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**CONFINED ZONE DISPERSION
FLUE GAS DESULFURIZATION DEMONSTRATION**

18 1993

**Quarterly Report No. 7
For the Period
May 1, 1992 to August 16, 1992**

**Prepared for:
U.S. Department of Energy
Pennsylvania Electric Company
Pennsylvania Energy Development Authority
New York State Electric & Gas Corporation
Rockwell Lime Company**

**Prepared by:
Bechtel Corporation
Fifty Beale Street
San Francisco, California 94105-1895**

February 1, 1993

**Cooperative Agreement No. DE-FC22-90PC90546
Patents Cleared by Chicago on February 26, 1993**

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Section 1

SUMMARY

This is the seventh quarterly report for this project. It covers work performed on Phase 3a from May 1, 1992, through August 16, 1992 – a little longer than the regular 3-month period in order to include the end of the parametric testing and the completion of design, procurement, installation, facility construction and the training of the new plant operators.

August 17, 1992 will mark the start of Phase 3b, the CZD demonstration with one year of continuous operation. CZD operations will be fully automated and integrated with power plant operations and will be directed by plant operators from the power plant control room.

This last period of Phase 3a included the following activities:

- Lime procurement of different types of lime in order to conduct the parametric test program and the one-year continuous demonstration
- Completion of design, procurement and installation
 - Based on the results of the parametric tests, completion of the design packages and procurement of all process equipment, instruments and controls needed to automate and integrate the operation of the CZD system with boiler #15 at Seward Station
 - Installation of all instruments and controls needed for continuous operation, monitoring, and data collection

The following modifications and additions were also implemented during Phase 3a:

- New atomizer lances that permitted a better distribution of atomized lime slurry in the flue gas duct were installed. As expected, these new atomizer lances contributed to a higher percentage of SO₂ removal.
- The arrangement of manually controlling the lime slurry concentration by diluting the high lime slurry concentration and injecting it directly into the header – ahead of the distribution to the atomizers – could not be easily automated. For this reason, automatic control of the lime slurry was implemented in the lime slurry sump. When the lime slurry is at the desired concentration, it is transferred to the lime slurry feed tank and then pumped to the lime distribution header with no further dilution.
- The existing transfer pipeline was replaced by a larger one to permit a bigger flow rate of the lower-lime-concentration lime slurry.

- The existing sump pump required a booster pump in series to transfer the lime slurry to the vibrating screen and then to the lime feed tank. A new, larger sump pump with a higher head was installed to accommodate the higher flow rate of diluted lime slurry. This eliminated the need for the booster pump; a second sump pump was installed as a standby pump.
- The existing lime slurry feed pump had a low head and required a booster pump in series. Two new centrifugal pumps with a larger capacity and head were installed to replace the existing pumps. One of these pumps is on standby.
- New, retractable soot blowers kept the turning vanes in the flue gas duct clean as well as the new thermocouple lances installed in the turning vanes.
- New instruments were required for the continuous operation and full automation of the system. These included:
 - a) Level control instruments for the lime sump and lime slurry feed tanks.
 - b) Instruments for automatic density control in the lime sump.
 - c) An automatic switch to handle an emergency condition when the lime slurry injection is changed to the water injection and the lime slurry piping is flushed. (To avoid increases in stack opacity, a water injection in the duct is required for a few hours after the lime slurry injection is turned off.) By the push of a button, the lime slurry injection could be put back in operation. The sump pump and the lime feed pump will not be affected by an emergency condition because the lime slurry will automatically change to recirculation.
 - d) The lime slurry injection rate is automatically controlled by the temperature set point in the duct. Therefore, the boiler load variation will not affect the CZD operation.
 - e) Remote monitoring and control from the equipment control room in the lime preparation area includes the:
 - lime silo high- or low-level alarm
 - lime silo baghouse blower (on or off)
 - screw conveyor (on or off)
 - lime silo star valve VSD current draw
 - lime slurry sump level and level setpoint
 - lime slurry density and density setpoint
 - f) The instrumentation and controls (I&C) system consists of the instrumentation, distributed control system (DCS) hardware, chart recorder, cabling, and other related equipment.

