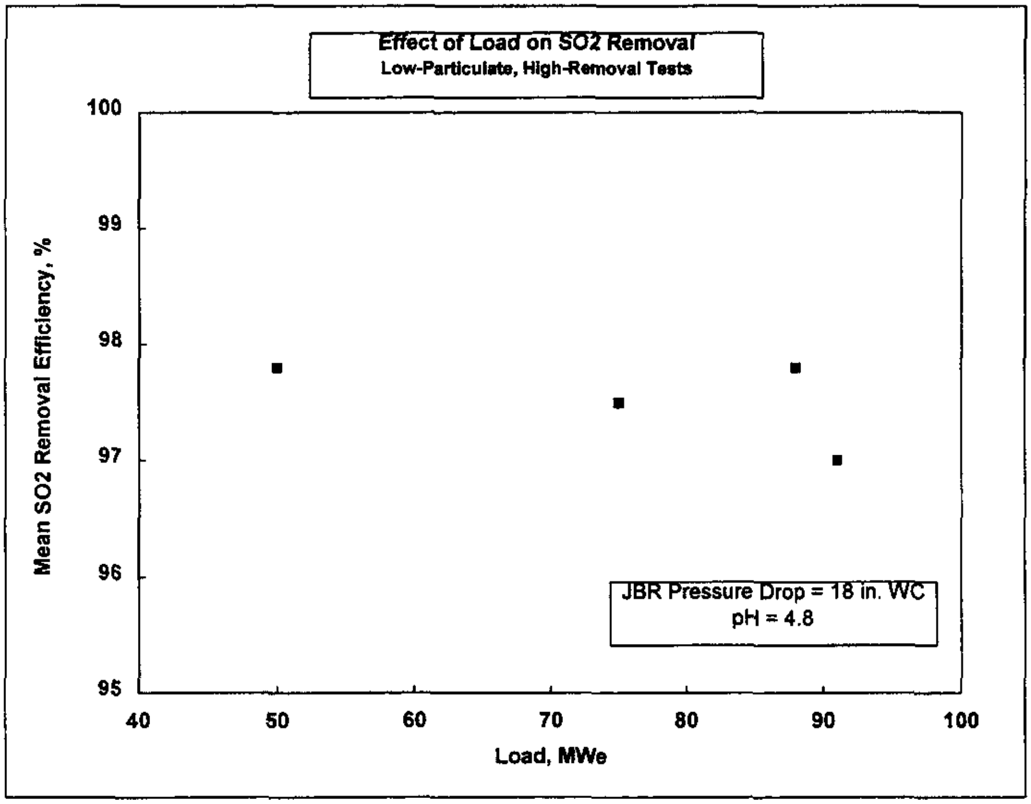

Figure 3-19. SO_2 Removal Efficiency During Low-Particulate High Removal Tests

removal efficiency during these tests, with the average removal efficiency varying from 97.0 to 97.8 percent.

The High-Particulate High Removal tests were conducted at a pH of 4.0 and a JBR ΔP of 20 in. WC. The lower pH was necessary to avoid aluminum fluoride blinding. The ESP was detuned to achieve 90% particulate removal during these tests. Short-term parametric tests were conducted at loads of about 50, 75, and 100 MWe, followed by a load-following test at an average boiler load of 56.5 MWe. Figure 3-20 presents the results of these tests. Greater than 98% SO_2 removal efficiency was achieved during all these tests, under all boiler loads, and there was no statistically significant variation in efficiency with boiler load. The moderate ash loading to the scrubber had no discernible impact on scrubber performance during this test period.

Tests were conducted during both the Low- and High-Particulate test periods to determine the impact of different limestone reagents on scrubber performance and gypsum crystal morphology.

The Low-Particulate Alternate Limestone tests demonstrated the performance of the project's original "baseline" limestone, from Martin Marietta Aggregates (MMA), with an alternative limestone supplied by Dravo Lime. All tests were conducted with the program coal (2.5% sulfur). The results are presented in Figures 3-21 and 3-22. In general, the SO_2 removal efficiency obtained when using the alternate (Dravo) limestone were similar to or slightly lower than those obtained using the MMA limestone. However, because the Dravo limestone resulted in improvements in the properties of the gypsum produced, the decision was made to switch to this limestone for the remainder of the demonstration program.

The High-Particulate Alternate Limestone tests were conducted using a limestone supplied by Florida Rock. At the time these tests were conducted, the plant was firing low-sulfur compliance coal (about 1.25% sulfur), so the original scope of these tests was modified to

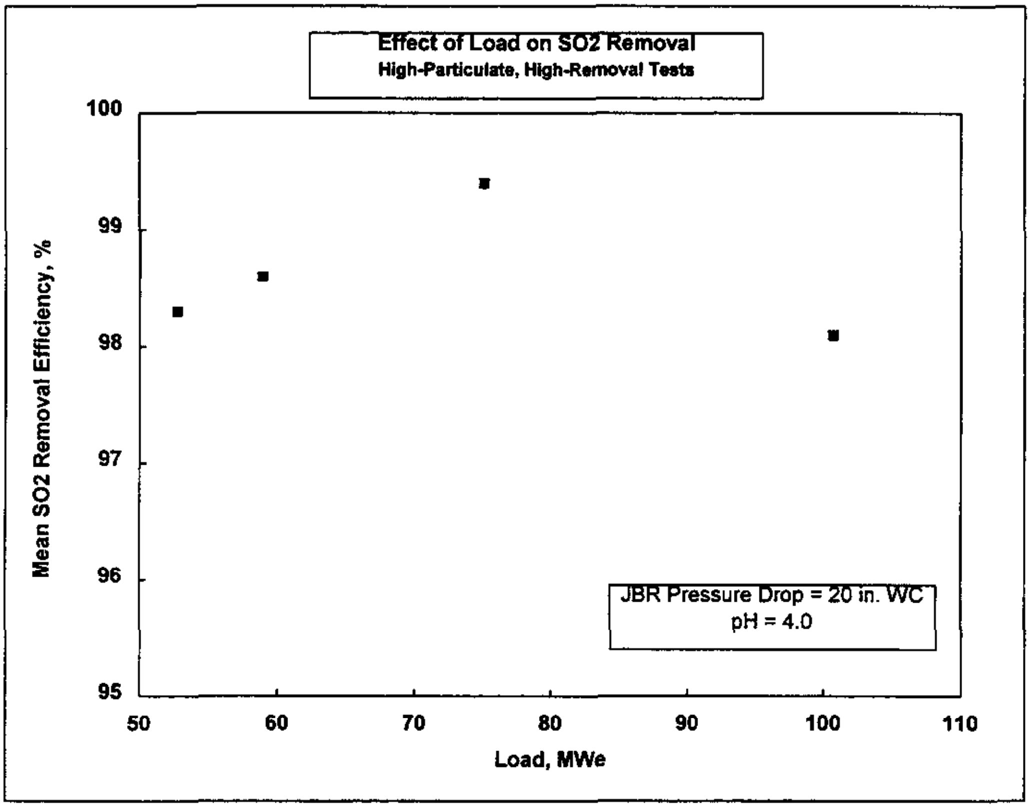

Figure 3-20. SO_2 Removal Efficiency During High-Particulate High Removal Tests

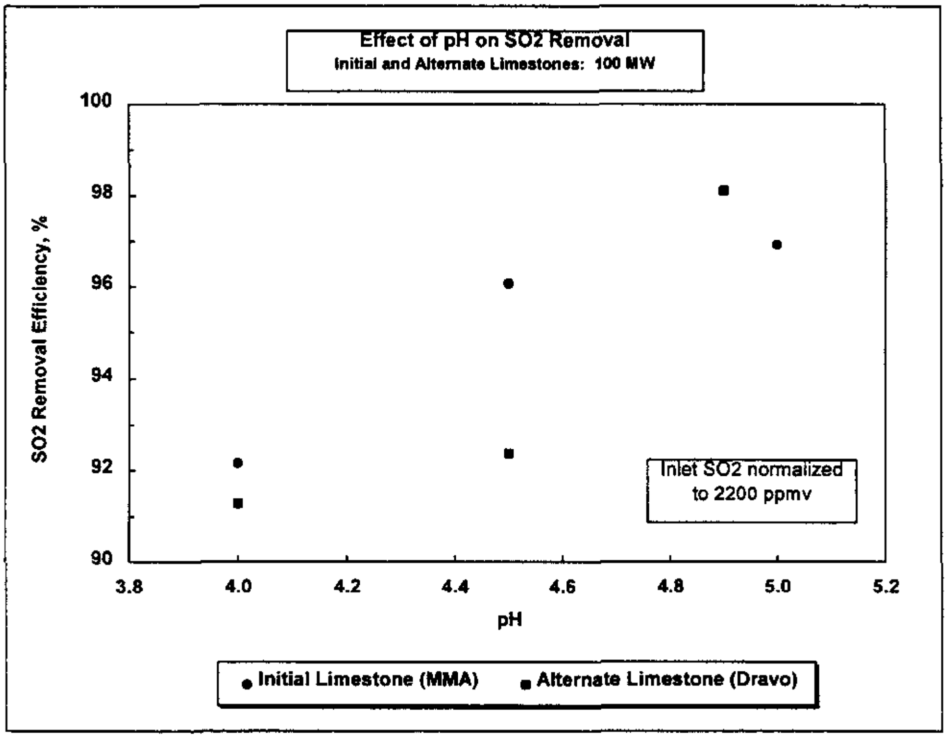

Figure 3-21. Effect of pH and Limestone on SO_2 Removal Efficiency During Low-Particulate Tests at 100 MWe

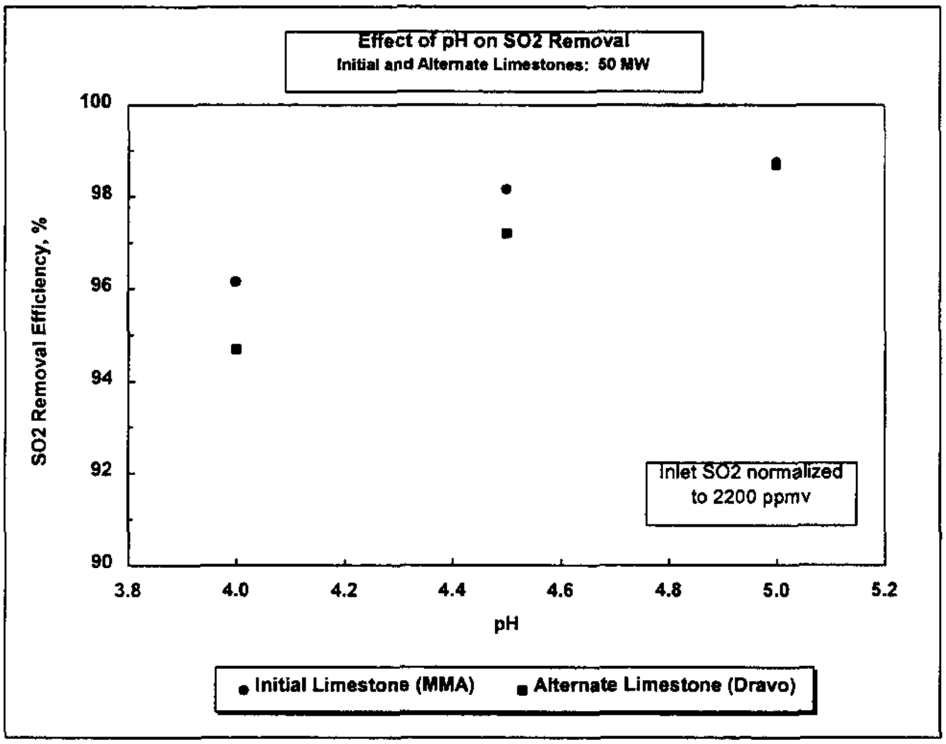

Figure 3-22. Effect of pH and Limestone on SO_2 Removal Efficiency During Low-Particulate Tests at 50 MWe

provide data that could be used to develop a parametric regression model for the prediction of scrubber performance at the low inlet SO_2 concentrations. No direct comparisons to tests conducted with the Dravo limestone could be made because of the differences in flue gas SO_2 concentration resulting from the use of different coals. Tests were conducted at pH levels of 4.0 and 3.75, boiler loads from 50 to 100 MWe, and JBR ΔP levels from 10 to 18 in. WC. The results are shown in Figures 3-23 and 3-24. The results generally followed the expected trend of increasing SO_2 removal efficiency with increasing JBR ΔP. However, during the pH 3.75 tests the effects of load were somewhat uncharacteristic since SO_2 removal efficiency was unaffected by boiler load at the highest JBR ΔP levels.

Alternate Coal tests were conducted to evaluate system performance and flexibility while the boiler burned a coal with a sulfur content significantly higher than that of the baseline coal (2.5% sulfur). During the Low-Particulate Alternate Coal tests, the coal sulfur content was approximately 4.3 percent. Although the same coal was ordered for the High-Particulate Alternate Coal tests, the average sulfur content of the coal fired in these tests was 3.4 percent.

Figures 3-25 and 3-26 present the results for the Low-Particulate tests and include, for comparison, results from comparable Parametric tests (i.e., 50 and 75 MWe, JBR ΔP 16 in. WC) for three pH levels. SO_2 removal efficiencies were lower for the high-sulfur coal at both load levels and all pH levels tested, as expected.

