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ELECTRIC POWER RESEARCH INSTITUTE HIGH-SULFUR TEST CENTER

REPORT TO THE STEERING COMMITTEE

March 1994

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This monthly report is a compilation of monthly progress reports by EPRI contractors (Radian Corporation, Gilbert/Commonwealth, Electric Power Technologies, Inc (EPT)) connected with the High Sulfur Test Center (HSTC). This report is intended to provide timely information to the HSTC co-sponsoring organizations. All data and results should be considered preliminary. Neither EPRI, members of EPRI, Radian, Gilbert/Commonwealth, EPT, nor any person acting on behalf of any of them: (a) makes any warranty, express or implied, with respect to the use of any information, apparatus, method, or process disclosed in this report or that any such use may not infringe privately owned rights; or (b) assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

TABLE OF CONTENTS

EXECUTIVE SUMMARY.....	iv
SECTION I FACILITY STATUS.....	1
GENERAL.....	1
Pilot Wet FGD System	1
Mini Pilot Wet FGD System.....	2
SCR System	3
Auxiliary Systems.....	3
Financial Report.....	5
SECTION II PILOT AND MINI-PILOT TEST ACTIVITY	7
Pilot.....	7
Mini-Pilot	25
On-Line Chemical Monitoring.....	36
APPENDIX A Test Schedules	39
APPENDIX B Pilot and Mini-Pilot data	42
HSTC COSPONSORS DISTRIBUTION.....	65

LIST OF FIGURES

Figure

1	1993 Operation & Maintenance Costs.....	5
2	Gas Path Configuration for Suncor Testing.....	17
3	Dewatering Configurations used during Suncor Tests	18
4	SO ₂ Removal Efficiency and L/G results for test SUN-1.....	19
5	Process Flow Diagram for GCLS test series.....	29
6	Effect of DBA concentration on SO ₂ removal efficiency	30
7	Effect of Suspended solids concentrations on Dewatering	31
8	Effect of FLRT Solids concentration on Gypsum RS.....	32
9	Effect of Suspended solids on Scaling rates.....	33
10	On-Line Limestone Utilization measurements	38

LIST OF TABLES

Table

1	Monthly Operating Costs By Task.....	6
2	Suncor Test Plan Parameters.....	20
3	Summary of Key Results from the Suncor Test block.....	21
4	Summary of Particle Size Analyses of Suncor Limestone.....	22
5	Summary of Results from test SUN-7	23
6	Summary of Results from tests SUN-4 and SUN-6.....	24
7	Summary of GCLS Operating Conditions.....	34
8	Summary of GCLS Process Performance Results	35

LIST OF COMMON ABBREVIATIONS

A-S-H.....	Allen Sherman Hoff
BES.....	Bulk Entrainment Separator
CRG.....	Clean Raw Gas
CLS.....	Clear Liquor Scrubbing
DBA.....	Di-Basic Acid
DRG.....	Dirty Raw Gas
EDR.....	Electrodialysis Reversal Membrane Unit
ESP.....	Electrostatic Precipator
FF.....	Fabric Filter
FGD.....	Flue Gas Desulfurization
FLRT.....	First Loop Reaction Tank
FRP.....	Fiberglass Reinforced Plastic
G/C.....	Gilbert/Commonwealth Inc.
GEESI.....	General Electric Environmental Services Inc.
HME.....	Horizontal Mist Eliminator
HSSD.....	High Sulfur Spray Dryer
HSTC.....	High Sulfur Test Center
HYPAS.....	Hybrid Pollution Abatement System
ID.....	Induced Draft
L/G.....	Liquid to Gas Ratio, (gal/1000ft ³)
MFT.....	Master Fuel Trip
MRT.....	Main Reaction Tank
NTU.....	Number of Transfer Units
NYSEG.....	New York State Gas & Electric
O&M.....	Operations & Maintenance
PJFF.....	Pulse Jet Fabric Filter
RTD.....	Resistance Temperature Detector
RWST.....	Recycle Water Storage Tank
SCBA.....	Scott Air Packs
SDA.....	Spray Dry Absorber
UMIST.....	Univ. of Manchester Inst. of Science & Technology
VME.....	Vertical Mist Eliminator
VSD.....	Variable Speed Drive
WDPF.....	Westinghouse Distributed Process Control System

EXECUTIVE SUMMARY

Operations and maintenance continued this month at the Electric Power Research Institute's High Sulfur Test Center. The Suncor Limestone Reagent and Dewatering tests were completed on the Pilot unit this month. As this test block ended, the Pilot unit was modified for the High Velocity Scrubbing tests. This testing began on March 28, 1994 with test PHV-AN. As Phase II of the Mini-Pilot Clear Liquor Scrubbing test block was completed this month, the unit was taken off-line.

Testing on the Cold-Side Selective Catalytic Reduction (SCR) unit continued this month as ammonia slip measurements were conducted. Catalyst material from the reactor was inspected and sampled during a scheduled outage this month in preparation for a low temperature test block.

Pilot and Mini-Pilot Testing Highlights

Pilot

The pilot system was commissioned by Suncor, Inc. for a two-week period in March to investigate the performance of a particular type of limestone in a forced-oxidation FGD system. The objectives of the tests were to determine if 92% SO₂ removal efficiency could be achieved at an inlet SO₂ concentration of 4000 ppm with a limestone utilization of 94%, and to evaluate methods of dewatering the reaction tank slurry to at least 83 wt.% solids.

Seven SUN tests were completed with five different dewatering configurations. The configurations included use of a centrifuge or a vacuum belt filter with or without a thickener or a hydroclone for primary dewatering. Various polymer dosages and addition locations were tested to aid in the removal of fines from the system. All other test conditions remained constant and were designed to simulate, to the extent possible, the chemistry and flue gas conditions anticipated for the proposed full-scale system.

The results of the SUN tests showed that the system could achieve the required SO₂ removal at the stated test conditions. The operating pH ranged from 5.8 to 6.0 which suggests that the Suncor limestone is fairly reactive. However, the limestone is of a very poor quality with an inerts level of about 25%, resulting in about 20% inerts in the reaction tank slurry. The high level of inerts is believed to be the primary cause of the very poor solids properties compared to gypsum typically produced in full-scale forced-oxidation systems. Only by operating the dewatering system at unrealistic conditions (e.g., discarding the entire hydroclone overflow with 60% of the waste solids) was it possible to obtain a handleable filter cake. Although most of the SUN tests were not run for more than a couple of solids residence times, it is unlikely that solids properties would improve significantly over a longer period of

operation, because test data showed that the fines in the system were generally increasing under most test conditions. However, because there was not enough time to optimize operation of the dewatering equipment, it is possible that an acceptable quality of waste solids could be achieved with the appropriate equipment configuration and operating set points.

In April, the pilot High Velocity test program will begin. The objective of this test block is to evaluate scrubbing efficiency and mist eliminator performance at flue gas velocities up to 15 feet per second in a counter-current, forced-oxidation, limestone FGD system. The information obtained will increase the general understanding of the impacts of high velocity scrubber operation and will aid member utilities in determining if scrubbing additional flue gas in an existing scrubber is a feasible option as part of their overall compliance with the 1990 CAAA.

Mini-Pilot

Phase II of the Clear Liquor Scrubbing (CLS) test program was completed on the mini-pilot system in March. The overall objective of this test program was to develop a limestone-based, clear liquor scrubbing system with improved costs and performance over existing lime and limestone slurry scrubbing processes. The final series of CLS tests investigated performance of a forced-oxidation, clear liquor scrubbing system. Advantages of this type of system include the production of gypsum with exceptional dewatering properties and higher limestone utilization due to sparging the limestone reactor with forced-oxidation air.

A total of eight Gypsum Clear Liquor Scrubbing (GCLS) tests were performed, six of which were completed in March. The primary variables included the limestone reactor solids concentration, dissolved calcium level, and absorber internals (packing and/or tray). The main test objectives were to minimize the gypsum relative saturation in the scrubbing liquor and absorber effluent to prevent scaling; to minimize the solid-phase residence time and thereby achieve the lowest capital costs for the proposed system; and to investigate the relative performance of absorber internals for increasing the SO₂ removal efficiency.

The results of the GCLS tests showed the importance of suppressing (by sodium addition) or reducing (by chloride removal) the dissolved calcium concentration to minimize the increase in gypsum R.S. across the absorber. The test results suggest that the calcium level should be controlled below 25 mM (1000 ppm), with the optimum level for a given system depending on the economics of the method used to remove chloride or suppress calcium. It was also determined that a relatively high reactor suspended solids concentration (about 15 wt.%) was required to achieve the best dewatering characteristics and the lowest scaling potential. SO₂ removal results showed that the same removal could be achieved with a tray or with Munter's type 12060 packing, with the packing providing a much lower pressure drop (0.5 in. H₂O vs. 1.4 in. H₂O). A more open type of packing, Munter's PN-Fill,

resulted in only 56% SO₂ removal versus 74% with the 12060 packing. Finally, use of packing supported by a 39% open tray increased SO₂ removal to 92%, although the absorber pressure drop increased to 4.3 in. H₂O.

The results of an economic analysis suggested that the forced-oxidation process could significantly reduce capital and operating costs relative to conventional full-scale forced-oxidation slurry processes. Although no further tests are scheduled for the mini-pilot system for the remainder of 1994, based on the favorable economics, future testing of this process concept is possible.

On-Line Chemical Monitoring

The current focus of the On-Line Chemical Monitoring (OLCM) project is the evaluation of a prototype system which was designed and constructed at the HSTC earlier this year. In March, testing of the system began with an evaluation of the procedure for measuring limestone loading in an inhibited-oxidation slurry. Several months of tests are scheduled for the prototype system after which testing in a full-scale facility is planned.

SECTION I FACILITY STATUS

GENERAL

The NYSEG Kintigh Station provided flue gas to the HSTC facility 100% of the time during this performance period. As the Kintigh Station operated with a variety of coals, fluctuations in the HSTC inlet SO₂ concentrations were experienced.

Safety training for the month was conducted by the Operations Supervisor, Maintenance Supervisor, and the Shift Supervisors. "Safe Lifting and Carrying" was the topic of the month. Inspections were completed on the Facility air-packs, fire extinguishers, and other safety equipment to insure that there were no deficiencies in the equipment.

There were no injuries or close call reports filed for the month of March. By continuing to emphasize safe work habits at the HSTC, we have raised the total number of days without a lost time injury to 685 as of 3/31/94.

The monthly safety meeting with the NYSEG Kintigh Station was rescheduled and will be held concurrently with the meeting for April. The OSHA safety training activities with NYSEG continued this month. These classes are held on two consecutive days per week for a ten week period; they cover the following topics: Confined Space Entry; Incipient Fire Training; CPR and Blood Borne Pathogens; Hearing Conservation; Inorganic Arsenic and Ref. Ceramic Fibers; Respirators; and First Aid.

PILOT WET FGD SYSTEM

The equivalent and actual availabilities for the HSTC Pilot FGD System testing were both 99% during this period. The Pilot Wet FGD System did not operate during the following periods:

- March 3 for 4 hours due to pluggage in a recirculation nozzle.
- March 31 for 3 hours due to VME pipe cleaning.

The Suncor Limestone Reagent and Dewatering tests were completed this month with tests SUN-1 through SUN-7. These tests involved the use of both the Centrifuge and the Vacuum Belt Filter. The operational parameters for the Pilot Wet Scrubber included: gas flow at 8250 scfm; 2000 and 4000 ppm inlet SO₂; recycle slurry flows of 1400 and 1300 gpm; and an absorber inlet temperature of 315°F.

Upon the completion of the Suncor tests, the unit was purged and flushed. Modifications were then made to the Pilot VME sections for the High Velocity Scrubbing Tests. In this new configuration, the unit was restarted on March 28, 1994

with test PHV-AN. The operational parameters for the Pilot Wet Scrubber included: gas flow at 9800 scfm; 2000 ppm inlet SO₂; recycle slurry flows of 1300 gpm; and an absorber inlet temperature of 315°F.

The following maintenance work was completed to the Pilot Wet Scrubber unit during this performance period:

- Thirty-eight 55 gallon drums were loaded with slurry and reaction tank product for shipment back to Suncor.
- The Ball Mill and PSI were made ready for reagent preparation.
- Scheduled maintenance was performed on the centrifuge.
- Pump 14 was returned to service for reaction tank blowdown operations.

MINI-PILOT WET FGD SYSTEM

The equivalent and actual availabilities for the HSTC Mini-Pilot FGD System testing were both 88% during this period. The Mini-Pilot Wet FGD System did not operate during the following periods:

- March 1 for 5 hours due to tray cleaning & inspection.
- March 2 for 2 hours due to scale removal and downcomer cleaning.
- March 7 for 1 hours due to tray & inlet cleaning.
- March 13 - 15 for 53 hours due to unit reconfiguration & ESP repairs.
- March 18 for 20 hours due to absorber packing installation & test change.
- March 21 for 3 hours due to seal repairs on pump 14.
- March 24 for 4 hours due to packing removal.
- March 26 for 5 hours due to a packing change.

Phase II of the Clear Liquor Scrubbing test block was completed with tests GCLS-2; 3; 4; 5; and 6. These tests utilized the Thickener at various recycle rates and the SBRT for absorber recycle feed. The operational parameters for the Mini-Pilot Wet Scrubber included: gas flow at 750 scfm; 2000 ppm inlet SO₂; recycle slurry flows of 17 gpm; and an absorber inlet temperature of 310°F. The system was purged and flushed while the associated equipment was prepared for inspection, repair, and long-term storage.

The following maintenance work was completed to the Mini-Pilot Wet Scrubber unit during this performance period:

- The centrifuge was flushed, disassembled, cleaned, and lubricated.
- The absorber tray was cleaned between testing.
- The clipper seal was inspected, cleaned, and installed on Pump 14.
- The absorber tray was removed and modified as 35 additional 1.375" holes were added per a Radian request. The tray was then installed with the packing in the absorber.

- A missing VME piece was fabricated and replaced in the absorber.
- The ESP was inspected and minor repairs were made to "A" field; an insulator was replaced and several broken hot deck wires were repaired.

COLD-SIDE SELECTIVE CATALYTIC REDUCTION SYSTEM (SCR)

The equivalent and actual availabilities for the HSTC SCR System testing were both 84% during this period. The SCR System did not operate during the following periods:

- March 11 - 16 for 118 hours due to inspection & sampling of the Engelhard catalyst.

Testing continued this month on the SCR unit at baseline conditions as several ammonia slip measurements were conducted. The unit was taken off-line for a brief outage this month to inspect and sample the Engelhard catalyst before low temperature testing begins next month. The operational parameters for the SCR unit included: gas flow at 2000 scfm; catalyst inlet temperatures of 600-650°F; inlet NH₃ pressures of 50 psi; and NH₃/NO_x ratios of 0.7 to 1.0.

The following maintenance work was completed on the SCR unit during this performance period:

- The monthly inspection of all safety equipment was completed.
- No major maintenance was required during this reporting period.

MISCELLANEOUS

Ball mill operation was normal this month and included the preparation of reagent for the Suncor Limestone Reagent testing. The grind prepared for normal HSTC operation was 90% passing 325 mesh screen. The grind prepared for the Suncor tests was 95% passing 200 mesh screen.

Work continued this month on the development of the On-Line Chemistry Monitor (OLCM) prototype. An on-site planning meeting was held on March 30-31 to discuss the future development activities and testing of the prototype.

In a full-scale demonstration test block, the Outokumpu Mintec particle size indicator (PSI-200) remains at PSI Energy's Gibson Station. As this test block continues into April, plans will be made to relocate the PSI unit, or provide a new unit, to the last scheduled utility demonstration site, the Hoosier Energy Merom Station.

The following general plant maintenance activities were completed this month:

- Centrifuge sludge and ash were hauled to the NYSEG landfill.
- All daily and weekly vehicle checklists were completed.
- Day shift file maintenance and idled equipment rotation continues.
- The monthly inspection of all safety equipment was completed.
- Vibration surveys were taken on all booster fans.
- Scheduled electrical maintenance activities were completed on the HSTC and WASF substations, booster fans, VSD's, and lighting transformers.
- The HSTC/WASF lighting was replaced and repaired as necessary.
- The OLCM prototype unit was tested, checked, and is currently in operation.
- The HSTC trenches were cleaned by an outside contractor.
- All Pilot worklist items were completed.
- Preparations began for an upcoming Carbon Injection Test block.
- The solenoids and pulse diaphragms were replaced on the waste silo.
- Several Gaitronics units were repaired.
- The Yale forklifts were serviced, repaired, and inspected.

FINANCIAL REPORT

The Financial Report for the four Operations and Maintenance contract tasks are summarized below for February 1994, the year to date, and for the contract total.

Table 1
Monthly Operating Costs by Task

	March	Year to Date	Contract Total
Task 100	\$ 120,008	\$ 310,311	\$ 11,605,919
Task 200	\$ 17,691	\$ 33,331	\$ 6,870,798
Task 300	\$ 3,765	\$ 10,119	\$ 1,021,266
Task 400	\$ 352	\$ 10,919	\$ 39,212
TOTAL	\$ 141,816	\$ 364,680	\$ 19,537,195

Task Definitions:

Task 100: Operation & Maintenance Labor
Task 200: Purchased Materials
Task 300: Engineering Support
Task 400: Training

The attached graph illustrates the budgeted and actual expenses for HSTC O&M activities through March 1994.

Figure 1
1994 Operation & Maintenance Costs

SECTION II PILOT AND MINI-PILOT TEST ACTIVITY

PILOT

Summary of Operations

Suncor, Inc. commissioned the use of the pilot system from February 28, 1994, through March 10, 1994, as part of an ongoing evaluation of sulfur dioxide control technologies. Seven tests were completed during the SUN test block. This section describes the process configuration and summarizes process operation during this test program.