- g) A new environmental monitoring system (EMS) based on the dilution method, includes:
 - SO₂ in and out
 - NO_x in and out
 - CO₂ in and out.
- h) A new flue gas flow monitor that monitors the flue gas flow rate in the duct at the inlet and outlet

Completion of Facility Construction

Completion of facility construction included the following:

- Improved facilities for lime unloading and storage to support the increased capacity required for continuous operation of the CZD system:
 - Installation of automated lime feed system.
 - Improvement of the lime receiving and storage system.
- Insulation of piping and provision of weather protection and enclosures as required to permit continuous, all-year operation of the CZD system.
- Provision of construction management support to Penelec, as requested. Penelec had prime control and responsibility for all construction activities at Seward Station.

Startup (Checkout) and Operator Training for Continuous Operation

The following steps were taken in preparation for startup and continuous operation:

- A startup engineer was provided to supervise the commissioning of all new CZD components and systems.
- Penelec's operators were trained to run the CZD system and perform the tasks required to conduct the one-year continuous demonstration. A videotape presentation and shift supervisors' handbook were also prepared.
- Procedures were established for the coordination of data collection and reduction with Penelec's plant management and operations personnel.

CZD Parametric Testing

During the month of May 1992, the lime injection tests with the new lance configuration indicated that higher flow rates of lime slurry were necessary to achieve an adiabatic saturation temperature at the B-cross section of the duct. With the old lance configuration, significant temperature reduction at the B-section started at about 30 gpm, while the new configuration permits flow rates

of at least 40 gpm before significant reduction occurs. This confirms the more uniform and complete mixing of the flue gas and injected lime. It also permits larger quantities of slurry to be injected and therefore will result in a higher percentage of SO₂ removal.

During the month of June 1992, lime injection parametric testing was suspended due to installation of the new lime-feed and transfer pumps. In-duct operations were limited to water testing and traverses for duct temperature distribution and flue gas flow. As a result, the continuous six-month demonstration run will not commence before the middle of August 1992.

During the month of July 1992, lime injection testing resumed during the week of July 6 using the new, heavy-duty lime-feed pumps. Since the lime preparation pit was under renovation, fresh-slaked calcitic lime was trucked daily from Conemaugh Station. SO₂ removal rates of up to 52% were obtained during these tests. Over 40% of removal was obtained in one test with more than one-third of the atomizers shut off. These tests have confirmed the improved operation of the new atomizer lance configuration.

Operator training was started during the week of July 13 for the eight new operators hired by Penelec for the continuous demonstration. Arrangements were also finalized for continuous deliveries of lime to support the six-month demonstration run. Type-S pressure-hydrated dolomitic lime was selected for the continuous demonstration. It will be shipped from Rockwell by railcar to Industry, PA and will be transported from there to Seward Station by self-unloading truck.

During the first two weeks of the month of August 1992, the lime slurry injection testing continued with fresh-slaked calcitic lime trucked daily from Conemaugh Station. The lime slurry concentration varied from 9.5% to 16.5%. The peak SO₂ removal, when operating with a 9.5% lime slurry concentration, was 44.8% and the average SO₂ removal was 40.1%. With 15.7% lime slurry concentration, the peak SO₂ removal was 52.1%, and the average SO₂ removal was 45.5%.

It was decided to use pressure-hydrated dolomitic lime for the CZD continuous demonstration because it was expected to obtain a higher percent of NO_x removal with the dolomitic lime than with the calcitic lime.

Figure 1-1 shows the original and current milestone schedule for the Phase 3a parametric test program. In essence, Phase 3a was expanded to include two periods of parametric testing: six months of batch testing, ended December 31, 1991, and 7 1/2 months of testing, ended August 16, 1992, during and after conversion to continuous operation. Phase 3a was expanded to include installation or replacement of equipment and instrumentation, as described above, and as originally included in Phase 3b.

The project schedule for Phase 3a – completion of design, procurement, and installation of the new equipment and instrumentation – is presented in Tables 3-1 through 3-6 of Section 3. Each of these schedules is updated monthly.