The data from the High-Particulate Alternate Coal tests are shown in Figure 3-27. These results show the expected increases in SO_2 removal efficiency with increasing JBR ΔP and decreasing boiler load. Figure 3-27 also contains data from comparable Low-Particulate Alternate Coal tests conducted at an inlet SO_2 concentration of 3,500 ppmv (at 3% O_2). When these data were normalized to 3,000 ppmv using the regression model developed under this program, the SO_2 removal efficiencies compared well to those observed during

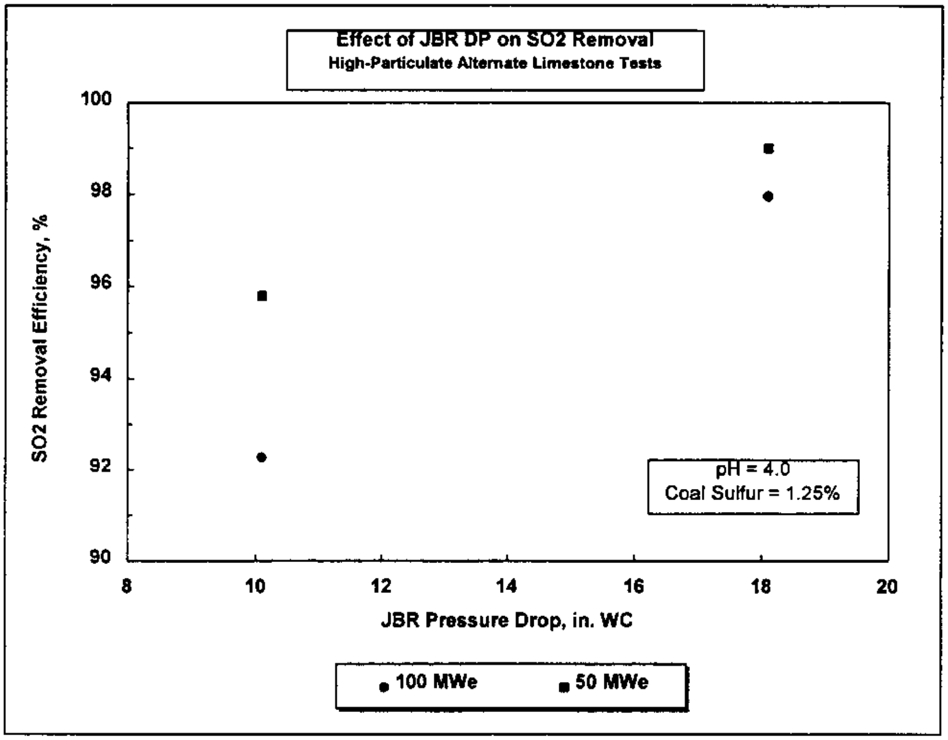

Figure 3-23. Effect of JBR ΔP on SO_2 Removal Efficiency During High-Particulate Alternate Limestone Tests at pH = 4.0

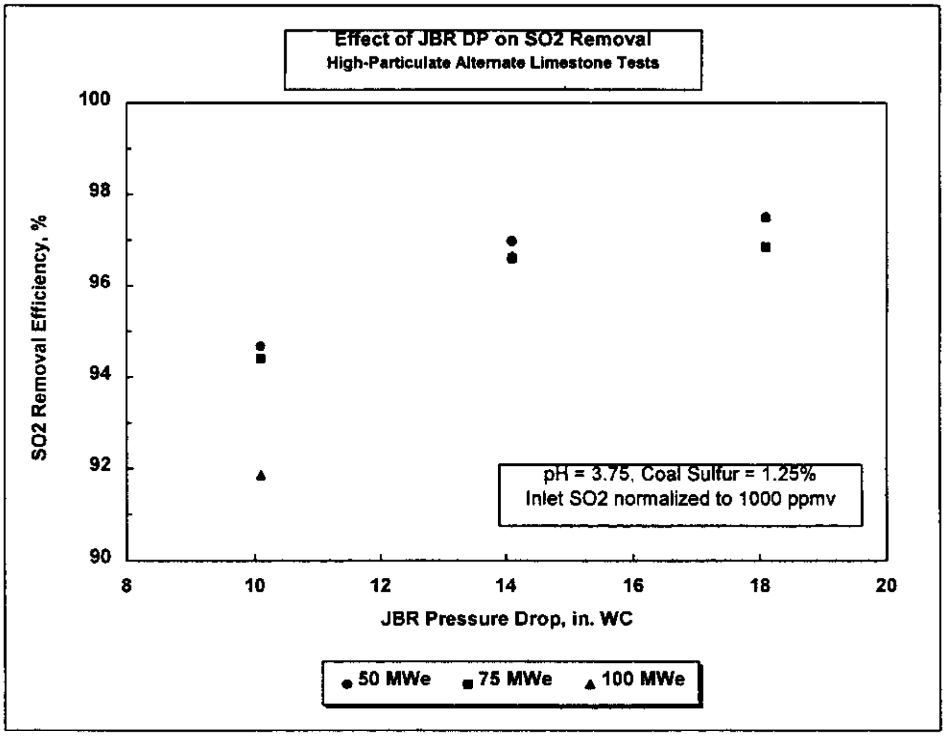

Figure 3-24. Effect of JBR ΔP on SO_2 Removal Efficiency During High-Particulate Alternate Limestone Tests at pH = 3.75

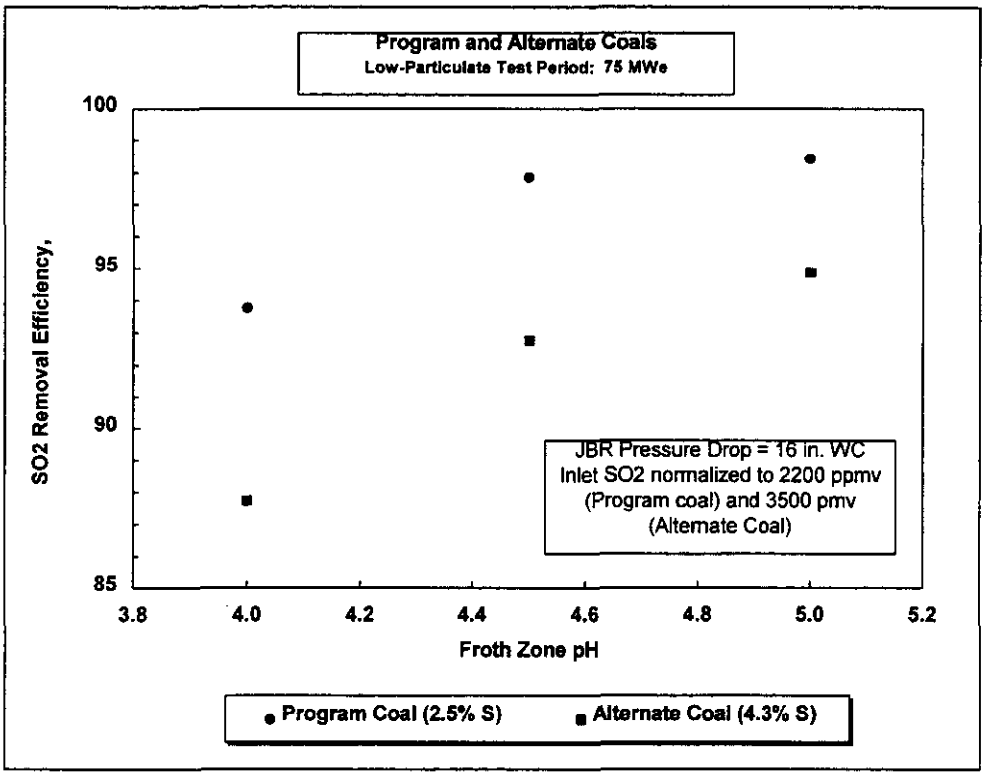

Figure 3-25. Comparison of SO_2 Removal Efficiency for Baseline and Alternate Coals at 75 MWe

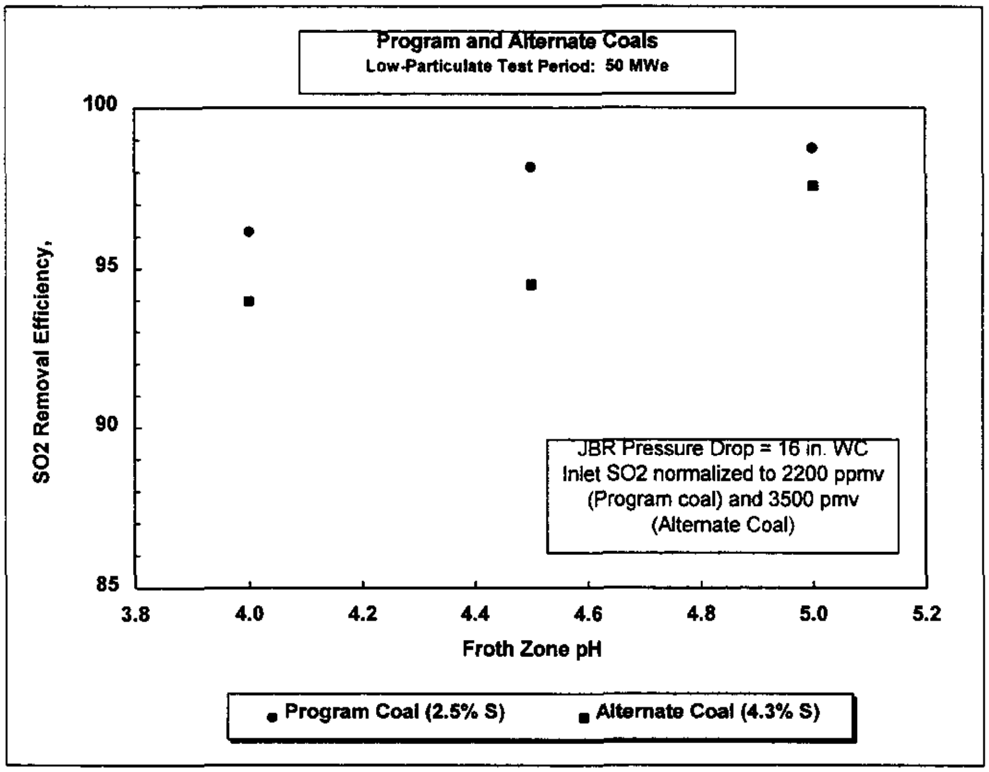

Figure 3-26. Comparison of SO_2 Removal Efficiency for Baseline and Alternate Coals at 50 MWe

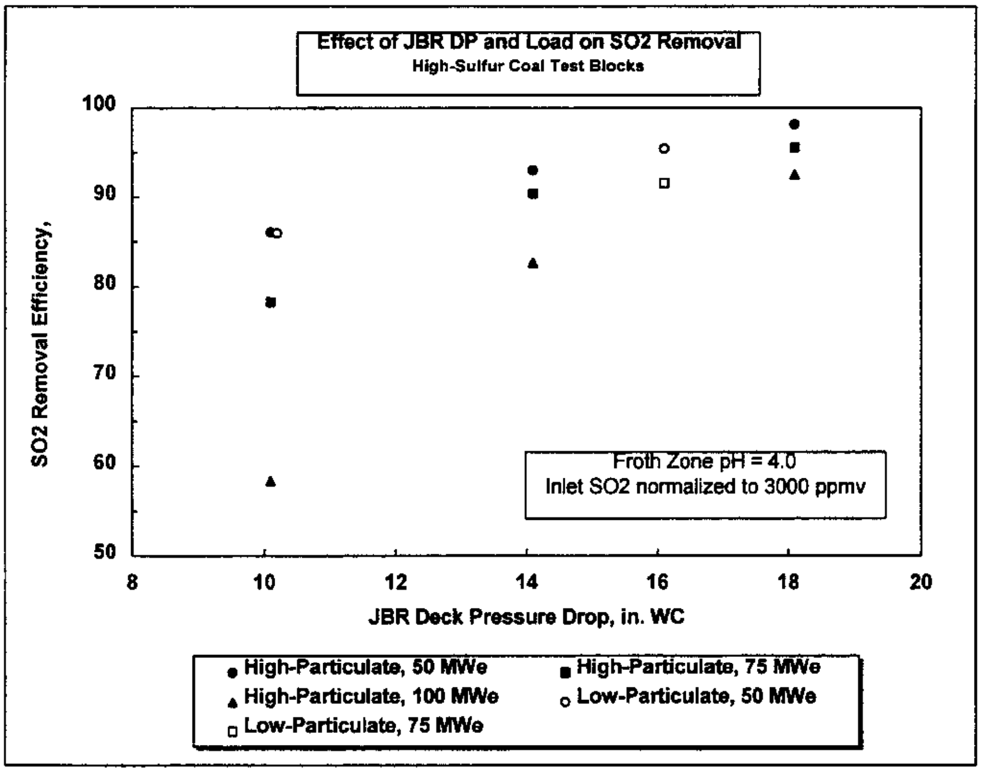

Figure 3-27. Effect of JBR ΔP and Load on SO_2 Removal Efficiency During Low- and High-Particulate High-Sulfur Test Blocks

the High-Particulate Alternate Coal tests. It is significant that the removal efficiency did not decrease at high ash loading conditions.

3.1.1.2 Particulate Matter

Particulate matter (PM) samples were obtained by Southern Research Institute (SRI) from the flue gas inlet to the JBR and stack gas streams during the first nine parametric tests of both the Low- and High-Particulate test periods. During the Low-Particulate tests, the ESP was operated fully energized, while during the High-Particulate tests, target ESP efficiencies from 0 to 95% were achieved by completely de-energizing the ESP or by energizing selected fields. In addition to ESP efficiency, the primary test variables included boiler load (i.e., the quantity of flue gas passing through the JBR) and JBR pressure drop. The nine Low-Particulate tests were all conducted at a scrubber slurry pH of 4.5; the first four High-Particulate tests were conducted at the same pH, but, because of low limestone utilization caused by aluminum fluoride blinding, the scrubber was operated at lower pH levels during the remaining tests.

The ESP and scrubber operating conditions and the average measured PM loading results (in lb/MMBtu) are summarized in Table 3-2. The complete results are tabulated in Appendix A. As shown, the stack gas PM loading was always below the Plant Yates permit limit of 0.24 lb/MMBtu during both test periods. Except when operating with the ESP fully de-energized, the combined ESP and JBR were also able to achieve PM loadings lower than the federal New Source Performance Standard NSPS) of 0.03 lb/MMBtu.

During the Low-Particulate tests, the JBR inlet gas loadings showed a general decrease as the load decreased, consistent with the fact that ESPs are typically more efficient at lower gas flow rates, all other factors being equal. The particulate removal efficiency across the JBR was about 90% for all of the tests conducted at 75 and 100 MWe and for the 50 MWe test conducted at a pressure drop of 8 in. WC. Lower apparent removals were obtained for the remaining Period 1 tests at 50 MWe, but this was due to decreases in the JBR inlet gas loading, and not to increases in the stack gas loading.

TABLE 3-2
PARTICULATE LOADING IN JBR INLET AND STACK GAS

Test No.	Unit Load, MWe	Approximate ESP Eff., %	JBR ΔP, in. WC	JBR Inlet PM Loading, lb/MMBtu	Stack Gas PM Loading, lb/MMBtu [a,b]
Low-Particulate Parametric Tests					
P1-1	100	99	8	0.081	0.009
P1-2	100	99	12	0.085	0.011
P1-3	100	99	16	0.114	0.010
P1-4	75	99	8	0.095	0.010
P1-5	75	99	12	0.072	0.008
P1-6	75	99	16	0.042	0.006
P1-7	50	99	8	0.087	0.008
P1-8	50	99	12	0.023	0.006
P1-9	50	99	16	0.019	0.006
High-Particulate Parametric Tests					
P2-1	50	95	10	0.196	0.013
P2-2	50	95	16	0.168	0.011
P2-3	100	95	10	0.434	0.017
P2-4	100	95	16	0.525	0.010
P2-5	100	90	16	0.819	0.015
P2-6	100	0	10	5.778	0.049
P2-7	100	0	16	5.293	0.042
P2-8	50	0	10	5.046	0.056
P2-9	50	0	16	4.927	0.049

Notes:

[a] Federal NSPS is 0.03 lb/MMBtu for units for which construction began after 9/18/78.

[b] Plant Yates' permit limit is 0.24 lb/MMBtu as an existing unit.

For the High-Particulate tests, the average stack gas PM loading obtained for the moderate inlet loading associated with the first five tests was about 0.013 lb/MMBtu, which was comparable to the loading in the Low-Particulate tests. For the high inlet mass loadings associated with the tests when the ESP was filly de-energized, the average outlet PM loading was higher, at about 0.049 lb/MMBtu.

Particle size distribution measurements were made at both the scrubber inlet and outlet sampling locations. Details are presented in SRI's test reports.(3,4) Figures showing the cumulative percent versus particle diameter measurements from those reports are reproduced in Appendix B. These measurements showed that the scrubber was more efficient at removing the larger particles.

