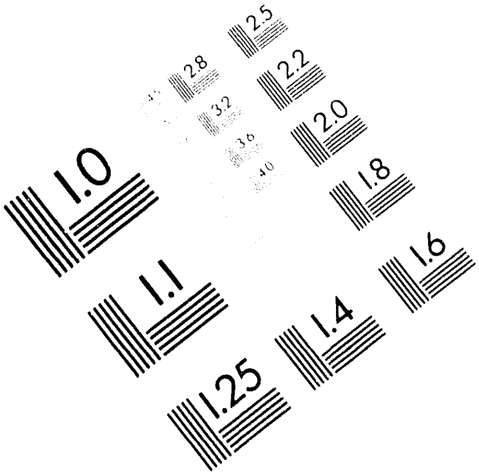

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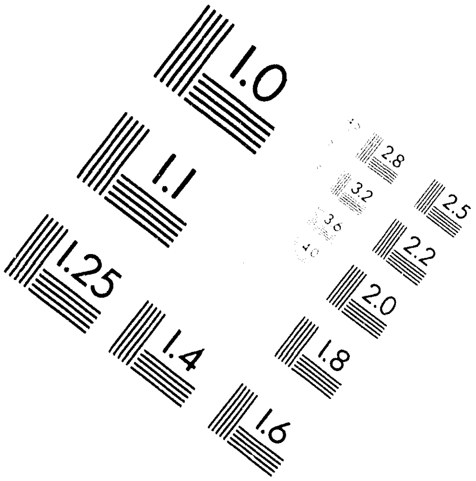

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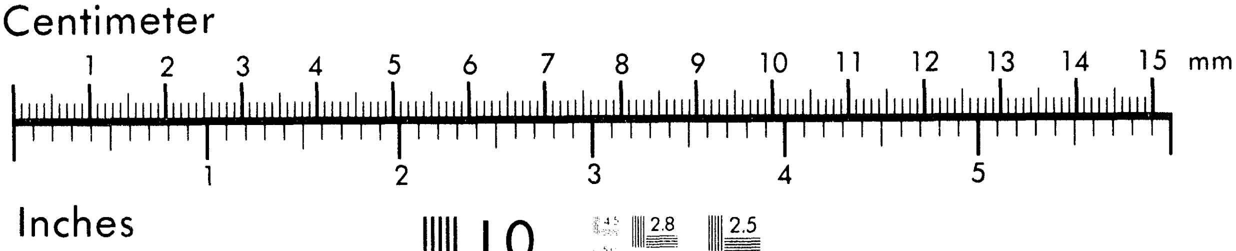

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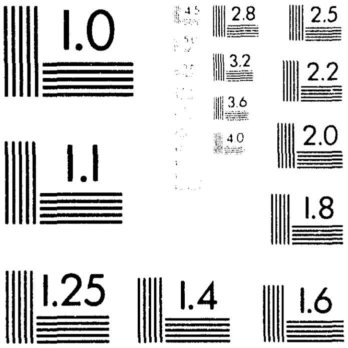

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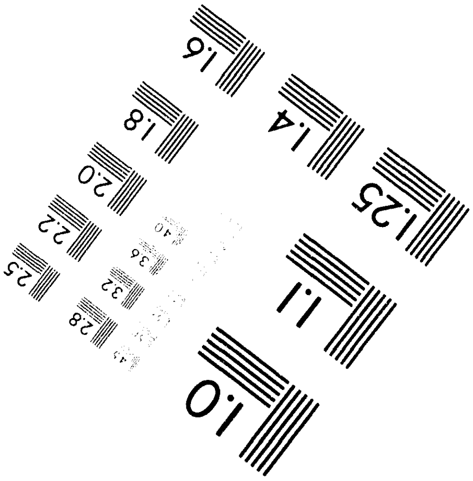

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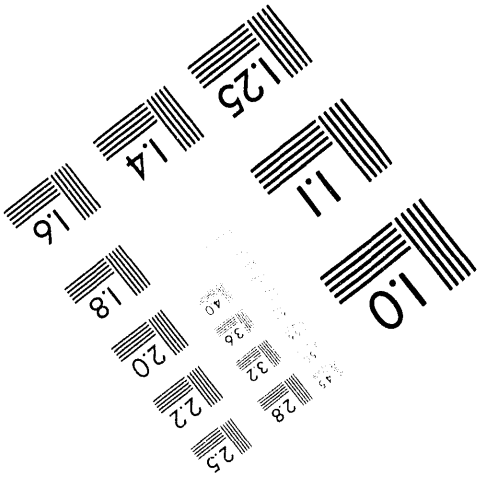

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High SO_2 Removal Efficiency Testing

DE-AC22-92PC91338

Technical Progress Report

January - March 1994

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28 April 1994

MASTER

1.0 INTRODUCTION

This document provides a discussion of the technical progress on DOE/PETC project number DE-AC22-92PC91338, "High Efficiency SO_2 Removal Testing", for the time period 1 January through 31 March, 1994. The project involves testing at six full-scale utility flue gas desulfurization (FGD) systems, to evaluate low capital cost upgrades that may allow these systems to achieve up to 98% SO_2 removal efficiency. The upgrades to be evaluated mostly involve using additives in the FGD systems. The "base" project involved testing at the Tampa Electric Company Big Bend station. All five potential options to the base program have been exercised by DOE, involving testing at the Hoosier Energy Merom Station (Option I), the Southwestern Electric Power Company (SWEPCo) Pirkey Station (Option II), the PSI Energy Gibson Station (Option III), the Duquesne Light Elrama Station (Option IV), and the New York State Electric and Gas Company Kintigh Station (Option V). By the end of March 1994, testing has been completed for the base project and for Options I through IV, but has not yet begun for Option V.

The remainder of this document is divided into four sections. Section 2, Project Summary, provides a brief overview of the status of technical efforts on this project. Section 3, Results, summarizes the outcome from these technical efforts during the quarter. Results for each site for which there were significant technical efforts are discussed in separate subsections. In Section 4, Plans for the Next Reporting Period, an overview is provided of the technical efforts that are anticipated for the second quarter of calendar year 1994. Section 5 includes a brief acknowledgment.

2.0 PROJECT SUMMARY

On the base program, testing was completed at the Tampa Electric Big Bend Station in November 1992. The upgrade option tested was DBA additive. Project efforts during the first quarter of calendar year 1994 primarily consisted of project management activities and reporting.

For Option I, at the Hoosier Energy Merom Station, results from another program co-funded by the Electric Power Research Institute (EPRI) and the National Rural Electric Cooperative Association are being combined with results from DOE-funded testing. Three upgrade options have been tested: DBA additive, sodium formate additive, and high pH set point operation. All testing was completed by November, 1992. Project efforts during the current quarter were also primarily in data reduction and reporting.

Option II has involved testing at the Southwestern Electric Power Company Pirkey Station. Baseline testing was conducted in February 1993. Both sodium formate and DBA additives were tested as potential upgrade options at Pirkey. Parametric testing was conducted with DBA additive in March 1993 and with sodium formate in April 1993. Based on results from these parametric tests, DBA appeared to be the more attractive upgrade option for this site. Consequently, a DBA additive consumption test was conducted in May 1993. No sodium formate additive consumption test is to be conducted. There were only reporting activities for this site during the current quarter.

On Option III, for testing at the PSI Energy Gibson Station, baseline testing was conducted in May 1993. Parametric testing with sodium formate additive began in September 1993 and was completed with the conclusion of a sodium formate consumption test in early October 1993. These results were discussed in the previous quarterly Technical Progress Report. A DBA additive performance and consumption test was conducted in late February through mid-March 1994. Preliminary results from these tests are discussed in Section 3 of this progress report.

Option IV is for testing at the Duquesne Light Elrama Station. The FGD system employs magnesium-enhanced lime reagent and venturi absorber modules. Baseline testing was completed in July 1993. An EPRI-funded model evaluation of potential upgrade options for this FGD system, along with a preliminary economic evaluation, determined that the most attractive upgrade options for this site were to increase thiosulfate ion concentrations in the FGD system liquor to lower oxidation percentages and increase liquid-phase sulfite alkalinity, and to increase the venturi absorber pressure drop to improve gas/liquid contacting. Parametric testing of these upgrade options was conducted in late March 1994. Preliminary results from these tests are also discussed in Section 3 of this progress report.

Option V, for testing at the New York State Electric and Gas Company Kintigh Station, was exercised in September 1993. There were no significant efforts related to this testing during the current quarter.

3.0 RESULTS

Results from the base program (at the Tampa Electric Big Bend Station) and the first optional site (Hoosier Energy Merom Station) were presented in detail in the April 1993 quarterly Technical Progress Report, and updates were included in the July 1993 and September 1993 reports. For the second optional site (the Southwestern Electric Power Company Pirkey Station), results were presented in the July 1993 quarterly Technical Progress Report and updated in the September 1993 report. These sites will not be discussed further in this report.

For the third optional site (the PSI Energy Gibson Station), baseline testing was conducted in May 1993, and those results were presented in the July 1993 quarterly report. Parametric testing at this site was completed in early October, and these results were discussed in the January 1994 Technical Progress Report. A DBA performance and consumption test was conducted at this site in February and March 1994. Preliminary results from this test are discussed below.