Figure 1-1 Phase 3a Parametric Test Program, Including Equipment Installation for Continuous Run

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Section 2

INTRODUCTION

The CZD process involves injecting a finely atomized slurry of reactive lime into the flue gas duct work of a coal-fired utility boiler. The principle of the confined zone is to form a wet zone of slurry droplets in the middle of the duct confined in an envelope of hot gas between the wet zone and the duct walls. The lime slurry reacts with part of the SO₂ in the gas, and the reaction products dry to form solid particles. A solids collector, typically an electrostatic precipitator (ESP) downstream from the point of injection, captures the reaction products along with the fly ash entrained in the flue gas.

The features that distinguish the CZD process from other similar injection processes are:

- Injection of an alkaline slurry directly into the duct, instead of injection of dry solids into the duct ahead of a fabric filter.
- Use of an ultrafine calcium/magnesium hydroxide, type S pressure-hydrated dolomitic lime. This commercial product is made from plentiful, naturally occurring dolomite.
- Low residence time, made possible by the high effective surface area of the Type S lime.
- Localized dispersion of the reagent. Slurry droplets contact only part of the gas while the droplets are drying, to remove up to 50 percent of the SO₂ and significant amounts of NO_x. The process uses dual fluid rather than rotary atomizers.
- Improved electrostatic precipitator performance via gas conditioning from the increased water vapor content, and lower temperatures.

The waste product is composed of magnesium and calcium sulfite and sulfate, with some excess lime. This product mixed with fly ash is self-stabilizing because of the excess lime values, and thus tends to retain heavy metals in insoluble forms within the fly ash.

The demonstration is being conducted at Penelec's Seward Station, Unit No. 15. This boiler is a 147 MWe coal-fired unit, which utilizes Pennsylvania bituminous coal (approximately 1.2 to 2.5% sulfur). One of the two flue gas ducts leading from the boiler has been retrofitted with the CZD technology. The first existing ESP installed in the station is immediately behind the air preheater. The second ESP, installed about 15 years ago, is about 80 feet away from the first ESP. The station has two more boilers (#12 and #14) that burn the same coal and are

connected to the common flue gas stack. The arrangement of Seward Station is shown in Figure 2-1.

The goal of this demonstration is to prove the technical and economic feasibility of the CZD technology on a commercial scale. The process is expected to achieve 50% SO₂ removal at lower capital and O&M costs than other systems.

The U.S. Department of Energy and Bechtel Corporation are engaged in a cooperative project to demonstrate the CZD Technology. DOE is providing half, or \$4.6 million, of the project's total \$9.2 million cost. Others contributing to the project are Pennsylvania Electric Company (\$3 million), Bechtel (\$760,000), the Pennsylvania Energy Development Authority (\$750,000), New York Gas and Electric Company (\$100,000), and Rockwell Lime Company (\$23,000).

To achieve its objectives, the project is divided into the following three phases:

- Phase 1: Design and Permitting
- Phase 2: Construction and Start-up
- Phase 3: Operation and Disposition

Phase 1 activities were completed on January 31, 1991. Phase 2 activities were essentially concluded on July 31, 1991, and Phase 3a, Parametric Testing, was initiated on July 1, 1991. This Quarterly Technical Progress Report covers Phase 3a activities from May 1, 1992 through August 16, 1992.

For further information on the structure of this demonstration project, Appendix A provides a project description by phase, a work breakdown structure (WBS) Diagram, and a detailed description of the WBS.

Figure 2-1 Seward Station Arrangement

Section 3

PROJECT STATUS

This section of the report provides details of the work performed from May 1 through August 16, 1992, covering engineering and procurement of the instrumentation and equipment needed to automate the CZD system and installation, construction management, and travel. It also describes the activities carried out as part of the parametric test program.

Figure 3-1 shows the Seward Station simplified process flow diagram. Figures 3-2 through 3-5 show the Seward CZD system overview, lime storage and slurry preparation, the lime slurry feed system, and lime slurry injection, respectively, all for continuous operation.