Over 99.99 wt. % of the particulate larger than 10 μm was removed during both Low- and High-Particulate tests. The removal of particulates between 1 and 10 μm varied from 97.3% to 99.6% during the High-Particulate tests, which was slightly higher than that observed during the Low-Particulate Parametric test block. The removal efficiency for sub-micrometer particulates ranged between 69% and 85% during the High-Particulate Parametric tests.

3.1.1.3 Sulfur Trioxide

SO_3 concentrations in the JBR inlet gas and stack gas were measured by SRI three to four times during each of the first nine parametric tests of both the Low- and High-Particulate test periods. The individual measurements are provided in Appendix A, and mean values are shown in Table 3-3. Low concentrations of SO_3 were found in both streams (approximately 1-4 ppmv, corrected to 3% O_2).

During the Low-Particulate tests apparent SO_3 removal efficiencies between 25-35% were measured, except at the 75 MWe boiler load condition. The reasons for no apparent reduction in SO_3 concentration at this condition are not known, but may be due to errors associated with representative sample collection.

TABLE 3-3
AVERAGE SO_3 CONCENTRATION IN JBR INLET AND STACK GAS

Test No.	Unit Load, MWe	Approximate ESP Eff., %	pH	JBR ΔP, in. WC	JBR Inlet SO_3, ppmv [a]	Stack Gas SO_3, ppmv [a]	Removal, % [b]
Low-Particulate Parametric Tests							
P1-1	100	99	4.5	8	3.7	2.7	27.0
P1-2	100	99	4.5	12	3.4	2.7	20.6
P1-3	100	99	4.5	16	3.3	2.3	30.3
P1-4	75	99	4.5	8	2.5	2.6	-4.0
P1-5	75	99	4.5	12	2.9	3.4	-17.4
P1-6	75	99	4.5	16	2.8	3.0	-7.1
P1-7	50	99	4.5	8	1.9	1.7	10.5
P1-8	50	99	4.5	12	2.3	1.5	34.8
P1-9	50	99	4.5	16	3.8	2.4	36.8
High-Particulate Parametric Tests							
P2-1	50	95	4.5	10	1.6	2.7	-67
P2-2	50	95	4.5	16	1.4	2.2	-57
P2-3	100	95	4.5	10	1.9	3.0	-53
P2-4	100	95	4.5	16	1.7	1.0	40
P2-5	100	90	4.0	16	1.5	1.3	14
P2-6	100	0	3.5	10	1.4	0.6	61
P2-7	100	0	3.5	16	0.9	<0.3	>70
P2-8	50	0	3.5	10	1.5	<0.2	>87
P2-9	50	0	3.5	16	1.4	0.4	70

[a] All values normalized to 3% 0_2.

[b] % Removal = [(JBR Inlet-Stack Gas)/JBR Inlet] x 100%.

During the High-Particulate tests apparent SO_3 removal efficiencies from 60% to over 87% were observed when the ESP was de-energized. The measured SO_3 concentration actually increased across the scrubber during the tests when the ESP was partially energized. Again, the reasons for this are not known, but could be due to errors associated with representative sample collection.

3.1.1.4 Water Vapor

Water vapor concentrations in the JBR inlet gas and stack gas were measured during each of the first nine parametric tests for each of the two test periods. The average results for each test are summarized in Table 3-4, together with predicted stack gas concentrations based on the assumption that the stream was saturated at the measured temperature and pressure. As expected, the water vapor content of the stack gas was typically at or above the predicted saturation point.

3.1.2 Compliance Monitoring

As part of the EMP, the opacity of the flue gas inlet to the JBR was monitored using a continuous opacity meter. Georgia Power Company provides quarterly reports to the Georgia Department of Natural Resources detailing the daily excess opacity emissions. Copies of these reports have been attached as appendices to the quarterly EMP progress reports. A summary of the daily excess opacity emissions measured during the Low-Particulate test period is provided in Table 3-5. The applicable emission limit for this source is 40% opacity during any six-minute monitoring period. The table shows the number of minutes during which this limit was exceeded as well as the total number of minutes of operating time for each quarter. The fraction of time the opacity limit was exceeded during the Low-Particulate test period was very small (i.e., 0.42% of the total operating time). The majority of the excess emissions occurred during boiler startup or shutdown periods.

Because the opacity meter for Unit 1 was located upstream of the JBR, the opacity measured by this meter usually exceeded the 40% limit during the High-Particulate tests. Since these measurements were not representative of the opacity of the flue gas stream at the point of discharge, Georgia Power obtained a variance to the plant's air permit for the duration of High-

TABLE 3-4
AVERAGE WATER VAPOR CONCENTRATION IN JBR INLET AND STACK GAS

Test No.	Load, MWe	JBR ΔP, in. WC	Average H_2O, Vol. %		Predicted @ Sat'n
			JBR Inlet	Stack Gas	
Low-Particulate Parametric Tests					
P1-1	100	8	6.7	11.8	11.3
P1-2	100	12	8.3	13.0	12.0
P1-3	100	16	7.1	12.0	12.1
P1-4	75	8	7.4	12.1	12.4
P1-5	75	12	6.9	10.9	11.2
P1-6	75	16	6.7	11.4	11.0
P1-7	50	8	6.8	9.3	9.6
P1-8	50	12	7.6	11.0	10.1
P1-9	50	16	6.1	10.7	9.8
High-Particulate Parametric Tests					
P2-1	50	10	7.7	9.5	8.6
P2-2	50	16	6.8	10.8	9.8
P2-3	100	10	7.1	12.5	11.4
P2-4	100	16	7.5	12.0	11.3
P2-5	100	16	6.8	13.0	10.5
P2-6	100	10	7.1	14.5	11.9
P2-7	100	16	7.2	14.0	10.9
P2-8	50	10	6.7	10.5	9.1
P2-9	50	16	6.6	12.3	10.6

TABLE 3-5
JBR INLET GAS EXCESS OPACITY EMISSIONS SUMMARY: LOW-PARTICULATE TEST PERIOD [a,b]

	1st Quarter 1993	2nd Quarter 1993	3rd Quarter 1993	4th Quarter 1993	1st Quarter 1994
Total operating time	100,421	76,497	112,305	86,603	109,380
Duration of excess opacity emissions due to:					
Startup/shutdown	156	840	174	210	570
Control equipment problems	0	0	0	0	0
Process problems	0	30	0	0	6
Other known causes	0	0	0	0	72
Unknown causes	0	0	0	0	0
Total duration of excess missions, % of operating time	0.16%	1.14%	0.15%	0.24%	0.59%

Notes:

[a] All times in minutes.

[b] A variance was obtained for the High-Particulate test period; opacity was not monitored during this period.

Source: Quarterly Air Emission Reports prepared by Georgia Power for Georgia DNR.

Particulate testing that exempted the plant from reporting excess opacities from Unit 1. EPA Method 9 visual opacity readings of the flue gas from the CT-121 unit's stack were conducted during the early portion of the High-Particulate Parametric testing with the ESP completely de-energized. The readings obtained during these tests were typically in the range from 5 to 10% opacity. No additional opacity monitoring was conducted during the High-Particulate test period.

3.2 Aqueous Stream Monitoring Results

Aqueous stream monitoring results for the two scrubber test periods are summarized in the paragraphs below. Tables containing the complete set of results for all EMP parameters are provided in Appendix A.

Table 3-6 shows the actual and planned monitoring frequencies for each of the aqueous stream parameters. As shown, the majority of the monitoring specified in the EMP was performed as planned. The few exceptions to this statement have already been discussed in Section 2.

3.2.1 Supplemental Monitoring

Aqueous CT-121 scrubber process streams monitored as part of the scrubber demonstration project's EMP included limestone slurry, makeup water, gypsum stack return, JBR froth zone, and JBR draw-off. Results for each stream are discussed below.

3.2.1.1 Limestone Slurry

Limestone from three different sources was used during portions of the CT-121 scrubber demonstration project. The initial "program limestone" from Martin Marietta Aggregates (MMA) was used during the Low-Particulate Parametric and Long-Term tests, and the High Removal tests. Limestone from Dravo Lime's Saginaw, Alabama, quarry was used during the Low-Particulate Alternate Limestone and Alternate Coal tests, and, based on the favorable gypsum characteristics obtained, it was subsequently used during the majority of the High-Particulate test

TABLE 3-6
AQUEOUS PROCESS STREAMS: ACTUAL AND PLANNED MONITORING [a]

	Ash Transport Water		**Final Plant Discharge**		**JBR Froth Zone**		**JBR Draw-Off**	
Parameter	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**
Liquid Phase								
pH			29/28 [a]	21/20	56/54	40/40	56/54	41/40
Total Suspended Solids	29/28	21/20						
Oil & Grease	29/28	21/20						
Chloride					56/54	40/40		
Sulfite					55/54	40/40		
Sulfate					56/54	40/40		
Carbonate					55/54	39/40		
Trace Elements					4/6	9/9		
Solid Phase								
Solids Content					56/54	40/40	56/54	41/40
Inert Content					17/54	4/40	56/54	41/40
Calcium					50/54	4/40	56/54	41/40
Magnesium							56/54	41/40
Sulfite							55/54	41/40
Sulfate					50/54	4/40	56/54	41/40
Carbonate					49/54	5/40	56/54	41/40
Trace Elements							8/6	9/9
TCLP							1/1 [b]	0/1

	Limestone Slurry		**Gypsum Stack Return**		**Makeup Water**	
Parameter	**Period 1**	**Period 2**	**Period 1**	**Period 2**	**Period 1**	**Period 2**
Liquid Phase						
pH			57/54	39/40	3/14	4/9
Total Suspended Solids						
Oil & Grease						
Chloride			57/54	41/40	5/14	9/9
Sulfite					2/14	5/9
Sulfate			57/54	41/40	5/14	9/9
Carbonate			56/54	41/40	1/14	4/9
Trace Elements			4/6	7/9		
Solid Phase						
Solids Content	55/54	38/40				
Inert Content	55/54	41/40				
Calcium	55/54	41/40				
Magnesium	55/54	41/40				
Sulfite						
Sulfate						
Carbonate	55/54	41/40				
Trace Elements						
TCLP						

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[a] 29/28=29 actual/28 planned.

[b] A sample was obtained for TCLP analysis, but maximum allowable holding time was exceeded.

blocks. A third limestone, from Florida Rock's Rome, Georgia, quarry, was used during the High-Particulate Alternate Limestone test period.

The solids content of the limestone slurry during all test periods is plotted against the sample date in Figure 3-28. The mean slurry solids content during the Low-Particulate test period was 30% by weight. The variability as measured by the coefficient of variation (COV—defined as the sample standard deviation divided by the sample mean) was 12 percent. During the High-Particulate tests, the mean slurry solids content was slightly less at 28.7 wt.%, with a COV of 7 percent.

The limestone composition over time is shown in Figure 3-29. As shown, the composition for each limestone was relatively constant. Table 3-7 shows the mean and standard deviation for each constituent for each of the three limestones used. All three limestones consisted primarily of calcium carbonate with a small amount of magnesium carbonate and inert material. Both of the alternate limestones contained slightly more magnesium carbonate than the MMA limestone. The inerts content of the Florida Rock limestone was about twice that of the MMA limestone, whereas the Dravo Lime limestone contained roughly half the inerts of the MMA limestone.

3.2.1.2 Makeup Water

The makeup water monitoring results obtained during both scrubber testing periods are given in Table 3-8. The results are consistent with the fact that the majority of the scrubber makeup water was taken from Plant Yates' ash pond.

3.2.1.3 Gypsum Stack Return

The composition of the gypsum stack return liquor is plotted against time in Figure 3-30. The chloride concentration showed considerable variation as the amount of water in the scrubber system fluctuated over time and as coals with different chlorine contents were burned. The sulfate concentration was relatively constant, at around 1,000 mg/L. The results observed were consistent with a typical scrubber system operating with a relatively tightly closed water balance.

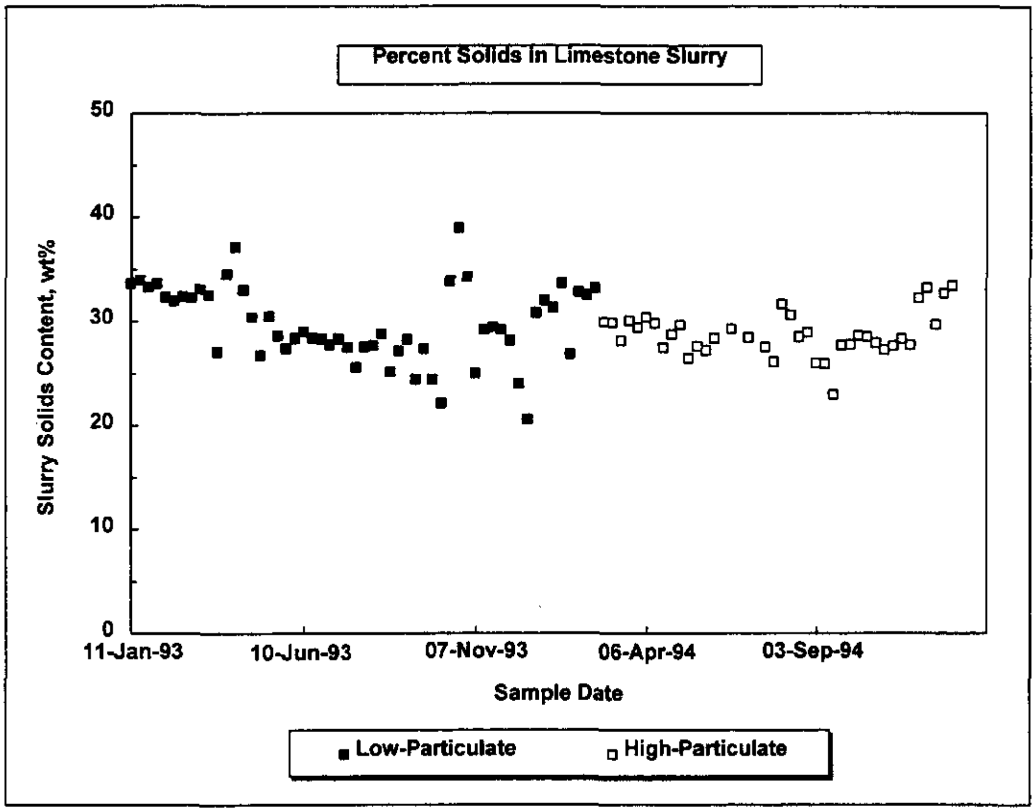


Figure 3-28. Limestone Slurry Solids Content During Low- and High-Particulate Test Periods