Baseline testing at the fourth optional site (Duquesne Light's Elrama Station) was completed in July 1993. Those results were discussed in the September 1993 quarterly report. The results of EPRI-funded FGDPRISM modeling and preliminary economic evaluations of potential upgrades for this FGD system were discussed in the previous, January 1994 Technical Progress Report. During the current quarter, parametric testing of the most promising upgrade options was conducted. These results are also discussed below.

For the fifth optional site (the New York State Electric and Gas Company's Kintigh Station), there were have been no technical efforts yet. The option was exercised by DOE in September 1993, but the host utility has not yet scheduled any of the planned testing for this site.

3.1 PSI Energy Gibson Station, Unit 5 Results

This subsection summarizes preliminary results from DBA performance and consumption tests at PSI Energy's Gibson Station. Parametric tests with DBA additive were begun on February 24th and completed on March 14, 1994. These results will be used to determine the economic viability of DBA addition compared to other options for enhanced SO_2 removal at this station.

3.1.1 System Description

PSI Energy's Gibson Generating Station is located in Gibson County near Owensville, Indiana. Figure 3-1 is a simplified flow diagram for a single module of the Gibson Unit 5 FGD system. Flue gas exits the boiler and passes through the ESP for particulate control. From the ESP, the flue gas passes through ID fans and booster fans and then into the FGD system. Four modules treat flue gas from the 650-MW unit. At full load, the unit can be operated with all four modules in service, or with only three modules in service and the fourth off-line as a spare.

The absorber modules are of the Kellogg/Weir horizontal configuration. In this configuration, flue gas flows horizontally through the rectangular cross-section absorber vessel. Recirculating slurry is introduced through spray headers at the top of the absorber, so the spray is directed across the flue gas flow rather than countercurrent to the direction of gas flow as in most vertical spray towers. There are four spray headers on each absorber, with one slurry recirculation pump per header. At full-load and for high-sulfur-coal operation, all four pumps and spray headers are normally operated. Flue gas exiting the absorber section flows through a two-stage, horizontal-gas-flow mist eliminator to the stack. A portion of the flue gas bypasses all four absorbers and goes directly to the stack. The amount bypassed is minimized to decrease tendencies for the stack liner to "lean", which can be caused by large variations in the temperatures of flue gas streams entering the stack.

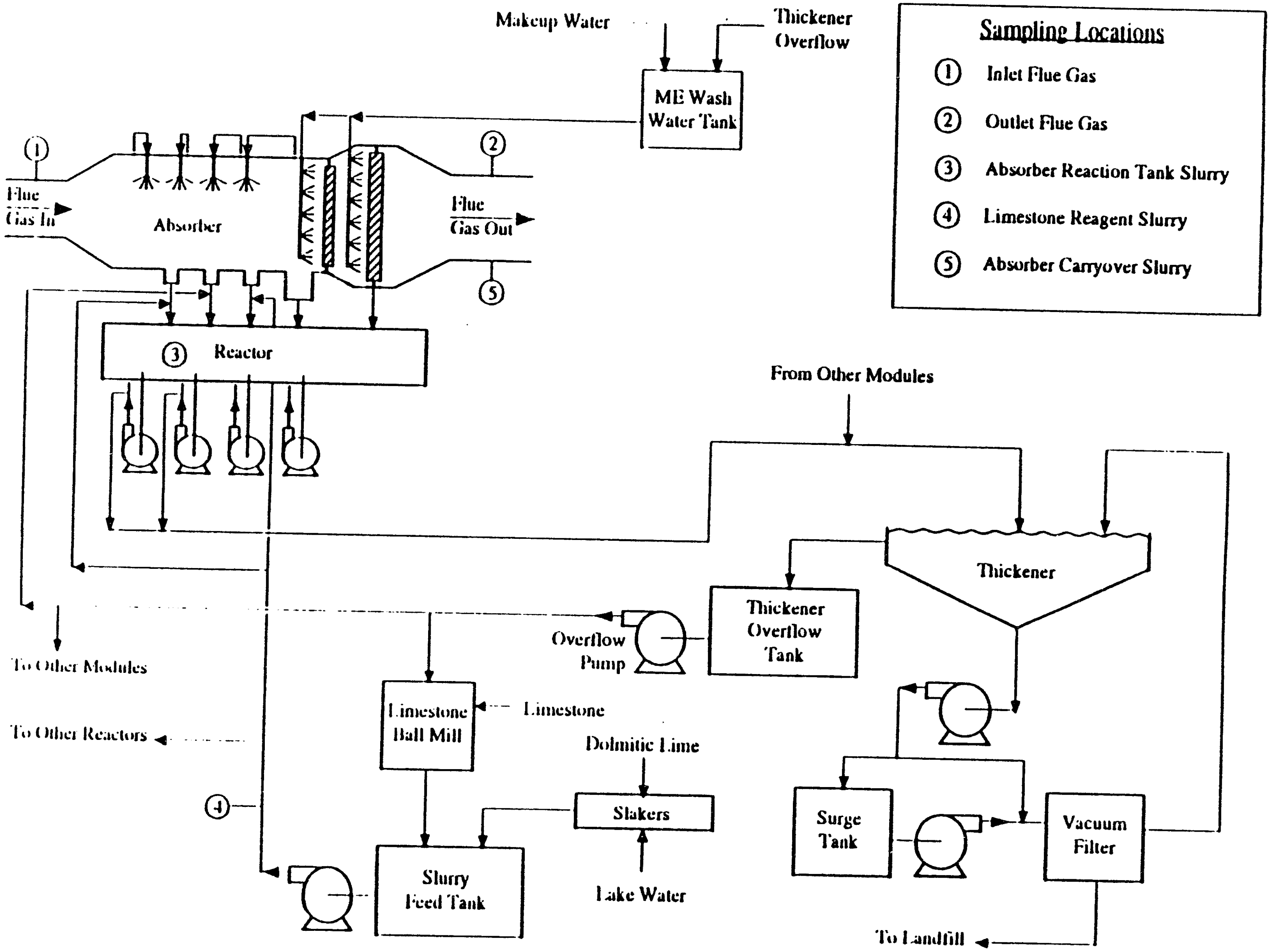

Figure 3-1. Flow Diagram for Gibson Station's FGD System

After contacting the flue gas, the recirculating slurry drains to a rectangular reaction tank below the absorber. Gibson Unit 5 operates in an inhibited-sulfite-oxidation mode. This was the first limestone FGD system to add elemental sulfur for in-situ generation of thiosulfate to inhibit sulfite oxidation. Waste slurry is bled to dewatering from the discharge of the first recycle pump (with respect to the direction of flue gas flow). Fresh limestone reagent slurry is fed to the opposite end of the tank. Dolomitic lime is slaked and mixed with the limestone slurry to introduce magnesium as an additive to increase SO_2 removal efficiency.

Waste slurry blowdown from the absorber is fed to either of two thickeners. The overflow from the thickeners flows to a reclaim-water tank. Concurrently, the underflow sludge is pumped to a surge tank and then to vacuum filters for secondary dewatering. The filtrate is sent to the reclaim-water tank, and the filter cake is sent to pug mills and blended with fly ash for on-site disposal. Reclaimed water from the thickeners and vacuum filters is used for limestone grinding, mist eliminator wash, and FGD system makeup.

The system normally achieves approximately 87% SO_2 removal. The normal sulfur content of the coal fired in Unit 5 is approximately 3.5%, which produces an inlet SO_2 loading to the FGD system of approximately 6 lbs SO_2 per 10^6 Btu. The approximate inlet SO_2 level for the consumption test was slightly higher, around 6.35 lbs SO_2 per 10^6 Btu.

3.1.2 Test Plan

The consumption tests were conducted on all four modules. An even gas flow was maintained to all four modules. If load dropped below 400-MW, a module was taken out of service. The booster fan power demand was varied with load to minimize the amount of flue bypass around the absorbers. The average load through the test period was 540-MW.

The DBA concentration was maintained at approximately 1300 ppm. This test was conducted with a pH set point of 5.4, which corresponds to a limestone utilization of approximately 85%. DBA was added to the limestone slurry storage tank to distribute the additive evenly throughout the FGD system.

During the consumption test, four inventories of the unit were taken by determining the DBA levels at the following locations:

- Modules A, B, C, and D:
- Limestone slurry tank;
- Process surge tank;
- Thickener;
- Thickener overflow tank; and
- Mist eliminator feed tank.

One DBA sample taken from each location was sent to Radian's laboratories in Austin for analysis by ion chromatography. The results of these off-site DBA analyses are not yet available. A separate set of samples was collected and analyzed on-site every day by buffer capacity titrations. This allowed the on-site engineer to track the DBA concentrations in the system and adjust the feed rate as necessary.

In addition to samples collected for DBA analysis, diluted filtrate samples were collected from Module A to characterize the chemistry of the FGD system. Slurry samples also were collected from Module A to characterize solids dewatering properties, limestone utilization, and sulfite oxidation. A sample of filter cake was collected every day for weight percent solids and solid-phase additive concentration analyses.

Other process data were collected from the FGD control room, including tank levels, fan amps, pump amps, unit load, outlet SO_2 concentration, and module slurry pH. The Gibson station also provided coal sulfur content data for this period.

3.1.3 Test Results

Test results available to date are presented below. Analytical data for samples taken during the test period are not yet available, so the results presented below are based on on-site measurements and should be considered "preliminary."

Process Data

Process data are available on-line for most of the scrubber process instrumentation. All of the data are stored on magnetic tape, and selected data can be printed for 5-minute intervals. Table 3-1 summarizes 12-hour average values for these data points.