3.1 COMPLETION OF DESIGN PROCUREMENT AND INSTALLATION (WBS 1.3.3)

Engineering, procurement, and field work were accomplished for automation of the CZD system with a concurrent extension of the parametric test program. The status of individual items is described below:

- Installation of additional four soot blowers on the duct bottom was completed. These cover the entire bottom area of the duct from the injection lances to the turning vanes.
- Installation of the new lime transfer line to permit transfer of lime slurry from the preparation area to the feed tanks on a continuous basis, was completed. This line will be capable of handling the increased flows required at the desired dilution.
- The new, heavy-duty, lime slurry feed pumps were put into operation for the fresh-slaked lime tests and performed satisfactorily.
- The lime slurry feed tank level control system was calibrated and put into service.
- Automation of the lime preparation area, including the density control system and level controller, was completed. The remote control connections were started for operation of the system from the main station control room.
- Modifications to the data acquisition and analysis equipment were completed to permit the unit to be used for process control.

Figure 3-1 Seward Station Overall Process Flow Diagram

Figure 3-2 Seward CZD System Overview

Figure 3-3 Lime Storage and Slurry Preparation – Continuous Operation

Figure 3-4 Lime Slurry Feed System – Continuous Operation

Figure 3-5 Lime Slurry Injection – Continuous Operation

3.2 COMPLETION OF FACILITY CONSTRUCTION (WBS 1.3.4)

The following facility construction activities were accomplished during this period:

- Steel support structures were installed on the top of the duct to permit installation of four retractable soot blowers at the turning vanes. These four sootblowers will complete the system for automated duct cleaning.
- Facilities were installed for improving lime unloading and storage to support the increased capacity required for continuous operation of the CZD system.
- The automated lime feed system was installed.
- The automated lime transfer system was installed.
- Construction management support was provided to Penelec as requested. Penelec had prime responsibility for the construction activities at Seward Station.

3.3 INSTRUMENTATION AND CONTROLS SYSTEM FOR AUTOMATION

The instrumentation and controls (I&C) system consists of the instrumentation, distributed control system (DCS) hardware, chart recorders, cabling, and other related equipment to support the safe and proper control of the CZD process.

The general types of equipment that constitute the CZD architecture are as follows:

- Primary sensing elements that sense equipment and process stream parameters
- Field transmitters, which receive the signal from a primary sensing element and convert it to a 4-20 mA current loop or other industry standard output, with enclosures to suit the process area environment
- Final control elements that provide actuation or throttling capability, some of which are of an electropneumatic type and utilize an instrument air supply
- Instrument signal wiring that is routed between the field transmitters to controllers, local indicators, and the DCS enclosures located at three locations in the plant and back to the final control elements
- A DCS, based upon a Bailey Controls architecture, which includes electronic processors and other devices to monitor and control the CZD process
- Chart recorders which provide additional display, trending, and data logging capabilities to the system

A simplified block diagram of the DCS is presented as Figure 3-6. The architecture drawing shows the various elements of DCS components and their location throughout the plant.

3.3.1 Lime Preparation DCS Enclosure

In the lime preparation building, the DCS consists of the modules located in the remote input/output (RIO) No. 2 enclosure. This enclosure is a Bailey Control Mini-90. All system instrumentation to the DCS for the lime mixing system is wired to this enclosure and transmitted to the processor in the control room over the fiber optic link. This enclosure accepts digital and analog signals for both inputs and outputs (I/O). This enclosure is sized for additional I/O and loop controllers for future expansion of the DCS in this area, if desired.

The two loop controllers located in this enclosure are Bailey Controls model DCS. These controllers are identical to those presently in use for Seward's combustion control system.

3.3.2 Lime Slurry Feed in the B-Duct Area

The DCS components for this area are located in two cabinets. The first cabinet is labeled "RIO No. 1" and contains all of the I/O modules for interfacing to field transmitter, thermocouples, and switches. The second enclosure contains the two loop controllers and two Leeds & Northrup (L&N) chart recorders. The L&N chart recorders are described in greater detail later in this section.