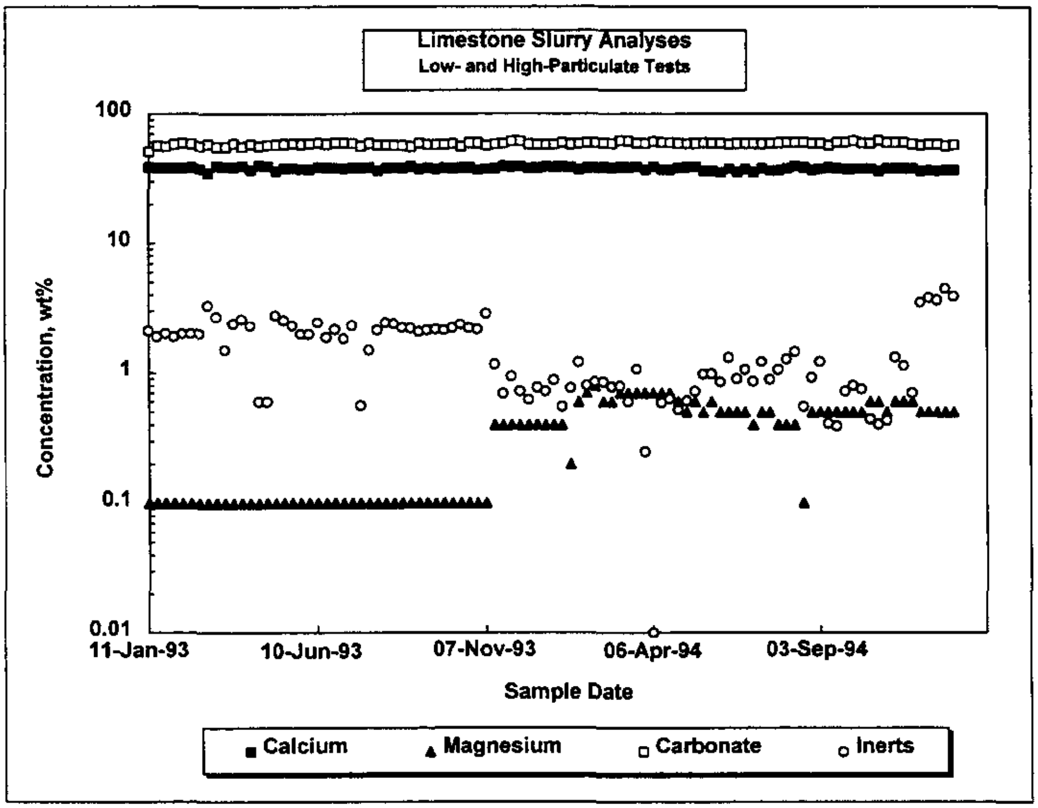


Figure 3-29. Limestone Composition During Low- and High-Particulate Test Periods

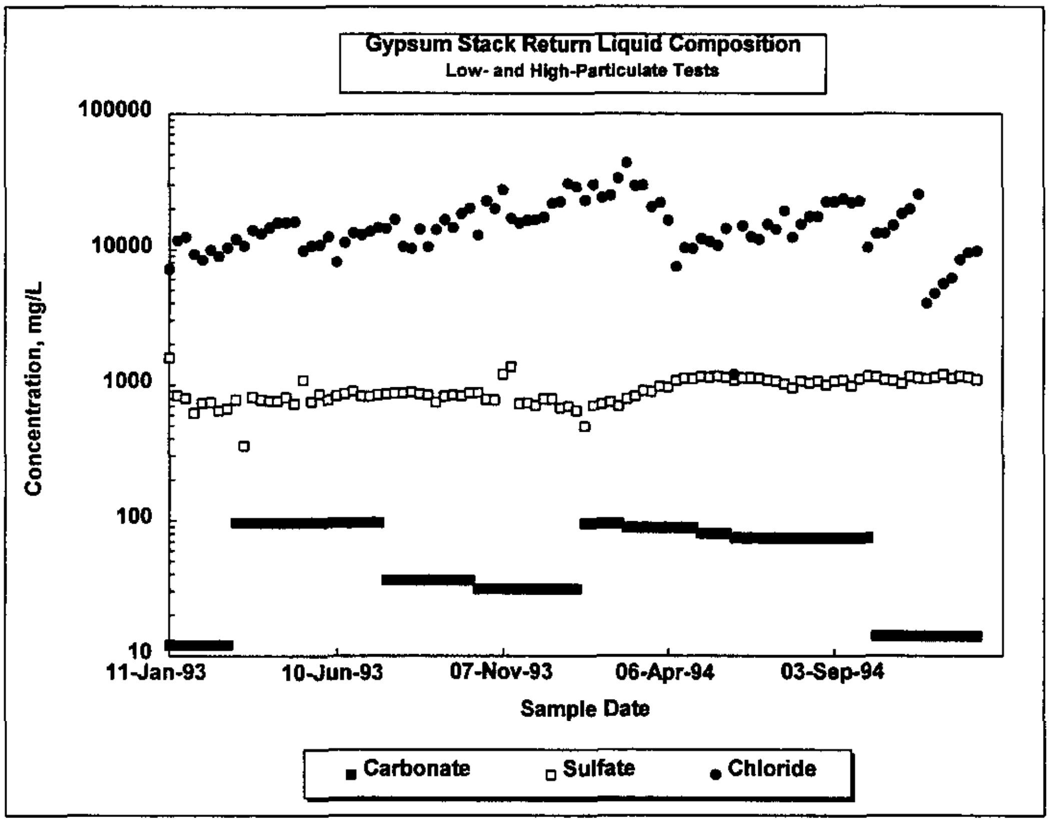


Figure 3-30. Gypsum Stack Return Liquor Composition During Low- and High-Particulate Test Periods

TABLE 3-7
SUMMARY OF LIMESTONE COMPOSITION: LOW- AND HIGH-PARTICULATE TESTING PERIODS

	Initial Limestone (Martin Marietta)		**1st Alternate (Dravo Lime)**		**2nd Alternate (Florida Rock)**	
Parameter	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**
Calcium	38.2	1.0	37.8	1.1	36.4	0.2
Magnesium	0.1	0.1	0.5	0.1	0.5	0.0
Carbonate	57.9	1.8	59.6	1.0	57.4	0.7
Inerts	1.9	0.7	0.8	0.3	3.9	0.4

TABLE 3-8
MAKEUP WATER ANALYSES

		Liquid Phase, mg/L			
Date	**pH**	**Carbonate**	**Sulfite**	**Sulfate**	**Chloride**
Low-Particulate Tests					
06-Jun-93	6.75	—	0.8	46	42
09-Aug-93	6.08	36	0.8	152	22
04-Oct-93	—	—	—	67	35
10-Jan-94	7.36	—	—	13	37
14-Feb-94	—	—	—	110	138
High-Particulate Tests					
25-Apr-94	5.95	0.0	0.0	114	238
30-May-94	—	—	—	72	257
01-Jun-94	—	—	—	72	257
27-Jun-94	4.95	—	—	125	52
07-Jul-94	—	73.8	0.0	116	113
10-Aug-94	5.65	0.0	0.0	130	151
12-Sep-94	4.61	0.0	0.0	147	1685
24-Oct-94	—	—	—	84	13
06-Dec-94	—	—	0.0	84	53

Aqueous phase trace element concentrations in the gypsum stack return liquor are provided in Appendix A, Table A-8.

3.2.1.4 JBR Froth Zone

The JBR froth zone slurry solids content is shown in Figure 3-31. The mean solids content during the Low-Particulate tests was nearly 21 wt. %, with a coefficient of variation of 14 percent. During the High-Particulate tests, the mean solids content was 17 wt. %, with a coefficient of variation of 19 percent. The solids set-point chosen for the High-Particulate Alternate Coal and Alternate Limestone test periods was the reason for the lower mean value during the High-Particulate test period.

The composition of the JBR froth zone liquor, shown in Figure 3-32, exhibited the same trends as the gypsum stack return stream, i.e., relatively wide fluctuations in chloride content and steady sulfate concentrations.

The JBR froth zone solids consisted primarily of calcium sulfate, based on the relative concentrations of calcium and sulfate ions and typically low measured sulfite concentrations. The results are presented graphically in Figure 3-33. The data show that the absorbed sulfur dioxide was usually completely converted from sulfite to sulfate in the JBR. A small amount of carbonate was also typically present, due to unconverted limestone. Because of the similarities in the composition of the JBR froth zone and draw-off solids, the decision was made early in the High-Particulate test period to discontinue analysis of the JBR froth zone solids.

Measured trace element concentrations in the JBR froth zone liquor are provided in the Appendix A, Table A-11.

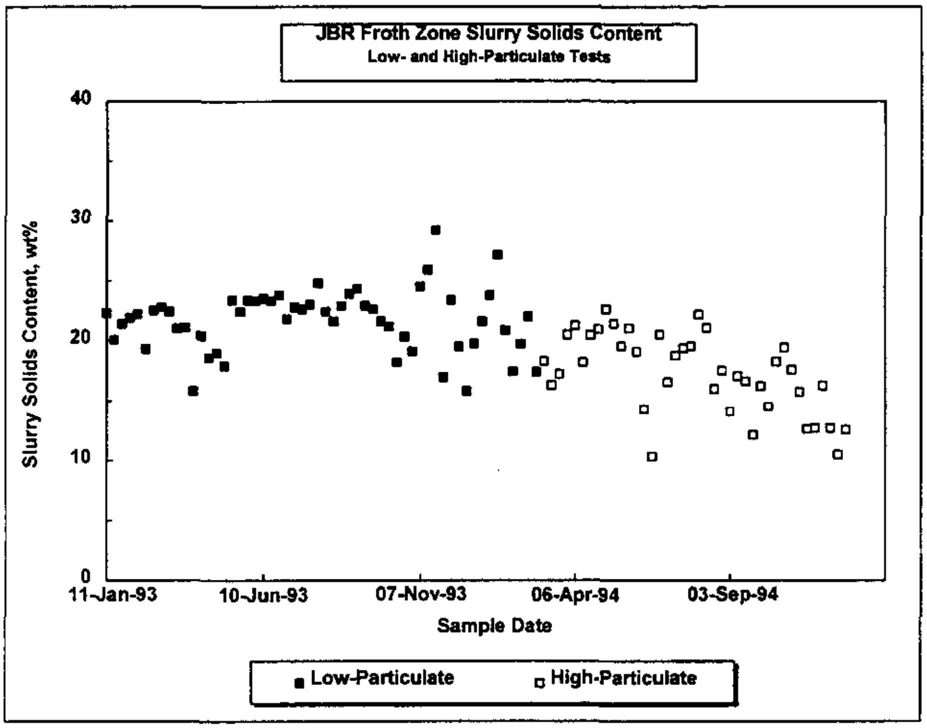


Figure 3-31. JBR Froth Zone Slurry Solids Content During Low- and High-Particulate Test Periods

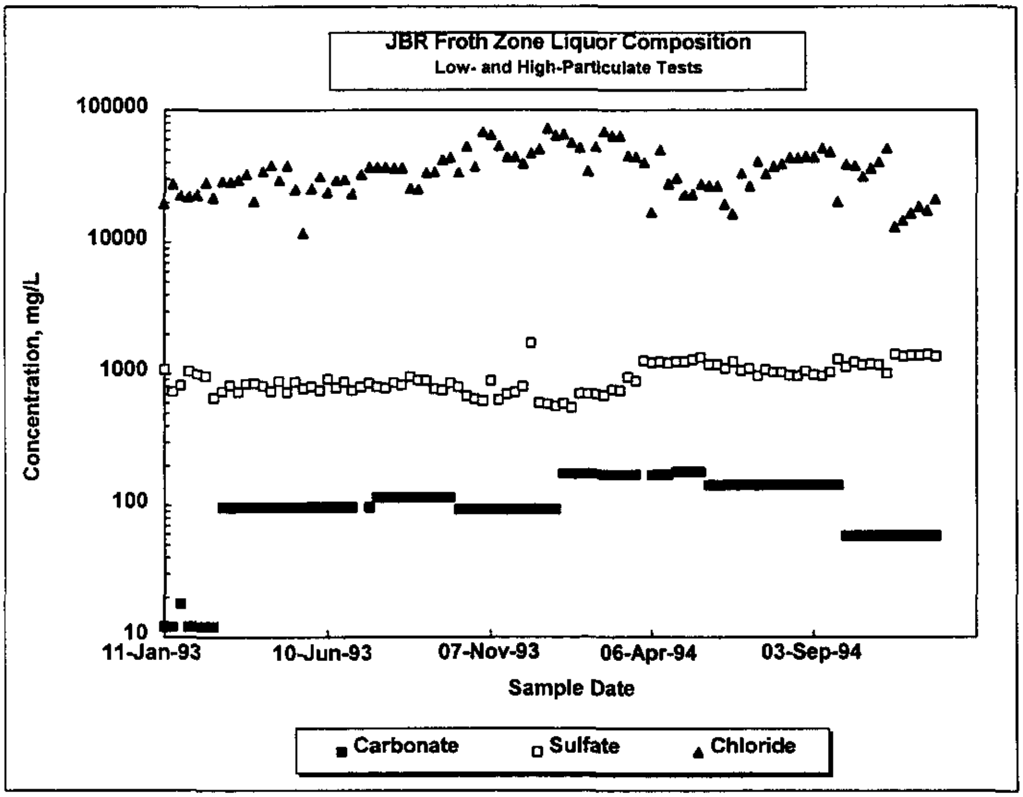


Figure 3-32. JBR Froth Zone Liquor Composition During Low- and High-Particulate Test Periods

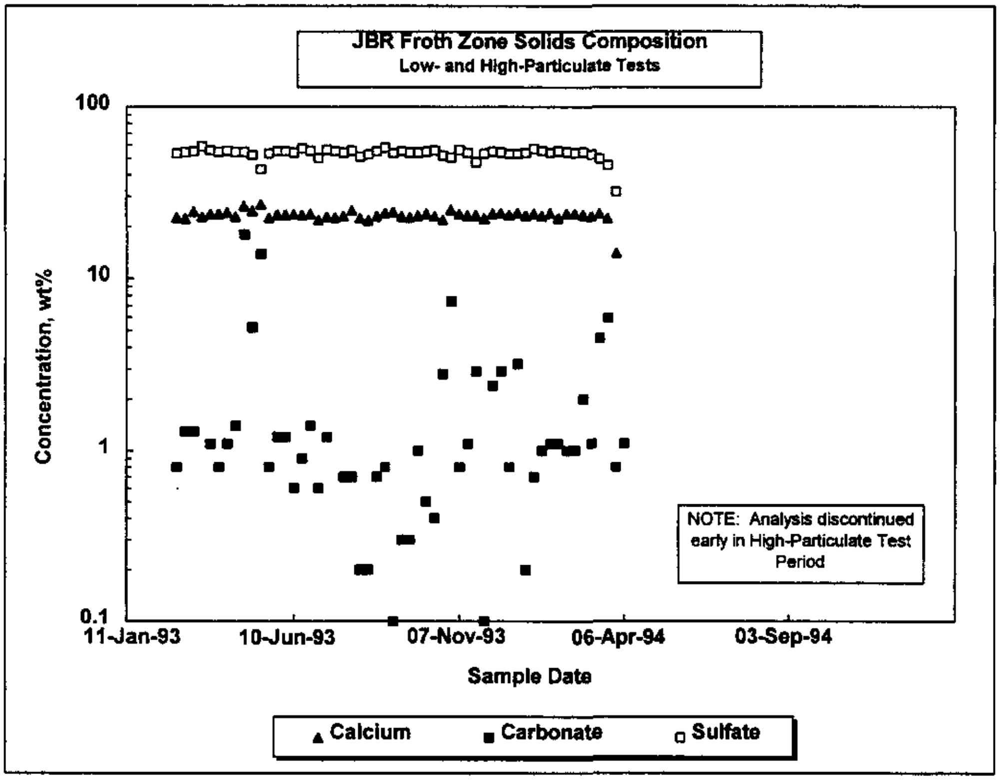


Figure 3-33. JBR Froth Zone Solids Composition Data Only Shown for First (Low-Ash) Period

3.2.1.5 JBR Draw-Off

As shown in Figure 3-34, the solids content of the JBR draw-off slurry was comparable to that measured in the JBR froth zone stream. The mean solids content was 21.0 wt.% during the Low-Particulate tests and 18.8 wt.% during the High-Particulate tests; coefficients of variation were 12% and 18.6%, respectively. As with the JBR froth zone stream, the solids content set-point during High-Particulate Alternate Coal and Alternate Limestone test blocks was the biggest contributor to the lower mean solids content during this period.