Process Description

Figure 2 shows the gas path used for the SUN tests. The pilot system was used to simulate a full-scale scrubber at Suncor's proposed conditions. Flue gas passed through the pilot spray dryer absorber (SDA) and the electrostatic precipitator (ESP) before entering the pilot scrubber. The SDA was used to inject lime slurry during the SUN tests to reduce the flue gas HCl concentration at the wet scrubber inlet, thus, better simulating Suncor's flue gas conditions. An HCl analyzer was used to continuously monitor the scrubber inlet HCl concentration.

Figure 3 illustrates the five dewatering configurations used during the SUN test series. In the first dewatering configuration (used in SUN-1, -2, and -7), the solids were removed from the system by feeding the centrifuge directly from the first loop reaction tank (FLRT). In the second configuration (SUN-3), the solids in the reaction tank were first fed to the thickener for primary dewatering with polymer. The underflow from the thickener was then fed to the thickener underflow storage tank (TUST) before being sent to the centrifuge. In the third dewatering configuration (SUN-4), the fines were removed from the reaction tank by feeding slurry to a hydrocyclone where the underflow was returned to the FLRT and the overflow was discarded. The fourth configuration (SUN-5) was similar to the second configuration except that the vacuum belt filter was used for secondary dewatering. Finally, in the fifth configuration (SUN-6), the underflow from the hydrocyclone was dewatered using the vacuum belt filter.

Operating Summary

The first two trucks of Suncor limestone arrived on February 28. Numerous unloading problems delayed ball-milling until late in the evening on March 1. On March 2, with the first two trucks of limestone unloaded to the HSTC silos, the second two trucks were parked near the Kintigh Station boiler to warm the limestone and make them easier to unload.

The pilot unit was brought on-line on March 2 with SUN-1 (Baseline SO₂ Removal Test). The objective of SUN-1 was to achieve 92% SO₂ removal efficiency with an inlet SO₂ concentration of 4000 ppm and a limestone utilization of 94%. The original test parameters from the test plan are listed in Table 2. The system was configured with only a centrifuge for dewatering directly from the reaction tank according to configuration #1 in Figure 3.

At start-up, the slurry feed rate to the absorber was set at the pilot baseline flow rate of 1300 gpm using two spray headers. With the limestone feed rate set to get approximately 94% limestone utilization, the slurry flow to the absorber was increased to 1500 gpm using three spray headers to get approximately 92% SO₂ removal. Solids blowdown began late in the evening. The pilot unit was taken off-line briefly on March 3 to remove some blockage from a spray nozzle on header #1. Moisture in the limestone trucks made it impossible to unload any more limestone from the second two trucks. Also, sieving problems in Edmonton made it unlikely that any new limestone would be available later in the test block. Consequently, a decision was made to end SUN-1 and reduce the inlet SO₂ concentration from 4000 ppm to 2000 ppm for the remaining tests to make the available limestone last for approximately 10 days.

On the evening of March 3, the inlet SO₂ concentration was dropped to 2000 ppm for SUN-2 (Baseline Dewatering Test). The objective of SUN-2 was to collect baseline dewatering data using a centrifuge fed directly from the reaction tank (as in SUN-1). The limestone feed rate was again set for 94% utilization, and the liquid rate was lowered to a baseline level of 1300 gpm. To obtain a similar solids residence time, the reaction tank level was lowered from 18 to 12 ft. Sulfite oxidation remained high (>99%) even at the lower tank level.

By March 4, the solids concentration in the FLRT was continuing to rise. It appeared that the solids concentration in the recycle water in the recycle water storage tank (RWST) was much higher than usual. It was likely that the centrifuge was not able to remove many of the fines from the blowdown stream which were then recycled back to the reaction tank with the recycle water. By March 5, the solids concentrations in the RWST and in the FLRT were still rising. The test was ended that evening.

The system was reconfigured on March 5 for SUN-3 (Thickener, Polymer, and Centrifuge Dewatering) in an attempt to remove a greater portion of the fines. The objective of SUN-3 was to remove a greater portion of the fines from the system by incorporating a thickener with polymer as the primary dewatering device. Again, the centrifuge was used to dewater solids from the thickener underflow storage tank according to configuration #2 in Figure 3.

Betz 1100 polymer was initially added to the thickener feed well at a rate of 0.01 lb polymer/ton of dry solids. Part of the underflow was recirculated back to the thickener feed well with a small bleed stream sent to the TUST for centrifuge dewatering. By March 6, the thickener overflow was cloudy. The polymer feed rate was increased to 0.03 lb polymer/ton of dry solids. On March 7, the thickener overflow was still cloudy. Laboratory tests indicated that a polymer concentration of about 0.6 lb polymer/ton of dry solids would result in reasonable settling rates. Large amounts of polymer were added to the thickener, attempting to get clear overflow. Even with this large polymer dosage, the overflow from the thickener was still cloudy. The test was ended that evening.

The objective of SUN-4 was to remove some of the fines from the system while returning the larger particles back to the FLRT. Using a hydrocyclone, as illustrated in configuration #3 in Figure 3, the overflow stream was discarded while the underflow solids were returned to the FLRT. Hydrocyclone performance and solids settling rates were evaluated for the short duration of this test. A 4-inch hydrocyclone (0.375-inch apex diameter, 1-inch vortex finder diameter) was placed in service for SUN-4 to discard the fines in the overflow while concentrating the solids in the underflow. After approximately 6 hours of hydrocyclone operation, the test was ended.

On March 8, the vacuum belt filter was started for SUN-5. The objective of SUN-5 was to collect performance data using the vacuum belt filter for solids dewatering. With the thickener used as the primary dewatering device, the thickener underflow slurry was pumped to the vacuum belt filter and dewatered as illustrated in configuration #4 in Figure 3. Polymer was added to the pump suction directly before the vacuum belt filter.

When solids blowdown began, the filter immediately blinded, and the centrifuge was put back into service temporarily. By this time, the overflow from the thickener was clear, although the solids in the underflow were extremely thick and difficult to pump. By evening, a second attempt at filtering the solids was made by adding polymer (0.3 lb polymer/ton of dry solids) to the pump suction directly upstream of the vacuum belt filter. With a 1.5 gpm solids blowdown stream and a filter speed of 14 ft/min, a relatively dry filter cake fell off the filter on its own for approximately 2 hours. Operation of the vacuum belt at these conditions was extremely difficult with no filtrate getting to the second vessel. The test was ended on March 9.

On March 9, the hydrocyclone was placed back in service for SUN-6. The objective of SUN-6 was to collect performance data from the vacuum belt filter when dewatering the hydrocyclone underflow. The system was configured according to configuration #5 in Figure 3. The underflow slurry was sent to the hold tank and then fed to the vacuum belt filter without polymer at about 2 gpm with a filter speed of about 15 ft/min. The solids dewatered very easily, producing a 1-inch filter cake.

This dewatering sequence was run for approximately 4 hours. Following SUN-6, the centrifuge was started once again for SUN-7.

On March 10, the first samples were taken for SUN-7. In SUN-7, adjustments were made to the centrifuge to collect performance data at different centrifuge settings. The dewatering sequence is illustrated in configuration #1 in Figure 3. Shortly after data were collected at three different settings, the system was taken off-line when the limestone supply was depleted.

Summary of Results

Suncor, Inc. commissioned the use of the pilot system from February 28, 1994, through March 10, 1994, as part of an ongoing evaluation of sulfur dioxide control technologies. Suncor processes oil sand into synthetic crude oil in a large facility in Ft. McMurray, Alberta. In the process, the utility plant boilers burn petroleum coke with a high sulfur content, hence producing a flue gas which contains sulfur dioxide. Currently, Suncor is permitted to release 259 metric tons of sulfur dioxide into the atmosphere each day. With federal and provincial environmental regulations being tightened, Suncor must reduce its plant-side SO₂ emissions by mid-1996.

In order to meet these more stringent air regulations, the Suncor Utility Plant is considering the use of wet limestone FGD technologies to reduce emissions. Due to the very remote location of the facility, a cheap source of high quality limestone is not available. For this reason, Suncor would like to use limestone from a deposit beneath the oil sand layer that is currently being mined. However, this deposit contains a very poor quality limestone that could potentially cause significant dewatering and operating problems if used in an FGD system. Testing at the HSTC was conducted to explore the feasibility of using Suncor's limestone in a forced-oxidation FGD system.

The overall objectives of the Suncor test block were:

- To achieve 92% SO₂ removal at an inlet SO₂ concentration of 4000 ppm with a limestone utilization of approximately 94%; and
- To determine if there is a solids dewatering method capable of producing a handleable byproduct with less than 17 wt.% moisture.

Table 3 summarizes the key test results from this test block. Complete tables of analytical results and process data summary reports for each of the Suncor tests are appended to this report.

FGD Solids Characteristics

Overall, the FGD solids produced during the Suncor test block were extremely poor as compared to typical gypsum solids. Solids settling and dewatering results are presented in Table 3. For typical FGD gypsum solids, the thickener unit area required to settle a ton of solids per day to 30 wt.% is between 0.5 and 2 ft²; thickener unit areas for the Suncor solids ranged from 86 to 194 ft²/ton per day, almost 200 times the typical unit area. Likewise, the form filtration rates for the Suncor solids were approximately 2 lb/ft² · hr compared to 2000 lb/ft² · hr for typical gypsum solids. One encouraging result is that the filter cake produced from the form filtration test was approximately 80 wt.%, a reasonable value for FGD gypsum for this analytical test. Although it is extremely unlikely that a filter could be economically viable for these solids, gypsum stacking may be possible.

The overall poor solids properties appear to be caused by the relatively high concentration of fine particles which apparently enter the system with the inerts in the limestone. Typical FGD solids will contain between 1 wt.% and 5 wt.% inerts, where the Suncor solids contained approximately 20 wt.% throughout the test block. One concern with using Suncor limestone in an FGD process was that complete oxidation of the sulfite would be difficult. However, achieving complete oxidation was not a problem using the HSTC pilot unit. Hence, incomplete sulfite oxidation does not appear to be a factor in the poor solids properties.

Although steady-state conditions were not achieved with respect to the solids for each set of test conditions, the extremely poor solids properties are not likely to improve significantly over a longer period of steady-state operation.

Suncor Limestone Evaluation

The limestone provided by Suncor was mined in Ft. McMurray, Alberta. The limestone was then shipped to Edmonton to be chipped and loaded into pneumatic trucks before being transported to the HSTC. This preparation process is not typical of a full-scale FGD system, but the HSTC limestone silos require limestone shipments via pneumatic truck. Unfortunately, the wide range of stone sizes, moisture in the trucks, and freezing temperatures made it very difficult to unload. Consequently, only two of the first four trucks could be unloaded, making it necessary to run most of the tests at a reduced inlet SO₂ concentration.

At one point, an attempt was made to sieve the chipped limestone in Edmonton to remove some of the finer particles. On-site analysis of the two fractions (using a 1/4 inch mesh) showed that this separation would not drastically affect the carbonate content. The coarser portion had a slightly higher carbonate content at 7.3 mmol/g compared to 6.6 mmol/g in the finer fraction (73 wt.% CaCO₃ vs. 66 wt.% CaCO₃ assuming all carbonate is present as calcium carbonate). However, numerous

plugging problems with the sieves in Edmonton made it impossible to produce a more handleable limestone for testing.

Once in the HSTC silos, the limestone slurry was prepared using the HSTC ball mill. During the Suncor test series, limestone slurry samples were collected and analyzed on a daily basis. From these analyses, the limestone had the following average characteristics:

- 37 wt.% limestone slurry;
- 95% passing 200 mesh;
- 68 wt.% CaCO_3 ;
- 5 wt.% MgCO_3 ; and
- 25 wt.% Inerts.

These average values were taken from data collected throughout the Suncor test block. For individual sampling data, refer to the analytical results tables appended to this report.

The most unusual characteristic of this limestone is the very high inerts content. The baseline limestone used at the HSTC typically has less than 3% inerts compared to 25% in the Suncor limestone. Since the inerts must be dewatered with any gypsum produced, a high inerts concentration in the limestone can increase the size of dewatering equipment significantly. More importantly, the inerts will often make up a large portion of the fines in the reaction tank slurry which may lead to slow solids settling rates, filter blinding episodes, and hindered gypsum crystal growth. Recycle and build-up of fines in the process slurry is likely unless steps are taken to remove fines from dewatering system streams such as hydrocyclone overflows and/or centrate.

One possible method for increasing the limestone quality is to remove part of the inerts fraction with a hydrocyclone or a series of hydrocyclones before using the limestone as reagent. In a preliminary laboratory analysis of this option, Suncor limestone slurry was passed through a series of sieves ranging from 200 to 635 mesh. The fraction in each cut was then analyzed for solid-phase calcium, magnesium, carbonate, and inerts. The results from these analyses are presented in Table 4. Notice that the finest fraction (particles less than 20) was not analyzed, but the components were estimated through a material balance around the total sample and the coarser samples.

Since nearly 85% of the limestone sample contained particles that were less than 20 in diameter, it is unclear whether a hydrocyclone could successfully concentrate the calcium carbonate while removing most of the inerts. In the coarsest fractions, the calcium carbonate was concentrated as high as 85% while the inerts were reduced from 26 to 14%. However, this fraction makes up only 2.3% of the total sample, and it is unlikely that a hydrocyclone scheme could be designed to economically separate

this fraction for use. It appears that many of the fine limestone particles have the same particle size range as the inerts. Consequently, it may be impractical to attempt to separate the inerts from the limestone by using classification methods like hydrocyclones. However, other methods, such as flotation, that use chemical differences rather than particle size could be successful.

SO₂ Removal Efficiency

One of the objectives of this test block was to ensure that Suncor limestone can achieve 92% SO₂ removal at an inlet SO₂ concentration of 4000 ppm and a limestone utilization of approximately 94% in a wet limestone scrubber. To meet this objective, SUN-1 was run for approximately 17 hours until stable SO₂ removal was achieved.

Figure 4 plots the SO₂ removal efficiency and L/G results for SUN-1 over the brief duration of the test. Note that the unit was taken off-line for a short period of time during the test to remove debris from one of the spray nozzles. A fairly consistent SO₂ removal efficiency of 92.2% was achieved with an inlet SO₂ concentration of 4000 ppm and a limestone utilization of 91%. Although these conditions were tested for less than a day, the limestone appeared to be very reactive, resulting in a slurry pH of 5.8 at this relatively high limestone utilization. The 92% SO₂ removal efficiency was achieved at an average L/G of 151 gal/macf. Keep in mind that the L/G ratio for the pilot unit cannot be directly scaled up to reflect the L/G required in a full-scale system due to the small absorber diameter.

Centrifuge Dewatering

In four of the seven Suncor tests, a horizontal centrifuge was used for solids dewatering. This section describes the dewatering results from SUN-2 and SUN-7, where the centrifuge was used as the primary dewatering device, and SUN-3, where the centrifuge was used as the secondary dewatering device.

Throughout the Suncor test block, the centrifuge was capable of producing a waste product with a solids concentration of 76 wt.% or greater. On a number of occasions, the solids concentration was well above the 83 wt.% goal mentioned in the test objectives. However, the solids were extremely difficult to handle even at the higher solids concentrations. Furthermore, a significant quantity of fines were not being removed with the centrifuge product—a potentially serious problem on a full-scale system. In early tests, it became evident that a large amount of fines were being recycled back to the reaction tank through the mist eliminator wash and the flue gas quench.

The solids concentration in the centrate was measured at approximately 2 wt.% on a number of occasions. Although this value seems insignificant, this fraction accounts for about 10% of the solids being fed to the centrifuge—a recovery rate of 90%, where the recovery rate for a centrifuge is defined as:

$$\text{Recovery Rate, \%} = \frac{\text{Total Solids in Cake Product}}{\text{Total Solids Fed to Centrifuge}} \times (100)$$

Since the centrifuge motor speed can affect the recovery rate of the solids, four different operating conditions were evaluated during SUN-7. Table 5 summarizes the results from this short series of tests. By lowering the motor speed, the recovery rate remained near 90%. Although it appears that reasonable recovery rates cannot be achieved using a centrifuge, the short duration of these tests probably did not allow the system to stabilize, and the results may not reflect the eventual performance of a properly sized centrifuge operating at the correct set points.

Overall, it appears that the centrifuge alone, without polymer or fines treatment, could not successfully dewater the solids produced using Suncor limestone. The centrate contains so many fines (about 10% of the total solids produced in the process) that they must be removed to avoid building fines in the process. One option is to add polymer to the centrifuge feed; another is to remove fines from the centrate by using a secondary dewatering method such as a settling pond, a thickener with polymer, a pressure filter, or other fines treatment processes.

Effect of Polymer

In two of the seven Suncor tests, a thickener with polymer addition was used as the primary dewatering device. In SUN-3, a centrifuge was used for secondary dewatering, while a vacuum belt filter was used in SUN-5. In all tests with polymer, Betz 1100 polymer was used, typically in 1 g/L concentrations. The thickener has a diameter of 7 ft and a volume of approximately 2700 gallons.

In laboratory tests, the fines could be removed from the system with the proper amount of polymer. With a polymer concentration of 0.6 lb polymer/ton of dry solids, the thickener unit area required to settle solids to 30 wt.% dropped from over 100 ft²/ton/day to less than 5 ft²/ton/day. Although this high polymer dosage does not seem economical for a large quantity of solids, it may potentially be reasonable if polymer is added to a stream containing only the fines, such as the centrate or hydrocyclone overflow stream.

At one point, the polymer was capable of maintaining clear overflow from the thickener. This occurred at a very high polymer dosage of approximately 0.3 lb polymer/ton of dry solids. Although the thickener overflow was clear, the underflow became increasingly difficult to handle until it eventually could not be pumped. The use of polymer requires more study to define optimum dosages and

underflow concentrations to determine if the use of polymer can be done economically and practically.

Hydrocyclone Dewatering

A 4-inch hydrocyclone was used during two of the Suncor tests (SUN-4 and SUN-6) to gather dewatering data. Table 6 summarizes the key results from these two tests.

