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High SO_2 Removal Efficiency Testing

DE-AC22-92PC91338

Quarterly Status Report - April - June 1995

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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 April through 30 June 1995. 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 being evaluated mostly involve using performance 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 Hoosier Energy's Merom Station (Option I), Southwestern Electric Power Company's Pirkey Station (Option II), PSI Energy's Gibson Station (Option III), Duquesne Light's Elrama Station (Option IV), and New York State Electric and Gas Corporation's Kintigh Station (Option V). The originally planned testing has been completed for all six sites.

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 technical efforts during the quarter, or results from prior quarters that have not been previously reported. In Section 4, Plans for the Next Reporting Period, an overview is provided of the technical efforts that are anticipated for the third quarter of calendar year 1995. Section 5 contains 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. Base project efforts during the second quarter of calendar year 1995 consisted only of project management and reporting activities.

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 have been 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. There were only minor reporting activities for this site during the current quarter.

Option II involved testing at the Southwestern Electric Power Company Pirkey Station. Both sodium formate and DBA additives were tested as potential upgrade options. All of the testing at this site was completed by May 1993. There were only minor reporting activities for this site during the current quarter.

On Option III, for testing at the PSI Energy Gibson Station, testing with sodium formate additive was completed in early October 1993, and a DBA additive performance and consumption test was completed in March of 1994. There were only reporting efforts for this site during the current quarter.

Option IV is for testing at the Duquesne Light Elrama Station. The FGD system employs magnesium-enhanced lime reagent and venturi absorber modules. 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 March of 1994. A draft Technical Note summarizing the results from this site was submitted to DOE and to the utility for review in early January 1995. There were no other significant activities for this site during the current quarter.

Option V is for testing at the NYSEG Kintigh Station. Baseline testing was conducted in July 1994. Parametric testing at this site was conducted in late August, and a sodium formate additive consumption test was conducted in September 1994. Results from this parametric and additive consumption testing were included in the Technical Progress Report for the time period of October through December 1994. This report was submitted in January 1995. During the first quarter of calendar year 1995, FGDPRISM modeling of these test results and economic evaluations of upgrade options were conducted. A draft Technical Report of these results were submitted to DOE and to NYSEG for review. Results of the modeling and economic evaluation for this site are included in the next section of this report.

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 October 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 October 1993 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 of 1993, and these results were discussed in the January 1994 Technical Progress Report. A DBA performance and consumption test was conducted in February and March of 1994. Preliminary results from this test were discussed in the April 1994 Technical Progress Report. An update of the results from this site was presented in the previous quarterly report.

Baseline testing at the fourth optional site (Duquesne Light's Elrama Station) was completed in July 1993. Those results were discussed in the October 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 January 1994 Technical Progress Report. In March of 1994 parametric testing of the most promising upgrade options was conducted. The preliminary results of these tests were discussed in the April 1994 Technical Progress Report. A draft of the Technical Note for this site was submitted to DOE on January 4, 1995. An overview of the new results presented in this draft technical note was included in the Technical Progress Report for the time period October through December 1994, dated 3 February 1995.

For the fifth optional site, at the New York State Electric and Gas Corporation's (NYSEG's) Kintigh Station, baseline, parametric, and additive consumption tests were completed during the third quarter of 1994. Results from the baseline testing at this site were discussed in the Technical Progress Report for the third quarter of calendar year 1994, dated December 1994. The parametric and additive consumption tests at this site were also completed late in the third quarter. These results were discussed in the previous quarterly Technical Progress Report. In the first quarter of calendar year 1995, FGDPRISM modeling of the Kintigh FGD system was completed, as were the economic evaluations of potential upgrade options for this site, and a draft report discussing these results was submitted to DOE and to NYSEG. These results are discussed below.

The remainder of this section provides an update on these results from NYSEG's Kintigh Station. There is a review of the test results from this site, and an overview of the results of FGDPRISM modeling and economic analyses of the upgrade options considered for this site.