As mentioned above, the composition of the JBR draw-off solids was very consistent with the composition measured in the JBR froth zone draw-off solids; the JBR draw-off solids composition data from both test periods are shown in Figure 3-35. The solids consisted primarily of calcium sulfate, with a small amount of unconverted carbonate; the sulfite concentration was typically very low. The JBR draw-off solids were also analyzed periodically for trace elements; the results are presented in Appendix A, Table A- 13.

3.2.2 Compliance Monitoring

Compliance monitoring of ash transport water and final plant discharge was performed during both scrubber testing periods. The results presented here were compiled from quarterly compliance reports submitted by Georgia Power Company to the Environmental Protection Division of the Georgia Department of Natural Resources. Copies of these compliance reports were included as appendices to each of the quarterly EMP progress reports submitted to DOE as part of this project.

Table 3-9 summarizes the results obtained during each testing period; means, standard deviations, numbers of data points, and ranges are shown for each monitored parameter, together with the corresponding NPDES permit limits. There were no exceedances of the plant's NPDES permit limits for these streams during either testing period.

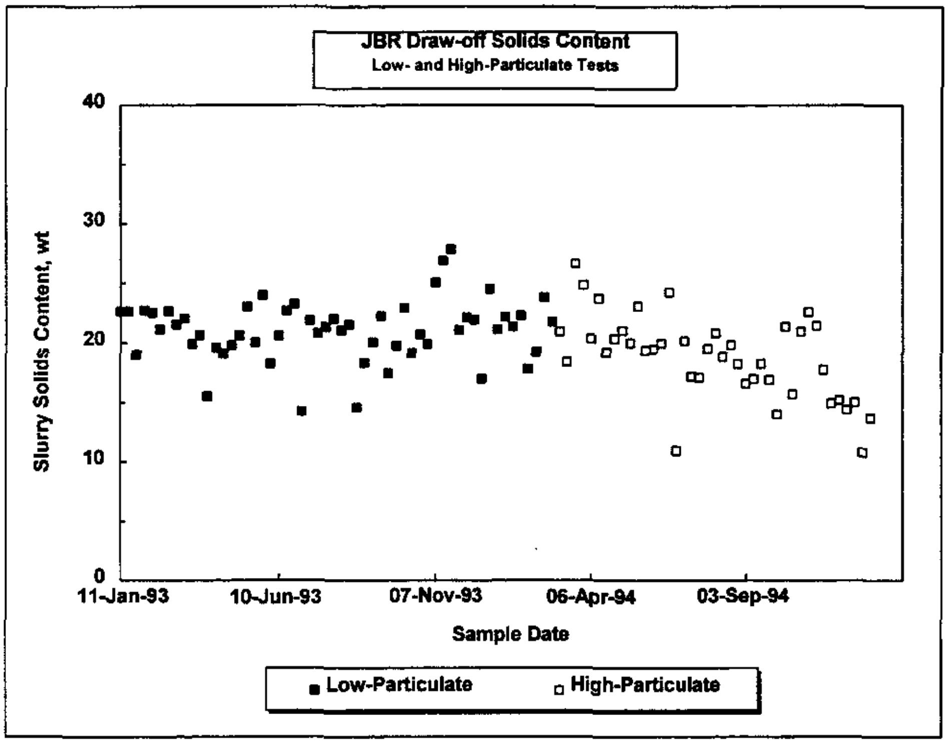


Figure 3-34. JBR Draw-off Slurry Solids Content During Low and High-Particulate Test Periods

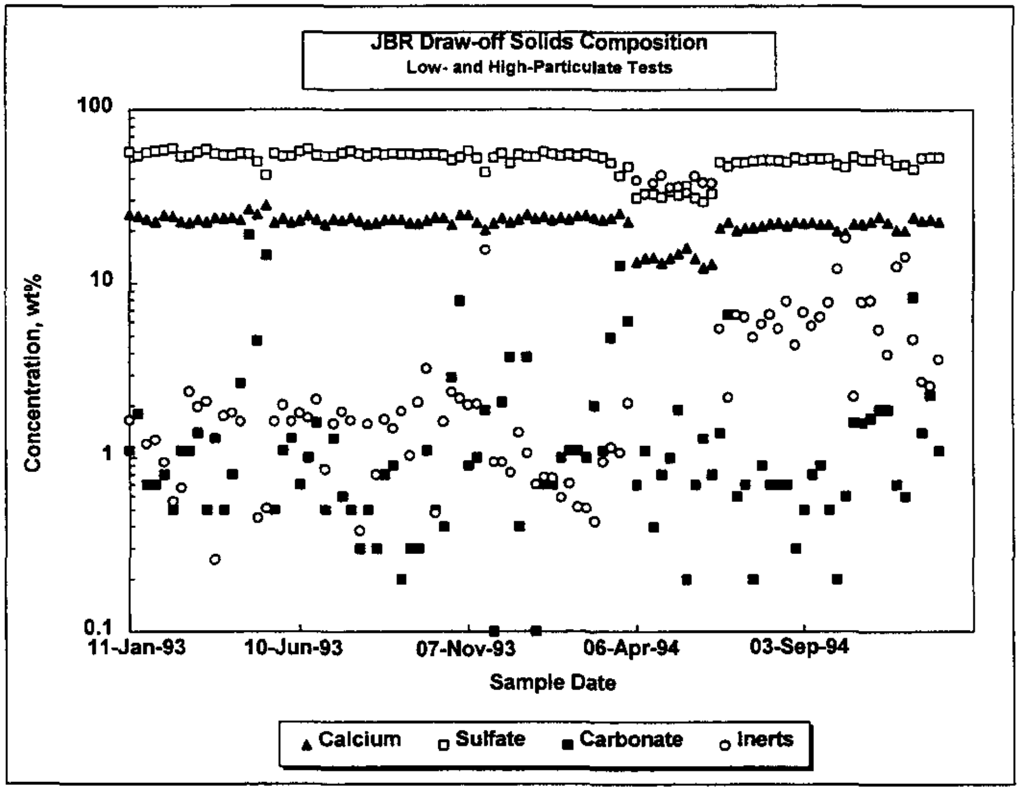


Figure 3-35. JBR Draw-off Solids Composition During Low- and High-Particulate Test Periods

TABLE 3-9
AQUEOUS STREAMS: COMPLIANCE MONITORING RESULTS

Parameter	Average	Standard Deviation	No. of Data Points	Range	Permit Limits
Ash Transport Water					
TSS (mg/L)					
Low-Particulate Test Period	1.8	0.8	29	1 - 4	30 Ave./100 Max.
High-Particulate Test Period	2.2	2.2	21	0 - 10	30 Ave./100 Max.
Oil & Grease (mg/L)					
Low-Particulate Test Period	<5	0	29	0 - <5	15 Ave./20 Max.
High-Particulate Test Period	0	0	21	0 - 0	15 Ave./20 Max.
Final Plant Discharge					
pH					
Low-Particulate Test Period	6.71	0.24	29	6.14 - 7.22	6.0 Min./9.0 Max.
High-Particulate Test Period	6.89	0.21	21	6.26 - 7.19	6.0 Min./9.0 Max.

3.3 Solid Stream Monitoring Results

Monitoring of the coal feed to the Unit 1 boiler was included in the EMP to provide data on composition changes that could affect the interpretation of the other monitoring results. Table 3-10 shows the actual and planned monitoring frequencies for the coal analyses that were performed as part of the EMP. Monitoring was performed substantially as planned during both testing periods. Detailed tables of coal proximate, ultimate, and trace element analyses are provided in Appendix A.

A statistical summary of the daily coal analyses from both Low- and High-Particulate test periods is provided in Table 3-11. Figure 3-36 presents these results graphically on an as-burned basis. As can be seen, the variation in sulfur, moisture, and ash content accounted for the major differences in coal composition. The SO_2 concentration in the flue gas inlet to the JBR was directly proportional to the coal sulfur content, as shown in Figure 3-37, where average SO_2 concentrations are plotted against average coal sulfur content for each of the Low- and High-Particulate test blocks.

TABLE 3-10
SOLID STREAMS: ACTUAL AND PLANNED MONITORING

Parameter	Coal Feed	
	Low-Particulate Test Period	**High-Particulate Test Period**
Proximate Analysis, Sulfur, and HHV	303/303 [a]	185/183
Ultimate Analysis, Chlorine and Fluorine	6/3	5/2
Trace Elements	2/3	5/2

[a] 303/303 = 303 actual/303 planned.

TABLE 3-11
STATISTICAL SUMMARY OF DAILY COAL ANALYSES

	Low-Particulate Parametric Tests			**Low-Particulate Long-Term Tests**		
Parameter	**Mean**	**Std. Dev.**	**Range**	**Mean**	**Std. Dev.**	**Range**
Moisture, wt.%	12.89	1.17	6.66 - 15.37	11.74	1.01	8.31 - 14.28
Volatiles, wt. %	33.9	1.1	26.4 - 35.0	33.9	0.7	31.5 - 35.3
Fixed C, wt. %	43.5	1.2	41.2 - 48.6	45.0	0.8	43.3 - 48.9
Ash, wt. %	9.68	0.74	8.7 – 11.36	9.41	0.58	8.59 - 11.27
Sulfur, wt. %	2.42	0.18	1.53 - 2.70	2.34	0.13	1.76 - 2.84
HHV, Btu/lb	11,185	269	10,690 - 12,340	11,431	207	11,024 - 12,481

	Low-Particulate Auxiliary Tests [a]			**Low-Particulate Alternate Coal Tests**		
Parameter	**Mean**	**Std. Dev.**	**Range**	**Mean**	**Std. Dev.**	**Range**
Moisture, wt. %	12.49	1.11	8.98 - 14.98	8.95	1.10	7.19 - 10.85
Volatiles, wt. %	33.6	0.5	32.2 - 34.4	37.9	0.6	36.7 - 38.8
Fixed C, wt. %	44.3	0.8	42.8 - 48.1	43.2	0.7	41.7 - 44.5
Ash, wt. %	9.60	0.53	8.47 - 10.80	9.89	0.25	9.43 - 10.62
Sulfur, wt. %	2.37	0.16	1.71 - 2.62	4.30	0.09	4.17 - 4.49
HHV, Btu/lb	11,272	180	10,847 - 12,058	11,936	139	11,670 - 12,141

[a] Includes Alternate Limestone and High Removal tests.

All parameters are reported on an as-burned basis.

TABLE 3-11 (CONTINUED)

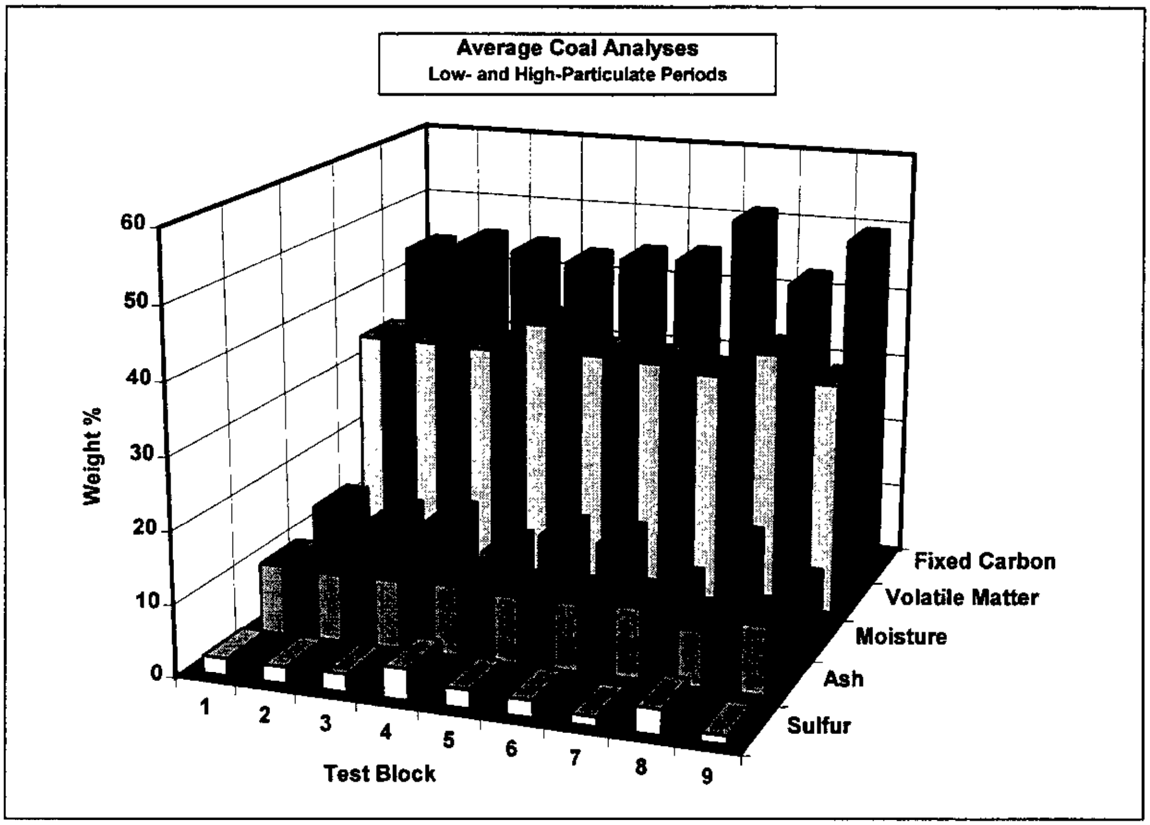
Parameter	Low-Particulate Parametric Tests			Low-Particulate Long-Term Tests		
	Mean	**Std. Dev.**	**Range**	**Mean**	**Std. Dev.**	**Range**
Moisture, wt.%	12.24	0.81	10.91 - 14.38	12.10	1.24	8.89 - 15.07
Volatiles, wt. %	34.09	0.58	32.90 - 34.90	33.71	0.52	32.44 - 33.71
Fixed C, wt. %	44.30	0.53	42.98 - 45.33	44.76	0.71	43.33 - 46.64
Ash, wt. %	9.39	0.18	9.11 - 9.99	9.47	0.99	8.43 - 12.56
Sulfur, wt. %	2.53	0.13	2.32 - 2.80	2.27	0.13	2.03 - 2.65
HHV, Btu/lb	11,293	113	10,990 - 11,491	11,356	147	11,009 - 11,735

Parameter	High-Particulate High Removal Tests[a]			High-Particulate Alternate Coal Tests		
	Mean	**Std. Dev.**	**Range**	**Mean**	**Std. Dev.**	**Range**
Moisture, wt. %	6.15	1.24	4.55 - 9.28	13.23	0.81	12.34 - 14.92
Volatiles, wt. %	32.66	0.51	31.89 - 33.61	36.50	0.38	35.71 - 37.19
Fixed C, wt. %	51.28	1.06	49.35 - 53.05	42.48	0.56	41.43 - 43.39
Ash, wt. %	9.93	0.48	9.28 – 10.96	7.77	0.25	7.35 - 8.16
Sulfur, wt. %	1.26	0.10	1.14 - 1.43	3.43	0.08	3.23 - 3.54
HHV, Btu/lb	12,735	253	12,309 - 13,178	11,482	117	11,260 - 11,627

Parameter	High-Particulate Alternate LimestoneTests[a]		
	Mean	**Std. Dev.**	**Range**
Moisture, wt. %	8.20	0.65	7.08 - 9.49
Volatiles, wt. %	32.86	0.39	31.95 - 33.36
Fixed C, wt. %	49.38	0.48	48.49 - 50.17
Ash, wt. %	9.55	0.17	9.24 - 9.80
Sulfur, wt. %	1.15	0.06	1.02 - 1.27
HHV, Btu/lb	12,385	105	12,172 - 12,534

[a] Includes Alternate Limestone and High Removal tests.