The loop controllers in this area are of a stand-alone type, Bailey's CLC03, which allows them to continue controlling the flow of lime slurry and water into the duct even if the rest of the DCS fails for any reason. This allows operators to shift to local-only control of lime or water injection into the duct.

It is highly recommended that the DCS and other instrumentation in this area receive their 120 Vac power through a small uninterruptible power supply (UPS). This would allow full control capability of lime injection into the duct, even in the event of loss of power. This capability would also enable the ready/standby interlock to work during loss of power.

3.3.3 CZD Multifunction Processors

The CZD DCS uses three of Bailey Control's multifunction processors (MFPs). Two are of the MFP-01 type and the third is an MFP-02.

The two MFP-01s are central to the operation of the CZD process. All CZD I/O signals wired to the various modules in the lime preparation building and the duct B shack converge as data into these modules. The modules are programmed or configured, with all interlock, analog, and digital controls, and calculations for CZD.

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LIME PREP BUILDING

RIO No. 2
(MINI 90)

SLAVE EXPANDER BUS

NOTES

1. ALL INPUTS, OUTPUTS, CALCULATIONS AND LOGIC FOR THE THREE MULTI-FUNCTION PROCESSORS (MFPs) AND THE TWO LOOP COMMAND CONTROLLERS ARE DESCRIBED IN BAILEY CONTROLS DWG. D 8130484B.
2. ALL REQUIRED TERMINATION UNITS AND INTERCONNECT CABLE NOT SHOWN ON THIS DRAWING.
3. THE MFP AT ADDRESS 20 IS CONFIGURED WITH A 'HOT STANDBY' MFP WHICH IS CAPABLE OF RUNNING THE PROCESS IF THE PRIMARY MFP FAILS OR IS TAKEN OFF LINE FOR SERVICING.
4. THE MFP AT ADDRESS 10 HANDLES ONLY 'DATA SWITCHING' TO AND FROM THE L&N CHART RECORDERS.
5. THE L&N CHART RECORDERS ARE USED PRIMARILY FOR LOCAL INDICATION AND RECORDING OF CZD AND SEWARD PLANT OPERATING DATA.

LEGEND

- ACS - ANALOG (OR DIGITAL) CONTROL STATION
 ASI - ANALOG SLAVE INPUT MODULE
 ASO - ANALOG SLAVE OUTPUT MODULE
 AR - ANALYZER RECORDER (CHART RECORDER)
 CO3 - LOOP COMMAND CONTROLLER
 CIS - CONTROL I/O SLAVE MODULE
 DSI - DIGITAL SLAVE INPUT MODULE (120VAC)
 DSO - DIGITAL SLAVE OUTPUT MODULE (120VAC)
 L&N - LEEDS & NORTHRUP
 MFP - MULTI-FUNCTION PROCESSOR
 RIO - REMOTE I/O MODULE

Figure 3-6 CZD DCS Architecture Diagram

**CZD DISTRIBUTED CONTROL SYSTEM
(DCS) ARCHITECTURE DIAGRAM
(CONTINUOUS OPERATION)**

JOB NO. 21178-003	
DRAWING NO.	REV.
21178-J-301	2

The two MFP-01s are also configured to be fully redundant. This means that both MFPs are programmed with the identical program at all times and each receives the same data from the I/O modules at the same time. During operation, only one MFP-01 actually executes the configuration. The second MFP acts as a hot standby by monitoring the status of the first and takes over complete control of configuration execution in the event that the first MFP fails or is taken off line by the DCS technician. This hot standby capability is quite convenient in that modifications to the configuration can be accomplished without shutting down any part of the CZD system. In addition, if changes are made to the configuration or to one module, when that module is placed back into execution, it will update the other module with the new configuration.

The MFP-01s accept and send out information through the various slave modules. The slave module located in the plant control room accepts the data and log inputs provided by Penelec's environmental group for the monitoring of stack and duct opacity, SO₂ concentration, etc. This slave module is interfaced directly to the MFP-01s through the slave bus. The slave buses for RIOs No. 1 and 2 are routed over a single pair of fiber optic cables to each remote enclosure. RIO modules allow data to be transferred to and from the two remote enclosures to be multiplexed over the fiber optic link. The fiber optic link allows data to be transferred at such high speeds that the remote I/O slaves are treated the same as the one in the control room by the MFP-01s.