For both hydrocyclone tests, the solids recovery rates were extremely low (43 and 34%, respectively) where the solids recovery rate is defined as:

$$\text{Recovery Rate, \%} = \frac{\text{Total Solids in Underflow}}{\text{Total Solids in Feed}} \times (100)$$

For both hydrocyclone tests, the solids in the overflow were discarded. The low solids recovery rates were caused by a combination of variables including the design and operating characteristics of the hydrocyclone. Changing the apex, hydrocyclone diameter, feed pressure, feed rate, and other hydrocyclone variables could alter the results significantly. Due to the short duration of the Suncor test block, many of these variables were not explored. Additional hydrocyclone testing would be necessary to define the design and operating characteristics of a hydrocyclone system for this application.

The results from SUN-4 show that the hydrocyclone can successfully remove a large portion of the inerts in the overflow stream; however, nearly 60% of the solids had to be discarded to achieve this low inerts level. The feed solids were 18 wt.% inerts, the overflow solids were 28 wt.% inerts, and the underflow solids were only 5 wt.% inerts. By removing the fines, the form filtration rate increased from 3 lb/hr · ft² to over 1500 lb/hr · ft² (close to a typical gypsum filtration rate). The solids properties of the underflow stream from the hydrocyclone were typical of most FGD gypsum solids with a final settled wt.% of 72 and a 87 wt.% filter cake (from the form filtration test). On the other hand, with only limited data, it is unclear whether a higher solids recovery rate would result in reasonable fines removal with improved solids properties.

In SUN-6, the hydrocyclone underflow stream was successfully dewatered using the vacuum belt filter to greater than a 90 wt.% filter cake. Again, these solids account for only 34% of the total solids in the system. With such a low solids recovery rate, a more thorough investigation of the use of the hydrocyclone is necessary to make any economic evaluation of this type of dewatering device.

Vacuum Belt Filter

A vacuum belt filter can generally remove a greater portion of fines than a centrifuge. Unfortunately, a high fines concentration can lead to filter blinding. In

two Suncor tests (SUN-5 and SUN-6), the vacuum belt filter was used as the secondary dewatering device.

In SUN-5, the thickener underflow was initially fed to the vacuum belt filter directly, but the filter blinded immediately. In a second attempt, polymer was added to the pump suction feeding the vacuum belt at a rate of 0.3 lb polymer/ton of dry solids. With the extra polymer, a half-inch cake was produced with a solids concentration of 82 wt.%. Although very thin, this cake was dense enough to fall from the filter into the dumpsters on its own. Operation at these conditions was very difficult, and there were some filtrate pump problems that allowed the filtrate receiver to fill with liquor and kept the filter from operating at optimum performance. The filter cake had a considerable amount of moisture on it for the length of the filter—the cake may have air-dried while moving down the belt. It may be possible, although not very economical, to design a filter specific to solids characteristics of the Suncor gypsum.

Filter operation was more successful during SUN-6 when the hydrocyclone underflow was fed to the vacuum belt without polymer. Although only the coarsest 34% of the reaction tank solids were dewatered during this test, a handleable filter cake with a solids concentration of 91 wt.% was produced. It is possible the solids recovery rate could be improved while still being able to filter the underflow. A more detailed evaluation of the option, however, is necessary to determine if this method is economically viable.

While operation of the vacuum belt filter was extremely difficult with the poor solids being produced, treating the feed stream prior to sending it to the filter (either with polymer or a hydrocyclone) appears to be one potential dewatering option. The limited testing at the HSTC was not sufficient, however, to determine if this option is technically or economically feasible for Suncor's full-scale operation.

Future Testing

The Pilot High Velocity (PHV) test block will begin in April following the conclusion of the mini-pilot clear liquor scrubbing testing. New mist eliminators and ME wash headers will be installed as part of the PHV test block. Initially, the gas rate will be varied from 10 to 15 ft/s at two different slurry recirculation rates. This test block is scheduled to run until August of this year.

March 1994

Figure 2. EPRI HSTC Pilot Wet FGD Suncor Gas Path

Figure 3. Pilot Dewatering Configurations for Suncor Tests

Figure 4. SO₂ Removal Efficiency and Liquid-to-Gas Ratio for SUN-1

Table 2**Operating and Chemistry Conditions for Pilot Suncor Tests**

Parameter	Value	Units
Inlet Gas Rate	8250	scfm
Inlet SO ₂ Concentration	4000	ppmv
Inlet O ₂ Concentration	As Received	
Inlet HCl Concentration	45	ppm
Inlet Temperature	324	°F
Slurry Recirculation Rate	1700	gpm
L/G	150	gal/macf
Reaction Tank Slurry Volume	10000	gal
Adiabatic Saturation Temperature	120	°F
Slurry pH	5	pH
Slurry Solids Concentration	13	wt. %
Dissolved Chloride Concentration	350	mM
Dissolved Magnesium Concentration	90	mM
Dissolved Sodium Concentration	20	mM
Oxidation Air Rate	440	max. scfm
Sulfite Oxidation	100	%
Limestone Type	SUNCOR	
Limestone Grind	95	%<200 mesh
Limestone Slurry Solids Concentration	35	wt. %

Table 3

Summary of Suncor Test Results

Test ID	L/G (gal/macf)	Reaction Tank pH	Liquid Ca (mM)	Liquid Mg (mM)	Liquid SO ₃ (mM)	SO ₂ Removal (%)	Sulfite Oxidation (%)	Limestone Utilization (%)	Slurry Inerts (wt %)	Thickener Unit Area for 30 wt % (sq ft/tpd)	Form Filtration Rate (lb/hr-sq ft)	Filter Cake (wt %)
SUN-1 *	151	5.7	31	110	0.1	92.2	100	91	18	85	-	-
SUN-2	134	5.9	20	153	0.1	92.1	100	92	21	125	-2	-
SUN-3	133	6.0	17	150	0.6	93.1	100	-	-	-	-	-
SUN-4	134	5.9	-	-	-	93.2	100	90	18	145	3	78
SUN-5	133	5.9	17	148	0.1	93.1	100	94	20	194	2	80
SUN-6	134	5.8	-	-	-	92.9	-	-	-	-	-	-
SUN-7	133	5.9	17	140	0.0	93.0	100	93	22	179	-	-

* This test was run at 4000 ppm inlet SO₂; all other tests were run at 2000 ppm inlet SO₂.

Table 4**Summary of Particle Size Analyses of Suncor Limestone**

Particle Size (μ)	Fraction In Cut (wt%)	Ca (mmol/g)	Mg (mmol/g)	CO₃ (mmol/g)	Inerts (wt%)	CaCO₃ (wt%)	MgCO₃ (wt%)
Total	100.0	6.61	0.61	7.40	26.2	66.10	5.14
< 20	84.4	-	-	-	28.36 *	63.92 *	4.60 *
25 to 20	0.5	6.86	1.30	8.33	18.0	68.60	10.96
38 to 25	3.9	7.22	1.31	8.34	15.7	72.20	11.04
45 to 38	3.1	7.62	1.13	8.24	14.6	76.20	9.53
75 to 45	5.8	8.08	0.81	8.20	13.5	80.80	6.83
> 75	2.3	8.45	0.42	8.23	14.3	84.50	3.54

*Calculated by difference between total and coarser fractions.

Table 5**Suncor Centrifuge Performance Results**

Sample ID	Centrifuge Motor Speed (rpm)	Centrifuge Product (wt%)	Centrate (wt%)	Centrifuge Feed (wt%)	Recovery Rate (%)
1	2000	72.34	2.21	14.18	87.1
2	1800	88.98	2.13	16.05	88.9
3	1600	83.10	1.94	17.89	91.3
4	1000	79.50	2.71	18.83	88.6

Table 6**Suncor Hydroclone Performance Results**

	Test SUN-4	Test SUN-6
Hydroclone Diameter (in.)	4	4
Apex Diameter (in.)	0.375	0.375
Vortex Finder Diameter (in.)	1	1
Feed Pressure (psi)	6	7
Hydroclone Feed		
Flow Rate (gpm)	16.04	17.01
Solids Conc. (wt%)	15.31	19.32
Solid Ca (mmol/g)	4.31	-
Solid Mg (mmol/g)	0.22	-
Solid CO ₃ (mmol/g)	0.50	-
Inerts (wt%)	17.6	20.2
Hydroclone Underflow		
Flow Rate (gpm)	1.36	1.38
Solids Conc. (wt%)	56.67	59.45
Solid Ca (mmol/g)	5.80	5.51
Solid Mg (mmol/g)	0.16	0.13
Solid CO ₃ (mmol/g)	0.48	0.39
Inerts (wt%)	5.0	5.7
Hydroclone Overflow		
Flow Rate (gpm)	14.68	15.63
Solids Conc. (wt%)	10.94	13.84
Solid Ca (mmol/g)	4.26	3.87
Solid Mg (mmol/g)	0.25	0.29
Solid CO ₃ (mmol/g)	0.53	0.48
Inerts (wt%)	29.2	32.3
Solids Recovery Rate (%)	43	34

MINI-PILOT

Summary of Operations

In March, Phase II of the Clear Liquor Scrubbing test block concluded with a series of Gypsum Clear Liquor Scrubbing (GCLS) tests. Six GCLS tests were completed in March. The process flow diagram for this test series is shown in Figure 5.

GCLS-2 was begun on February 23. The objective of this test was to determine the effect of a lower solids residence time on solids properties and system performance. To lower the solids residence time in the reaction tank (FLRT) from 43 hours to 16 hours, the blowdown rate from the thickener to the centrifuge was increased to lower the thickener underflow solids concentration from 30 wt.% to 17 wt.%. The solids recycle rate to the FLRT was also reduced, which caused the FLRT solids concentration to drop from 17 wt.% to 6 wt.%. The liquid calcium level was also decreased from 48 Mm to 34 Mm by increasing the sodium concentration. The test was ended on March 1.

Following GCLS-2, the unit was taken off-line to inspect and clean the tray. Some granular scale was found beneath the tray, but nowhere else in the absorber. The scale flaked off easily and could likely be controlled with some type of wash system. After the brief shutdown, test GCLS-3 was started by lowering the solids residence time in the FLRT and increasing the sodium concentration with soda ash addition. On March 2, the unit was taken off-line once again to clear the downcomer hose. Apparently, some blockage in the downcomer forced the absorber effluent to flow to the reaction tank through the loop seal. On March 3, the polymer feed rate was increased from 7 ml/min (1 g/L) to 15 ml/min to lower the solids concentration in the scrubbing liquor. Adjustments were made to the centrifuge motor speed on March 4, and problems continued with centrifuge operation until the centrifuge tripped on March 5. The test was ended on March 5.

On March 5, the liquid chloride level was cut in half by dumping process liquor for GCLS-4. Lime slurry was injected in the spray dryer to remove HCl from the flue gas prior to entering the absorber. To increase the solids residence time, the thickener underflow solids concentrations and recycle rate were increased on March 7. The test was ended on March 13 when the unit was taken off-line to cool the ESP and install packing in the absorber.

On March 14, the ESP was opened and inspected. Low temperatures and low gas flows were causing ash buildup on the panels, and, consequently, arcing. While the unit was off-line, Munters type 12060 packing was installed in the absorber and the tray was removed for the start of GCLS-5. A 1" lip support ring was installed beneath the packing, and the packing was held in place with a second 1" ring just above the packing. The objective of this test was to demonstrate scale-free operation with packing. The test was started on March 15 after the ESP was back in service. The tray pressure drop increased dramatically over the next three days until the unit

was finally taken off-line on March 18 to inspect the packing. Although a great deal of solids were deposited towards the bottom of the packing around the edges, very little scale was discovered, and the packing was cleaned easily with warm water.

While off-line, a 39%-open tray was installed beneath the packing for GCLS-6. With the tray in place, removal increased from approximately 70% to over 90%. Initially, the tray pressure drop rose dramatically, but, by March 19, the tray pressure drop seemed to stabilize. On March 21, the unit was taken off-line to inspect the clipper seal on the thickener underflow recycle pump. The unit was off-line only briefly. On March 22, the ESP fan tripped when a damper was accidentally closed. Again, the unit was off-line for only a short period of time. With the tray pressure drop holding steady, the unit was taken off-line on March 24 to inspect the packing. Some solids had accumulated near the bottom edges of the packing in regions of low gas flow, but no significant scale was discovered. The packing was reinstalled without cleaning, and the test was ended on March 26.

For GCLS-7, the tray was removed, and Munters type PN-Fill packing was installed in the absorber. The objective of this test was to collect SO₂ removal data for the PN-Fill packing when no tray was used. The test was run for only two days, and the unit was taken off-line on March 28 when the pilot unit was brought on-line. Inspection of the packing showed no significant solids buildup or scale anywhere in the absorber.

Summary of Results

Phase II of Clear Liquor Scrubbing concluded in March. The overall goal of this test block was to develop a limestone-based, clear liquor scrubbing system that has improved costs and performance over existing limestone slurry scrubbing processes. The initial test series in Phase II (FSBR and FMRT) focused on an inhibited-oxidation system with formate. The GCLS tests used a forced-oxidation system with DBA and focused on ways to control the gypsum relative saturation (scaling potential) of the clear liquor. The primary variables in the GCLS series were reaction tank solids concentration, chloride removal by lime injection upstream of the mini-pilot, calcium suppression by adding sodium to the reaction tank, and packing/tray type.

The first three tests conducted in March varied the solids residence time with the ultimate goal of reducing the size of the reaction tank and thereby lowering capital costs of the proposed system. The last three tests used two types of packing both with and without a tray to gather performance and operation data. Tables 7 and 8 summarize the operating conditions and process performance results of the GCLS tests. The process configuration for the GCLS tests is shown in Figure 5. Process data summary reports and daily analytical results for the GCLS tests are appended to this report.

SO₂ Removal Efficiency

Figure 6 illustrates the effect of DBA concentration on SO₂ removal efficiency both with and without packing. Note that all of the GCLS tests were performed with approximately 4000 ppm DBA in the scrubbing liquor. (The variations in DBA level shown in Figure 6 were a result of normal fluctuations in process operation and were not intentional.) For the first five GCLS tests performed without packing, the SO₂ removal appears to be gas-film limited with a DBA concentration as low as 3500 ppm. When the DBA concentration increased from 3500 ppm to 5000 ppm, the SO₂ removal remained at approximately 70%.

In GCLS-5, with only the Munters type 12060 packing in the absorber, the SO₂ removal efficiency was similar at about 74 %. This SO₂ removal efficiency is similar to the value predicted by Munters (72%) using 2 ft of packing in the mini-pilot absorber. The absorber pressure drop decreased from 1.4 in. H₂O with only the tray to 0.5 in. H₂O with only the packing in the absorber. These results demonstrate that packing could be used instead of a tray to reduce fan size and/or fan power consumption while achieving similar SO₂ removal efficiency as long as the scaling potential remained low.

In GCLS-6, type 12060 packing was used in combination with a 39%-open tray. With this configuration, the SO₂ removal efficiency increased to 92%, although the absorber pressure drop also increased to 4.3 in. H₂O. The high pressure drop across the tray and packing could make this combination more expensive to operate than the other configurations, although a much higher removal efficiency was achieved.

In the final test, GCLS-7, Munters type PN-Fill packing was installed without a tray to gather comparison data with the other packing types. As expected, the much more open PN-Fill packing resulted in a much lower SO₂ removal efficiency. (Note that during the Phase I tests, PN-Fill used with a tray gave the same removal as type 12060 packing with a tray.) The SO₂ removal efficiency was only 56% with the PN-Fill packing, compared to 74% with the 12060 packing. With a much more open packing type, the absorber pressure drop was also much lower, measuring less than 0.1 in. H₂O.

Solids Characterization

The solids produced in the GCLS tests had somewhat better settling and dewatering characteristics compared to gypsum from a slurry process. As shown in Table 8, the thickener unit areas ranged from 0.1 ft²/ton per day to 0.8 ft²/ton per day, and the form filtration rates were measured at greater than 2000 lb/hr*ft² for all samples tested. The filter cake solids concentrations from the filter leaf test were also consistently high for this analytical method, ranging from 71 wt.% to 86 wt.%. The thickener unit area and filter cake results suggest that the best properties are

achieved at higher reaction tank solids concentrations (Figure 7). The overall high quality of gypsum solids produced could result in lower capital and operating costs for the solids dewatering equipment.

Gypsum Relative Saturation

A main factor in the evaluation of the GCLS process is the scaling potential in the absorber and the feasibility of using a tray or packing to enhance SO₂ removal. Scaling potential in the rest of the system equipment and piping is also important. Therefore, during the GCLS tests, the gypsum relative saturation was calculated for the clear liquor solution in the SBRT (absorber feed tank) and in the absorber effluent.

Figure 8 shows the effect of reaction tank solids concentration on the gypsum relative saturation in the scrubbing liquor and in the absorber effluent. Although increasing the reaction tank solids concentration lowered the gypsum relative saturations in both streams, the increase in R.S. across the absorber remained relatively constant at approximately 0.1 for all conditions tested. One way to minimize the effect of sulfate pickup (i.e., sulfite oxidation in the absorber) on the gypsum R.S. in the absorber is to suppress the calcium and, thus, increase the sulfate level. By increasing the sulfate level in the scrubbing liquor, the relative increase in sulfate across the absorber becomes less significant. A similar sulfate pickup rate will consequently have less of an impact on the gypsum relative saturation when the initial sulfate level is high. In theory, the sulfate level could be increased to a point where the increase in gypsum relative saturation becomes insignificant. To do this, however, could require costly additives and/or chloride removal.

Scaling coupons in the SBRT and the thickener had accumulations typically less than 3 mg/day*in² (an acceptable rate). As shown in Figure 9, there was a general trend of increasing scaling rate with decreasing solids concentration. During a few tests, however, some solids accumulation was discovered beneath the tray and/or in the packing. Both types of solids buildup were easily removed by washing with water. It is possible that any solids buildup could be avoided by washing the bottom of the tray or packing at some minimum frequency.