3.1 Results of FGD System Upgrade Evaluations at NYSEG's Kintigh Station

3.1.1 Review of Test Results for this Site

The NYSEG Kintigh Station is a 700-MW facility located near Barker, New York, that typically fires a 2.0 to 2.8 % sulfur coal. The unit is equipped with a limestone reagent FGD system employing open spray absorbers. The FGD system is equipped with six absorbers, each of which has five recycle pumps independently feeding five spray header levels. At design conditions, only four modules and four spray headers per module are required to be in operation. The FGD system operates in an inhibited oxidation mode. Sodium formate additive was the only upgrade option tested at this site.

Baseline tests showed that the SO_2 removal efficiency of the test module at normal full-load operating conditions (pH 5.6, flue gas velocity of 9 ft/s, four recycle pumps in service) was about 86%. Parametric tests were conducted with sodium formate additive. The results are summarized in Figures 1 and 2. Results at the normal operating pH of 5.6 showed that with a formate ion concentration of 3800 ppm in the recycle slurry liquor, the test module's

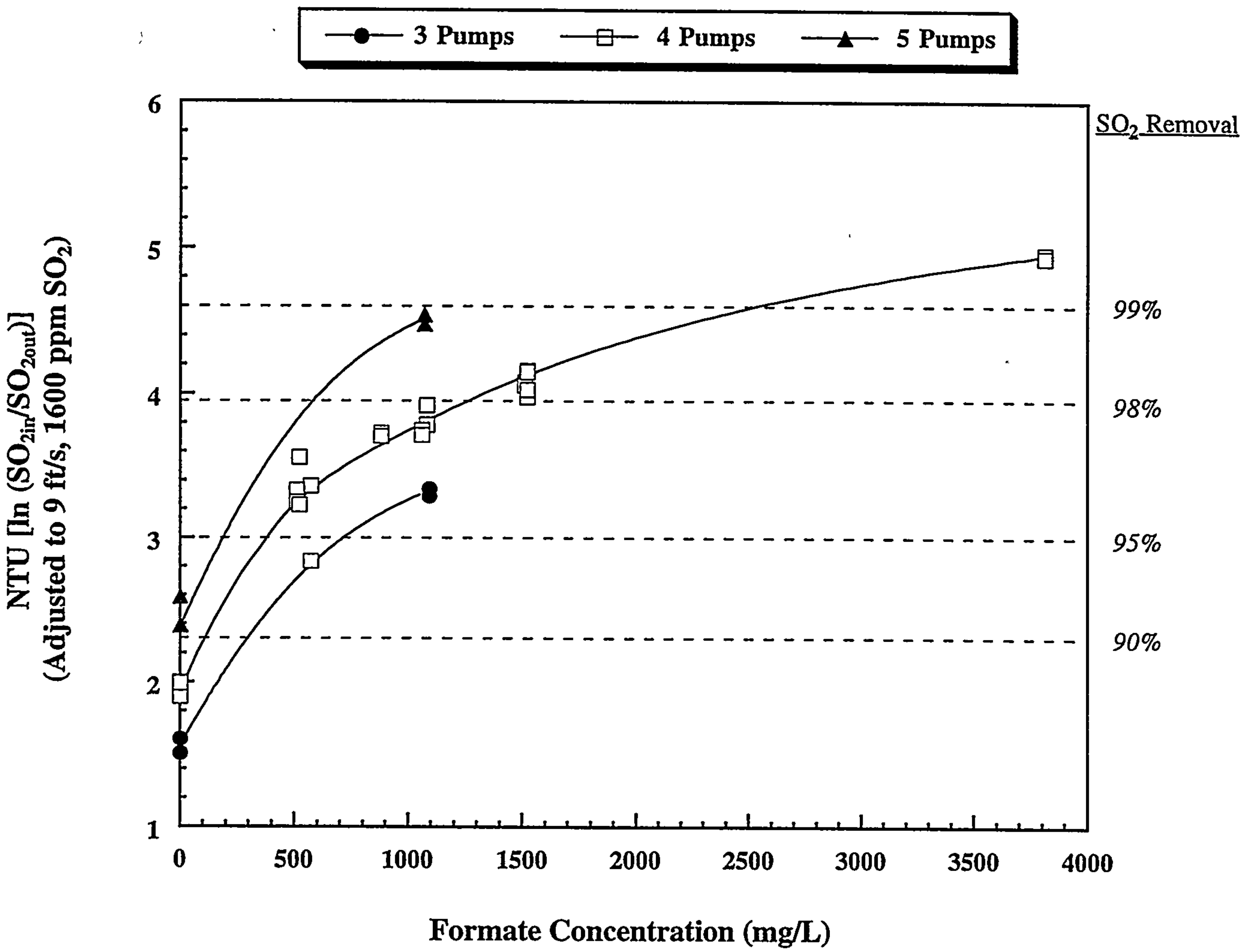

Figure 1. Adjusted NTU vs. Formate Concentration for Tests at pH = 5.6

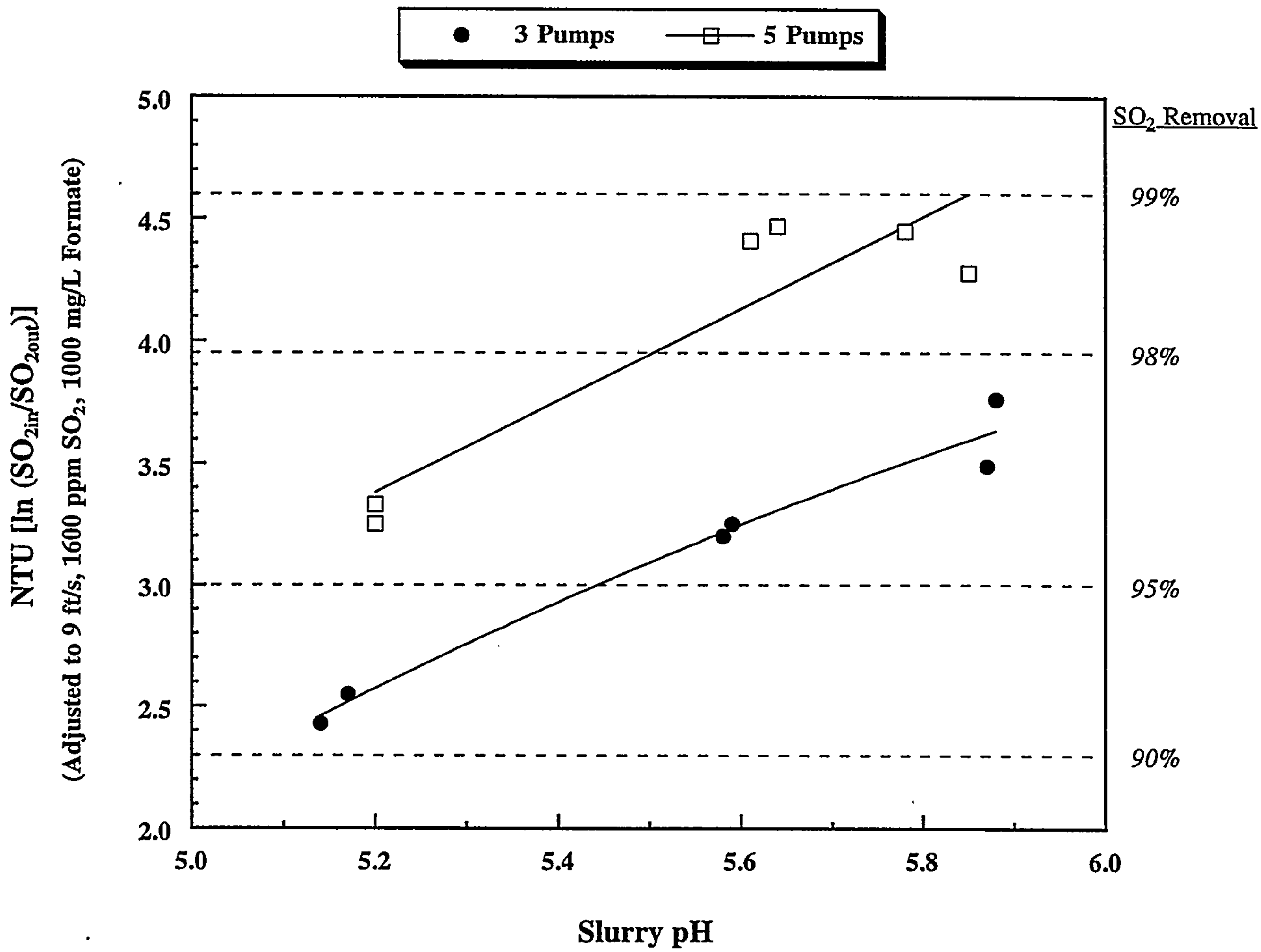

Figure 2. Adjusted NTU vs. pH for Tests with 1000 ppm Formate