All parameters are reported on an as-burned basis.



Key:

1 Low-Particulate Parametric Tests
2 Low-Particulate Long-Term Tests
3 Low-Particulate Auxiliary Tests
4 Low-Particulate Alternate Coal Tests
5 High-Particulate Parametric Tests
6 High-Particulate Long-Term Tests
7 High-Particulate High Removal Tests
8 High-Particulate Alternate Coal Tests
9 Period 2 Alternate Limestone Tests

Figure 3-36. Results of Average Coal Proximate Analyses for All Test Blocks

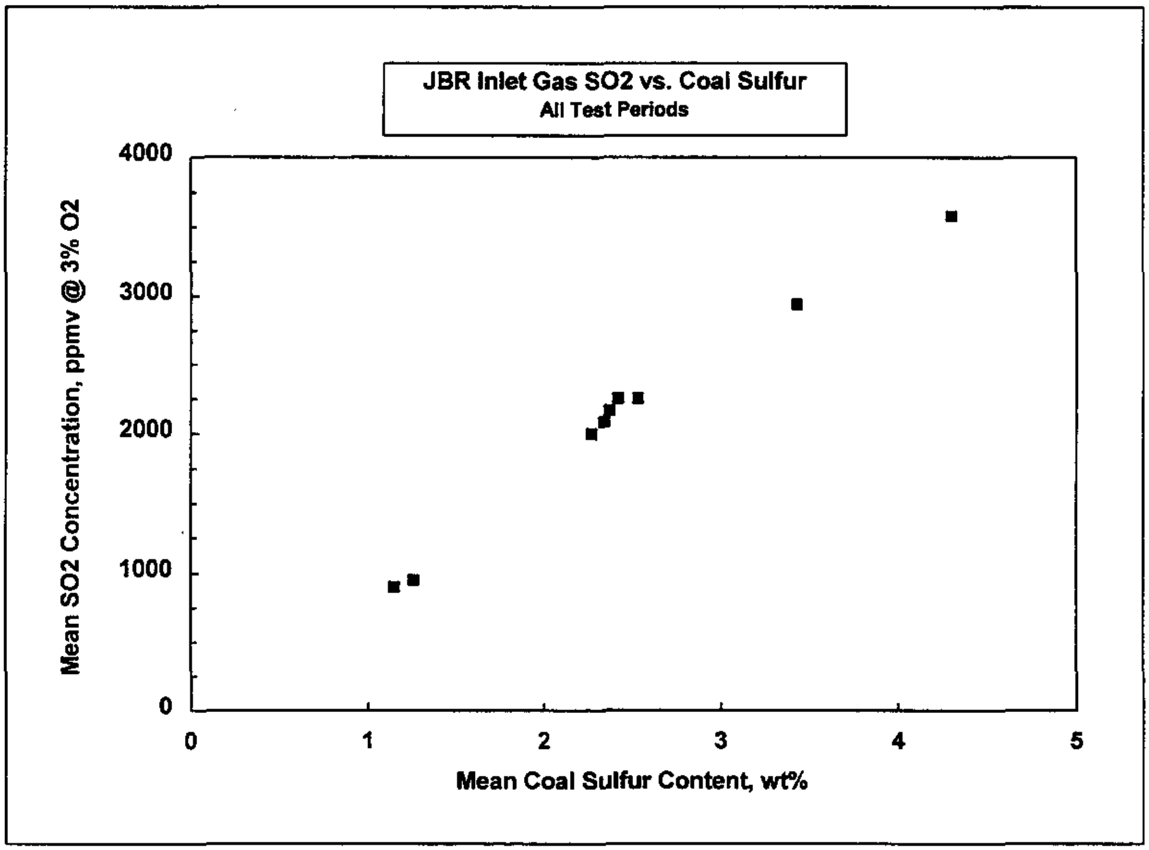


Figure 3-37. Effect of Coal Sulfur Content on JBR Inlet Gas SO_2 Concentration

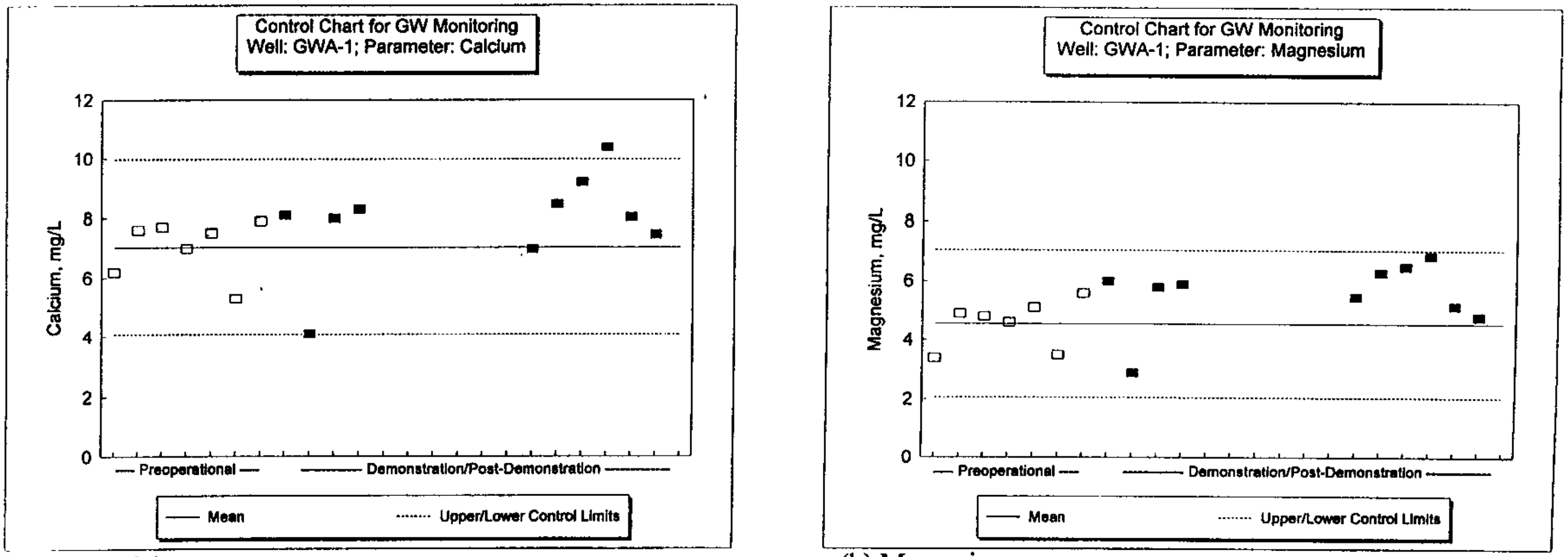
3.4 Groundwater Monitoring Results

Groundwater from monitoring wells located near the perimeter of the gypsum stacking area was monitored once every two months from September 1990 through July 1991, once in September 1992 (following a delay in the initiation of Low-Particulate testing), and quarterly beginning in the fourth quarter of 1992. Monitoring continued for two years following the completion of the CT-121 demonstration (i.e., through the fourth quarter of 1996). Tables containing the complete set of data from the groundwater monitoring through the third quarter of 1996 are provided in Appendix C.

The Shewhart control chart method was used to help determine whether the material in the gypsum stacking area is having an impact on groundwater quality.(5) The monitoring data from the period prior to the initiation of the scrubber demonstration (i.e., the preoperational period) were used to determine mean values and ranges for a selected set of representative monitoring parameters. The representative parameters were those present in appreciable concentrations in the JBR draw-off slurry, including the major cations and anions (i.e., calcium, magnesium, chloride, sulfate, sodium, silicon, barium, and nitrate/nitrite), as well as several other indicator parameters including pH, total dissolved solids, specific conductance, and alkalinity.

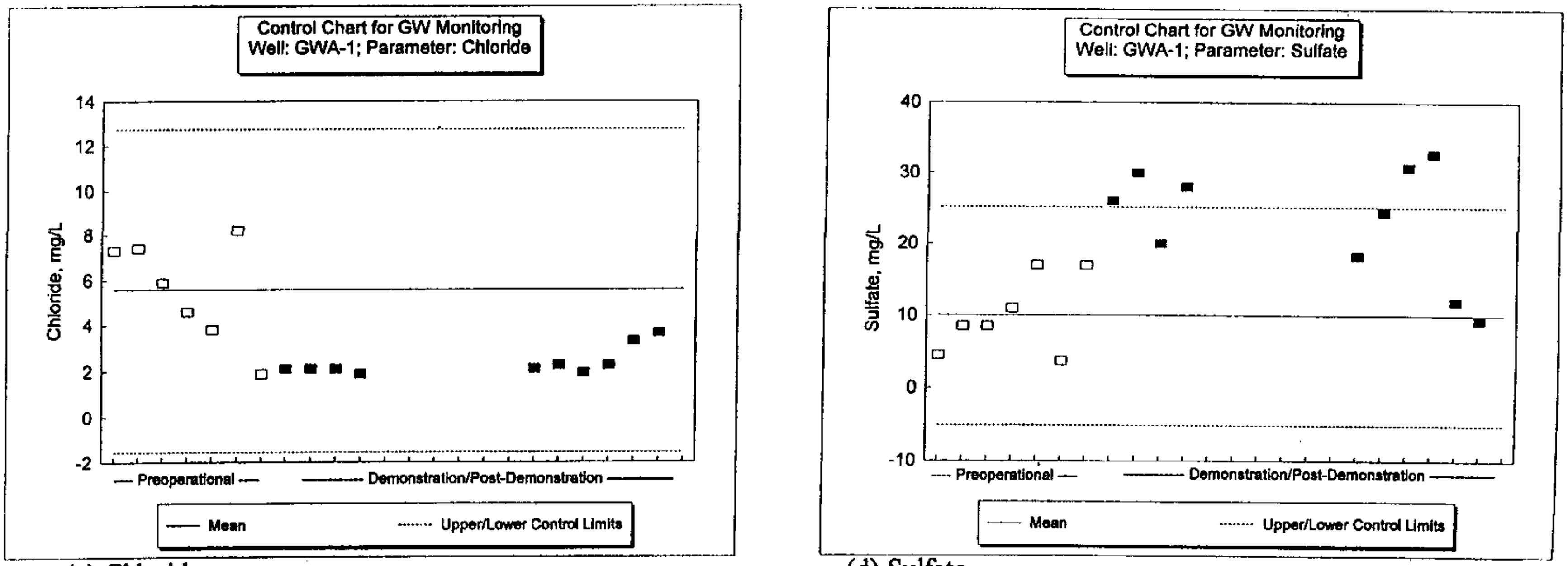
When the value for any given groundwater monitoring parameter was found to be consistently outside the control chart confidence intervals, it was assumed that a significant change had occurred in the value for that parameter. A single exceedance for a given monitored parameter served as an indicator of possible change, and particular attention was paid to the value obtained during the next quarter's monitoring for that parameter. To minimize the probability of falsely inferring that a change in groundwater composition had occurred, 3-sigma confidence intervals around the mean were computed.

A complete set of control charts for each of the 12 selected parameters for each of groundwater monitoring wells is provided in Appendix D. Example control charts for key species are provided in Figures 3-38 through 3-40. Data are presented for the upgradient well, GWA-1, and two