Future Testing

No further mini-pilot testing is planned for the remainder of this year. For the rest of 1994, the pilot system will be used for the High Velocity test block and for toxics testing. Test block schedules are appended to this report.

Figure 5. Mini-Pilot Process Flow Diagram for Gypsum Clear Liquor Scrubbing Tests

Figure 6. Effect of DBA Concentration on SO₂ Removal Efficiency

Figure 7. Effect of Suspended Solids Concentration on Solids Dewatering Properties

Figure 8. Effect of FLRT Solids Concentration on Gypsum Relative Saturation for GCLS Tests Without Packing

Figure 9. Effect of Suspended Solids Concentration on Scaling Rate

Table 7

Summary of GCLS Operating Conditions*

Test ID	Tray or Packing	SBRT pH	FLRT pH	Absorber Effluent pH	DBA (ppm)	Ca (mM)	Na (mM)	Cl (mM)	Thickener Underflow Recycle Rate (gpm)	Thickener Underflow Solids Conc. (wt. %)	Reaction Tank Solids Conc. (wt. %)	Solids Residence Time (hrs)
GCLS-1	T	5.79	5.53	4.64	3500	57	199	266	17	29	17	36
GCLS-1P	T	5.72	5.50	4.66	4100	48	209	269	17	31	18	38
GCLS-2	T	5.80	5.53	4.54	4200	34	238	229	7.5	17	6	11
GCLS-3	T	5.71	5.50	4.64	5000	20	339	223	3.0	19	3	6
GCLS-4	T	5.62	5.50	4.46	3500	25	192	129	6.3	44	14	28
GCLS-5	P1 **	5.65	5.52	4.49	3800	24	211	146	6.2	39	12	23
GCLS-6	T, P1	5.72	5.50	4.56	3800	18	323	130	6.2	38	12	18
GCLS-7	P2	5.61	5.52	4.81	3600	19	265	122	6.0	33	—	—

*All tests were run at an L/G of 20 gal/macf and 2000 ppm inlet SO₂.

**P1 = Munters' type 12060 packing; P2 = Munters' type PN-Fill packing.

Table 8

Summary of GCLS Process Performance Results

Test ID	SO ₂ Removal (%)	Oxidation (%)	Limestone Utilization (%)	Absorber Feed Solids Conc. (wt%)	Absorber Feed Gypsum R.S.	Absorber Effluent Gypsum R.S.	Average Scaling Rate (mg/day/ft ²)	Scaling Rate Std. Dev. (mg/day/ft ²)	Thickener Unit Area (ft ² /ton/day)	Final Settled Solids (wt%)	Form Filtration Rate (lb/hr/ft ²)	Filter Cake (wt%)
OCLS-1	68	98	97.8	0.33	1.09	1.26	0.94	1.21	0.18	73	3600	85
GCLS-1P	69	98	96.3	0.27	1.08	1.13	0.71	1.32	0.28	70	3600	84
GCLS-2	71	100	93.5	0.07	1.12	1.25	2.15	1.06	0.52	54	4200	73
GCLS-3	70	100	96.0	0.27	1.11	1.19	2.74	1.44	0.79	56	2600	79
GCLS-4	71	100	98.3	0.02	1.10	1.15	0.91	0.68	0.48	69	2200	86
GCLS-5	74	100	98.2	—	1.15	1.28	1.45	0.95	—	—	—	—
GCLS-6	92	100	98.3	0.04	1.11	1.19	2.08	1.61	0.21	62	6800	71
GCLS-7	56	100	99.0	0.03	1.17	1.21	0.88	0.59	0.11	66	4500	82

ON-LINE CHEMISTRY MONITOR

Summary of Operations and Testing

The overall objective of the on-line chemical monitoring (OLCM) project is to develop a chemical monitoring system for FGD processes which is capable of performing near- continuous measurements of key FGD chemical parameters. Recent activities for the project have focused on the development of a prototype system which will be used to demonstrate the OLCM technology at host full-scale FGD facilities. The full-scale prototype contains all of the components of the OLCM system, including two automatic titrators, a continuous slurry sampling system, and a continuous filtration system with automatic flush capabilities, in a weather-proof enclosure.

Construction of the prototype system was completed during March, and testing of the system was begun. The initial objective of this testing is to evaluate the long-term reliability and maintenance requirements of the system. A second objective is to continue evaluating a procedure to measure limestone loading (solid-phase carbonate) in an inhibited FGD process slurry.

Testing of the OLCM system is being performed with slurry saved from the Mini-pilot Liquid Redox Sulfur (MLRS) test block. Characteristics of this slurry include 0.5 mmol/g solid-phase carbonate (94% limestone utilization), 3% sulfite oxidation, and approximately 5 mM soluble sulfite. The test slurry is continuously pumped from a 50- gallon, heated, agitated, storage tank to the OLCM system and returned to the tank. The chemistry of the test slurry will be modified and controlled through the addition of sulfite, dibasic acid (DBA), or limestone to facilitate evaluation of the prototype.

Evaluation of the prototype system was begun at the end of March. Initial test plans called for hourly measurements of limestone loading and soluble sulfite. However, the initial evaluation of the continuous filtration system indicated that the flowrate of the automatic filter backflush was too high, resulting in a rapid failure of the filter media. As a result, soluble sulfite measurements have not been performed. Repair of the backflush system will require the replacement of several valves and the installation of a rotometer to measure the backflush flowrate. The valves and rotometer have been ordered and should be installed shortly.

On-line limestone loading measurements, from the end of March to early April, are shown graphically in Figure 10. (The "raw" concentration data were converted to units of percent limestone utilization.) With the exception of the first few days of operation, the data indicate that the OLCM system is capable of making consistent measurements which agree well with measurements of grab samples performed in the on-site analytical laboratory. The scatter that is evident during the first few days of operation was reduced by adjusting the titration end-point and by adjusting the strengths of some of the reagents.

Future Plans

Future testing of the OLCM system will involve a continued evaluation of limestone loading measurements of inhibited slurry. Tests will be run at two additional limestone loading levels and two additional soluble sulfite levels. Evaluation of inhibited limestone loading measurements in the presence of DBA is also planned. Soluble sulfite and DBA measurements will also be performed once the modifications to the continuous filtration system are completed.

A key objective throughout the near-term testing will be to evaluate the operating reliability and maintenance requirements for the OLCM system, including the operation and reliability of the continuous slurry and filtration sampling systems. Plans call for collecting chemical data at a frequency of once per hour during the evaluation period. Records will be maintained to document maintenance that is performed and problems that occur. In addition, operating data will be collected on a regular basis (once or twice per day), including OLCM system inlet pressure and flowrate, filtration system inlet pressure and output (flowrate), filter backflush flowrate, and slurry sampling system output.

Figure 10. On-Line Limestone Utilization Measurements of Inhibited-Oxidation Slurry

APPENDIX A
TEST SCHEDULES

1 9 9 3					
JUL	AUG	SEP	OCT	NOV	DEC
TVA Chloride Removal	Air Toxics		Additive Consumption		System/Vendor Specific
Hydroclone Dewatering	Air Toxics/ Hydroclone Dewatering	HYDROCLONE OUTAGE	Air Toxics/ Hydroclone Dewatering	Unit Down	

1 9 9 4					
JAN	FEB	MAR	APR	MAY	JUN
Unit Down		High-Velocity Tests			
Unit Down		Suncor Limestone Tests	Unit Down	High-Velocity Tests	

1 9 9 4					
JUL	AUG	SEP	OCT	NOV	DEC
Air Toxics					
High-Velocity Tests		Air Toxics			

Plan at last
Steering Committee Meeting

Revised Plan

Outage

Pilot Test Schedule

1 9 9 3					
JUL	AUG	SEP	OCT	NOV	DEC
Alternative Organic Acids for SO ₂ Removal			Tailored Collaboration		Vendor Specific
High Ca Lime / Add.		Limestone Clear Liquor Scrubbing (Phase II)	OUTAGE	Limestone Clear Liquor Scrubbing (Phase II - Inhibited Oxidation)	

1 9 9 4					
JAN	FEB	MAR	APR	MAY	JUN
Limestone Clear Liquor Scrubbing (Phase II)	Alternate Sulfur Addition	Limestone Clear Liquor Scrubbing (Phase II)	Unit Down		
LS Clear Liquor Scrubbing (Phase II - Inhibited Oxid.)	Alternate Sulfur Addition	Limestone Clear Liquor Scrubbing (Phase II - Forced Oxidation)		Unit Down	

1 9 9 4					
JUL	AUG	SEP	OCT	NOV	DEC
Unit Down					
Unit Down					

Plan at last
Steering Committee Meeting

Revised Plan

OUTAGE

Mini-Pilot Test Schedule

APPENDIX B
PILOT AND MINI-PILOT DATA

March 1994

Pilot FLRT Liquid Analytical Summary: HSTC Pilot Suncor Tests

Test	Date	FLRT pH	ABS pH	Temp (C)	L-Ca++ (mM)	L-Mg++ (mM)	L-Na+ (mM)	L-K+ (ppm)	L-Al (ppm)	L-Fe (ppm)	L-Mn (ppm)	L-Cl- (mM)	L-CO3=	L-SO3=	L-SO4=	CaSO3 RS	CaSO4 RS	CaCO3 RS
SUN-1	Wed-3/02	4.93	2.92	50.7	54.65	60.89	13.74	-	-	-	-	182.41	-	0.21	-	-	-	-
SUN-1	Thu-3/03	5.72	4.72	51.8	30.63	109.95	11.84	-	-	-	-	-	-	0.13	-	-	-	-
SUN-1	Thu-3/03	5.81	-	50.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Averages	5.77	4.72	51.0	30.63	109.95	11.84	-	-	-	-	182.41	-	0.13	-	-	-	-
SUN-2	Fri-3/04	5.95	4.65	49.8	22.71	139.82	12.80	-	-	-	-	-	-	0.00	-	-	-	-
SUN-2	Fri-3/04	5.69	-	50.0	-	-	-	-	-	-	-	-	-	0.00	-	-	-	-
SUN-2	Sat-3/05	5.90	4.63	50.1	17.71	167.14	157.85	-	-	-	-	-	-	0.26	-	-	-	-
SUN-2	Averages	5.85	4.64	50.0	20.21	155.48	85.33	-	-	-	-	-	-	0.09	-	-	-	-
SUN-3	Sun-3/06	5.98	4.71	50.8	17.60	157.85	15.45	-	-	-	-	-	-	0.66	-	-	-	-
SUN-3	Mon-3/07	5.96	4.80	50.9	16.20	142.97	13.97	-	-	-	-	-	-	0.44	-	-	-	-
SUN-3	Averages	5.97	4.76	50.9	16.90	150.41	14.71	-	-	-	-	-	-	0.55	-	-	-	-
SUN-4	Mon-3/07	6.01	-	51.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Averages	6.01	-	51.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Tue-3/08	5.78	4.48	49.9	16.85	132.39	13.35	54.21	0.56	0.07	46.55	82.86	1.00	0.12	92.45	0.04	1.02	0.01
SUN-5	Tue-3/08	6.01	-	50.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Wed-3/09	6.00	4.78	50.5	16.72	162.85	15.74	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Averages	5.93	4.63	50.1	16.79	147.62	14.35	54.21	0.56	0.07	46.55	82.86	1.00	0.12	92.45	0.04	1.02	0.01
SUN-6	Wed-3/09	6.00	-	50.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Averages	6.00	-	50.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	5.79	4.83	51.1	17.06	139.94	13.10	57.98	0.54	0.08	11.81	73.86	1.94	0.00	101.74	0.00	1.08	0.02
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Averages	5.79	4.83	51.1	17.06	139.94	13.10	57.98	0.54	0.08	11.81	73.86	1.94	0.00	101.74	0.00	1.08	0.02

**Pilot Hydroclone Overflow Solid Analytical Summary:
HSTC Pilot Suncor Tests**

Test	Date	Wt% Solids	Ca (mmol/g)	Mg (mmol/g)	SO3 (mmol/g)	SO4 (mmol/g)	CO3 (mmol/g)	Inerts (wt%)	Molar Closure (%)	Weight Closure (%)	Solids On (%)	Unit (%)	Thickener	Initial Wt%	Final Settled Wt%	Filtration Rate (lb/hr-sqft)	Filter Cake Wt%
													Unit Area (sqft/ftd)				
SUN-1	Wed-3/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Thu-3/03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Thu-3/03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Fri-3/04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Fri-3/04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Sat-3/05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-3	Sun-3/06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-3	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-3	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	16.16	-	-	-	-	0.55	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	15.23	-	-	-	-	0.56	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	10.94	4.26	0.25	0.00	3.62	0.53	29.20	4.2	-2.1	100.0	87.7	709.26	10.94	37.65	1	73.36
SUN-4	Averages	10.94	4.26	0.25	0.00	3.62	0.53	29.20	4.2	-2.1	100.0	87.7	709.26	10.94	37.65	1	73.36
SUN-5	Tue-3/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Tue-3/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Wed-3/09	13.84	3.87	0.29	0.00	3.68	0.48	32.30	0.0	0.0	100.0	88.5	-	-	-	-	-
SUN-6	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Averages	13.84	3.87	0.29	0.00	3.68	0.48	32.30	0.0	0.0	100.0	88.5	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

March 1994

Pilot Hydroclone Underflow Solid Analytical Summary: HSTC Pilot Suncor Tests

Test	Date	Wt% Solids	Ca (mmol/g)	Mg (mmol/g)	SO3 (mmol/g)	SO4 (mmol/g)	CO3 (mmol/g)	Inerts (wt%)	Molar Closure (%)	Weight Closure (%)	Solids On. (%)	Solids Util. (%)	Thickener	Initial Wt%	Final Settled Wt%	Filtration Rate lb/hr-sqft	Filter Cake Wt%
													Unit Area (sqft/tpd)				
SUN-1	Wed-3/02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Thu-3/03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Thu-3/03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Fri-3/04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Fri-3/04	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Sat-3/05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-3	Sun-3/06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-3	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-3	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	64.24	-	-	-	-	0.68	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	60.43	-	-	-	-	0.55	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	56.67	5.80	0.16	0.00	5.00	0.48	5.00	3.5	-1.4	100.0	91.7	na	37.66	72.32	1509	86.52
SUN-4	Averages	60.43	5.80	0.16	0.00	5.00	0.57	5.00	3.5	-1.4	100.0	91.7	na	37.66	72.32	1509	86.52
SUN-5	Tue-3/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Tue-3/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Wed-3/09	99.45	5.51	0.13	0.00	5.76	0.39	5.70	-4.3	6.5	100.0	93.4	-	-	-	-	-
SUN-6	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Averages	99.45	5.51	0.13	0.00	5.76	0.39	5.70	-4.3	6.5	100.0	93.4	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

**Pilot FLRT Solid Analytical Summary:
HSTC Pilot Suncor Tests**

Test	Date	FLRT Wt% Solids	Ca (mmol/g)	Mg (mmol/g)	SO3 (mmol/g)	SO4 (mmol/g)	CO3 (mmol/g)	Inerts (wt%)	Molar Closure (%)	Weight Closure (%)	Solids		IR		CP Wt%	FC Wt%	Thickener		Form	
											Ox. (%)	Util. (%)	Ox. (%)	Util. (%)			Unit Area (sqft/tpd)	Initial Wt%	Final Settled Wt%	Filtration Rate lb/hr*sqft
SUN-1	Wed-3/02	4.37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Thu-3/03	17.48	5.07	0.15	0.01	4.90	0.49	18.00	-1.7	6.4	99.8	90.8	100.0	96.2	76.46	-	-	-	-	-
SUN-1	Thu-3/03	16.77	-	-	-	-	-	-	-	-	-	-	-	-	77.65	-	85.49	16.67	44.72	-
SUN-1	Averages	17.13	5.07	0.15	0.01	4.90	0.49	18.00	-1.7	6.4	99.8	90.8	100.0	96.2	77.06	-	85.49	16.67	44.72	-
SUN-2	Fri-3/04	19.51	-	-	-	-	-	-	-	-	-	-	100.0	98.3	78.68	-	-	-	-	-
SUN-2	Fri-3/04	18.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-	126.36	17.15	40.42	~ 2
SUN-2	Sat-3/05	17.15	4.93	0.20	0.00	5.21	0.43	21.10	-4.7	12.7	100.0	92.0	100.0	99.1	79.69	-	123.12	17.15	37.57	-
SUN-2	Averages	18.23	4.93	0.20	0.00	5.21	0.43	21.10	-4.7	12.7	100.0	92.0	100.0	98.7	79.19	-	124.74	17.15	39.00	-
SUN-3	Sun-3/06	19.25	-	-	-	-	-	-	-	-	-	-	100.0	97.2	78.53	-	-	-	-	-
SUN-3	Mon-3/07	19.79	-	-	-	-	-	-	-	-	-	-	100.0	96.2	80.74	-	-	-	-	-
SUN-3	Averages	19.52	-	-	-	-	-	-	-	-	-	-	100.0	97.7	79.64	-	-	-	-	-
SUN-4	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	15.3	4.3	0.2	0.0	4.7	0.5	17.6	-6.6	0.1	100.0	89.6	-	-	-	-	145.18	15.31	40.53	3
SUN-4	Averages	15.31	4.31	0.22	0.00	4.67	0.50	17.60	-6.6	0.1	100.0	89.6	-	-	-	-	145.18	15.31	40.53	3
SUN-5	Tue-3/08	14.01	4.88	0.17	0.00	5.16	0.31	20.20	-4.0	10.2	100.0	94.1	-	-	72.34	-	193.78	14.01	38.84	2
SUN-5	Tue-3/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82.32	-	-	-	-
SUN-5	Wed-3/09	19.32	-	-	-	-	-	-	-	-	-	-	100.0	99.4	74.02	-	-	-	-	-
SUN-5	Averages	16.67	4.88	0.17	0.00	5.16	0.31	20.20	-4.0	10.2	100.0	94.1	100.0	99.4	73.18	82.32	193.78	14.01	38.84	2
SUN-6	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.65	-	-	-	-
SUN-6	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	90.99	-	-	-	-
SUN-6	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	88.32	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	79.89	-	179.13	16.05	40.52	-
SUN-7	Thu-3/10	16.05	4.64	0.16	0.00	4.77	0.35	21.70	-3.2	5.8	100.0	92.9	-	-	88.98	-	-	-	-	-
SUN-7	Thu-3/10	17.89	-	-	-	-	-	-	-	-	-	-	-	-	83.10	-	-	-	-	-
SUN-7	Thu-3/10	18.83	-	-	-	-	-	-	-	-	-	-	-	-	79.51	-	-	-	-	-
SUN-7	Averages	17.59	4.64	0.16	0.00	4.77	0.35	21.70	-3.2	5.8	100.0	92.9	-	-	82.87	-	179.13	16.05	40.52	-