SO_2 removal efficiency could be increased to 99.4 percent. The project target of 95% removal could be achieved with a formate ion concentration of only 500 ppm.

In a subsequent long-term additive consumption test, sodium formate was added to the entire FGD system to maintain an average formate ion concentration of 1080 ppm in the recycle slurry liquor. At this formate concentration, the module SO_2 removal efficiency averaged about 97 percent. The total sodium formate consumption rate was measured to be equivalent to 16.6 lb/ton of SO_2 removed. Of the total consumed, 12% was solution loss with the moist filter cake, 32% was lost by precipitation into the filter cake solids, 6% was lost by vaporization into the flue gas, and the remaining 50% was attributed (by difference) to degradation. The sodium formate additive had no measurable effect on the process chemistry or on the dewatering properties of the calcium sulfite byproduct solids.

3.1.2 FGDPRISM Modeling Results

The FGDPRISM model is calibrated to test results by adjusting several parameters. The parameters are adjusted to achieve the best fit with respect to liquid-phase chemistry, limestone utilization, and SO_2 removal efficiency for the cases used in the calibration. For the Kintigh FGD system, the main parameters of the calibration were:

- Limestone reactivity;
- Gas- and liquid-film thicknesses for the spray droplets; and
- Calcium sulfite/sulfate solid solution precipitation rate.

The limestone reactivity is adjusted by changing a variable called the surface area factor, and the limestone reaction rate constant (k) to match the observed limestone utilization and pH in the reaction tank.

The gas-film and liquid-film thicknesses are adjusted to match the mass-transfer characteristics of the absorber. For the spray section in the absorber, the model predicts gas/liquid surface area by determining the trajectory of each slurry droplet as it passes through the absorber. The mass-transfer film thicknesses are then varied to match observed SO_2 removals, since film thicknesses and surface area together determine the SO_2 removal performance (i.e., K x A when SO_2 removal is expressed in terms of Number of Transfer Units, or NTU). In order to improve the ability of FGDPRISM to match the observed effect of flue gas velocity on SO_2 removal efficiency, it was also necessary to adjust the gas-film thickness as a linear function of flue gas velocity.

The calcium sulfite/sulfate solid solution precipitation rate is adjusted by varying the rate constant to match predicted and measured relative saturation values calculated for solid calcium sulfite and sulfate compounds.