DBA Consumption Test Performance

Additive consumption testing began on February 24th, and ended on March 14th. There were six days during the test when the unit was down, March 4th through 10th. Data were not collected during this time. The tests were completed at a normal pH of 5.4, and with four modules in service. The average load for the test period was 540-MW and the average stack SO_2 concentration was equivalent to 0.57 lb SO_2 per 10^6 Btu, respectively. The overall SO_2 removal averaged 91%, but the average absorber SO_2 removal was near the target value, approximately 97%. The overall SO_2 removal was lowered by the bypass of approximately 6.5% of the total unit flue gas flow. The absorber SO_2 removal performance was determined by observing stack SO_2 emission data during brief periods with no bypass, and confirmed by material balance based on the average amount of flue gas bypass.

Table 3-2 summarizes the DBA concentrations measured on site for each inventory during the consumption test. Diluted filtrates were collected for each module listed above for off-site measurement of DBA concentration by ion chromatograph. The

Table 3-1

Average Values for On-Line Process Data

Date	Time	Load	CO_2	SO_2 Out	Density A	Fan A	Fan B	Fan C	Fan D	pH A	pH B	pH C	pH D	Reagent (TPH)
2-21	mid-0700	302	9.3	0.88		76	78	82	84	5.38	5.34	5.39	5.39	23
2-21	0700-1900	586	11.7	0.81	15.8	88	81	90	89	5.42	5.43	5.42	5.42	29
2-22	1900-0700	496	10.9	0.64	19.0	83	82	86	71	5.45	5.35	5.38	5.62	29
2-22	0700-1900	629	11.8	0.56	20.6	89	85	91	90	5.41	5.40	5.39	5.42	30
2-23	1900-0700	514	10.7	0.55	20.3	81	83	86	86	5.47	5.48	5.40	5.45	30
2-23	0700-1900	612	10.3	0.61	20.1	87	86	90	88	5.44	5.41	5.40	5.44	29
2-24	1900-0700	532	9.8	0.55	21.1	82	83	87	88	5.46	5.37	5.40	5.47	30
2-24	0700-1900	627	11.2	0.62	21.4	87	86	90	89	5.45	5.39	5.41	5.50	28
2-25	1900-0700	532	11.1	0.51	22.1	83	83	87	87	5.43	5.44	5.48	5.45	28
2-25	0700-1900	601	12.2	0.54	22.2	87	84	90	88	5.45	5.44	5.46	5.45	28
2-26	1900-0700	565	12.3	0.51	22.1	83	84	87	87	5.43	5.37	5.46	5.44	27
2-26	0700-1900	581	11.1	0.43	21.5	84	85	89	88	5.48	5.42	5.38	5.47	29
2-27	1900-0700	535	10.8	0.49	21.6	82	83	86	87	5.44	5.38	5.48	5.46	30
2-27	0700-1900	481	10.8	0.48	20.0	80	81	84	86	5.47	5.43	5.39	5.48	30
2-28	1900-0700	485	10.5	0.59	19.2	80	80	84	86	5.41	5.38	5.50	5.41	23
2-28	0700-1900	575	11.3	0.57	18.5	84	83	87	88	5.47	5.43	5.42	5.49	28

Table 3-1

(Continued)

Date	Time	Load	CO_2	SO_2 Out	Density A	Fan A	Fan B	Fan C	Fan D	pH A	pH B	pH C	pH D	Reagent (TPH)
3-1	1900-0700	503	10.6	0.52	19.1	81	82	85	86	5.43	5.36	5.36	5.45	29
3-1	0700-1900	564	11.1	0.58	21.7	84	84	87	87	5.46	5.37	5.41	5.45	29
3-2	1900-0700	542	11.0	0.57	22.4	82	83	86	87	5.41	5.31	5.40	5.41	31
3-2	0700-1900	602	11.0	0.65	21.3	87	86	90	89	5.43	5.40	5.41	5.45	30
3-3	1900-0700	523	10.9	0.53	39.8	81	84	89	88	5.42	5.39	5.39	5.43	29
3-3	0700-1900	569	10.8	0.52	47.9	85	85	89	89	5.42	5.40	5.37	5.40	29
3-4	1900-0700	517	10.4	0.60	47.7	82	82	86	87	5.41	5.26	5.40	5.33	28
3-10	1530-1900	61	6.8	1.96	45.9	0	0	0	0	7.58	7.70	7.34	7.67	0
3-11	1900-0700	331	10.2	0.46	46.2	72	73	73	80	5.68	5.70	5.63	6.97	3
3-11	0700-1900	538	11.4	0.67	46.2	85	80	87	88	5.35	5.34	5.28	5.37	27
3-12	1900-0700	482	10.4	0.58	46.2	81	81	85	85	5.39	5.34	5.40	5.40	30
3-12	0700-1900	562	10.8	0.65	45.9	87	84	90	90	5.42	5.38	5.47	5.48	29
3-13	1900-0700	499	10.4	0.54	46.1	82	82	85	86	5.48	5.42	5.47	5.43	30
3-13	0700-1900	577	10.5	0.67	46.4	87	85	90	89	5.42	5.42	5.47	5.46	30
3-14	1900-0700	553	10.1	0.67	46.3	85	84	87	87	5.49	5.39	5.43	5.43	29
3-14	0700-1900	559	9.8	0.71	46.3	86	86	88	89	5.45	5.33	5.48	5.49	31

Table 3-2

Summary of DBA Inventory

Tank	Tank Capacity, gal	Solids, wt.%	Specific Gravity	DBA Conc., ppm	DBA Inventory, lb
	Inventory 1	Inventory 1	Inventory 1	Inventory 1	Inventory 1
Mod. A	280,051	20.8	1.16	1416	3,025
Mod. B	280,051	23.7	1.18	1687	3,537
Mod. C	280,051	18.9	1.14	1400	3,025
Mod. D	280,051	17.3	1.13	1382	3,015
Thickener	2,113,848	10.0	1.08	1243	21,298
TUF Tank	157,500	37.2	1.29	50	53
TOF Tank	165,578	0	1.02	1043	1,467
ME Tank	131,990	0	1.02	846	949
LS Tank	329,940	20.0	1.15	960	2,428
Total	4,019,061				38,797

TUF - Thickener Underflow
TOF - Thickener Overflow
ME - Mist Eliminator Wash
LS - Limestone Slurry

Table 3-2

(Continued)

Tank	Tank Capacity, gal	Solids, wt.%	Specific Gravity	DBA Conc., ppm	DBA Inventory, lb
	Inventory 2	Inventory 2	Inventory 2	Inventory 2	Inventory 2
Mod. A	280,051	17.4	1.13	1382	3,013
Mod. B	280,051	19.3	1.15	1340	2,889
Mod. C	280,051	14.8	1.11	1201	2,657
Mod. D	280,051	14.1	1.11	1154	2,563
Thickener	2,113,848	10.0	1.08	919	15,746
TUF Tank	41,250	35.4	1.28	703	199
TOF Tank	158,379	0	1.02	822	1,106
ME Tank	131,990	0	1.02	850	953
LS Tank	300,330	20.0	1.15	2046	4,710
Total	3,866,002				33,837

TUF	- Thickener Underflow
TOF	- Thickener Overflow
ME	- Mist Eliminator Wash
LS	- Limestone Slurry

Table 3-2

(Continued)

Tank	Tank Capacity, gal	Solids, wt.%	Specific Gravity	DBA Conc., ppm	DBA Inventory, lb
	Inventory 3	Inventory 3	Inventory 3	Inventory 3	Inventory 3
Mod. A	280,051	24.4	1.18	1276	2,663
Mod. B	280,051	24.4	1.18	1396	2,914
Mod. C	280,051	17.0	1.13	1199	2,620
Mod. D	280,051	15.4	1.12	1087	2,397
Thickener	2,113,848	10.0	1.08	1304	22,343
TUF Tank	75,000	3.6	1.04	1249	783
TOF Tank	158,379	0	1.02	1100	1,480
ME Tank	133,682	0	1.02	1163	1,321
LS Tank	374,355	20.0	1.15	2000	5,739
Total	3,975,469				42,260

TUF - Thickener Underflow
TOF - Thickener Overflow
ME - Mist Eliminator Wash
LS - Limestone Slurry

Table 3-2

(Continued)

Tank	Tank Capacity, gal	Solids, wt.%	Specific Gravity	DBA Conc., ppm	DBA Inventory, lb
	Inventory 1	Inventory 1	Inventory 1	Inventory 1	Inventory 1
Mod. A	280,051	20.0	1.15	1235	2,651
Mod. B	280,051	22.5	1.17	1565	3,307
Mod. C	280,051	16.8	1.13	1291	2,824
Mod. D	280,051	18.4	1.14	1185	2,568
Thickener	2,113,848	10.0	1.08	764	13,091
TUF Tank	165,000	38.0	1.30	764	846
TOF Tank	158,379	0	1.02	700	942
ME Tank	131,990	0	1.02	700	785
LS Tank	342,630	20.0	1.15	2000	5,252
Total	4,032,052				32,267

TUF	- Thickener Underflow
TOF	- Thickener Overflow
ME	- Mist Eliminator Wash
LS	- Limestone Slurry

results from the on-site buffer capacities show an average DBA concentration of 1300 ppm. The DBA concentration decreased towards the end of the test period due to problems with the additive feed system.