(a) Calcium

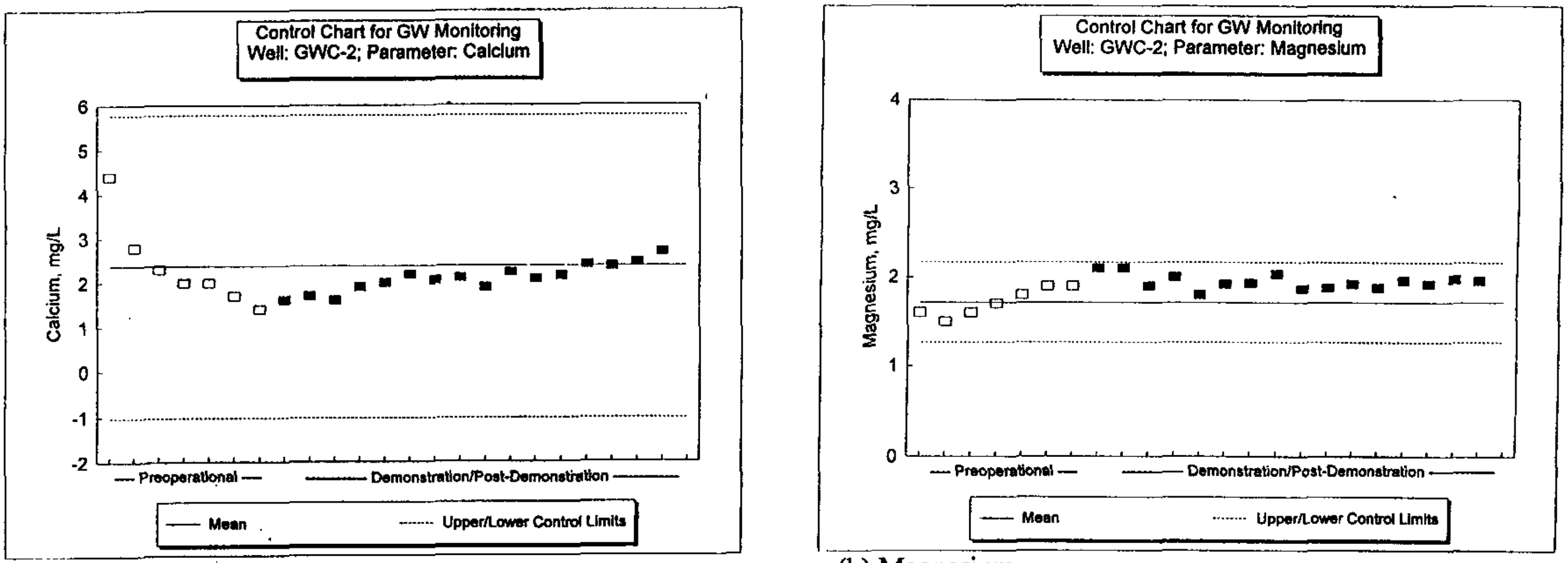
(b) Magnesium



(c) Chloride

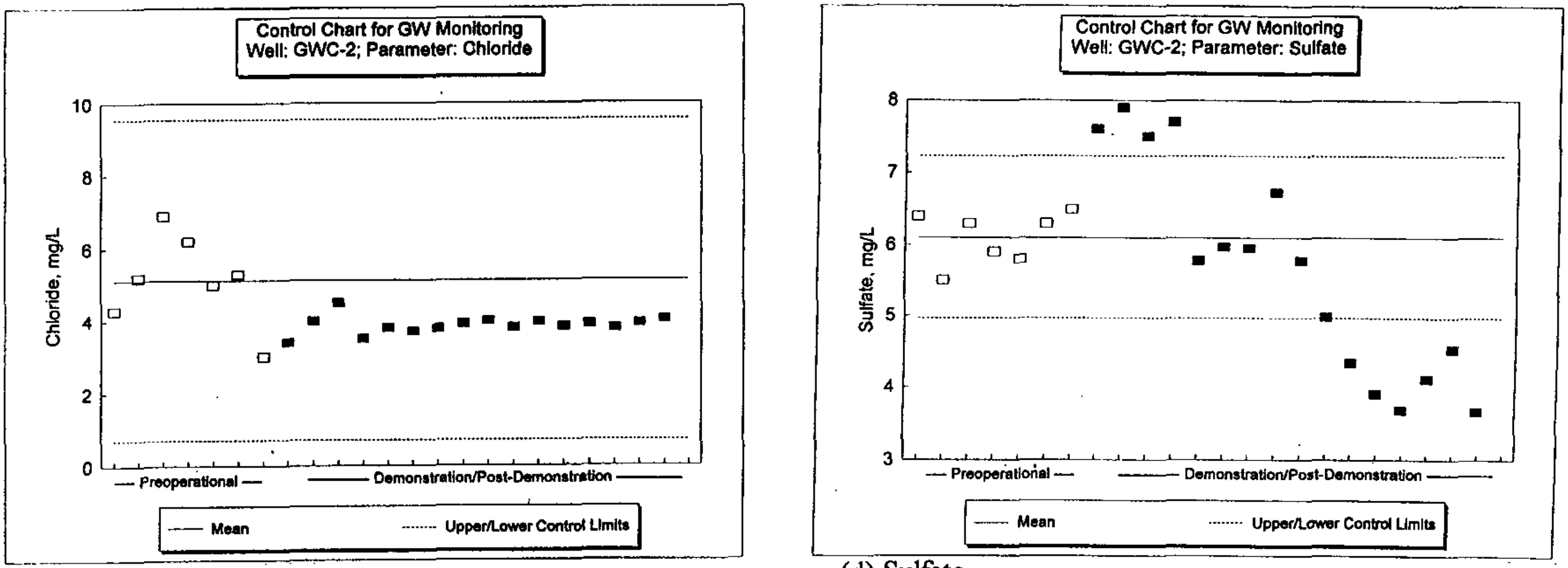
(d) Sulfate

Figure 3-38. Control Charts for Representative Species from Well GWA-1 (Upgradient)



(a) Calcium

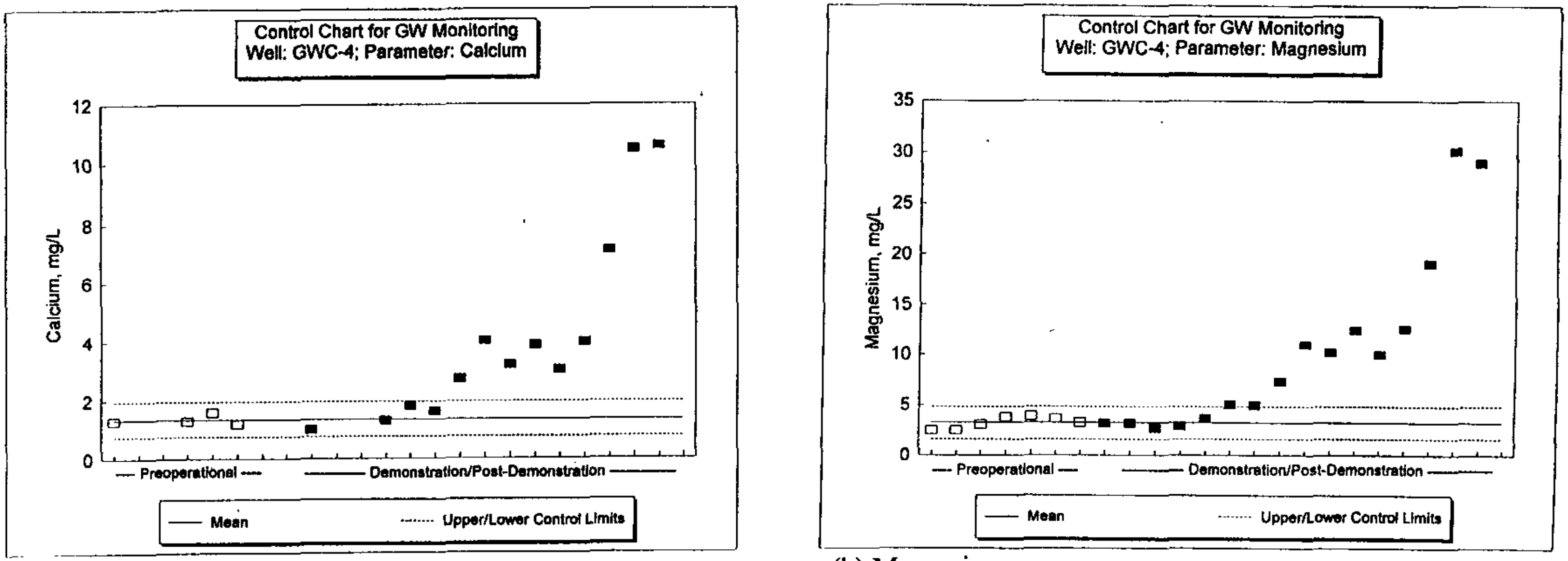
(b) Magnesium



(c) Chloride

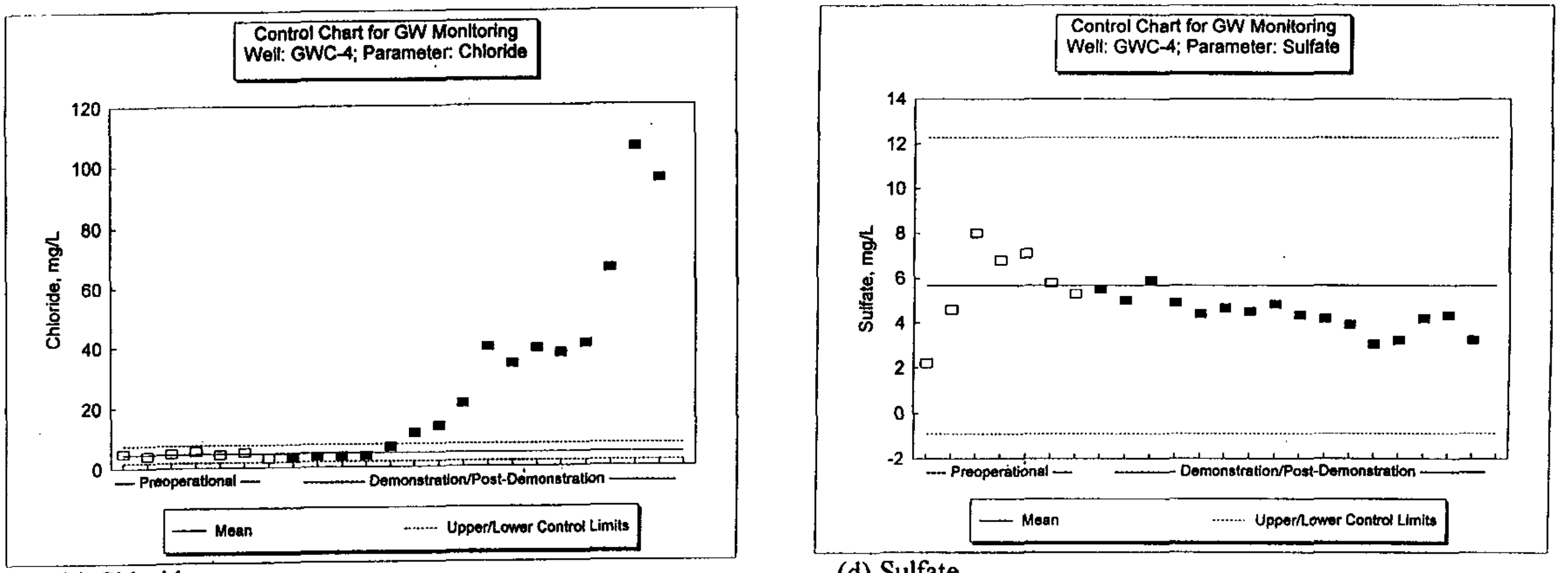
(d) Sulfate

Figure 3-39. Control Charts for Representative Species from Well GWC-2 (Downgradient)



(a) Calcium

(b) Magnesium



(c) Chloride

(d) Sulfate

Figure 3-40. Control Charts for Representative Species from Well GWC-4 (Downgradient)

downgradient wells, GWC-2 and GWC-4. The locations of these and other groundwater monitoring wells were shown previously in Figure 2-1.

Based on an inspection of the control charts, the concentrations of chloride, magnesium, and calcium in the water from downgradient well GWC-4 have shown significant increases over the concentrations of these species measured during the preoperational period. A generally upward trend in the concentrations of these gypsum constituents was first noticed in the fourth quarter of 1993. There have been no significant increases in the levels of these species in either the upgradient well or the other downgradient wells.

The source(s) of the higher levels of gypsum constituents in well GWC-4 is (are) not clearly apparent. However, there are several potential sources, and three of the more plausible are briefly described below:

- A breach of the dike surrounding the gypsum pond occurred on July 24, 1993. The breach happened in the vicinity of well GWC-4. Since the increase in the levels of chloride, magnesium, and calcium in GWC-4 was first noticed in the fourth quarter of 1993, it seemed likely that the increase was the result of the dike breach. The validity of this assumption appeared to be reinforced in the first quarter of 1995, when the levels of the three species declined in GWC-4. Such a decline would be expected as the amount of spilled material remaining in the soil diminished due to gradual downward migration in the soil. However, no further decrease in the GWC-4 concentrations occurred over the following three quarters of 1995. In fact, further increases in the levels of chloride, magnesium, and calcium were noted in the first and second quarters of 1996; the concentrations measured during the third quarter of 1996 were similar to those from the second quarter. Although this behavior could still be due to the 1993 breach (e.g., due to changes in rainfall patterns and/or acidity of the rain that could cause higher migration rates and/or increased leaching of the soil), other factors could be contributing to or causing higher levels of gypsum constituents in the groundwater in the vicinity of GWC-4.

- The groundwater sampling team has noticed that there appear to have been periodic leaks from a slurry pump and associated valves and fittings that are in close proximity (i.e., within 30-40 feet) to GWC-4. Slurry has periodically leaked onto the ground and flowed across the soil surface to form small pools within 10-15 feet of GWC-4. This material could be the source of at least some of the increased levels of chloride, magnesium, and calcium observed during the first three quarters of 1996.

- The possibility that the increased levels of the gypsum slurry constituents in GWC-4 could be caused by a leak in the liner under the gypsum stacking area cannot be discounted. There is no indication of leakage in the monitoring results from the other wells, but this does not preclude the presence of a liner leak at a location immediately upgradient from GWC-4.

At this time, it is not possible to determine which, if any, of the possible causes described above is contributing the bulk of the chloride, etc., being seen in GWC-4. Some clarification may be forthcoming as more results of the continuing groundwater monitoring activities become available.

3.5 Quality Assurance/Quality Control

The environmental monitoring plan for the CT-121 demonstration project at Plant Yates included a quality assurance/quality control plan. That plan described procedures for producing data of acceptable quality, including:

- Adherence to accepted sampling and analytical methods;
- Adequate documentation and sample custody procedures; and
- Quality assurance measures.

This section presents the results from each of these QA/QC procedures that were performed during either Low- or High-Particulate test periods.

3.5.1 Adherence to Accepted Methods

The sampling and analytical methods specified in the EMP were summarized in Section 2 of this report. As noted, the specified procedures were used with only a few exceptions; the alternate methods were used because they offered advantages such as improved detection limits or longer sample holding times.

Compliance with analytical method protocols by personnel conducting groundwater sampling and by the on-site laboratory personnel was assessed as part of technical systems audits conducted by Radian Corporation personnel during the 1st quarter of 1993 and 2nd quarter of 1994. Complete reports of both audits were included as appendices to quarterly EMP progress reports. The 1993 audit found no deficiencies in the groundwater monitoring; sample collection and documentation procedures specified in the Groundwater Monitoring Test Plan had been effectively implemented. Procedures and quality control practices had also been implemented in the on-site laboratory but several recommendations were made, including consistent use of these procedures and additional personnel training. There were no formal recommendations requiring responses.

The purpose of the 1994 audit was to assess compliance of the project's on-site laboratory with quality control procedures and practices that had been established and implemented for the project. The auditing personnel observed the collection and analysis of scrubber process samples. All of the QC procedures established for the laboratory had been implemented and were being complied with, and an appropriate level of quality control was practiced. No major problems were observed, and no formal recommendations requiring responses were made.

3.5.2 Documentation and Sample Custody

For compliance monitoring, the documentation and custody procedures that are part of the state-approved compliance monitoring programs for Plant Yates were followed during EMP activities. Procedures for documentation and sample custody for supplemental monitoring were reviewed as part of the 1993 technical systems audit, as discussed above. No major problems were found; some minor recommendations were made of improvements to log book formats.

Documentation for instrument calibration checks and related maintenance activities were recorded in five log books that were maintained on site at Plant Yates:

1. CEM flow rates and gas concentrations;
2. pH instrument calibrations;
3. ΔP cells;
4. Density measurements; and
5. Flow meters.

3.5.3 Quality Assessment Measures

Quality assessment measures performed as part of the EMP for the CT-121 demonstration project included 1) duplicate tests; 2) comparison of SO_2 measurements by the CEMs and EPA Method 6; 3) duplicate groundwater samples and duplicate analyses; and 4) analysis of groundwater sample splits by two independent laboratories. The results obtained from each of these measures are summarized below.

3.5.3.1 Duplicate Tests

A measure of the reproducibility of the SO_2 removal test results was obtained by performing duplicate tests. Key operating parameters such as unit load and scrubber operating conditions (i.e., JBR pressure drop and slurry pH) were duplicated to the extent possible for these tests. Because of differences in the JBR inlet gas SO_2 concentrations caused by variations in coal sulfur content, the SO_2 removal efficiency data for a given set of tests were normalized to a common inlet SO_2 concentration using the scrubber performance model. This model was developed by regressing the parametric data obtained during the demonstration project, so that direct comparisons of performance could be made. The results shown in Table 3-12 are from tests conducted during both test periods, and show good agreement between duplicate tests for all but a few of the High-Particulate Parametric tests. The High-Particulate tests were conducted with the ESP partially de-energized, which resulted in progressive increases in JBR fouling over time due to the presence of excess fly ash solids. The impact of this progressive fouling on SO_2 removal can be clearly seen where extended period of time elapsed between duplicate tests, such as tests P2-6 and P2-31, and P2-12 and P2-26.