March 1994

March 1994

Pilot RSST Solid Analytical Summary: HSTC Pilot Suncor Tests

Test	Date	L.S. Wt% Solids	Ca (mmol/g)	Mg (mmol/g)	CO3 (mmol/g)	Inerts (wt%)	% Pass 200.0 Mesh	% Pass 325.0 Mesh	% Pass 400.0 Mesh	% Pass 500.0 Mesh	% Pass 635.0 Mesh	MgCO3 (%) (Mg Ind.)	MgCO3 (%) (Mg Dep.)	CaCO3 (%) (Ca Ind.)	CaCO3 (%) (Ca Dep.)	Molar Closure (%)	Weight Closure (%)
SUN-1	Wed-3/02	48.11	7.29	0.57	7.67	22.80	93.0	-	-	-	-	4	5	71	73	1.2	-0.6
SUN-1	Thu-3/03	40.88	-	-	7.28	-	92.9	-	-	-	-	-	-	-	-	-	-
SUN-1	Thu-3/03	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-1	Averages	40.88	-	-	7.28	-	92.9	-	-	-	-	4	5	71	73	1.2	-0.6
SUN-2	Fri-3/04	40.45	6.70	0.59	7.80	25.90	-	-	-	-	-	11	5	72	67	-3.4	1.0
SUN-2	Fri-3/04	35.95	-	-	7.39	-	-	-	-	-	-	-	-	-	-	-	-
SUN-2	Sat-3/05	37.12	-	-	6.41	-	-	-	-	-	-	11	5	72	67	-3.4	1.0
SUN-2	Averages	37.84	6.70	0.59	7.20	25.90	-	-	-	-	-	11	5	72	67	-3.4	1.0
SUN-3	Sun-3/06	35.59	6.96	0.63	6.44	25.20	-	-	-	-	-	5	5	58	70	8.2	-6.7
SUN-3	Mon-3/07	36.97	-	-	6.65	-	96.4	-	-	-	-	5	5	58	70	8.2	-6.7
SUN-3	Averages	36.28	6.96	0.63	6.55	25.20	96.4	-	-	-	-	5	5	58	70	8.2	-6.7
SUN-4	Mon-3/07	-	-	-	-	-	95.9	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Mon-3/07	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-4	Averages	-	-	-	-	-	95.9	-	-	-	-	-	-	-	-	-	-
SUN-5	Tue-3/08	35.97	-	-	7.40	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Tue-3/08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-5	Wed-3/09	34.83	6.61	0.61	7.40	26.20	97.7	91.9	88.8	84.9	84.4	8	5	68	66	-1.2	-1.4
SUN-5	Averages	35.40	6.61	0.61	7.40	26.20	97.7	91.9	88.8	84.9	84.4	8	5	68	66	-1.2	-1.4
SUN-6	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Wed-3/09	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-6	Averages	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	33.71	6.49	0.60	7.22	26.00	-	-	-	-	-	7	5	72	65	-0.9	-3.2
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Thu-3/10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SUN-7	Averages	33.71	6.49	0.60	7.22	26.00	-	-	-	-	-	7	5	72	65	-0.9	-3.2

SUN-1 Process Summary Report
(3/02/94 18:00:00 to 3/03/94 18:00:00)

Process Variable	Average	Max	Min	Std.Dev.	Points
SO2 Removal (%)	92.2	93.5	90.0	0.9	17
L/G Ratio (gal/macf)	151	158	147	3	17
Reaction Tank - pH	5.74	5.77	5.70	0.01	17
Absorber - pH	3.92	4.87	3.54	0.45	17
Flue Gas Flow Rate (scfm)	8335	8551	8010	124	17
Header 1 Flow (gpm)	655	680	646	12	17
Header 3 Flow (gpm)	694	704	680	7	17
Header 5 Flow (gpm)	148	151	140	4	17
Blowdown to Sump Rate (gpm)	0.42	0.48	0.00	0.14	19
Centrifuge Feed Rate (gpm)	11.30	15.00	5.25	3.20	17
Facility Inlet SO2 Conc. (ppm)	1140	1616	810	306	17
Inlet HCl Conc. (ppm)	20	25	12	5	17
Inlet SO2 Concentration (ppm)	4000	4006	3993	3	17
Outlet SO2 Concentration (ppm)	293	375	243	33	17
Inlet O2 Concentration (%)	7.57	7.90	7.05	0.21	17
Outlet O2 Concentration (%)	8.42	8.67	8.01	0.17	17
Absorber Gas Velocity (ft/sec)	8.40	8.61	8.09	0.12	17
Inlet Gas Temperature (F)	315	318	307	3	17
Outlet Gas Temperature (F)	126	127	125	1	17
SO2 Absorbed (mmole/L)	6.50	6.69	6.27	0.13	17
Solids Residence Time (hrs)	7.4	7.7	7.3	0.1	17
Slurry Residence Time (min)	3.82	3.84	3.80	0.01	17
Absorber Pressure Drop (in. H2O)	11.56	13.29	9.18	1.40	17
Spray Zone Pressure Drop (in. H2O)	2.23	2.32	1.95	0.13	17
Oxidation Air to Rxn Tank (scfm)	440	440	436	1	17
Lime Rate to SDA (gpm)	0.98	0.98	0.97	0.00	17
NYSEG Load (MW)	682	692	666	8	17

SUN-2 Process Summary Report
(3/4/94 00:00:00 to 3/5/94 18:00:00)

Process Variable	Average	Max	Min	Std.Dev.	Points
SO2 Removal (%)	92.1	93.2	90.8	0.6	41
L/G Ratio (gal/macf)	134	134	133	0	41
Reaction Tank - pH	5.90	6.05	5.65	0.10	41
Absorber - pH	4.53	4.73	4.28	0.12	41
Flue Gas Flow Rate (scfm)	8250	8254	8250	1	41
Header 1 Flow (gpm)	650	650	649	0	41
Header 3 Flow (gpm)	650	650	650	0	41
Header 5 Flow (gpm)	0	0	0	0	41
Blowdown to Sump Rate (gpm)	0.46	0.48	0.00	0.07	41
Centrifuge Feed Rate (gpm)	11.53	14.90	8.30	1.41	41
Facility Inlet SO2 Conc. (ppm)	1381	1605	957	159	41
Inlet HCl Conc. (ppm)	15	25	11	3	41
Inlet SO2 Concentration (ppm)	2000	2003	1996	2	41
Outlet SO2 Concentration (ppm)	149	173	128	12	41
Inlet O2 Concentration (%)	7.51	7.75	7.14	0.18	41
Outlet O2 Concentration (%)	8.60	8.77	8.36	0.12	41
Absorber Gas Velocity (ft/sec)	8.27	8.28	8.25	0.01	41
Inlet Gas Temperature (F)	301	302	299	1	41
Outlet Gas Temperature (F)	123	124	122	1	41
SO2 Absorbed (mmole/L)	3.70	3.74	3.64	0.03	41
Solids Residence Time (hrs)	15.1	15.3	14.9	0.1	41
Slurry Residence Time (min)	4.39	4.40	4.39	0.00	41
Absorber Pressure Drop (in. H2O)	3.10	3.14	3.07	0.02	41
Spray Zone Pressure Drop (in. H2O)	1.79	1.81	1.77	0.01	41
Oxidation Air to Rxn Tank (scfm)	330	330	330	0	41
Lime Rate to SDA (gpm)	0.98	0.98	0.97	0.00	41
NYSEG Load (MW)	683	691	632	12	41

SUN-3 Process Summary Report
(3/6/94 18:00:00 to 3/7/94 18:00:00)

Process Variable	Average	Max	Min	Std.Dev.	Points
SO2 Removal (%)	93.1	93.6	92.5	0.3	24
L/G Ratio (gal/macf)	133	134	133	0	24
Reaction Tank - pH	6.01	6.02	6.00	0.01	24
Absorber - pH	4.86	5.09	4.69	0.15	24
Flue Gas Flow Rate (scfm)	8250	8250	8240	2	24
Header 1 Flow (gpm)	650	650	649	0	24
Header 3 Flow (gpm)	650	650	650	0	24
Header 5 Flow (gpm)	0	0	0	0	24
Blowdown to Sump Rate (gpm)	0.49	0.49	0.49	0.00	24
Centrifuge Feed Rate (gpm)	3.30	-	-	-	-
Thickener Recycle Rate (gpm)	10.00	-	-	-	-
Thickener Feed Rate (gpm)	8.38	8.60	8.30	0.13	24
Facility Inlet SO2 Conc. (ppm)	870	895	833	15	22
Inlet HCl Conc. (ppm)	25	27	19	2	24
Inlet SO2 Concentration (ppm)	2000	2004	1996	2	24
Outlet SO2 Concentration (ppm)	130	141	120	6	24
Inlet O2 Concentration (%)	7.15	7.44	6.81	0.16	24
Outlet O2 Concentration (%)	8.33	8.53	8.06	0.13	24
Absorber Gas Velocity (ft/sec)	8.28	8.29	8.26	0.00	24
Inlet Gas Temperature (F)	302	302	302	0	24
Outlet Gas Temperature (F)	124	125	124	0	24
SO2 Absorbed (mmole/L)	3.74	3.77	3.72	0.01	24
Solids Residence Time (hrs)	14.9	15.0	14.8	0.1	24
Slurry Residence Time (min)	4.39	4.40	4.39	0.00	24
Absorber Pressure Drop (in. H2O)	3.15	3.17	3.12	0.01	24
Spray Zone Pressure Drop (in. H2O)	1.82	1.84	1.80	0.01	24
Oxidation Air to Rxn Tank (scfm)	330	331	329	0	24
Lime Rate to SDA (gpm)	1.00	1.05	0.63	0.08	24
NYSEG Load (MW)	689	693	681	3	24

SUN-4 Process Summary Report
(3/7/94 19:00:00 to 3/8/94 00:00:00)

Process Variable	Average	Max	Min	Std.Dev.	Points
SO2 Removal (%)	93.2	93.9	92.5	0.5	5
L/G Ratio (gal/macf)	134	135	133	1	5
Reaction Tank - pH	5.86	6.00	5.72	0.10	5
Absorber - pH	4.92	5.07	4.71	0.14	5
Flue Gas Flow Rate (scfm)	8250	8252	8250	1	5
Header 1 Flow (gpm)	649	650	648	1	5
Header 3 Flow (gpm)	650	650	650	0	5
Header 5 Flow (gpm)	0	0	0	0	5
Hydrocyclone Feed Rate (gpm)	15.77	-	-	-	-
Blowdown to Sump Rate (gpm)	0.49	0.49	0.49	0.00	5
Facility Inlet SO2 Conc. (ppm)	823	830	817	5	5
Inlet HCl Conc. (ppm)	18	20	17	1	5
Inlet SO2 Concentration (ppm)	2000	2003	1996	2	5
Outlet SO2 Concentration (ppm)	127	141	116	10	5
Inlet O2 Concentration (%)	7.40	7.64	7.27	0.13	5
Outlet O2 Concentration (%)	8.60	8.90	8.43	0.16	5
Absorber Gas Velocity (ft/sec)	8.24	8.27	8.19	0.03	5
Inlet Gas Temperature (F)	302	302	302	0	5
Outlet Gas Temperature (F)	121	124	116	3	5
SO2 Absorbed (mmole/L)	3.75	3.77	3.71	0.02	5
Solids Residence Time (hrs)	14.9	15.0	14.8	0.1	5
Slurry Residence Time (min)	4.40	4.40	4.39	0.00	5
Absorber Pressure Drop (in. H2O)	3.12	3.18	3.03	0.05	5
Spray Zone Pressure Drop (in. H2O)	1.81	1.84	1.75	0.03	5
Oxidation Air to Rxn Tank (scfm)	330	331	329	1	5
Lime Rate to SDA (gpm)	0.93	0.98	0.76	0.09	5
NYSEG Load (MW)	691	692	689	1	5

SUN-5 Process Summary R 4
(3/8/94 04:00:00 to 3/9/94 13:00:00)

Process Variable	Average	Max	Min	Std.Dev.	Points
SO2 Removal (%)	93.1	93.8	92.0	0.5	33
L/G Ratio (gal/macf)	133	134	133	0	33
Reaction Tank - pH	5.93	6.02	5.73	0.08	33
Absorber - pH	4.74	4.95	4.54	0.10	33
Flue Gas Flow Rate (scfm)	8251	8268	8250	3	33
Header 1 Flow (gpm)	650	650	649	0	33
Header 3 Flow (gpm)	650	650	650	0	33
Header 5 Flow (gpm)	0	0	0	0	33
Blowdown to Sump Rate (gpm)	0.49	0.50	0.42	0.01	33
Vacuum Belt Feed Rate (gpm)	1.50	-	-	-	-
Thickener Underflow Density (wt%)	41.68	62.41	23.05	11.77	30
Thickener Feed Rate (gpm)	9.19	12.00	1.93	2.15	33
Facility Inlet SO2 Conc. (ppm)	1133	1560	807	244	33
Inlet HCl Conc. (ppm)	19	24	15	3	33
Inlet SO2 Concentration (ppm)	2000	2006	1979	5	33
Outlet SO2 Concentration (ppm)	129	151	117	9	33
Inlet O2 Concentration (%)	7.47	8.31	7.18	0.25	33
Outlet O2 Concentration (%)	8.54	9.06	8.32	0.16	33
Absorber Gas Velocity (ft/sec)	8.27	8.28	8.26	0.01	33
Inlet Gas Temperature (F)	302	302	302	0	33
Outlet Gas Temperature (F)	123	124	122	1	33
SO2 Absorbed (mmole/L)	3.74	3.76	3.69	0.02	33
Solids Residence Time (hrs)	14.9	15.1	14.8	0.1	33
Slurry Residence Time (min)	4.39	4.40	4.39	0.00	33
Absorber Pressure Drop (in. H2O)	3.30	3.42	3.11	0.06	33
Spray Zone Pressure Drop (in. H2O)	1.81	1.86	1.73	0.05	33
Oxidation Air to Rxn Tank (acfm)	330	330	330	0	33
Lime Rate to SDA (gpm)	0.98	0.98	0.97	0.00	33
NYSEG Load (MW)	681	690	625	14	33

SUN-6 Process Summary Report
(3/9/94 13:00:00 to 3/9/94 18:00:00)

Process Variable	Average	Max	Min	Std.Dev.	Points
SO2 Removal (%)	92.9	93.4	92.5	0.3	5
L/G Ratio (gal/macf)	134	134	133	1	5
Reaction Tank - pH	5.84	5.90	5.80	0.03	5
Absorber - pH	4.78	4.81	4.72	0.03	5
Flue Gas Flow Rate (scfm)	8250	8250	8250	0	5
Header 1 Flow (gpm)	648	650	646	1	5
Header 3 Flow (gpm)	650	650	650	0	5
Header 5 Flow (gpm)	0	0	0	0	5
Hydrocyclone Feed Rate (gpm)	16.00	-	-	-	-
Blowdown to Sump Rate (gpm)	0.50	0.50	0.50	0.00	5
Vacuum Belt Feed Rate (gpm)	2.03	2.50	1.54	0.31	5
Thickener Underflow Density (wt%)	33.58	35.49	31.04	1.57	5
Facility Inlet SO2 Conc. (ppm)	1087	1177	1022	58	5
Inlet HCl Conc. (ppm)	17	18	16	1	5
Inlet SO2 Concentration (ppm)	2001	2005	1993	4	5
Outlet SO2 Concentration (ppm)	134	142	124	6	5
Inlet O2 Concentration (%)	7.20	7.43	7.08	0.12	5
Outlet O2 Concentration (%)	8.42	8.65	8.25	0.14	5
Absorber Gas Velocity (ft/sec)	8.25	8.28	8.20	0.03	5
Inlet Gas Temperature (F)	303	305	302	1	5
Outlet Gas Temperature (F)	121	124	116	4	5
SO2 Absorbed (mmole/L)	3.74	3.76	3.71	0.02	5
Solids Residence Time (hrs)	14.9	15.0	14.8	0.1	5
Slurry Residence Time (min)	4.40	4.41	4.39	0.00	5
Absorber Pressure Drop (in. H2O)	3.13	3.22	3.03	0.07	5
Spray Zone Pressure Drop (in. H2O)	1.80	1.84	1.74	0.04	5
Oxidation Air to Rxn Tank (acfm)	330	330	330	0	5
Lime Rate to SDA (gpm)	0.98	0.98	0.98	0.00	5
NYSEG Load (MW)	689	691	688	1	5

SUN-7 Process Summary R v1
(3/9/94 18:00:00 to 3/10/94 11 00)