The fiber optic link is also impervious to electrical noise of any type. This includes the highly noisy environment found in power plants.

The two MFP-01s also export and import data over the plant loop network. Network access allows data concerning the operating state of the No. 15 Boiler to be incorporated into calculations or displays. Network access also allows all of the CZD operating data to be transmitted to and from operator display stations (or even other controllers).

3.3.4 L&N Chart Recorders

The L&N chart recorders are used by engineers and operators to view, datalog, and/or trend CZD and boiler data right at the duct or ESP control room. The flexibility in viewing much of the plant operating data at these locations is an important asset in the setup and tuning of the CZD system. Originally configured to handle all of CZD's processing requirements, the MFP-02 module is now dedicated to data switching with the L&N chart recorders. Because it is connected to the MFP-02 over the RS-485 network, it permits the chart recorders to receive most all of their I/O over this data link.

The chart recorder in the ESP control room (AR-01) is dedicated to monitoring the performance of the Buell ESP.

3.3.5 Operator Interface Units

Operator interface units (OIUs) enable the control room operators to:

- View the overall operation of CZD
- Perform trending of CZD performance
- Make changes to flow and/or density setpoints to adjust CZD operation in response to boiler load changes
- Alert the operator as to alarm conditions
- Allow viewing of temperature profiles and skin temperatures

3.4 PROJECT SCHEDULE FOR PHASE 3a – COMPLETION OF DESIGN, PROCUREMENT, AND INSTALLATION OF NEW EQUIPMENT AND INSTRUMENTATION

The completion of design, procurement, and installation of new equipment and instrumentation were planned to occur in a short period of time. Because some of the equipment (centrifugal pumps, sump pumps, star valve reducer and motor, 4-way valves, etc.) and control and instrumentation (nuclear-type density gauge, etc.) were delivered late, it was necessary to reschedule the mobile maintenance task work. Every few weeks an updated schedule by task was made to coordinate CZD testing with work in the lime feed area, lime preparation area, and balance of the plant (B.O.P.) area, and with controls and instrumentation.

Table 3-1 shows the initial schedule. The updated schedules are included in Appendix D.

**Table 3-1
Initial Project Schedule for Phase 3a - May 14, 1992**

DATE	TESTING	LIME FEED	LIME PIT	B.O.P.	CONTROLS	INSTRUMENTATION
18-May	Factorial testing - Dolomitic	Remove top layer of lime chips from tank area. Install level transmitter in tank A				
19-May	Factorial testing - Dolomitic	Install level transmitter in tank B		Retractable soot blowers on site		
20-May	Factorial testing - Dolomitic	Install partial drains		Start install lime transfer line. Start platform drawings		
21-May	Factorial testing - Dolomitic	Install lever transmitter transmitters		Install lime transfer line		
22-May	Factorial testing - Dolomitic	Install level transmitter conduit		Install lime transfer line.		Bailey DCS part/comp
23-May	SATURDAY					
24-May	SUNDAY					
25-May	MEMORIAL DAY					
26-May		Remove piping & Electrical, remove Lime feed pumps. Connect level transmitters to control system.		Install lime transfer line. Review platform drawings		Delivery of bailey equip for lime prep bldg
27-May		Remove foundations & form for new		Install lime transfer line. Fabricate platform		Install Bailey mini-90
28-May		Pour foundations	Clean feed system on 2nd level	Install lime transfer line. Fabricate platform		Wire mini -90 power
29-May		Pour sealing surface over area forming a drainage pattern	Clean pit outer surface	Install lime transfer line. Fabricate platform		Terminate fiber optics
30-May	SATURDAY					
31-May	SUNDAY					
1-Jun		Install pumps	Remove Piping & Electrical	Install lime transfer line. Fabricate platform. Form pad for environmental enclosure.	Feed rate control system on site. Install ready standby wiring	
2-Jun		Install pumps	Remove pumps	Install lime transfer line. Install platform. Pour pad for environmental enclosure.	Install ready standby wiring	
3-Jun		Install piping	Remove cover	Install lime transfer line. Install platform	Install ready standby wiring	
4-Jun		Install instrumentation, Terminate Power, Install seal water, finish piping	Survey foundation,	Install lime transfer line. Install platform	Install ready standby wiring	