The final calibration parameters were:

Gas-film thickness (at 9 ft/sec gas velocity): 4.0 microns
Liquid-film thickness: 0.06% of droplet diameter
Reaction rate constant: 1.6×10^{-5}
Surface area factor: 1.0
Solid solution rate constant: 3.0×10^{-8}

Figure 3 compares predicted versus observed SO_2 removal for all of the cases simulated. The only case for which the predicted SO_2 removal was substantially different than the actual removal was a baseline test at very low SO_2 removal efficiency (68.5% actual vs. 58.7% predicted removal efficiency). This data point falls well outside the range of interest for this project, though. For the remaining 17 cases, the average predicted SO_2 removal efficiency was less than 0.1 percentage points higher than the average observed values, with a standard deviation of only 1.1 percentage points of removal efficiency.

The calibrated model was used to make a predictive simulation of a high-efficiency SO_2 removal condition that was not tested at full scale. This was to estimate the effectiveness of a finer limestone grind on SO_2 removal. The model predicted that the SO_2 removal across the module could be raised from approximately 86 to 97% by increasing the

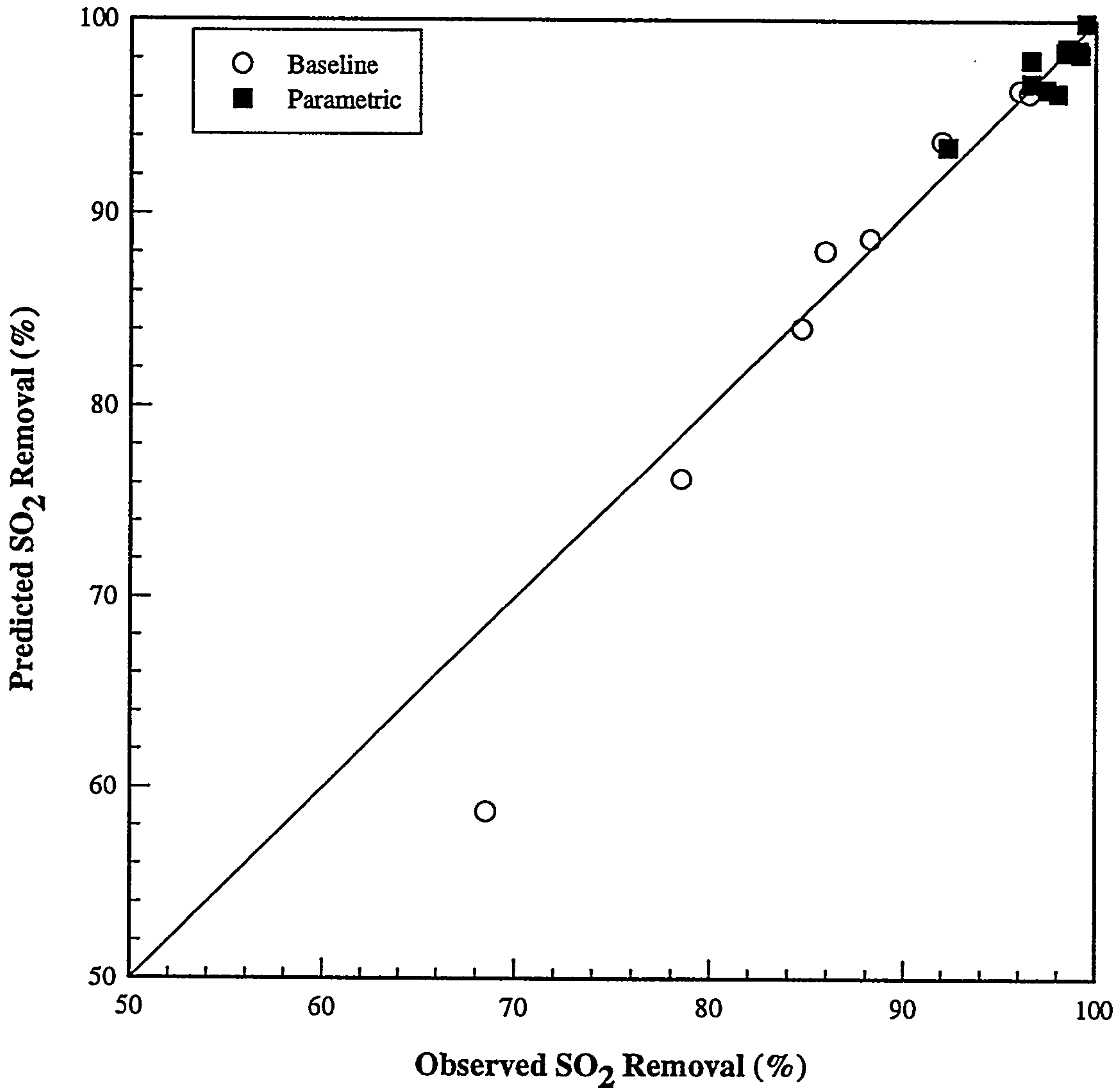

Figure 3. Kintigh FGDPRISM Calibration: Predicted vs. Observed Removal

limestone fineness from the observed value of 52% <200 mesh and 42% <400 mesh to a value of 93% <200 mesh and 85% <400 mesh. This was at the standard operation conditions of four modules in service with four pumps each operating but at an increased pH set point of 5.8. With the finer limestone grind, though, the limestone utilization was predicted to only slightly decrease to 84% from the observed baseline value of approximately 85 percent.

3.1.3 Economic Evaluation Results

The economics of sodium formate addition were evaluated based on a capital cost of $300,000 for a 100 lb/hr additive storage and delivery system, vendor quotes for delivered sodium formate additive costs, and operating cost data provided by NYSEG. The basis for these economic evaluations is summarized in Table 1.