Process Variable	Average	Max	Min	Std.Dev.	Points
SO2 Removal (%)	93.0	93.5	92.3	0.4	17
L/G Ratio (gal/macf)	133	133	133	0	17
Reaction Tank - pH	5.93	6.06	5.72	0.09	17
Absorber - pH	4.69	4.78	4.59	0.05	17
Flue Gas Flow Rate (acfm)	8250	8250	8250	0	17
Header 1 Flow (gpm)	650	650	649	0	17
Header 3 Flow (gpm)	650	650	650	0	17
Header 5 Flow (gpm)	0	0	0	0	17
Blowdown to Sump Rate (gpm)	0.50	0.50	0.49	0.00	17
Centrifuge Feed Rate (gpm)	10.00	10.00	10.00	0.00	17
Facility Inlet SO2 Conc. (ppm)	1291	1640	804	282	17
Inlet HCl Conc. (ppm)	16	19	13	2	17
Inlet SO2 Concentration (ppm)	1999	2005	1993	3	17
Outlet SO2 Concentration (ppm)	131	145	122	8	17
Inlet O2 Concentration (%)	7.67	8.35	7.50	0.22	17
Outlet O2 Concentration (%)	8.68	9.19	8.56	0.16	17
Absorber Gas Velocity (ft/sec)	8.28	8.28	8.28	0.00	17
Inlet Gas Temperature (F)	305	305	305	0	17
Outlet Gas Temperature (F)	123	124	123	0	17
SO2 Absorbed (mmole/L)	3.74	3.76	3.70	0.02	17
Solids Residence Time (hrs)	14.9	15.1	14.8	0.1	17
Slurry Residence Time (min)	4.39	4.40	4.39	0.00	17
Absorber Pressure Drop (in. H2O)	3.13	3.21	3.07	0.05	17
Spray Zone Pressure Drop (in. H2O)	1.78	1.81	1.75	0.02	17
Oxidation Air to Rxn Tank (acfm)	330	330	330	0	17
Lime Rate to SDA (gpm)	0.98	0.98	0.98	0.00	17
NYSEG Load (MW)	670	690	572	35	17

EPRI HIGH SULFUR TEST CENTER PILOT ABSORBER TEST CALENDAR

March 1994 (Updated April 15)

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
30	31	1 Suncor Limestone SUN-1 4000 ppm SO ₂ 94% Utilization 92% Removal	2 Suncor Limestone SUN-1	3 Suncor Limestone SUN-1	4 Suncor Limestone SUN-2 2000 ppm SO ₂ Baseline Centrifuge Dewatering	5 Suncor Limestone SUN-2
6 Suncor Limestone SUN-3 2000 ppm SO ₂ Thickener + Polymer w/ Centrifuge	7 Suncor Limestone SUN-3 SUN-4 Hydrocyclone	8 Clear Liquor Scrubbing II SUN-5 2000 ppm SO ₂ Thickener + Polymer w/ Vacuum Belt Filter	9 Clear Liquor Scrubbing II SUN-5 SUN-6 Hydrocyclone w/ Vacuum Belt Filter	10 Clear Liquor Scrubbing II SUN-7 Centrifuge Performance	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28 Pilot High Velocity PHV-A1N 9,800 scfm 111 LG Munters VME					

EPRI HIGH SULFUR TEST CENTER PILOT ABSORBER TEST CALENDAR

April 1994 (Updated April 15)

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
					¹ Pilot High Velocity PHV-A1N 9,800 scfm L/G = 111 gal/macf Old Nozzles	² Pilot High Velocity PHV-A1N
³ Pilot High Velocity PHV-A1N	⁴ Pilot High Velocity PHV-A1N	⁵ Pilot High Velocity PHV-A1N	⁶ Pilot High Velocity PHV-A1N	⁷ Pilot High Velocity PHV-A 8,250 scfm L/G = 133 gal/macf	⁸ Pilot High Velocity PHV-A	⁹ Pilot High Velocity PHV-A
¹⁰ Pilot High Velocity PHV-A1 9,800 scfm L/G = 111 gal/macf	¹¹ Pilot High Velocity PHV-A1	¹² Pilot High Velocity PHV-A1	¹³ Pilot High Velocity PHV-A1	¹⁴ Pilot High Velocity PHV-A1	¹⁵ Pilot High Velocity PHV-A2 9,800 scfm L/G = 145 gal/macf	¹⁶ Pilot High Velocity PHV-A2
¹⁷ Pilot High Velocity PHV-A2	¹⁸ Pilot High Velocity PHV-A7 14,900 scfm L/G = 73 gal/macf	¹⁹ Pilot High Velocity PHV-A7	²⁰ Pilot High Velocity PHV-A8 14,900 scfm L/G = 95 gal/macf	²¹ Pilot High Velocity PHV-A8	²² Pilot High Velocity PHV-A3 11,250 scfm L/G = 96	²³ Pilot High Velocity PHV-A3
²⁴ Pilot High Velocity PHV-A4 11,250 scfm L/G = 126 gal/macf	²⁵ Pilot High Velocity PHV-A4	²⁶ Pilot High Velocity PHV-A5 12,900 scfm L/G = 83 gal/macf	²⁷ Pilot High Velocity PHV-A5	²⁸ Pilot High Velocity PHV-A5	²⁹ Pilot High Velocity PHV-A6 12,900 scfm L/G = 109 gal/macf	³⁰ Pilot High Velocity PHV-A6

Mini-Pilot SBRT Liquid Analytical Summary: CLS Phase II (GCLS Configuration)

GCLS Phase II (GCLS Configuration)																						Average Scaling Accum (mg/day.in2)	STD Scaling Accum (mg/day.in2)
Test	Date	PLRT pH	SBRT pH	L-Ca++ (mM)	L-Mg++ (mM)	L-Na+ (mM)	L-K+ (ppm)	L-Al (ppm)	L-Fe (ppm)	L-Mn (ppm)	L-Cl- (mM)	L-CO3=	L-SO3=	L-SO4=	ICE DBA (ppm)	ICE Adipic (mM)	ICE Glutaric (mM)	ICE Succinic (mM)	CaSO3 RS	CaSO4 RS	CaCO3 RS		
OCLS-1*	Wed/02/09	5.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCLS-1*	Thu/02/10	5.47	-	18.93	21.88	217.19	-	-	-	-	-	-	1.88	-	-	-	-	-	-	-	-	-	-
OCLS-1*	Fri/02/11	5.46	-	20.80	28.38	174.84	-	-	-	-	-	-	0.25	-	-	-	-	-	-	-	-	-	-
OCLS-1*	Fri/02/11	5.12	5.46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCLS-1*	Sat/02/12	5.33	5.50	44.84	31.19	289.09	-	-	-	-	-	-	0.63	2408	2.57	10.03	6.81	-	-	-	-	-	-
OCLS-1*	Sat/02/13	5.46	5.71	52.27	35.36	216.80	-	-	-	-	-	-	0.63	2639	2.77	10.91	6.73	-	-	-	-	-	-
OCLS-1	Mon/02/14	5.48	5.86	58.99	37.16	196.24	-	-	-	-	264.93	2.48	1.17	24.56	2722	2.62	11.32	7.16	1.48	1.82	0.11	-	-
OCLS-1	Tue/02/15	5.48	5.78	51.99	37.86	185.12	-	-	-	-	-	-	1.38	2985	2.82	12.04	7.66	-	-	-	-	0.23	1.38
OCLS-1	Wed/02/16	5.43	5.72	61.52	48.33	225.26	-	-	-	-	-	-	1.13	4196	4.89	17.60	10.81	-	-	-	-	1.83	1.24
OCLS-1	Thu/02/17	5.51	5.77	65.34	42.33	187.82	18.90	4.99	0.08	9.73	267.86	3.38	0.91	24.73	4255	4.86	17.77	11.16	1.20	1.16	0.13	1.57	1.81
OCLS-1	Average	5.48	5.76	57.48	38.27	198.21	18.54	4.99	0.88	9.73	264.48	2.93	1.15	34.65	3519	3.78	14.88	9.38	1.34	1.89	0.12	0.94	1.21
OCLS-1P*	Fri/02/18	5.52	5.78	48.99	43.36	221.42	-	-	-	-	-	-	1.86	3904	3.69	16.24	10.35	-	-	-	-	0.48	1.70
OCLS-1P*	Sat/02/19	5.47	5.71	50.39	42.98	210.92	-	-	-	-	-	-	0.87	3893	3.81	16.10	10.27	-	-	-	-	-	-
OCLS-1P	Sat/02/20	5.50	5.69	43.89	42.78	207.54	-	-	-	-	-	-	0.94	3916	3.82	16.17	10.37	-	-	-	-	-	-
OCLS-1P	Mon/02/21	5.46	5.74	48.09	46.81	209.25	17.98	6.51	0.01	14.41	278.79	3.12	0.83	28.77	4054	3.94	16.72	10.78	0.82	1.86	0.08	0.24	0.35
OCLS-1P	Tue/02/22	5.50	5.66	51.19	47.93	208.91	22.48	6.63	0.08	15.51	267.20	2.85	0.57	28.89	4200	3.76	17.48	11.39	0.52	1.89	0.06	1.17	2.28
OCLS-1P	Tue/02/22	5.50	5.69	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCLS-1P	Average	5.48	5.76	47.72	45.84	208.37	20.19	6.37	0.81	14.96	268.08	2.99	0.78	28.83	4057	3.84	16.79	10.85	0.67	1.88	0.87	0.71	1.32
OCLS-2*	Wed/02/23	5.52	5.75	50.35	44.48	187.44	-	-	-	-	-	-	0.48	3554	3.14	14.87	9.60	-	-	-	-	0.79	0.59
OCLS-2*	Thu/02/24	5.51	5.70	58.18	45.11	184.63	-	-	-	-	-	-	0.44	3521	3.77	14.36	9.11	-	-	-	-	1.38	1.29
OCLS-2	Fri/02/25	5.68	5.84	35.14	45.43	236.82	-	-	-	-	235.82	2.98	0.43	48.43	3402	3.71	13.79	8.81	0.35	1.11	0.08	1.19	0.94
OCLS-2	Sat/02/26	5.49	5.70	34.97	44.15	255.23	-	-	-	-	-	-	0.35	4513	4.76	18.54	11.62	-	-	-	-	-	-
OCLS-2	Sat/02/27	5.49	5.70	31.96	48.72	232.38	-	-	-	-	-	-	0.39	4170	4.36	17.21	10.69	-	-	-	-	-	-
OCLS-2	Mon/02/28	5.58	5.72	34.74	42.57	231.48	20.18	5.28	0.08	13.87	221.16	3.08	0.39	42.73	4184	4.11	17.83	10.65	0.27	1.17	0.05	1.86	0.85
OCLS-2	Tue/03/01	5.49	5.76	34.12	45.46	233.56	19.07	4.44	0.07	15.51	231.06	3.34	0.55	41.76	5013	4.48	21.14	13.29	0.39	1.89	0.06	3.41	1.38
OCLS-2	Tue/03/01	5.49	5.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCLS-2	Average	5.51	5.74	34.19	43.67	237.88	19.63	4.82	0.88	14.88	229.35	3.13	0.42	41.64	4540	4.28	17.54	11.81	0.34	1.12	0.86	2.15	1.86
OCLS-3*	Wed/03/02	5.48	5.81	34.95	42.48	295.47	-	-	-	-	-	-	1.24	4778	4.39	20.11	12.56	-	-	-	-	2.61	1.68
OCLS-3*	Thu/03/03	5.45	5.71	28.08	41.56	341.67	-	-	-	-	211.71	3.22	1.15	81.56	4785	4.39	20.08	12.66	0.37	1.87	0.02	1.53	1.25
OCLS-3	Fri/03/04	5.47	5.74	19.35	42.89	338.42	19.97	10.02	0.21	11.51	225.78	3.81	1.08	88.09	4908	4.15	20.90	13.88	0.32	1.88	0.03	3.95	1.63
OCLS-3	Sat/03/05	5.58	5.58	21.87	44.51	344.88	19.71	11.15	1.36	12.95	231.46	3.08	0.97	91.38	5249	4.34	22.28	14.19	0.25	1.18	0.01	-	-
OCLS-3	Sat/03/05	5.47	5.68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCLS-3	Average	5.47	5.68	28.17	42.98	338.78	19.84	10.59	0.79	12.23	222.98	3.34	1.84	87.81	4881	4.29	21.89	13.31	0.31	1.11	0.82	2.74	1.44
OCLS-4*	Sat/03/06	5.48	5.66	23.94	17.04	116.36	-	-	-	-	127.05	-	0.58	2856	3.87	12.81	6.97	-	-	-	-	-	-
OCLS-4*	Mon/03/07	5.47	5.67	24.25	19.13	117.66	-	-	-	-	-	-	1.88	2835	2.97	11.92	7.82	-	-	-	-	0.68	0.53
OCLS-4*	Tue/03/08	5.47	5.72	26.48	22.63	127.86	-	-	-	-	-	-	1.32	2805	2.92	11.82	6.94	-	-	-	-	1.29	0.67
OCLS-4*	Wed/03/09	5.58	5.72	26.00	24.44	127.12	-	-	-	-	-	-	1.07	2696	2.68	11.39	6.79	-	-	-	-	1.84	0.67
OCLS-4*	Thu/03/10	5.48	5.59	32.48	27.99	133.88	-	-	-	-	-	-	0.92	3628	3.61	15.34	9.12	-	-	-	-	1.86	0.64
OCLS-4	Fri/03/11	5.49	5.58	21.62	31.56	219.26	-	-	-	-	-	-	1.65	3681	3.62	15.64	9.22	-	-	-	-	0.97	0.66
OCLS-4	Sat/03/12	5.48	5.61	23.16	33.43	209.51	19.33	8.73	1.27	14.70	127.35	2.78	2.23	54.09	3448	3.39	14.66	8.63	0.90	1.12	0.02	-	-
OCLS-4	Sat/03/12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCLS-4	Sun/03/13	5.49	5.65	23.78	34.84	204.73	19.14	8.98	0.66	15.17	129.68	2.82	2.16	50.13	3383	3.28	14.44	8.46	0.98	1.08	0.02	0.70	0.75
OCLS-4	Average	5.48	5.61	25.26	31.86	191.23	19.34	8.86	0.97	14.94	128.52	2.80	1.74	52.11	3535	3.48	15.82	8.86	0.94	1.10	0.82	0.91	0.68
OCLS-5	Wed/03/16	5.53	5.83	24.97	32.73	191.06	-	-	-	-	-	-	1.88	3753	3.83	16.12	9.03	-	-	-	-	2.19	1.18
OCLS-5	Thu/03/17	5.51	5.60	23.58	36.67	224.12	-	-	-	-	144.85	2.48	1.81	57.69	3879	3.93	16.68	9.35	0.39	1.15	0.02	1.39	1.30
OCLS-5	Fri/03/18	5.47	5.55	23.78	38.04	219.05	-	-	-	-	-	-	1.18	3697	3.56	15.99	9.84	-	-	-	-	0.78	0.37
OCLS-5	Average	5.48	5.66	24.11	35.81	211.41	-	-	-	-	144.85	2.48	1.89	57.69	3776	3.77	16.26	9.14	0.39	1.15	0.82	1.45	0.95

March 1994

March 1994

Mini-Pilot SBRT Liquid Analytical Summary: CLS Phase II (GCLS Configuration)

Test	Date	FLRT pH	SBRT pH	L-Ca++ (mM)	L-Mg++ (mM)	L-Na+ (mM)	L-K+ (ppm)	L-Al (ppm)	L-Fe (ppm)	L-Mn (ppm)	L-Cl- (mM)	L-CO3= (mM)	L-SO3= (mM)	L-SO4= (mM)	ICE DBA (ppm)	ICE Adipic (mM)	ICE Glutaric (mM)	ICE Succinic (mM)	CaSO3 RS	CaSO4 RS	CaCO3 RS	Average Scaling Accum (mg/day.in2)	STD Scaling Accum (mg/day.in2)
OCLS-6*	Sun/03/19	5.52	5.28	16.83	33.20	355.82	-	-	-	-	-	-	0.21	-	3502	3.68	15.10	8.23	-	-	-	-	-
OCLS-6*	Sun/03/20	5.51	5.80	17.41	36.11	345.12	15.33	2.65	0.20	13.24	141.56	4.88	0.84	107.47	3346	3.34	14.59	7.90	0.24	1.16	0.04	1.02	0.31
OCLS-6*	Mon/03/21	5.50	5.66	16.19	36.33	324.36	-	-	-	-	-	-	2.52	-	3479	3.29	15.20	8.41	-	-	-	3.19	1.30
OCLS-6*	Tue/03/22	5.44	5.64	17.83	42.23	362.63	-	-	-	-	-	-	1.97	-	4716	4.53	20.50	11.43	-	-	-	0.73	0.32
OCLS-6*	Wed/03/23	5.48	5.73	17.36	42.23	342.11	-	-	-	-	-	-	1.60	-	4619	4.44	19.98	11.30	-	-	-	1.13	1.13
OCLS-6*	Thu/03/24	5.53	5.67	15.94	35.75	369.33	-	-	-	-	-	-	2.28	-	3823	3.71	16.34	9.53	-	-	-	3.03	2.09
OCLS-6	Fri/03/25	5.51	5.79	18.71	38.72	285.54	20.96	2.42	0.21	19.09	126.83	2.68	2.07	83.19	3573	3.53	15.34	8.75	0.73	1.11	0.02	-	-
OCLS-6	Sat/03/26	5.49	5.60	19.14	41.42	297.03	21.08	2.57	0.40	21.19	133.19	2.05	1.97	85.99	3953	3.67	17.07	9.86	-	-	-	-	-
OCLS-6	Sat/03/26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OCLS-6	Averages	5.51	5.29	17.93	38.63	283.97	21.02	2.50	0.31	20.14	138.81	2.37	2.11	84.59	3783	3.64	16.25	9.38	0.73	1.11	0.02	2.08	1.61
OCLS-7	Sun/03/27	5.53	5.30	18.07	40.32	274.22	-	-	-	-	-	-	1.44	-	3709	3.51	15.99	9.20	-	-	-	0.88	0.59
OCLS-7	Mon/03/28	5.48	5.64	19.47	37.22	256.57	15.44	1.99	0.46	17.52	121.83	2.04	1.15	78.99	3422	3.23	14.92	8.31	0.35	1.17	0.01	0.88	0.59
OCLS-7	Averages	5.51	5.27	18.77	38.77	265.40	15.44	1.99	0.46	17.52	121.83	2.04	1.30	78.99	3565.17	3.37	15.46	8.76	0.35	1.17	0.01	0.88	0.59