Table 3-1 (Continued)

DATE	TESTING	LIME FEED	LIME PIT	B.O.P.	CONTROLS	INSTRUMENTATION
5-Jun		Checkout & Test	Clean lime pit	Install lime transfer line. Install RB-11. Remove forms for environmental enclosure.	Install ready standby wiring	
6-Jun	SATURDAY					
7-Jun	SUNDAY					
8-Jun	Factorial test-fresh slaked	Checkout & Test	Reinforce foundation, Fabricate piping	Install lime transfer line. Install RB-12. Wire RB-11	Install Star valve reducer and motor	
9-Jun	Factorial test-fresh slaked		Install pumps, Install covers	Install lime transfer line. Install RB-13. Wire RB-12. Checkout RB-11	Install feed rate controller	
10-Jun	Factorial test-fresh slaked		Install Piping headers, Install instrumentation	Install lime transfer line. Install RB-14. Wire RB-13. Checkout RB-12	Wire and terminate lime feed rate controller	
11-Jun	Factorial test-fresh slaked		Tie in piping header to lime slurry transfer line.	Checkout lime transfer line. Wire RB-14. Checkout RB-13	Install Bailey loop controller	Wire density gauge & controller, Don Goodman on site
12-Jun	Factorial test-fresh slaked		Install electrical feeders, Install electrical in cabinet	Test lime transfer line. Checkout RB-14	Wire loop controller. Terminate fiberoptics	Calibrate DE-01, S/V Lime density control
13-Jun	SATURDAY					
14-Jun	SUNDAY					
15-Jun	Factorial test-fresh slaked		Install instrumentation, Terminate electrical		Connect water level valve to loop controller	
16-Jun	Factorial test-fresh slaked		Checkout & Test		Program and checkout Bailey loop controller	
17-Jun	Factorial test-fresh slaked		Checkout & Test			Transfer enclosure
18-Jun	Factorial test-fresh slaked					Place environmental enclosure
19-Jun	Factorial test-fresh slaked					Terminate power wiring to environmental enclosure
20-Jun	SATURDAY					Transfer environmental equipment from trailer to enclosure
21-Jun	SUNDAY					
22-Jun	Factorial test-calcitic					Recalibrate environmental equipment
23-Jun	Factorial test-calcitic					
24-Jun	Factorial test-calcitic					
25-Jun	Factorial test-calcitic					

3.5 CZD PARAMETRIC TESTING (WBS 1.3.2)

3.5.1 May 1992

The following tests were made and data compiled during May 1992:

- Eight water and lime slurry injection tests were completed between May 1 and May 18, 1992. During the rest of the month, Boiler #15 was shut down for maintenance.
- Lime injection tests with the new lance configuration indicated that the higher flowrates of lime slurry were necessary to achieve adiabatic saturation temperature at the B-cross section of the duct. With the old lance configuration, significant temperature reduction at the B-section started at about 30 gpm, while the new configuration permits flow rates of at least 40 gpm before significant reduction occurs. This confirms the more uniform and complete mixing of the fine gas and injected lime and will permit larger quantities of slurry to be injected.
- Lime slurry feed rates varied from 30 gpm to 45 gpm, and lime slurry concentration with pressure-hydrated dolomitic lime varied from 6.2% to 12%.
- The calculated percentage of SO₂ removal rates varied from 8% to 30%. The SO₂ removal rate increased sharply as the lime feed rate rose.
- Although there are indications of NO_x removal, the data are questionable due to problems with NO_x instrument calibration.
- During the lime slurry injection, the stack opacity percentage decreased and remained low. Following the lime slurry injection, low rate water injection was maintained for a few hours to keep the stack opacity percentage at a low level.