Preliminary Sodium DBA Consumption Estimate

A spreadsheet was constructed to track the inventory, estimate DBA solution losses with the filter cake, and estimate total SO_2 removal for the system. Table 3-2 also summarizes the initial and final DBA inventory results from that spreadsheet. To calculate these inventories, tank levels were entered in the spreadsheet to calculate tank volumes (although most of the tanks were at a constant level). Samples from the various tanks were then analyzed on site for approximate DBA concentration by buffer capacity titration. The appropriate liquid-phase DBA concentrations were entered in the spreadsheet to calculate the total pounds of DBA in the liquid inventory.

At least twice every test day, the DBA tanker was gauged to determine the amount of DBA added. The total tons of SO_2 removed for the consumption test was estimated from the tons of filter cake produced as determined by a weigh belt. To calculate tons of SO_2 removed from this value, the average limestone utilization assumed was 85%, and the sulfite oxidation percentage was assumed to be 10%. The laboratory personnel at Gibson determined the solids content of the filter cake at the beginning and the end of the test period, so that the filter cake tonnage could be put on a dry basis for this calculation.

Consumption data are summarized in Table 3-3. The average total consumption rate was estimated to have been 8.7 lbs of DBA per ton of SO_2 removed. The theoretical (solution) losses from the FGD system were 2.4 lbs of DBA per ton of SO_2 removed. The nonsolution losses (primarily coprecipitation and degradation) were approximately 6.3 lbs of DBA per ton of SO_2 removed.

Table 3-3

Summary of Additive Consumption

Condition	Amount	Unit
Initial Additive Inventory	38,797	lb DBA, dry basis
Final Additive Inventory	32,267	lb DBA, dry basis
Inventory Change	6,530	lb DBA Consumed, dry basis
Additive Introduced to System	33,976	lb DBA, dry basis
Total Additive Consumed	40,505	lb DBA, dry basis
SO_2 Removed, Based on Combustion Calculations	4,091	ton
SO_2 Removed, Based on Filter Cake Production	4,632	ton
Average Limestone Utilization	85	%
Sulfite Oxidation	10	%
Filter Cake Produced	18,839	ton
Filter Cake Solids Content	61.5	wt. %
Solution (Theoretical) Loss	2.4	lb DBA/ton SO_2 removed
Additive Consumption	8.7	lb DBA/ton SO_2 removed
Actual-to-Theoretical Ratio	3.6	A/T

Once the solid and liquor samples have been analyzed for DBA content by ion chromatography in Austin, these consumption rate estimates will be refined. Also, an estimate can be made of the additive coprecipitation loss rate.

3.2 Duquesne Light Elrama Station Results

This section summarizes preliminary results of the parametric SO_2 removal tests at Duquesne Light Company's Elrama FGD system. Performance test data and process data are summarized. Results of chemical analyses of process samples taken during the parametric tests are not yet available.

The objective of the parametric tests was to demonstrate the level of improvement in FGD system performance that is attainable through low cost upgrade options. The most promising low cost upgrade options were identified through the use of EPRI's FGDPRISM model. These included increased sodium thiosulfate concentrations to lower sulfite oxidation percentages and raise liquid-phase sulfite alkalinity, and increased venturi pressure drop to improve gas/liquid contacting in the absorbers. Tests were also performed at reduced pH to determine the potential for cost savings through improved lime utilization.

3.2.1 Test Approach

Figure 3-2 illustrates the physical arrangement of a single scrubber module at the Elrama Station. Flue gas and slurry sampling points are indicated in the figure. The FGD system consists of five individual modules; four are in service during normal full-load operation. Each module has its own ID fan present between the scrubber module and the external mist eliminator. For the parametric tests, Module 501 was selected as the test module, because the module was believed to be the cleanest module. (Module 401 was tested during the baseline tests and would have been the preferred test module had it been clean).

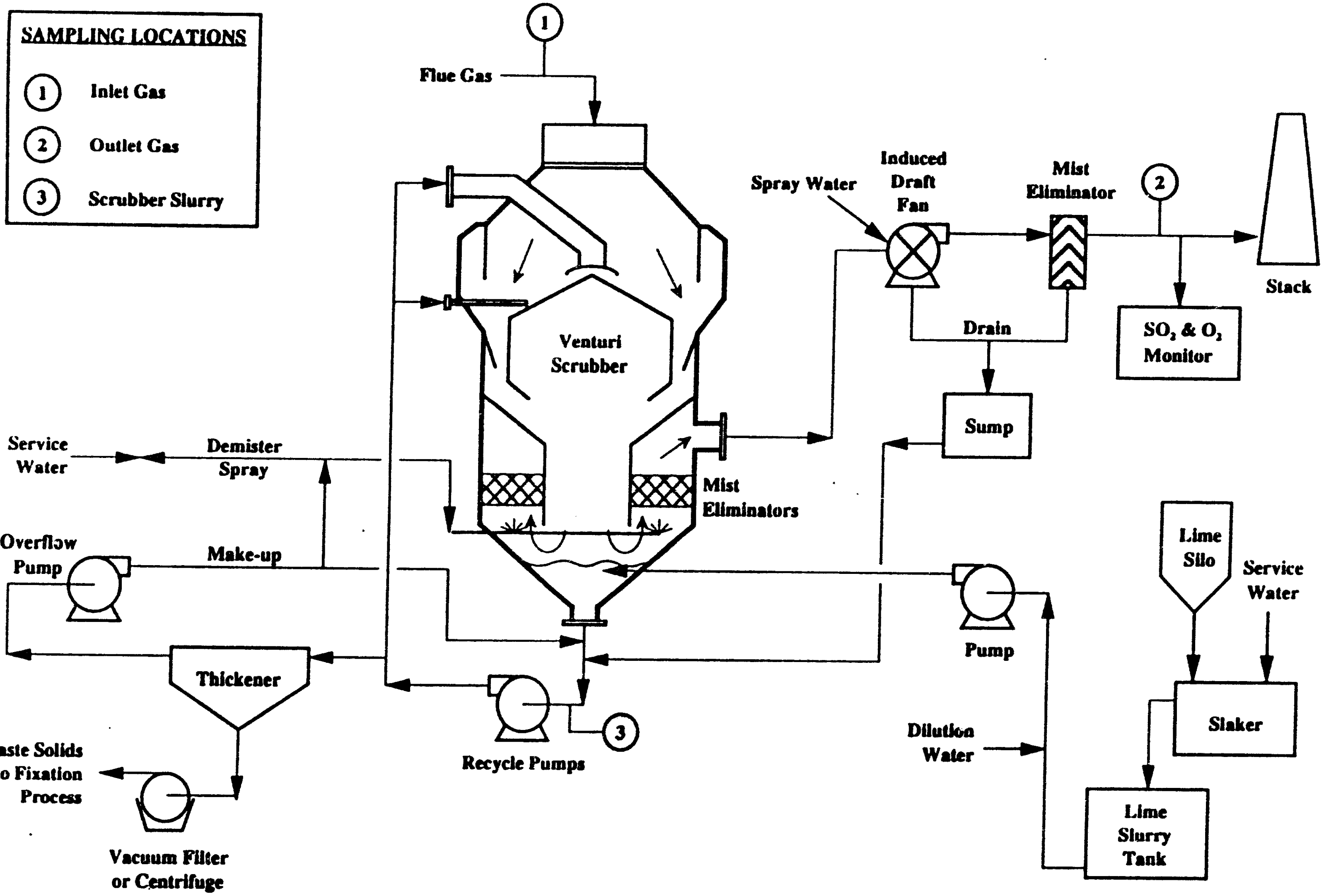

Figure 3-2. Schematic Flow Diagram of a Single Scrubber Train at the Elrama Station

Throughout the parametric tests, the gas flow was held constant by putting the fan control damper for Module 501 in manual and opening the damper completely. The inlet duct suction was held constant (by automatic control of the other fan control dampers), and the gas flow through Module 501 remained reasonably steady throughout these tests. The changes in venturi pressure drop made during the parametric tests (from 10 in. H_2O to 12 in. H_2O) did not measurably affect the gas flow through the module.

Independent variables tested included thiosulfate concentration, scrubbing liquor pH, and venturi pressure drop. The test plan for the parametric tests is shown in Table 3-4. For each test, the scrubbing liquor pH and venturi pressure drop were set by Elrama operation personnel. As during the baseline tests, controlling the scrubber vessel pH was often difficult. Primary pH control is provided by the addition of dilution water to the lime slurry pump suction. However, if the lime slurry becomes either too concentrated or too dilute, the dilution water cannot provide adequate control. The lime slurry concentration varies depending on the number of slakers in service, the rate at which each slaker is operating, and the demand for lime slurry in the scrubber vessels. Since the demand for lime varies with changes in station load, maintaining the proper lime slurry concentration can be very difficult. And when the lime slurry concentration is not in the proper range, controlling pH with the dilution water is simply not possible.

For many of the tests, one Duquesne Light employee devoted full attention toward controlling the test module pH. This involved manually adjusting the dilution water addition rate, and often required an operator to walk to the slaker building and make minor adjustments to the slaker speed. Yet even with these efforts, many of the tests had widely fluctuating pHs.