The results of the economic evaluations are summarized in Table 2. These results show that with a closed flue gas bypass, and using sodium formate additive at 1000 ppm in the recycle slurry to raise the module SO_2 removal efficiency to nearly 98% (the fourth case in the table), more than 10,000 additional tons per year of SO_2 could be removed by the Kintigh FGD system at an average additional cost of only $76/ton. Depending on the assumed value of SO_2 allowances, the estimated net annual value of the additional SO_2 removal for this optimum case ranged from $800,000 (assuming a value of $150/ton) to $1.8 million (assuming $250/ton).

As described above, the calibrated FGDPRISM model predicted that approximately 97% removal could be obtained by operating at a slightly higher pH with a finer limestone grind. This condition (the third case in Table 2) was predicted to remove an additional 9800 tons of SO_2 per year (relative to baseline performance) at an average cost of only $53 per additional ton removed. This finer grinding might be done by operating the reagent preparation system at a lower throughput for two shifts per day instead of the current one shift per day. Some modifications to the ball mill classifier would also be required. Additional tests would be required to verify the results of these FGDPRISM predictions, though.

Table 1

Economic Basis for Kintigh SO_2 Removal Upgrade Options

Maximum Continuous Rating	708 MW gross
Capacity Factor	86% (8000 hours at 660 MW avg.)
Average Flue Gas Flow	7.3 million lb/hr
Average Fuel Sulfur Content	3.58 lb/million Btu
Average Fuel Heating Value	12990 Btu/lb
Current Average Outlet SO_2	0.52 lb/million Btu
Current SO_2 Removal	71,000 tons/yr
Additional SO_2 Available for Removal	12,500 tons/yr
Capital Cost of Sodium Formate System	$300,000 for 100 lb/hr
Annualization Factor	0.17
Delivered Cost of Sodium Formate	$0.24/lb, $0.30/lb
Cost of Power	$0.017/kWhr
Sodium Formate Consumption Rate	16.6 lb/ton SO_2 at 1130 mg/L
Cost of Prepared Limestone	$12.50/ton
Cost of Additional Sludge Disposal	$7.50/ton
Increase in System ΔP to Treat all Flue Gas	0.6 in. H_2O
Decrease/Increase in System ΔP per Spray Pump	0.2 in. H_2O
Fan Efficiency	80%
Average Recycle Pump Power Consumption	280 kW
Current Average Limestone Utilization	85%