TABLE 3-12
REPLICATE TEST RESULTS: LOW- AND HIGH-PARTICULATE TEST PERIODS

Test No.	SO_2 Removal, %	Replicate Test No.	SO_2 Removal, %	% RPD [a]	Replicate Test No.	SO_2 Removal, %	% RPD
Low-Particulate Parametric Tests [b]							
P1-1	74.5	P1-22	74.0	0.7			
P1-2	91.3	P1-23	89.7	1.8			
P1-3	97.0	P1-24	96.1	0.9			
P1-19	81.6	P1-19R	78.5	3.9			
P1-20	94.2	P1-20R	93.8	0.4			
P1-21	98.4	P1-21R	98.2	0.2			
P1-35	86.3	P1-36	87.7	1.6			
Low-Particulate Alternate Limestone Tests [b]							
P1B-2	97.5	P1B-2R	96.9	0.6			
P1B-6	98.1	P1B-6R	98.3	0.2			
P1B-9	94.1	P1B-9R2	88.4	6.2	P1B-9R3	95.2	1.2
P1B-10	82.0	P1B-10R	76.5	6.9			
High-Particulate Parametric Tests [b]							
P2-6	64.5	P2-31	52.4	20.7			
P2-7	88.4	P2-33	87.5	1.0	P2-33R	77.5	13.1
P2-8	88.6	P2-16	82.0	7.8			
P2-9	95.9	P2-18	94.5	1.5			
P2-12	88.6	P2-26	70.9	22.2			
High-Particulate High Removal Tests [c]							
HR2-3	98.3	HR2-4	98.6	0.3			
High-Particulate Alternate Coal Tests [d]							
AC2-2	90.4	AC2-10	82.4	9.3			
AC2-5	78.6	AC2-5R	75.2	4.4			
High-Particulate Alternate Limestone Tests [c]							
AL2-1	97.8	AL2-1R	98.0	0.2			
AL2-3	97.7	AL2-3R	99.0	1.3			

[a] %RPD = Relative Percent Difference = $\frac{[\text{Larger Value} - \text{Smaller Value}]}{[\text{Larger Value} + \text{Smaller Value}]/2}$

[b] SO_2 removal efficiencies normalized to 2200 ppmv @ 3% O_2 in the flue gas inlet to the JBR.

[c] SO_2 removal efficiencies normalized to 1000 ppmv @ 3% O_2 in the flue gas inlet to the JBR.

[d] SO_2 removal efficiencies normalized to 3000 ppmv @ 3% O_2 in the flue gas inlet to the JBR.

3.5.3.2 SO_2 Measurements by CEMs and EPA Method 6

A measure of the accuracy of the SO_2 measurements obtained using the CEMs was provided during the first nine Low-Particulate Parametric tests when SO_2 concentrations in the flue gas inlet to the JBR and the stack gas were also measured using EPA Method 6. The average CEM and Method 6 results for each of these tests are shown in Table 3-13. The average percent difference in SO_2 concentration measured by the JBR inlet duct instrument and by Method 6 was 3.8 percent. The average percent difference between the stack concentrations measured by the CEM and those measured by Method 6 was 4.9 percent. At both locations, the CEM concentration measurements were lower than the levels measured by Method 6. Based on these results, the quality of the SO_2 concentration data obtained by the CEMs was judged to be adequate for the purposes of this project.

TABLE 3-13
COMPARISON OF AVERAGE SO_2 MEASUREMENTS BY CEM AND METHOD 6

	JBR Inlet Gas			**Stack Gas**		
Test No.	**CEM**	**Method 6**	**% Diff.** [a]	**CEM**	**Method 6**	**% Diff.** [a]
P1-1	2158	2286	-5.6	528	538	-1.9
P1-2	2185	2288	-4.5	188	205	-8.3
P1-3	2180	2267	-3.8	63	71	-11.3
P1-4	2156	2279	-5.4	388	385	0.8
P1-5	2166	2188	-1.0	120	128	-6.3
P1-6	2220	2314	-4.1	49	49	0.0
P1-7	2329	2376	-2.0	282	311	-9.3
P1-8	2323	2444	-5.0	95	106	-10.4
P1-9	2355	2421	-2.7	46	45	2.2
Average Difference			-3.8	Average Difference		-4.9

Units: ppmv @ 3% O_2.

[a] % Difference = [(CEM - Method 6)/Method 6] x 100 percent.

3.5.3.3 Groundwater Sample and Analytical Duplicates

An assessment of the quality of the groundwater monitoring data was made using duplicate samples and duplicate analyses. The complete results of these replicate analyses were included in the quarterly groundwater monitoring reports. An overall summary for the groundwater monitoring performed from the first-quarter 1993 through the third-quarter 1996 is provided in Appendix E for those analytical parameters that were present above detection limits. In general, acceptable accuracy was obtained for most parameters. When larger differences were observed between sample or analytical replicates, the parameters were typically present at concentrations less than five times the detection limit, where less accurate results can be expected, or the parameters were detected in the method blank.

Specifically, the difference between sample duplicates was less than 20% for nearly three quarters of the duplicate analyses performed. Of those duplicate analyses where the difference was greater than 20%, roughly two-thirds occurred when the parameter concentrations were less than five times the detection limit in both the sample and the field duplicate. Of the duplicate analyses performed on the field duplicate samples, there were only three instances where the relative percent difference exceeded the specified limit; in these cases the analytical parameters (TOX and TDS) were present at concentrations less than five times the method detection limit.

3.5.3.4 Groundwater Analyses by Independent Laboratories

During each groundwater monitoring campaign, sample splits were provided for analysis by both Radian and Savannah Laboratories, an independent laboratory selected by SCS. The results for all groundwater monitoring campaigns through the fourth quarter of 1996 were compared by computing the relative percent differences (RPDs) for species that were analyzed by both laboratories. Overall statistics based on these comparisons are provided in Table 3-14. Note that RPDs were not calculated for those species not measured above method detection limits by either laboratory. The mean RPDs were less than 20% for four of the seven detected analytes, which corresponds to the goal of Radian's laboratory for duplicate sample analyses. A higher average

TABLE 3-14
COMPARISON OF GROUNDWATER MONITORING BY INDEPENDENT LABORATORIES

Parameters [b]	Relative Percent Difference Statistics [a]		
	% RPD		Percent of Data
	Mean	Range	RPD ≤ 20%
Specific Conductance	16.1	0.0 - 97.1	78
Chloride	16.9	0.0 - 158.7	72
Sulfate	29.3	0.0 - 129.7	59
Calcium	11.9	0.0 - 81.6	83
Nitrate-Nitrite	32.1	0.0 - 192.9	63
Strontium	13.0	0.0 - 89.9	78
Total Dissolved Solids	22.4	0.0 - 111.1	63

[a] Relative Percent Difference (RPD) is defined as follows:

$$\text{RPD} = \frac{(\text{Larger Value - Smaller Value}) \times 100\%}{(\text{Larger Value + Smaller Value})/2}$$

[b] Additional parameters not measured above detection limits by either laboratory included fluoride, arsenic, boron, chromium, lead, mercury, selenium, uranium, and TOC.

RPD was found for sulfate, nitrate-nitrite, and total dissolved solids. In the majority of cases, the calculated RPDs were less than 20% for all detected parameters. The average RPDs were over 20% for sulfate, nitrate-nitrite, and TDS because of a relatively small number of data points where the calculated RPDs were large. These parameters were typically present at low concentrations, where analytical accuracy can be expected to be lower, and where small absolute differences can translate into large percentage differences. Based on these results, the groundwater monitoring data should be of sufficient quality to meet the purposes of the project.

3.6 Compliance Reporting

During the CT-121 demonstration project's two testing periods, compliance reports were submitted by Georgia Power Company to the Environmental Protection Division of the Georgia Department of Natural Resources (DNR), in accordance with the requirements of Plant Yates' Source 1 (Comprising Units 1-3) air operating permit (No. 4911-038-4833-0), as amended; and of Plant Yates' NPDES permit (Permit No. GA0001473). The air operating permit was amended effective December 28, 1990 to account for the CT-121 system. In addition, as part of the conditions of the DNR-issued permit for the gypsum stacking area, monitoring of the groundwater is required before, during, and for two years after the demonstration.

Copies of the compliance reports have been included as appendices to the quarterly and annual EMP reports for this project.

3.6.1 Summary of Quarterly Air Emission Reports

Plant Yates' air operating permit requires weekly monitoring of coal feed composition (i.e., sulfur, ash, moisture, and heating value), annual particulate matter emissions (as total particulate loading), and continuous monitoring of the opacity of the flue gas inlet to the JBR. A summary of the opacity exceedance data for the Low-Particulate testing period was presented earlier in this section. As mentioned previously, a variance to the opacity monitoring requirement was obtained for the duration of the High-Particulate testing period.

In addition, semiannual progress reports on the CT-121 project were submitted as required under the amended air operating permit. These reports discussed project activities and plans and contained a table of SO_2 removal efficiency data; all of the information contained in the semiannual reports has been incorporated into this EMP Final Report.

3.6.2 Summary of Quarterly Operational Monitoring Reports

Plant Yates' NPDES permit requires that the pH and concentrations of suspended solids and oil and grease be monitored twice a month for various aqueous discharge streams. Groundwater is monitored quarterly for anions, TOC, and metals; and semiannually for radionuclides. A summary of the data from the operational monitoring reports for those discharge streams that could have been affected by the CT-121 demonstration project was presented earlier in this section.

4.0 CONCLUSIONS

With the few exceptions discussed earlier in this volume, environmental monitoring was performed as described in the CT-121 demonstration project's Environmental Monitoring Plan. The following conclusions can be drawn from this project's environmental monitoring results:

- The CT-121 demonstration scrubber was capable of removing well over 90% of the flue gas SO_2 during parametric tests conducted using the 2.5% sulfur baseline coal. SO_2 removal efficiency was found to increase with increasing scrubber slurry pH and JBR deck pressure drop and to decrease with increasing boiler load and scrubber inlet flue gas SO_2 concentration. Progressive reductions in SO_2 removal efficiency were also observed as a result of JBR fouling over time. Scrubber modifications helped alleviate fouling-related changes in removal efficiency.

- The average SO_2 removal efficiency achieved during the Low-Particulate Long-Term load-following tests was nearly 94%, although it was necessary to operate at somewhat higher pH and pressure drop than originally expected. During the High-Particulate Long-Term test block, the average SO_2 removal efficiency was over 93%, partly due to abnormally low average boiler load demand. As expected, the impact of scrubber fouling due to high ash loading was also more pronounced during this test block. In addition, the scrubber pH set point had to be lowered to minimize the impact of aluminum fluoride blinding on limestone dissolution.

- SO_2 removal efficiencies greater than 97% were achievable during both Low- and High-Particulate tests by operating the scrubber at very high pH and JBR deck pressure drop set points.

- Similar SO_2 removal efficiencies were obtained during tests conducted with limestone from three different sources. Much greater variation in gypsum dewatering properties was found among the limestones used. This was an important factor leading to a change in the main program limestone following the Low-Particulate Alternate Limestone test block.

- Even when a 4.3% sulfur coal was used (well above the scrubber design value of 3.0% sulfur), the CT-121 scrubber achieved over 90% SO_2 removal efficiencies at most test conditions during Low- and High-Particulate operation. As expected, the SO_2 removal efficiency achieved at a given set of operating conditions was lower while burning the 4.3% sulfur than while burning the 2.5% sulfur baseline coal.

- The particulate matter loading in the JBR outlet gas was always well below the Plant Yates permit limit of 0.24 lb/MMBtu, even during High-Particulate tests. Except when operating with the ESP fully de-energized, the combined ESP/JBR was able to achieve particulate matter loadings below the 0.03 lb/MMBtu level specified in the federal New Source Performance Standard.

- The scrubber was found to be relatively inefficient in removing particles with an aerodynamic diameter smaller than 1 micrometer. The particle size distribution measured in the JBR outlet gas was relatively insensitive to changes in boiler load at a given JBR pressure drop.

- Sulfur trioxide (SO_3) concentrations in the JBR inlet and outlet gas streams were typically in the range from 1 to 4 ppmv (@ 3% O_2). There was little or no change in SO_3 concentration across the JBR except during the High-Particulate tests when the ESP was completely de-energized, when apparent SO_3 removals of 70% or greater were achieved.

- As expected, the JBR outlet gas was typically saturated with water vapor.

- The average limestone slurry solids concentrations during both the Low- and High-Particulate test periods were similar: 29-30% by weight. All three limestones used during the demonstration consisted primarily of calcium carbonate. The three limestones differed in their concentrations of magnesium carbonate and inerts.

- The concentrations of chloride and sulfate ions in the gypsum stack return liquor were consistent with those expected of a scrubber system operating with a closed water balance, with changes thought to be due to dilution and/or differences in coal chorine content over time. Chloride ion concentrations showed considerably more variation that did sulfate; the sulfate concentration remained relatively constant at approximately 1,000 mg/L. The composition of the JBR froth zone and draw-off liquor were consistent with the composition of the gypsum stack return liquor.

- The JBR froth zone and draw-off solids concentrations averaged about 21% by weight during the Low-Particulate test period; they were somewhat lower on average (about 17-18% by weight) during the High-Particulate test period, primarily due to a lower scrubber solids set point used during the latter part of the period when low sulfur coal was used. Both solids consisted primarily of calcium sulfate; very low concentrations of sulfite were found, consistent with the high level of scrubber slurry oxidation expected for this scrubber. Low carbonate concentrations were also typically found, indicative of the high limestone utilization achieved at most test conditions.

- There were no exceedances of Plant Yates' NPDES permit limitations in the monitored aqueous discharge streams (i.e., ash transport water and final plant discharge).

- The concentrations of chloride, magnesium, and calcium in the water from downgradient well GWC-4 have shown significant increases over the

5.0 RECOMMENDATIONS

Recommendations based on the monitoring performed under the EMP for this demonstration project include the following:

- The use of the colorimetric method for aqueous stream nitrate-nitrite (EPA 353.1) is recommended over the use of ion chromatography, since it provides an improved detection limit as well as a longer sample holding time.
- The measurement of coal trace element concentrations using ASTM methods based on atomic absorption spectrophotometry is recommended over inductively coupled argon plasma emission spectrometry.
- The concentrations of gypsum species (i.e., calcium, magnesium, and chloride) that have increased over the levels observed during the preoperational period in groundwater monitoring well GWC-4 should continue to be monitored, and more definitive reasons for the increases should be determined. Corrective action should be taken, if needed.

6.0 REFERENCES

1. Southern Company Services, Inc. "Environmental Monitoring Plan: CT-121 Flue Gas Desulfurization Project at Plant Yates," Birmingham, AL, January 16, 1995.

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3. Southern Research Institute. "Particulate Sampling of CT-121 Wet Scrubber, Georgia Power Company Plant Yates Unit 1: ESP Operational Test Phase, January 21-31, 1993 Tests," Birmingham, AL, March 19, 1993.

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4. Gilbert, Richard O., "Statistical Methods for Environmental Pollution Monitoring," Van Nostrand Reinhold Company, New York, 1987, pp. 193-200.

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