The venturi pressure drop also proved to be difficult to control. Control at the lower pressure drop (10 in. H_2O) was obtained through the automatic controls

Table 3-4

Parametric Test Plan for Elrama Station

Test Day	Test Order	Objective	Performance Indicators	Duration (days)	Scrubber Liquor pH	Thiosulfate Conc. ppm	Mg Conc. (ppm)	Venturi Pressure Drop (in.WC)
1		Set up						
2	1	Characterize FGD system performance with increased thiosulfate and venturi pressure drop at normal and reduced pH set points	SO_2 Removal Utilization Oxidation Solids Dewatering Relative Saturation	1/2	7.2	100	2600	10
	2			1/2	7.2	100	2600	12
3	3			1/2	7.2	500	2600	10
	4			1/2	7.2	500	2600	12
4	5			1/2	6.5	500	2600	10
	6			1/2	6.5	500	2600	12
5	7			1/2	7.2	1000	2600	10
	8			1/2	7.2	1000	2600	12
6	9			1/2	6.5	1000	2600	10
	10			1/2	6.5	1000	2600	12
7	11			1/2	7.2	1500	2600	10
	12			1/2	7.2	1500	2600	12
8	13			1/2	6.5	1500	2600	10
	14			1/2	6.5	1500	2600	12
9	15			1/2	7.2	2500	2600	10
	16			1/2	7.2	2500	2600	12
10	17			1/2	6.5	2500	2600	10
	18			1/2	6.5	2500	2600	12

without any difficulty. However, the higher pressure drop (12 in. H_2O) could not be achieved automatically. Of the 12 venturi throat dampers present on the scrubber module, one was missing entirely and one would not move. Several of the others first had to be manually stroked in and out to help them move more freely (especially on the first day of testing). Some required that the actuators be physically wired in place to keep the damper in the proper position for testing. Only through these efforts was it possible to achieve the 12 in. H_2O venturi pressure drop.

The thiosulfate concentration was relatively easy to control compared to the pH and venturi pressured drop. Since the baseline tests, Elrama has been running at sodium thiosulfate concentrations of 400 ppm to 500 ppm. Therefore, to repeat the baseline test conditions of roughly 100 ppm sodium thiosulfate, it was necessary to reduce the thiosulfate concentration. This was achieved by stopping sulfur addition roughly 24 hours before actual testing began. The thiosulfate concentration dropped to roughly 170 ppm sodium thiosulfate by the time testing began. The thiosulfate concentrations required for subsequent tests were achieved by adding sodium thiosulfate pentahydrate directly to Module 501. The sodium thiosulfate addition rate ranged from roughly 1/2 of a 50-lb bag every hour to maintain 500 ppm to one 50-lb bag every six minutes to maintain 2500 ppm. Sodium thiosulfate concentration measurements were made throughout the test periods, and adjustments to the sodium thiosulfate addition rate were made accordingly.

Performance measurements included simultaneous inlet and outlet SO_2 concentrations, inlet and outlet flue gas percent oxygen and carbon dioxide, and inlet and outlet flue gas moisture. During a typical test, the outlet gas velocity was measured at the beginning of the day using a 48-point traverse to verify that the flue gas flow was at the desired rate. Once it was verified that the flue gas flow was at the desired test level, simultaneous inlet and outlet Method 6 SO_2 samples were collected. Flue gas samples for Orsat analysis were collected as the Method 6 tests were conducted. Recycle liquor samples were collected during each test, and solids settling rate tests were conducted for each unique set of chemistry conditions. Recycle liquor flow measurements were also collected using a portable ultrasonic flow meter.

3.2.2 Test Results

The results reported below describe the data collected on site during the test period. The chemical analyses of process samples taken during the parametric tests are not yet completed, so no discussion of the effects of the variables studied on sulfite oxidation percentages, liquid-phase sulfite concentrations, or lime utilization are included.

SO_2 Removal Efficiency

Table 3-5 summarizes the actual test conditions and SO_2 removal results obtained on site. A summary of the pH measured by the portable pH meter, as well as an indication of the range over which the pH varied, is provided in Table 3-5. The estimate of the range over which the pH varied was provided by the control room strip chart. Evidence of the difficulty in controlling the pH can be seen in the estimated pH range; in some cases, the pH varied as much as 0.5 or more in test periods that typically lasted only 45 minutes. These swings in pH occurred in spite of the best efforts of Duquesne personnel to keep the pH steady.

The flue gas flow was measured at the outlet duct for each of the test conditions. Because of stratification in the flue gas velocity at the sampling location, a 48-point traverse was used to measure the velocity.

Two Method 6 sampling runs were completed during Test 1. The Orsat analysis (see Table 3-6) taken at the inlet location suggested that some ambient air

Table 3-5

Parametric Test Conditions and Results

Test No.	Run No.	Date	Time	pH	pH range	Flue Gas Flow (acfm)	Average Thiosulfate (ppm $Na_2S_2O_3$)	Inlet SO_2 (ppm dry)	Outlet SO_2 (ppm dry)	SO_2 Removal (%)	SO_2 Removal NTU
1	1	03/22/94	1151-1232	7.01	7.0-7.2	502972	170	979	106	90.5	2.22
1	2	03/22/94	1312-1352	6.70	6.7-6.9		170	922	97	90.8	2.25
2	1	03/22/94	1811-1847	7.34	7.1-7.4	513558	170	813	61	92.5	2.59
2	2	03/22/94	1911-1942	7.13	7.0-7.4		170	768	54	93.0	2.66
3	1	03/23/94	1356-1425	7.30	7.2-7.4	521812	454	955	79	91.7	2.49
3	2	03/23/94	1448-1520	6.93	6.4-7.0		454	924	89	90.4	2.34
4	1	03/23/94	1651-1722	7.17	7.1-7.2	495131	454	881	68	92.3	2.57
4	2	03/23/94	1745-1816	7.48	7.2-7.5		454	835	56	93.3	2.71
5	1	03/24/94	1038-1108	6.59	6.3-6.6	527971	437	872	121	86.1	1.97
5	2	03/24/94	1134-1204	6.37	6.2-6.4		437	770	128	83.4	1.80
6	1	03/24/94	1400-1430	6.20	6.2-6.5	490425	437	790	107	86.5	2.00
6	2	03/24/94	1456-1526	6.55	6.5-6.6		437	771	82	89.4	2.24
7	1	03/25/94	1012-1042	7.10	7.0-7.2	522681	1021	755	61	91.9	2.51
7	2	03/25/94	1116-1146	7.20	7.1-7.3		1021	721	55	92.3	2.57
8	1	03/25/94	1357-1427	6.98	6.9-7.2	502778	1021	751	52	93.1	2.67
8	2	03/25/94	1449-1519	7.17	7.1-7.3		1021	767	46	94.0	2.82
9	1	03/26/94	0944-1013	6.06	6.0-6.4	510029	1135	848	120	85.8	1.95
9	2	03/26/94	1145-1215	6.31	6.3-6.5		1135	853	84	90.2	2.32

Table 3-5

(Continued)

Test No.	Run No.	Date	Time	pH	pH range	Flue Gas Flow (acfm)	Average Thiosulfate (ppm $Na_2S_2O_3$)	Inlet SO_2 (ppm dry)	Outlet SO_2 (ppm dry)	SO_2 Removal (%)	SO_2 Removal NTU
10	1	03/26/94	1310-1340	6.34	6.3-6.5	516679	1135	669	54	91.9	2.51
10	2	03/26/94	1405-1435	6.47	6.4-6.6		1135	645	54	91.6	2.48
11	1	03/27/94	0939-1009	7.14	7.1-7.3	515839	1579	754	59	92.2	2.55
11	2	03/27/94	1032-1102	7.11	7.1-7.4		1579	842	57	93.2	2.69
12	1	03/27/94	1230-1330	7.05	7.0-7.3	531961	1579	830	49	94.1	2.83
12	2	03/27/94	1330-1359	7.27	7.1-7.3		1579	776	48	93.8	2.79
13	1	03/28/94	0953-1023	6.54	6.4-6.6	551775	1667	796	82	89.7	2.27
13	2	03/28/94	1054-1124	6.51	6.3-6.7		1667	776	78	89.9	2.29
14	1	03/28/94	1228-1258	6.45	6.4-6.7	540936	1667	901	64	92.9	2.64
14	2	03/28/94	1407-1437	6.33	6.3-6.5		1667	732	50	93.1	2.68
15	1	03/29/94	0935-1005	7.12	7.1-7.4	553794	2705	721	64	91.2	2.43
15	2	03/29/94	1028-1058	7.38	7.2-7.4		2705	866	66	92.4	2.58
16	1	03/29/94	1155-1225	7.16	7.1-7.3	498933	2705	943	58	93.9	2.79
16	2	03/29/94	1301-1331	7.14	7.1-7.3		2705	965	61	93.7	2.77
17	1	03/30/94	0905-0935	6.59	6.4-6.6	516126	2836	1093	114	89.6	2.26
17	2	03/30/94	0959-1029	6.36	6.3-6.5		2836	965	120	87.6	2.09
18	1	03/30/94	1113-1143	6.32	6.3-6.5	482231	2836	963	80	91.7	2.48
18	2	03/30/94	1307-1337	6.85	6.3-6.8		2836	879	64	92.7	2.62