Table 2

Economic Comparison of SO_2 Removal Upgrade Options

						Additional $/Year						Cost of Add'l SO_2 Removal		Net Annual Value ($ Thousand)	
Option	pH	Formate (mg/L)	LS Util	SO_2 % Removal	Add'l SO_2 Removed (tons)	NaCOOH Capital	NaCOOH	Add'l Fan KW	Add'l Pump KW	Add'l Reagent	Add'l Sludge	Total Annual Cost $	Avg $/ton SO_2	@ $250/ton	@ $150/ton
Current operation (4 pumps)	5.6	0	85	85.0	0	0	0		0	0	0	0			
Close bypass (4 pumps)	5.6	0	85	88.0	2500	0	0	28000		57000	43000	128000	51	500	250
Close bypass (4 pumps) Use finer grind	5.8	0	85	96.8	9840	0	0	28000		326000 [a]	167000	521000	53	1940	960
Close bypass (4 pumps) Add formate	5.6	1000	85	97.8	10640	55000	301000	28000		245000	181000	810000	76	1850	790
Close bypass (3 pumps) Add formate	5.6	1250	85	96.7	9730	57000	372000	19000	-152000	224000	165000	685000	70	1750	770
Maintain bypass (4 pumps) Add formate	5.6	1000	85	94.8	8140	55000	292000			187000	138000	672000	83	1360	550
Close bypass (4 pumps) Add formate, Lower pH	5.2	1250	89	95.4	8680	57000	367000	28000		117000	143000	712000	82	1460	590
Close bypass (4 pumps) Add formate, Higher pH	5.8	750	72	97.9	10770	53000	226000	28000		586000	199000	1092000	101	1600	520

[a] Increased reagent cost includes $100,000/year for increased reagent preparation O&M.

4.0 PLANS FOR THE NEXT REPORTING PERIOD

All of the testing currently planned for this project has been completed. Scheduled efforts during the third quarter of calender year 1995 will likely only consist of project management and reporting. For the base program (Big Bend site), a revised Topical Report has been submitted to DOE and is approved for publication. Options I and II (Hoosier Energy's Merom Station and SWEPCo's Pirkey, respectively) are in final reporting phases. Revised Technical Notes for these sites were prepared and submitted to DOE during the current quarter. Draft Topical Reports for these two sites have previously been submitted. These drafts will be revised to respond to review comments during the next quarter.

For the PSI Energy Gibson Station (Option III), a revised Technical Note summarizing results from both the sodium formate and DBA performance and additive consumption tests was submitted to DOE in May 1995. Work will begin on a draft Topical Report for this site during the next reporting period.

A draft Technical Note that summarized all test results, results of FGDPRISM modeling, and results of economic evaluations of upgrade options for the Duquesne Light Elrama site (Option IV) was submitted to DOE and to Duquesne Light in January 1995. A draft Topical Report for this site will be prepared in the third quarter of 1995, after review comments on the draft Technical Note are received from Duquesne Light.

For Option V, testing at the NYSEG Kintigh Station, a draft Technical Note summarizing these results was submitted in March 1995. A draft Topical Report for this site will likely be prepared during the third quarter of calendar year 1995, after review comments are received on the draft Technical Note.

There is also interest in demonstrating high-efficiency SO_2 removal operation for a longer period of time (three to six months) at one of the six sites participating in this project. At this time, the Tampa Electric Company Big Bend site appears to be the most favorable option for conducting such testing. During the next quarter, we will negotiate with Tampa Electric Company to finalize arrangements to conduct such longer-term testing. If such arrangements can be made, a Test Plan Addendum for this site will be prepared and submitted to DOE.

5.0 ACKNOWLEDGMENTS

Funding for the FGDPRISM modeling portion of this study is being provided by the Electric Power Research Institute.