**Mini-Pilot AE Liquid Analytical Summary:
CLS Phase II (GCLS Configuration)**

Test	Date	AE pH	L-Ca++ (mM)	L-Mg++ (mM)	L-Na+ (mM)	L-Cl- (mM)	L-CO3= (mM)	L-SO3= (mM)	L-SO4= (mM)	CaSO3 RS	CaSO4 RS	CaCO3 RS
OCLS-1 •	Wed/02/09	4.87	-	-	-	-	-	-	-	-	-	-
OCLS-1 •	Thu/02/10	3.90	-	-	-	-	-	-	-	-	-	-
OCLS-1 •	Fri/02/11	4.25	-	-	-	-	-	-	-	-	-	-
OCLS-1 •	Fri/02/11	4.26	-	-	-	-	-	-	-	-	-	-
OCLS-1 •	Sat/02/12	4.38	-	-	-	-	-	-	-	-	-	-
OCLS-1 •	Sun/02/13	4.61	-	-	-	-	-	-	-	-	-	-
OCLS-1	Mon/02/14	4.46	53.78	39.25	192.04	-	-	19.07	26.73	1.82	1.17	0.00
OCLS-1	Tue/02/15	-	-	-	-	-	-	-	-	-	-	-
OCLS-1	Wed/02/16	4.67	-	-	-	-	-	-	-	-	-	-
OCLS-1	Thu/02/17	4.70	68.64	42.79	190.45	-	-	19.15	27.26	3.98	1.34	0.16
OCLS-1	Average	4.61	61.21	41.82	191.25	-	-	19.11	27.68	2.98	1.38	0.08
OCLS-1P •	Fri/02/18	4.67	-	-	-	-	-	-	-	-	-	-
OCLS-1P •	Sat/02/19	4.63	-	-	-	-	-	-	-	-	-	-
OCLS-1P	Sun/02/20	4.61	-	-	-	-	-	-	-	-	-	-
OCLS-1P	Mon/02/21	4.63	51.32	45.44	208.82	-	-	12.76	28.69	1.73	1.13	0.00
OCLS-1P	Tue/02/22	4.62	-	-	-	-	-	-	-	-	-	-
OCLS-1P	Tue/02/22	-	-	-	-	-	-	-	-	-	-	-
OCLS-1P	Average	4.62	51.32	45.44	208.82	-	-	12.76	28.69	1.73	1.13	0.00
OCLS-2 •	Wed/02/23	4.57	-	-	-	-	-	-	-	-	-	-
OCLS-2 •	Thu/02/24	4.48	-	-	-	-	-	-	-	-	-	-
OCLS-2	Fri/02/25	4.58	39.28	45.39	221.86	237.27	2.54	15.17	41.82	1.35	1.28	0.00
OCLS-2	Sat/02/26	4.54	-	-	-	-	-	-	-	-	-	-
OCLS-2	Sun/02/27	4.52	-	-	-	-	-	-	-	-	-	-
OCLS-2	Mon/02/28	4.67	34.17	42.54	233.17	232.14	2.95	13.27	44.68	1.22	1.23	0.00
OCLS-2	Tue/03/01	4.72	-	-	-	-	-	-	-	-	-	-
OCLS-2	Tue/03/01	-	-	-	-	-	-	-	-	-	-	-
OCLS-2	Average	4.61	36.73	43.97	227.52	234.71	2.75	14.22	42.85	1.28	1.25	0.00
OCLS-3 •	Wed/03/02	5.22	-	-	-	-	-	-	-	-	-	-
OCLS-3	Thu/03/03	4.73	21.95	41.14	328.67	223.48	2.64	14.18	82.41	0.73	1.21	0.00
OCLS-3	Fri/03/04	4.69	-	-	-	-	-	-	-	-	-	-
OCLS-3	Sat/03/05	4.52	19.61	44.36	340.38	236.09	1.77	21.11	92.44	0.59	1.16	0.00
OCLS-3	Sat/03/05	-	-	-	-	-	-	-	-	-	-	-
OCLS-3	Average	4.65	20.78	42.75	334.53	229.75	2.21	17.61	87.43	0.66	1.19	0.00
OCLS-4 •	Sun/03/06	4.82	-	-	-	-	-	-	-	-	-	-
OCLS-4 •	Mon/03/07	4.28	-	-	-	-	-	-	-	-	-	-
OCLS-4 •	Tue/03/08	4.48	-	-	-	-	-	-	-	-	-	-
OCLS-4 •	Wed/03/09	4.28	-	-	-	-	-	-	-	-	-	-
OCLS-4	Thu/03/10	4.61	-	-	-	-	-	-	-	-	-	-
OCLS-4	Fri/03/11	4.55	-	-	-	-	-	-	-	-	-	-
OCLS-4	Sat/03/12	4.28	22.34	33.00	209.51	135.78	0.82	22.28	53.88	0.53	1.15	0.00
OCLS-4	Sat/03/12	-	-	-	-	-	-	-	-	-	-	-
OCLS-4	Sun/03/13	4.31	-	-	-	-	-	-	-	-	-	-
OCLS-4	Average	4.44	22.34	33.00	209.51	135.78	0.82	22.28	53.88	0.53	1.15	0.00
OCLS-5	Wed/03/16	4.75	-	-	-	-	-	-	-	-	-	-
OCLS-5	Thu/03/17	4.35	27.88	43.78	267.88	148.26	1.18	28.42	58.53	0.96	1.28	0.00
OCLS-5	Fri/03/18	4.23	-	-	-	-	-	-	-	-	-	-
OCLS-5	Average	4.44	27.88	43.78	267.88	148.26	1.18	28.42	58.53	0.96	1.28	0.00

March 1994

March 1994

Mini-Pilot AE Liquid Analytical Summary: CLS Phase II (GCLS Configuration)

Test	Date	AE pH	L-Ca++ (mM)	L-Mg++ (mM)	L-Na+ (mM)	L-Cl- (mM)	L-CO3= (mM)	L-SO3= (mM)	L-SO4= (mM)	CaSO3 RS	CaSO4 RS	CaCO3 RS
OCLS-6	Sat/03/19	5.44	-	-	-	-	-	-	-	-	-	-
OCLS-6	Sun/03/20	4.23	17.64	36.48	344.67	143.51	1.82	29.86	109.28	0.36	1.22	0.00
OCLS-6	Mon/03/21	4.28	-	-	-	-	-	-	-	-	-	-
OCLS-6	Tue/03/22	4.54	-	-	-	-	-	-	-	-	-	-
OCLS-6	Wed/03/23	4.60	-	-	-	-	-	-	-	-	-	-
OCLS-6	Thu/03/24	4.32	-	-	-	-	-	-	-	-	-	-
OCLS-6	Fri/03/25	4.57	19.15	38.96	288.39	129.01	1.61	24.69	86.55	0.79	1.19	0.00
OCLS-6	Sat/03/26	4.55	-	-	-	-	-	-	-	-	-	-
OCLS-6	Sat/03/26	-	-	-	-	-	-	-	-	-	-	-
OCLS-6	Averages	4.48	19.15	38.96	288.39	129.01	1.61	24.69	86.55	0.79	1.19	0.00
OCLS-7	Sun/03/27	4.71	-	-	-	-	-	-	-	-	-	-
OCLS-7	Mon/03/28	4.68	19.78	37.27	256.19	120.64	1.53	20.77	79.76	0.93	1.21	0.00
OCLS-7	Averages	4.70	19.78	37.27	256.19	120.64	1.53	20.77	79.76	0.93	1.21	0.00

Mini-Pilot THK Solid Analytical Summary: CLS Phase II (GCLS Configuration)

Test	Date	THK	PLRT	SBRT	Ca	Mg	SO3	SO4	CO3	Inerts	IR	Unit	Solids		Wt	Mol	Thickness	CPFC	Unit	Initial	Final	Filtration	Filter	DBA
		Wt%	Wt%	Wt%									Wt%	Wt%										
		Solids	Solids	Solids	(mmol/g)	(mmol/g)	(mmol/g)	(mmol/g)	(mmol/g)	(wt%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	Conc.
GCLS-1*	Wed/02/09	-	2.76	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GCLS-1*	Thu/02/10	-	11.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33	12.05	62.75	-	-	-
GCLS-1*	Fri/02/11	-	10.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	156,637
GCLS-1*	Fri/02/11	8.70	5.49	0.34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GCLS-1*	Sat/02/12	13.26	9.15	0.06	-	-	-	-	-	-	99.4	100.0	-	-	-	-	-	-	-	-	-	-	-	-
GCLS-1*	Sun/02/13	26.44	16.27	0.08	-	-	-	-	-	-	99.5	100.0	-	-	-	-	-	-	-	-	-	-	-	-
GCLS-1	Mon/02/14	28.10	18.39	0.08	-	-	-	-	-	-	99.4	99.3	-	-	-	-	-	84.74	-	-	-	-	-	-
GCLS-1	Tue/02/15	31.67	16.81	0.10	-	-	-	-	-	-	100.0	99.8	-	-	-	-	-	85.71	-	-	-	-	-	-
GCLS-1	Wed/02/16	27.10	16.89	0.17	-	-	-	-	-	-	100.0	99.0	-	-	-	-	-	86.36	-	-	-	-	-	-
GCLS-1	Thu/02/17	29.01	17.41	0.95	5.75	0.02	0.10	5.79	0.13	0.00	99.0	100.0	98.3	97.8	2.0	-2.1	87.31	0.17	20.32	74.39	4232	84.17	-	
GCLS-1	Average	28.97	17.38	0.33	5.75	0.02	0.10	5.79	0.13	0.00	99.6	99.3	98.3	97.8	2.0	-2.1	86.67	0.18	20.82	73.40	3561	84.84	173,680	
GCLS-1P*	Fri/02/18	31.54	20.43	0.30	-	-	-	-	-	-	100.0	99.1	-	-	-	-	-	87.31	-	-	-	-	-	-
GCLS-1P*	Sat/02/19	32.99	17.01	0.94	-	-	-	-	-	-	100.0	98.8	-	-	-	-	-	85.06	-	-	-	-	-	-
GCLS-1P	Sun/02/20	34.05	20.20	0.36	-	-	-	-	-	-	100.0	98.6	-	-	-	-	-	83.30	-	-	-	-	-	-
GCLS-1P	Mon/02/21	28.06	16.65	0.34	5.77	0.02	0.13	5.71	0.16	0.71	-	-	97.8	97.3	1.3	-1.8	86.01	-	-	-	-	-	-	-
GCLS-1P	Tue/02/22	31.00	19.28	0.12	5.81	0.03	0.16	5.67	0.20	0.75	-	-	97.3	95.3	2.0	-2.3	85.14	0.37	14.36	70.91	6365	84.39	193,196	
GCLS-1P	Tue/02/22	-	15.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.79	0.32	15.43	70.04	2171	83.27	-
GCLS-1P	Average	31.85	17.89	0.27	5.79	0.03	0.15	5.69	0.22	0.75	100.0	98.8	97.5	96.3	1.7	-2.0	85.91	0.28	17.16	70.10	3607	83.64	193,196	
GCLS-2*	Wed/02/23	28.05	9.24	0.07	-	-	-	-	-	-	100.0	94.4	-	-	-	-	-	85.79	-	-	-	-	-	-
GCLS-2*	Thu/02/24	24.02	9.25	0.05	-	-	-	-	-	-	100.0	97.3	-	-	-	-	-	85.06	-	-	-	-	-	-
GCLS-2	Fri/02/25	19.08	6.42	0.04	-	-	-	-	-	-	100.0	91.4	-	-	-	-	-	83.30	-	-	-	-	-	-
GCLS-2	Sat/02/26	17.75	5.90	0.04	-	-	-	-	-	-	100.0	97.6	-	-	-	-	-	86.01	-	-	-	-	-	-
GCLS-2	Sun/02/27	17.91	5.72	0.03	-	-	-	-	-	-	100.0	96.4	-	-	-	-	-	85.14	-	-	-	-	-	-
GCLS-2	Mon/02/28	15.42	6.22	0.04	5.93	0.09	0.08	5.78	0.42	1.14	-	-	100.0	93.1	4.0	-1.5	85.79	0.66	15.07	56.20	4403	77.04	-	
GCLS-2	Tue/03/01	15.09	5.05	0.21	6.04	0.03	0.08	5.99	0.30	0.60	-	-	100.0	93.9	6.2	-2.4	85.14	0.39	16.77	53.41	4103	71.63	-	
GCLS-2	Tue/03/01	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.79	0.32	15.43	70.04	2171	83.27	-
GCLS-2	Average	17.17	5.86	0.07	5.99	0.06	0.08	5.89	0.40	0.87	100.0	95.1	100.0	93.3	5.1	-2.0	88.77	0.52	15.08	54.80	4156	73.16	80,070	
GCLS-3*	Wed/03/02	14.34	2.19	0.26	-	-	-	-	-	-	100.0	97.8	-	-	-	-	-	89.70	-	-	-	-	-	-
GCLS-3	Thu/03/03	13.27	2.40	0.40	-	-	-	-	-	-	100.0	99.3	-	-	-	-	-	86.56	-	-	-	-	-	-
GCLS-3	Fri/03/04	20.94	3.25	0.26	5.84	0.03	0.08	6.14	0.20	0.75	-	-	100.0	96.7	6.5	-3.9	82.78	0.63	13.70	54.02	3013	77.70	80,070	
GCLS-3	Sat/03/05	19.84	2.64	0.05	5.88	0.04	0.08	6.08	0.29	1.08	-	-	100.0	95.3	6.8	-3.7	93.97	0.87	11.46	56.12	2418	80.48	-	
GCLS-3	Sat/03/05	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.87	11.80	57.37	2408	79.21	-	-
GCLS-3	Average	18.88	2.79	0.27	5.86	0.04	0.08	6.11	0.25	0.92	100.0	99.3	100.0	96.0	6.6	-3.8	87.77	0.79	12.32	55.84	2639	79.13	80,070	
GCLS-4*	Sun/03/06	14.25	1.86	0.03	-	-	-	-	-	-	100.0	98.6	-	-	-	-	-	78.36	-	-	-	-	-	-
GCLS-4*	Mon/03/07	18.96	2.50	0.01	-	-	-	-	-	-	-	-	-	-	-	-	-	78.29	-	-	-	-	-	-
GCLS-4*	Tue/03/08	14.98	3.29	0.20	-	-	-	-	-	-	-	-	-	-	-	-	-	91.45	-	-	-	-	-	-
GCLS-4*	Wed/03/09	26.56	7.71	0.70	-	-	-	-	-	-	100.0	99.4	-	-	-	-	-	90.26	-	-	-	-	-	-
GCLS-4	Thu/03/10	39.32	12.45	0.04	-	-	-	-	-	-	100.0	99.6	-	-	-	-	-	91.14	-	-	-	-	-	-
GCLS-4	Fri/03/11	42.93	13.89	0.04	-	-	-	-	-	-	100.0	98.3	-	-	-	-	-	92.69	-	-	-	-	-	-
GCLS-4	Sat/03/12	47.23	14.36	0.03	6.01	0.02	0.01	5.53	0.08	1.10	-	-	99.8	98.6	-1.2	3.5	90.87	0.40	16.74	69.01	2140	85.57	100,474	
GCLS-4	Sat/03/12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.40	19.09	67.06	2117	86.22	-	
GCLS-4	Sun/03/13	47.63	14.32	0.02	6.09	0.02	0.00	5.50	0.12	0.70	-	-	100.0	98.0	-1.5	4.2	92.16	0.40	18.63	69.81	1951	85.04	-	
GCLS-4	Average	44.28	13.81	0.03	6.05	0.02	0.01	5.52	0.10	0.90	100.0	99.0	99.9	98.3	-1.4	3.8	91.72	0.40	18.15	68.43	2236	85.21	100,474	
GCLS-5	Wed/03/16	32.30	9.07	-	-	-	-	-	-	-	100.0	98.8	-	-	-	-	-	93.99	-	-	-	-	-	-
GCLS-5	Thu/03/17	41.36	12.28	-	-	-	-	-	-	-	100.0	97.5	-	-	-	-	-	92.54	-	-	-	-	-	-
GCLS-5	Fri/03/18	43.81	13.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	93.50	-	-	-	-	-	-
GCLS-5	Average	39.25	11.58	-	-	-	-	-	-	-	100.0	98.2	-	-	-	-	-	93.34	-	-	-	-	-	-

March 1994

Mini-Pilot THK Solid Analytical Summary: CLS Phase II (GCLS Configuration)