Table 3-6

Orsat and Moisture Analysis Results

Test No.	Run No.	Outlet Gas Composition				Inlet Gas Composition			
		Oxygen (% O_2 dry)	Carbon Dioxide (% CO_2 dry)	Nitrogen (% N_2 dry)	Moisture (% H_2O)	Oxygen (% O_2 dry)	Carbon Dioxide (% CO_2 dry)	Nitrogen (% N_2 dry)	Moisture (% H_2O)
1	1 & 2	7.8	10.8	81.4	12.8	11.2	8.2	80.6	5.4
2	1 & 2	8.4	10.6	81.0	12.7	9.4	10.0	80.6	6.0
3	1 & 2	8.2	10.8	81.0	12.9	7.6	11.2	81.2	6.6
4	1 & 2				13.0	7.8	11.2	81.0	7.7
5	1 & 2	9.0	10.0	81.0	13.3	10.4	9.0	80.6	8.1
6	1 & 2	10.7	8.4	80.9	12.8				7.1
7	1 & 2	10.4	9.0	80.6	11.1	10.4	9.0	80.6	6.2
8	1 & 2	10.0	9.4	80.6	12.5	8.9	10.2	80.9	5.9
9	1 & 2	9.0	10.4	80.6	12.0	9.3	10.0	80.7	6.2
10	1 & 2	10.8	8.6	80.6	10.9	10.4	9.2	80.4	6.0
11	1 & 2	8.6	10.8	80.6	12.9	7.9	11.1	81.0	7.2
12	1 & 2				13.3	8.2	11.6	80.2	7.9
13	1 & 2	8.4	10.6	81.0	12.8	8.2	11.0	80.8	6.5
14	1 & 2	10.3	8.8	80.9	12.8	10.0	9.2	80.8	7.3
15	1 & 2	9.1	10.3	80.6	12.2	9.3	9.7	81.0	5.7
16	1 & 2	9.0	10.6	80.4	12.4	9.2	10.2	80.6	6.8
17	1 & 2	9.0	10.6	80.4	12.9	9.2	10.0	80.8	7.2
18	1 & 2				12.6	8.8	10.6	80.6	6.2

leaked into the sample probe, since the measured oxygen content in the inlet gas sample was much higher than the oxygen content measured in the outlet gas. The inlet SO_2 concentrations were therefore corrected to account for the air inleakage. Using the corrected inlet SO_2 concentrations, the SO_2 removal efficiencies measured for Test 1 were 90.5% and 90.8% with an average of 90.7%. Test 1 was performed at a pH of 7.2, a thiosulfate concentration of 170 ppm, and a venturi pressure drop of 10 in. H_2O. The Test 1 operating conditions approximated the baseline test conditions from the June 1993 baseline tests.

The results from the June 1993 baseline tests for similar operating conditions showed an SO_2 removal of approximately 86.1%. The difference between the June 1993 baseline and parametric test results is substantial (90.7% removal for the parametric tests versus 86.1% for the June 1993 baseline tests). Although chemistry differences between the tests may have some impact, the difference is believed to be largely a result of mechanical differences between the two scrubber vessels (such as the relative cleanliness, number of throat dampers working, etc.).

Test 2 conditions were similar to those of Test 1 with the exception that the venturi pressure drop was increased to 12 in. H_2O. Two Method 6 runs were performed during this test; SO_2 removal efficiencies of 92.5% and 93.0% were measured for an average removal of 92.8%. These results showed that an improvement in SO_2 removal was achieved with the increased pressure drop.

Tests 3 and 4 were conducted at an average sodium thiosulfate concentration of 454 ppm, a nominal 7.2 pH, and at venturi pressure drops of 10 and 12 in. H_2O, respectively. Two Method 6 traverses were performed for each test. SO_2 removal efficiencies of 91.7% and 90.4% were measured for an average removal of 91.1% during Test 3. The difference between the results of the two runs is believed to be a result of pH control difficulties. The second run of Test 3 was performed at an estimated pH range of only 6.4 to 7.0, while the first run was reasonably close to the 7.2 target pH.

Throughout the parametric tests, much of the variation between runs at a single test condition is believed to be a result of pH variations.

For Test 4, SO_2 removals of 92.3% and 93.3% were measured for an average removal of 92.8%. As with Test 3, variations in the test pHs are believed to cause (at least in part) the differences in the SO_2 removal results of the two runs.

Tests 5 and 6 were performed at an average sodium thiosulfate concentration of 437 ppm, a nominal pH of 6.5, and at venturi pressure drops of 10 and 12 in. H_2O, respectively. SO_2 removal efficiencies of 86.1% and 83.4% were measured for an average removal of 84.8% during Test 5. SO_2 removal efficiencies of 86.5% and 89.4% were measured for an average removal of 88.0% during Test 6. The objective of the low pH tests was to determine if it is possible to achieve improved SO_2 removal and simultaneously increase the lime utilization (and thereby reduce operating expenses). The SO_2 removal efficiencies measured during Tests 5 and 6 were lower than the baseline removal efficiency of 90.7%, so these tests did not meet the objective of improving the SO_2 removal.

Tests 7 and 8 were performed at an average sodium thiosulfate concentration of 1021 ppm, a nominal pH of 7.2, and at venturi pressure drops of 10 and 12 in. H_2O, respectively. SO_2 removal efficiencies of 91.9% and 92.3% were measured for an average removal of 92.1% during Test 7. SO_2 removal efficiencies of 93.1% and 94.0% were measured for an average removal of 93.6% during Test 8. These tests show that with the increase in sodium thiosulfate concentration, the SO_2 removal efficiency was improved by about 1.5 percentage points at the normal venturi pressure drop value of 10 in. H_2O, and by a little less than one percentage point during operation at the higher pressure drop.

Tests 9 and 10 were performed at an average sodium thiosulfate concentration of 1135 ppm, a nominal pH of 6.5, and at venturi pressure drops of 10 and 12 in.

H_2O, respectively. SO_2 removal efficiencies of 85.8% and 90.2% were measured for an average removal of 88.0% during Test 9. SO_2 removal efficiencies of 91.9% and 91.6% were measured for an average removal of 91.8% during Test 10. The results of Test 10 show that it is possible to achieve a modest improvement in SO_2 removal efficiency with higher thiosulfate concentrations (over the 90.7% baseline) even at a reduced pH set point of 6.5.

Tests 11 and 12 were performed at an average sodium thiosulfate concentration of 1579 ppm, a nominal pH of 7.2, and at venturi pressure drops of 10 and 12 in. H_2O, respectively. SO_2 removal efficiencies of 92.2% and 93.2% were measured for an average removal of 92.7% during Test 11. SO_2 removal efficiencies of 94.1% and 93.8% were measured for an average removal of 94.0% during Test 12. These results show that a slight further increase in SO_2 removal efficiency (about one-half percentage point) can be achieved at the 1500 ppm sodium thiosulfate level, relative to the values for a 1000 ppm sodium thiosulfate level.

Tests 13 and 14 were performed at an average sodium thiosulfate concentration of 1667 ppm, a nominal pH of 6.5, and at venturi pressure drops of 10 and 12 in. H_2O, respectively. SO_2 removal efficiencies of 89.7% and 89.9% were measured for an average removal of 89.8% during Test 13. SO_2 removal efficiencies of 92.9% and 93.1% were measured for an average removal of 93.0% during Test 14. The Test 14 results show another instance where an improvement in SO_2 removal efficiency (over the 90.7% baseline) is achieved at a pH of 6.5.

Tests 15 and 16 were performed at an average sodium thiosulfate concentration of 2705 ppm, a nominal pH of 7.2, and at venturi pressure drops of 10 and 12 in. H_2O, respectively. SO_2 removal efficiencies of 91.2% and 92.4% were measured for an average removal of 91.8% during Test 15. SO_2 removal efficiencies of 92.9% and 93.1% were measured for an average removal of 93.0% during Test 16. No increase in SO_2

removal efficiency was seen between the 1500 ppm sodium thiosulfate tests and these tests.

Tests 17 and 18 were performed at an average sodium thiosulfate concentration of 2836 ppm, a nominal pH of 6.5, and at venturi pressure drops of 10 and 12 in. H_2O, respectively. SO_2 removal efficiencies of 89.6% and 87.6% were measured for an average removal of 88.6% during Test 17. SO_2 removal efficiencies of 91.7% and 92.7% were measured for an average removal of 92.2% during Test 18. No increase in SO_2 removal efficiency was seen between the 1500 ppm sodium thiosulfate tests and these tests; instead, it appears that there was a decrease in removal efficiency.

Slurry Flow Measurements

Slurry flow measurements were obtained from three locations on the slurry supply line using an ultrasonic Doppler flow meter. The three locations sampled represented the total slurry flow to Module 401, the slurry flow to the tangential nozzles, and the slurry flow to the center (bull) nozzle. The sum of the flows to the tangential nozzles and center nozzle should be equal to the total flow to the scrubber. Each of the sample locations was reasonably distant from any flow disturbance, and stable readings were obtained at each location. A summary of the flow measurement data is provided in Table 3-7.

The average of the measured flow to the tangential nozzles was 9500 gpm and the average measured flow to the center nozzle was 8500 gpm. Adding these two flows gives a total flow of 18,000 gpm. This value agrees reasonably well (within 10%) with the average total measured flow of 16,200 gpm. The total measured flow is slightly lower than the total flow measured during the baseline tests (17,600 gpm). The

Table 3-7

Slurry Flow Measurement Results

Date	Total Flow (gpm)	Tangential Flow (gpm)	Top Flow (gpm)
3/22/94	15396	9322	8121
3/23/94	15465	9446	8574
3/24/94	16627	9443	8820
3/25/94	16157	9106	8631
3/26/94	16172	-	-
3/27/94	16454	-	-
3/28/94	16580	9728	8629
3/29/94	16522	9793	8503
3/30/94	16357	-	-

measured flow also tended to increase during the course of the parametric tests. This may be a result of some scale dissolving at the higher thiosulfate concentrations. There is, however, enough uncertainty in the flow measurements that it is difficult to be certain that the flow actually did increase.

As during the baseline tests, some uncertainty in the measured flow rates is due to an uncertainty in the pipe inside diameter. The inside diameter of the pipes was assumed to be the same as was determined for the baseline testing, and the diameters used during the baseline testing were based on an assumption of lining thickness. Since it is possible that the lining may have deteriorated significantly, the actual ID of the pipe at the measurement locations is uncertain.

For the parametric tests, the measured slurry flow rates correspond to a liquid-to-gas ratio (L/G) of approximately 29.3 to 33.5 gallons/1000 acfm using the total measured flow of 16,200 gpm as a basis.

Process Data

Process data were collected from the control room during each test. A summary of the process data is presented in Table 3-8.

Slurry Sample Chemical Analyses

Analysis of the scrubber samples was not completed as of the date of this report. Several key effects (such as sulfite concentration, oxidation, and lime utilization) cannot yet be evaluated.

Table 3-8

Plant Operating Data

Test No.	Run No.	Date	Time	Station Load (MW net)	Pump A Current (amps)	Pump B Current (amps)	Fan Current (amps)	Mist Eliminator Pressure Drop (in. H_2O)	Venturi Pressure Drop (in. H_2O)	Fan Damper Position (%)	Stack SO_2 (lb/MMBtu)
1	1	03/22/94	1151-1232	440	42	43	550	1.2	10	98	0.26
1	2	03/22/94	1312-1352	425	42	43	550	1.1	10	98	0.25
2	1	03/22/94	1811-1847	420	42	43	540	1.2	12.4	98	0.25
2	2	03/22/94	1911-1942	391	42	43	540	1.2	12.4	98	0.24
3	1	03/23/94	1356-1425	429	42	43	550	1.1	10	98	0.26
3	2	03/23/94	1448-1520	435	42	43	550	1.1	10	98	0.25
4	1	03/23/94	1651-1722	416	42	43	540	1.2	12.1	98	0.23
4	2	03/23/94	1745-1816	409	42	43	540	1.6	12.4	98	0.22
5	1	03/24/94	1038-1108	338	42	43	540	1.1	10	98	0.26
5	2	03/24/94	1134-1204	339	42	43	540	1.1	10	98	0.29
6	1	03/24/94	1400-1430	300	42	43	540	1	12	98	0.31
6	2	03/24/94	1456-1526	297	42	43	540	1	12	98	0.29
7	1	03/25/94	1012-1042	349	42	43	560	1.1	10	98	0.21
7	2	03/25/94	1116-1146	339	42	43	560	1.1	10	98	0.22
8	1	03/25/94	1357-1427	353	42	43	560	1.1	12	98	0.21
8	2	03/25/94	1449-1519	334	42	43	550	1.1	12	98	0.19
9	1	03/26/94	0944-1013	363	42	42.5	565	1.1	10	98	0.33
9	2	03/26/94	1145-1215	363	42	43	560	1.1	10	98	0.33

Table 3-8

(Continued)

Test No.	Run No.	Date	Time	Station Load (MW net)	Pump A Current (amps)	Pump B Current (amps)	Fan Current (amps)	Mist Eliminator Pressure Drop (in. H_2O)	Venturi Pressure Drop (in. H_2O)	Fan Damper Position (%)	Stack SO_2 (lb/MMBtu)
10	1	03/26/94	1310-1340	361	42	42.5	560	1.1	11.8	98	0.28
10	2	03/26/94	1405-1435	361	42	43	560	1.1	11.8	98	0.32
11	1	03/27/94	0939-1009	365	42	42.5	540	1.1	9.8	98	0.18
11	2	03/27/94	1032-1102	386	42	42.5	540	1.1	10	98	0.17
12	1	03/27/94	1230-1330	410	42	42.5	540	1.1	11.8	98	NA
12	2	03/27/94	1330-1359	428	42	42.5	540	1.1	11.8	98	0.21
13	1	03/28/94	0953-1023	451	42	42.5	550	1.1	10	98	0.17
13	2	03/28/94	1054-1124	450	42	42.5	550	1.1	10	98	0.16
14	1	03/28/94	1228-1258	454	42	42.5	550	1.1	12	98	0.15
14	2	03/28/94	1407-1437	254	42	42.5	550	1.1	12	98	0.22
15	1	03/29/94	0935-1005	295	42	43	530	1.1	10	98	0.19
15	2	03/29/94	1028-1058	293	42	43	530	1.1	10	98	0.2
16	1	03/29/94	1155-1225	293	42	43	540	1.1	12	98	0.21
16	2	03/29/94	1301-1331	291	42	43	530	1.1	12	98	0.22
17	1	03/30/94	0905-0935	321	42	43	570	1.1	10	98	0.38
17	2	03/30/94	0959-1029	322	42	43	570	1.1	10	98	0.41
18	1	03/30/94	1113-1143	320	42.5	43	570	1.1	12	98	0.37
18	2	03/30/94	1307-1337	306	41.5	43	570	1.1	12	98	0.32

Settling Test Data

The settling test data are summarized in Table 3-9. Settling tests were performed only on those tests where there were at least 5 to 6 hours of operation at the specified test conditions. Since the solids residence time in the reaction tank is roughly 1-1/2 hours, this ensured that the solids present in the reaction tank were actually generated at the conditions of the test.

Table 3-9 shows the unit area required to achieve 15, 20, 25, and 30 wt.% solids and also shows the final underflow weight percent solids. Unit area is a measurement of the solids settling rate expressed in the units of square feet/ton solids per day. The unit area represents the square feet of thickener area that would be required to settle one ton of solids per day to the specified weight percent solids. Smaller unit areas indicate better solids settling properties. The final underflow weight percent solids represents the weight percent solids of the settled solids after the solids have stopped settling. All of the settling tests performed during the parametric tests started with an 8 wt.% solids slurry.

Settling tests performed during the first days of the parametric tests showed that the settling tests needed to be performed the same day that the samples were collected. Samples which had been allowed to sit overnight showed significantly worse settling properties than those measured the same day the sample was collected. All of the results in the table are therefore from tests performed the same day as the sample was collected. A number of the reported unit areas represent extrapolated data. The extrapolations assume that the settling rate is constant until the slurry approaches the final underflow weight percent solids.

The settling test results show that the solids settling properties tended to improve at the elevated thiosulfate concentrations. For Test 2 conditions (which

Table 3-9

Settling Test Results

Test-Run Nos.	Date	pH (nominal)	Average Thiosulfate (ppm $Na_2S_2O_2$)	Required Unit Area				Final Underflow wt.%
				15 wt.%	20 wt.%	25 wt.%	30 wt.%	
2-2	03/21/90	7.2	170	30.1*	46.7*			25.7
4-2	03/22/90	7.2	454	20.5	28.3*			25.4
6-2	03/23/90	6.5	437	34.6*	58.0*	81.4*		29.5
8-1	03/24/90	7.2	1021	23.5*	38.2*	52.8*		28.1
10-2	03/25/90	6.5	1135	20.9	30.5*	40.2*		30.2
12-2	03/26/90	7.2	1579	20.2*	32.1*	44.0*		27.4
14-2	03/27/90	6.5	1667	18.0	24.9	30.2	34.3	31.8
16-2	03/28/90	7.2	2705	15.4	20.9	25.1		29.7
18-2	03/29/90	6.5	2836	14.3	19.8	23.5	28.9	31.3

* Extrapolated result.

approximated the baseline test case), a unit area of 30.1 sq. ft/tpd was required to settle the solids to 15 wt.%. This is consistent with the results from the baseline testing which showed that the unit area required for the recycle liquor to settle to a 15 wt.% solids varied from 23 to 30 square feet/ton solids per day. At the highest thiosulfate concentrations, the unit area required to settle the solids to 15 wt.% solids was roughly 15 sq. ft/tpd. The change in unit area indicates that the existing thickeners could clarify twice as much slurry at the high thiosulfate concentrations as they can at the low concentrations.

The final underflow solids weight percent also increased at the elevated thiosulfate concentrations. At the 170 ppm sodium thiosulfate concentration, the final underflow weight percent solids was approximately 25 wt.%. This is consistent with the results from the baseline testing where final underflow weight percent solids from the settling tests ranged from 22 wt.% to 24 wt.%. In the 2700 to 2800 ppm sodium thiosulfate concentration tests, the final underflow weight percent solids was approximately 30 wt.%.

SO_2 Removal Data Correlations

Figures 3-3 and 3-4 show the measured SO_2 removals for the pH 6.5 (nominal) and pH 7.2 (nominal) tests, respectively. Figure 3-3 shows that significant improvements in SO_2 removal are achieved at sodium thiosulfate concentrations up to approximately 1500 ppm for the pH 6.5 (nominal) tests. Further increasing the thiosulfate concentration does not further improve the SO_2 removal; in fact, the removal seems to begin to decrease at the highest sodium thiosulfate concentrations. Operating the venturi throats at a 12 in. H_2O pressure drop appears to improve the SO_2 removal roughly 3 to 4 percentage points over operation at a 10 in. H_2O pressure drop. The scatter in the data are believed to largely be a result of difficulties in accurately controlling pH.