Test	Date	THK	FLRT	SBRT						IR		Solids		Wt	Mol	Thickener		Final	Form	Filter	DBA
		Wt%	Wt%	Wt%	Ca	Mg	SO3	SO4	CO3	Iserts	Ox	Utl	Ox	Utl	Solids	Solids	CP/FC	Area	Settled	Filtration	Cake
		Solids	Solids	Solids	(mmol/g)	(mmol/g)	(mmol/g)	(mmol/g)	(mmol/g)	(wt%)	(%)	(%)	(%)	(%)	Close	Close	Wt%	(sq/ft/d)	Wt%	Rate	Wt%
OCLS-6	Sun/03/19	35.44	9.96	-	-	-	-	-	-	-	100.0	99.2	-	-	-	-	81.37	-	-	-	-
OCLS-6	Sun/03/20	41.45	13.60	-	-	-	-	-	-	-	-	-	-	-	-	-	90.88	-	-	-	-
OCLS-6	Mon/03/21	45.89	13.79	-	-	-	-	-	-	-	100.0	98.1	-	-	-	-	92.47	-	-	-	-
OCLS-6	Tue/03/22	36.45	5.84	0.02	-	-	-	-	-	-	-	-	-	-	-	-	94.01	-	-	-	-
OCLS-6	Wed/03/23	15.40	7.44	5.03	-	-	-	-	-	-	100.0	99.1	-	-	-	-	83.40	-	-	-	-
OCLS-6	Thu/03/24	-	11.16	0.03	-	-	-	-	-	-	-	-	100.0	99.0	4.0	-1.1	-	0.21	16.65	59.43	6459
OCLS-6	Fri/03/25	36.83	12.13	0.03	5.93	0.02	0.00	6.02	0.06	0.30	-	-	100.0	97.7	3.9	-1.0	-	0.20	15.98	62.33	7494
OCLS-6	Sat/03/26	39.21	13.07	0.06	5.93	0.04	0.00	5.95	0.14	0.60	-	-	100.0	97.7	3.9	-1.0	-	0.23	14.87	64.33	6489
OCLS-6	Sun/03/26	-	-	-	-	-	-	-	-	-	100.0	99.1	100.0	98.3	3.9	-1.0	-	0.21	15.70	62.03	6814
OCLS-6	Average	38.81	12.12	0.04	5.93	0.03	0.00	5.99	0.10	0.45	100.0	99.6	-	-	-	-	-	-	-	-	-
OCLS-7	Sun/03/27	16.09	15.26	0.04	-	-	-	-	-	-	100.0	99.6	-	-	-	-	-	0.11	14.14	65.67	4490
OCLS-7	Mon/03/28	30.22	6.27	0.02	6.02	0.01	0.00	6.01	0.06	0.40	100.0	99.6	100.0	99.0	4.3	-0.3	-	0.11	14.14	65.67	4490
OCLS-7	Average	23.46	10.77	0.03	6.02	0.01	0.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-

GCLS-1 Process Summary Report
(2/14/94 23:00:00 to 2/17/94 14:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	68.0	71.7	64.4	1.93	61
L/G Ratio (gal/macf)	19.8	20.0	19.7	0.07	61
Recirculating pH	5.79	6.64	5.65	0.13	61
Absorber pH	4.64	5.10	4.46	0.12	61
Reaction Tank pH	5.53	6.36	5.49	0.14	61
Flue Gas Flow Rate (scfm)	750	750	750	0.1	61
Gas Velocity (ft/sec)	8.2	8.2	8.2	0.01	61
Reagent Feed Rate (gpm)	0.068	0.075	0.054	0.01	61
Absorber Feed Rate (gpm)	17.0	17.0	17.0	0.0	61
Thickener Underflow Recycle (gpm)	17.2	17.6	16.9	0.1	61
SO2 Absorbed (mmole/L)	19.00	20.36	18.02	0.56	61
Absorber Tray ΔP (in H2O)	1.3	1.4	1.3	0.0	61
Inlet SO2 concentration, wet (ppm)	2001	2041	1994	7.0	61
Outlet SO2 concentration, wet (ppm)	605	672	544	36.0	61
Inlet O2 Concentration (%)	12.42	13.71	0.08	1.78	61
Outlet O2 Concentration (%)	11.06	12.71	0.04	1.94	61
Inlet HCl Concentration, wet (ppm)	16.30	20.06	12.82	2.08	61
Inlet Gas Temperature (F)	294	294	293	0.1	61
Outlet Gas Temperature (F)	120	123	119	0.8	61
Oxidation Air Rate (acfm)	55.0	55.0	55.0	0.00	61
Solids Residence Time In FLRT (hrs)	42.6	45.7	39.1	1.71	61

GCLS-1P Process Summary Report
(2/18/94 19:00:00 to 2/22/94 12:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	68.5	70.9	66.1	1.40	79
L/G Ratio (gal/macf)	19.9	20.1	19.7	0.11	79
Recirculating pH	5.72	5.80	5.68	0.02	79
Absorber pH	4.66	4.69	4.59	0.03	79
Reaction Tank pH	5.50	5.56	5.48	0.01	79
Flue Gas Flow Rate (scfm)	750	750	749	0.2	79
Gas Velocity (ft/sec)	8.2	8.2	8.1	0.01	79
Reagent Feed Rate (gpm)	0.073	0.090	0.050	0.01	79
Absorber Feed Rate (gpm)	17.0	17.0	17.0	0.0	79
Thickener Underflow Recycle (gpm)	16.6	16.9	16.4	0.1	79
SO2 Absorbed (mmole/L)	19.12	19.84	18.44	0.39	79
Absorber Tray ΔP (in H2O)	1.3	1.4	1.3	0.0	79
Inlet SO2 concentration, wet (ppm)	2000	2004	1995	2.1	79
Outlet SO2 concentration, wet (ppm)	595	641	548	26.7	79
Inlet O2 Concentration (%)	10.89	11.17	10.56	0.14	79
Outlet O2 Concentration (%)	10.53	10.96	10.23	0.17	79
Inlet HCl Concentration, wet (ppm)	16.39	21.62	8.59	3.83	79
Inlet Gas Temperature (F)	294	294	294	0.0	79
Outlet Gas Temperature (F)	119	122	117	1.2	79
Oxidation Air Rate (acfm)	55.00	55.01	54.99	0.00	79
Solids Residence Time In FLRT (hrs)	43.0	45.0	40.2	1.39	79

GCLS-2 Process Summary Report
(2/24/94 18:00:00 to 3/1/94 11:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	71.4	76.1	68.0	1.62	58
L/G Ratio (gal/macf)	19.5	20.3	19.2	0.21	58
Recirculating pH	5.80	7.14	5.67	0.23	58
Absorber pH	4.54	4.93	4.47	0.08	58
Reaction Tank pH	5.53	7.14	5.44	0.22	57
Flue Gas Flow Rate (scfm)	750	751	732	2.4	58
Gas Velocity (ft/sec)	8.4	8.4	8.1	0.05	58
Reagent Feed Rate (gpm)	0.068	0.085	-0.001	0.01	58
Absorber Feed Rate (gpm)	17.0	17.0	17.0	0.0	58
Thickener Underflow Recycle (gpm)	7.5	7.7	6.8	0.1	58
SO2 Absorbed (mmole/L)	19.95	21.25	19.03	0.45	58
Absorber Tray ΔP (in H2O)	1.5	1.7	1.3	0.1	58
Inlet SO2 concentration, wet (ppm)	2000	2004	1996	2.1	58
Outlet SO2 concentration, wet (ppm)	532	598	447	30.1	58
Inlet O2 Concentration (%)	11.20	11.54	10.85	0.14	58
Outlet O2 Concentration (%)	10.79	11.19	10.45	0.16	58
Inlet HCl Concentration, wet (ppm)	14.43	18.21	8.09	2.30	58
Inlet Gas Temperature (F)	332	336	310	6.8	58
Outlet Gas Temperature (F)	120	122	115	1.6	58
Oxidation Air Rate (acfm)	55.00	55.02	54.99	0.00	58
Solids Residence Time In FLRT (hrs)	15.6	16.6	14.6	0.43	58

GCLS-3 Process Summary Report
(3/3/94 1400:00 to 3/5/94 12:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	70.2	72.4	68.8	0.93	45
L/G Ratio (gal/macf)	20.0	20.1	19.9	0.05	45
Recirculating pH	5.71	5.87	5.60	0.07	45
Absorber pH	4.64	4.78	4.49	0.09	45
Reaction Tank pH	5.50	5.56	5.44	0.02	45
Flue Gas Flow Rate (scfm)	750	750	750	0.0	45
Gas Velocity (ft/sec)	8.2	8.3	8.2	0.02	45
Reagent Feed Rate (gpm)	0.068	0.078	0.052	0.00	45
Absorber Feed Rate (gpm)	17.0	17.0	17.0	0.0	45
Thickener Underflow Recycle (gpm)	3.0	3.1	3.0	0.0	45
SO2 Absorbed (mmole/L)	19.60	20.20	19.24	0.26	45
Absorber Tray ΔP (in H2O)	1.4	1.6	1.4	0.1	45
Inlet SO2 concentration, wet (ppm)	2000	2004	1997	2.0	45
Outlet SO2 concentration, wet (ppm)	560	586	517	17.6	45
Inlet O2 Concentration (%)	7.75	7.96	7.34	0.16	45
Outlet O2 Concentration (%)	7.42	7.67	7.01	0.17	45
Inlet HCl Concentration, wet (ppm)	13.53	17.91	11.45	1.52	45
Inlet Gas Temperature (F)	311	317	305	2.0	45
Outlet Gas Temperature (F)	122	124	120	0.9	45
Oxidation Air Rate (acfm)	55.00	55.00	55.00	0.00	45
Solids Residence Time In FLRT (hrs)	174.0	180.7	167.0	3.91	45

GCLS-4 Process Summary Report
(3/11/94 2:00:00 to 3/13/94 8:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	70.7	72.2	68.4	0.87	54
L/G Ratio (gal/macf)	19.8	20.1	19.7	0.06	54
Recirculating pH	5.62	5.71	5.53	0.04	54
Absorber pH	4.46	4.69	4.23	0.14	54
Reaction Tank pH	5.50	5.51	5.48	0.01	54
Flue Gas Flow Rate (scfm)	750	750	747	0.4	54
Gas Velocity (ft/sec)	8.3	8.3	8.2	0.04	54
Reagent Feed Rate (gpm)	0.067	0.075	0.058	0.00	54
Absorber Feed Rate (gpm)	17.0	17.0	17.0	0.0	54
Thickener Underflow Recycle (gpm)	6.3	6.9	5.8	0.3	54
SO2 Absorbed (mmole/L)	19.74	20.16	19.14	0.24	54
Absorber Tray ΔP (in H2O)	1.4	1.5	1.3	0.0	54
Inlet SO2 concentration, wet (ppm)	2000	2004	1996	2.0	54
Outlet SO2 concentration, wet (ppm)	547	595	519	17.4	54
Inlet O2 Concentration (%)	11.82	12.07	11.56	0.10	54
Outlet O2 Concentration (%)	11.32	11.62	11.02	0.13	54
Inlet HCl Concentration, wet (ppm)	14.71	16.32	11.52	1.17	54
Inlet Gas Temperature (F)	325	329	290	9.4	54
Outlet Gas Temperature (F)	118	120	114	1.5	54
Oxidation Air Rate (acfm)	56.38	59.99	55.00	2.22	54
Solids Residence Time In FLRT (hrs)	185.7	191.0	179.6	2.93	54

GCLS-5 Process Summary Report
(3/16/94 14:00:00 to 3/18/94 8:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	73.8	81.4	68.0	4.08	38
L/G Ratio (gal/macf)	19.5	19.7	19.3	0.15	38
Recirculating pH	5.65	5.78	5.60	0.04	38
Absorber pH	4.49	4.88	4.27	0.19	38
Reaction Tank pH	5.52	5.71	5.48	0.05	38
Flue Gas Flow Rate (scfm)	750	750	750	0.1	38
Gas Velocity (ft/sec)	8.3	8.4	8.2	0.06	38
Reagent Feed Rate (gpm)	0.069	0.085	0.028	0.01	38
Absorber Feed Rate (gpm)	17.0	17.0	17.0	0.0	38
Thickener Underflow Recycle (gpm)	6.2	6.4	5.1	0.2	38
SO2 Absorbed (mmole/L)	20.63	22.78	19.01	1.14	38
Absorber Tray ΔP (in H2O)	0.5	1.0	0.2	0.2	38
Inlet SO2 concentration, wet (ppm)	2000	2006	1994	2.5	38
Outlet SO2 concentration, wet (ppm)	485	593	347	74.5	38
Inlet O2 Concentration (%)	11.35	11.95	11.03	0.21	38
Outlet O2 Concentration (%)	10.89	11.47	10.57	0.20	38
Inlet HCl Concentration, wet (ppm)	12.66	15.78	9.12	2.25	38
Inlet Gas Temperature (F)	334	351	311	14.4	38
Outlet Gas Temperature (F)	115	116	113	1.2	38
Oxidation Air Rate (acfm)	55.00	55.00	55.00	0.00	38
Solids Residence Time In FLRT (hrs)	193.2	214.8	167.2	14.30	38

GCLS-6 Process Summary Report
(3/21/94 18:00:00 to 3/26/94 11:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	91.8	93.7	89.3	1.37	73
L/G Ratio (gal/macf)	20.0	20.2	19.7	0.11	73
Recirculating pH	5.72	6.15	5.52	0.08	73
Absorber pH	4.56	4.71	4.33	0.10	73
Reaction Tank pH	5.50	5.60	5.44	0.02	73
Flue Gas Flow Rate (scfm)	750	750	750	0.0	73
Gas Velocity (ft/sec)	8.2	8.2	8.1	0.02	73
Reagent Feed Rate (gpm)	0.085	0.132	0.059	0.01	73
Absorber Feed Rate (gpm)	17.0	17.0	17.0	0.0	73
Thickener Underflow Recycle (gpm)	6.2	8.5	2.8	0.6	73
SO2 Absorbed (mmole/L)	25.64	26.15	24.92	0.39	73
Absorber Tray ΔP (in H2O)	4.3	4.9	3.8	0.2	73
Inlet SO2 concentration, wet (ppm)	2000	2005	1995	2.3	73
Outlet SO2 concentration, wet (ppm)	154	199	118	25.5	73
Inlet O2 Concentration (%)	11.46	11.95	10.57	0.27	73
Outlet O2 Concentration (%)	11.05	11.56	10.23	0.27	73
Inlet HCl Concentration, wet (ppm)	13.42	15.91	11.98	0.89	73
Inlet Gas Temperature (F)	318	318	318	0.1	73
Outlet Gas Temperature (F)	116	118	109	1.7	73
Oxidation Air Rate (acfm)	59.99	60.00	59.98	0.00	73
Solids Residence Time In FLRT (hrs)	148.0	159.2	141.1	5.52	73

GCLS-7 Process Summary Report
(3/27/94 00:00:00 to 3/28/94 9:00:00)

Process Variable	Average	Max	Min	Std. Dev.	Points
SO2 Removal (%)	55.8	56.3	55.0	0.31	33
L/G Ratio (gal/macf)	19.5	19.8	19.1	0.09	33
Recirculating pH	5.61	5.73	5.27	0.11	33
Absorber pH	4.81	5.02	4.53	0.10	33
Reaction Tank pH	5.52	5.68	5.45	0.05	33
Flue Gas Flow Rate (scfm)	750	750	750	0.0	33
Gas Velocity (ft/sec)	8.3	8.3	8.3	0.01	33
Reagent Feed Rate (gpm)	0.050	0.064	0.036	0.01	33
Absorber Feed Rate (gpm)	17.0	17.0	16.6	0.1	33
Thickener Underflow Recycle (gpm)	6.0	6.6	3.4	0.5	33
SO2 Absorbed (mmole/L)	15.60	15.86	15.38	0.10	33
Absorber Tray ΔP (in H2O)	0.0	0.1	0.0	0.0	33
Inlet SO2 concentration, wet (ppm)	2000	2005	1996	2.7	33
Outlet SO2 concentration, wet (ppm)	830	845	820	5.8	33
Inlet O2 Concentration (%)	11.08	11.49	10.60	0.19	33
Outlet O2 Concentration (%)	10.72	11.14	10.26	0.19	33
Inlet HCl Concentration, wet (ppm)	11.31	13.25	7.53	1.76	33
Inlet Gas Temperature (F)	310	318	307	3.3	33
Outlet Gas Temperature (F)	120	122	118	1.0	33
Oxidation Air Rate (acfm)	59.99	59.99	59.99	0.00	33
Solids Residence Time In FLRT (hrs)	256.7	267.6	241.7	5.34	33

EPRI HIGH SULFUR TEST CENTER MINI-PILOT ABSORBER TEST CALENDAR

March 1994 (Updated April 15)

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1 Clear Liquor Scrubbing II GCLS-2	2 Clear Liquor Scrubbing II GCLS-3 4000 ppm DBA Forced Oxidation 3 wt% FLRT Conc.	3 Clear Liquor Scrubbing II GCLS-3	4 Clear Liquor Scrubbing II GCLS-3	5 Clear Liquor Scrubbing II GCLS-3
6 Clear Liquor Scrubbing II GCLS-4 4000 ppm DBA 14 wt% FLRT 25 mM Ca2+ Lime Injection	7 Clear Liquor Scrubbing II GCLS-4	8 Clear Liquor Scrubbing II GCLS-4	9 Clear Liquor Scrubbing II GCLS-4	10 Clear Liquor Scrubbing II GCLS-4	11 Clear Liquor Scrubbing II GCLS-4	12 Clear Liquor Scrubbing II GCLS-4
13 Clear Liquor Scrubbing II GCLS-4	14 Clear Liquor Scrubbing II Unit Down	15 Clear Liquor Scrubbing II GCLS-5 4000 ppm DBA 15 wt% FLRT Na Addition, 20 mM Ca 12060 Packing w/o Tray No Lime Injection	16 Clear Liquor Scrubbing II GCLS-5	17 Clear Liquor Scrubbing II GCLS-5	18 Clear Liquor Scrubbing II GCLS-5	19 Clear Liquor Scrubbing II GCLS-6 4000 ppm DBA 12 wt% FLRT Na Addition, 20 mM Ca 12060 Packing w/Tray No Lime Injection
20 Clear Liquor Scrubbing II GCLS-6	21 Clear Liquor Scrubbing II GCLS-6	22 Clear Liquor Scrubbing II GCLS-6	23 Clear Liquor Scrubbing II GCLS-6	24 Clear Liquor Scrubbing II GCLS-6	25 Clear Liquor Scrubbing II GCLS-6	26 Clear Liquor Scrubbing II GCLS-6
27 Clear Liquor Scrubbing II GCLS-7 4000 ppm DBA 11 wt% FLRT Na Addition, 20 mM Ca PN-Fill Packing w/o Tray No Lime Injection	28 Clear Liquor Scrubbing II GCLS-7	29 Unit Down Pilot On-Line	30 Unit Down Pilot On-Line	31 Unit Down Pilot On-Line		

March 1994

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