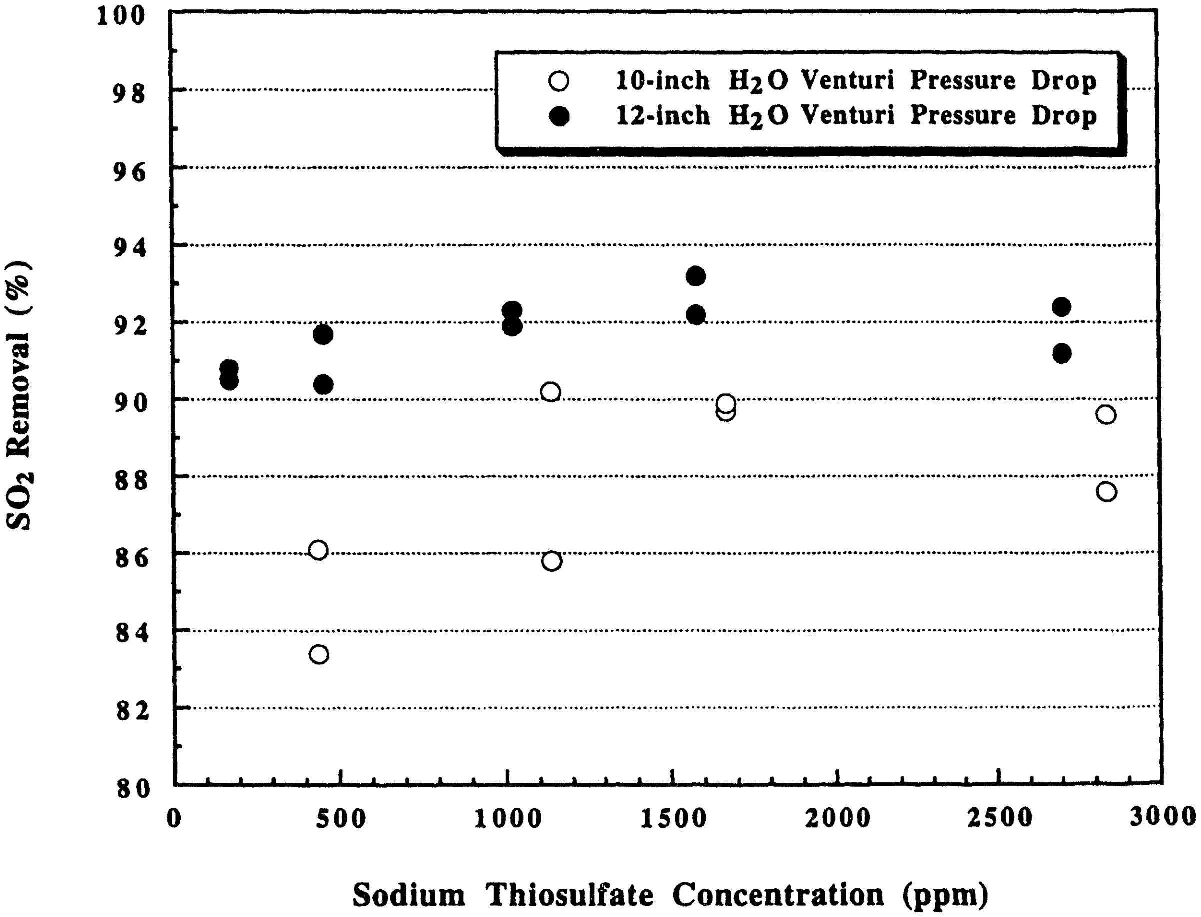

Figure 3-3. Effect of pH on SO_2 Removal

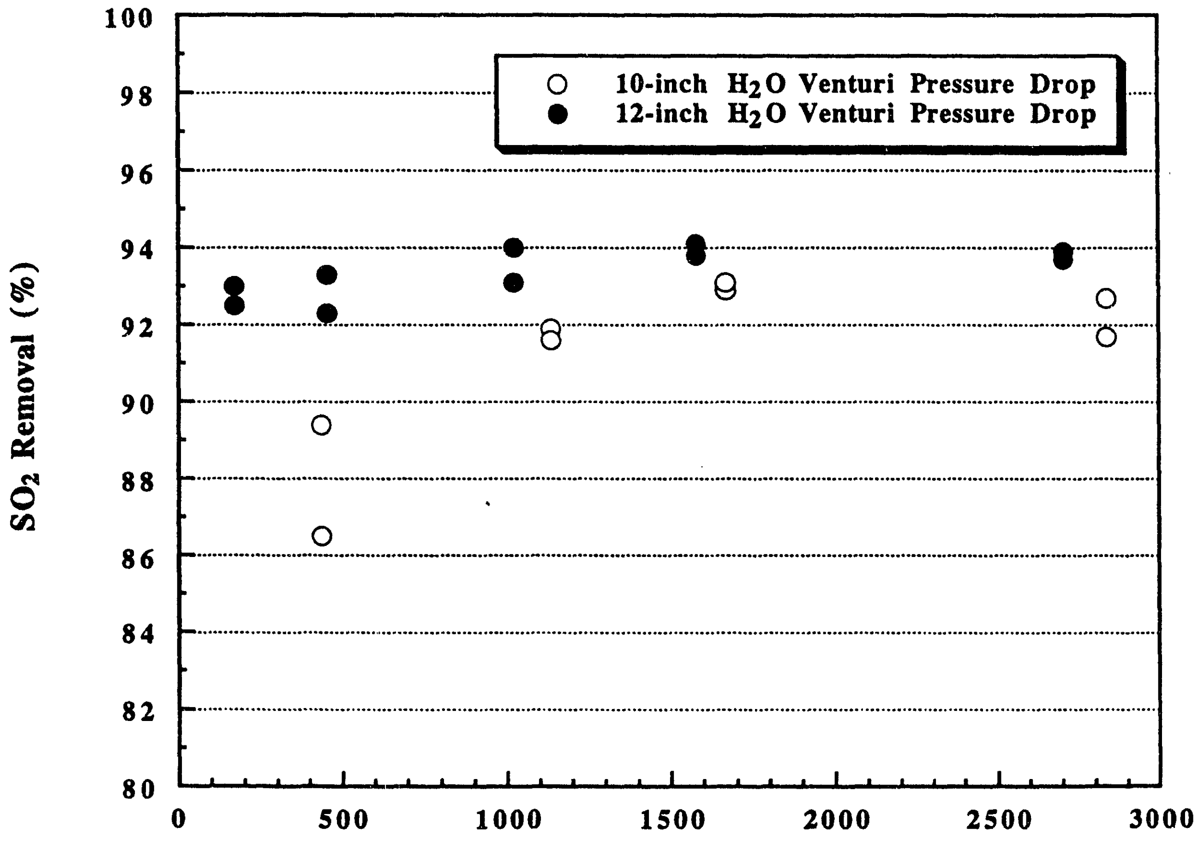

Figure 3-4. Effect of Venturi Pressure Drop on SO$_2$ Removal

Figure 3-4 shows that improvements in SO_2 removal are achieved at sodium thiosulfate concentrations up to approximately 1500 ppm for the pH 7.2 (nominal) tests also, although the magnitude of the increase is not as great. Further increasing the thiosulfate concentration above 1500 ppm does not appear to further improve SO_2 removal. Operating the venturi throats at a 12 in. H_2O pressure drop appears to improve the SO_2 removal roughly 1 to 2 percentage points over operation at a 10 in. H_2O pressure drop.

Data are not yet available to plot other effects of the test variables, such as the effect of sodium thiosulfate concentration on sulfite oxidation percentage or on liquid-phase sulfite concentrations, the effect of pH on lime utilization, etc. These effects will be investigated once the analytical data are available.

4.0 PLANS FOR THE NEXT REPORTING PERIOD

The base program (Tampa Electric Big Bend) and Options I through III (Hoosier Energy Merom, SWEPCo Pirkey, and PSI Energy Gibson, respectively), are in the final reporting phases. A draft Topical Report for the Tampa Electric site was submitted in March 1994. For the Hoosier Energy and SWEPCo sites, the draft versions of those Topical Reports should be completed during the second quarter of calendar year 1994.

For the PSI Energy Gibson Station (Option III), a Technical Note summarizing results from the sodium formate parametric tests and additive consumption test was completed in early April 1994. Since a DBA additive performance and consumption test was recently completed at this site as well, a detailed test report will be prepared for this effort during the next reporting period. Results from the DBA tests will be incorporated into the Topical Report for this site, which will likely be prepared in the third quarter of calendar year 1994.

Parametric testing of the most favorable upgrade options for the Duquesne Light Elrama site (Option IV) has tentatively been completed, as described in the previous section. However, it is possible that a second phase of parametric testing will be conducted in the next quarter, using a less expensive form of sulfur byproduct to generate thiosulfate ion in-situ in the scrubbing liquor. Otherwise, a draft Technical Note will be prepared during the next quarter, summarizing baseline and parametric test results, results of FGDPRISM modeling, and of an economic evaluations of the upgrade options tested.

For Option V, testing at the New York State Electric and Gas Company Kintigh Station, it is possible that baseline testing could be conducted toward the end of the next quarter. The exact timing of this testing has not yet been set, and will depend largely on when a Categorical Exclusion can be approved and a Host Site Agreement executed for this site.

5.0 ACKNOWLEDGMENTS

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7/12/94

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