Table C-1 in Appendix C shows operating conditions during May 1992 with parametric testing and the calculated percentage of SO₂ removal and temperature approach to saturation.

The adiabatic saturation temperature under operating conditions at Seward Station is about 120°F.

At the turning vanes, the 24 thermocouples give us the average temperature of the flue gas at the C-section.

The temperature approach to saturation is the difference between the average temperature at the C-section and the adiabatic saturation temperature.

At a flow rate of 50-55 gpm of atomized lime slurry into the duct, the average temperature at the C-section could reach 155-160°F.

$$155^{\circ} - 120^{\circ}\text{F (adiabatic saturation temperature)} = 35^{\circ}\text{F}$$

Temperature approach to saturation

A lower temperature approach to saturation will show a higher percentage of SO₂ removal.

The lowest temperature approach to saturation will show a higher percentage of SO₂ removal.

The lowest limit temperature at the C-section before wet solids impact and deposit on the turning vanes is about 150°F. Therefore, for safe operation under Seward Station conditions, with no solid deposits on the turning vanes, the average temperature at the turning vanes should not be less than 155°F, or 35°F temperature approach to saturation.

Temperature profile in the B-Duct on May 5, 1992

The graphs in Figures 3-7a through 3-7l show the temperature profile with the new atomizer lance configuration before water injection, and with water injection of 20 gpm, 30 gpm, 35 gpm, 40 gpm, and 50 gpm at the B-cross section (about 65 ft. from the injection point), and at the C-cross section (about 120 ft. from the injection point and immediately ahead of the turning vanes).

Figure 3-8 shows the plan view of the duct with thermocouple locations. The graphs in Figures 3-9a through 3-9f show the average and low temperatures during water injection of 18 to 45 gpm at B-, C-, D-, and E-cross sections.

"B" 0 GPM

5/5/92

**Figure 3-7a Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"B" 20 GPM

5/5/92

**Figure 3-7b Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"B" 30 GPM

5/5/92

**Figure 3-7c Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"B" 35 GPM

5/5/92

**Figure 3-7d Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"B" 40 GPM

5/5/92

**Figure 3-7e Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"B" 50 GPM

5/5/92

**Figure 3-7f Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"C" 0 GPM

5/5/92

**Figure 3-7g Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"C" 20 GPM

5/5/92

**Figure 3-7h Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"C" 30 GPM

5/5/92

**Figure 3-7i Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"C" 35 GPM

5/5/92

**Figure 3-7j Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"C" 40 GPM

5/5/92

**Figure 3-7k Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

"C" 50 GPM

5/5/92

**Figure 3-71 Temperature Profile with New Atomizer Lance Configuration
Before and with Water Injections at the B- and C-Cross Section**

Figure 3-8 Plan View of Duct with Thermocouple Locations

B, C, D & E CROSS-SECTION TEMPERATURES
VERSUS WATER FLOW RATE IN G.P.M.

Figure 3-9a Average and Low Temperatures During Water Injection of 18 to 45 gpm at B-, C-, D-, and E-Cross Section

B, C, D, E SECTION LOW TEMPERATURES 5/5/92

Figure 3-9b Average and Low Temperatures During Water Injection of 18 to 45 gpm at B-, C-, D-, and E-Cross Section

B SECTION TEMPERATURES 5/5/92

Figure 3-9c Average and Low Temperatures During Water Injection of 18 to 45 gpm at B-, C-, D-, and E-Cross Section

C SECTION TEMPERATURES 5/5/92

Figure 3-9d Average and Low Temperatures During Water Injection of 18 to 45 gpm at B-, C-, D-, and E-Cross Section

D SECTION TEMPERATURES 5/5/92

Figure 3-9e Average and Low Temperatures During Water Injection of 18 to 45 gpm at B-, C-, D-, and E-Cross Section

E SECTION TEMPERATURES 5/5/92

Figure 3-9f Average and Low Temperatures During Water Injection of 18 to 45 gpm at B-, C-, D-, and E-Cross Section

3.5.2 June 1992

Lime injection test operations were shut down during the month of June 1992 to allow installation of the new lime transfer and feed pumps. In-duct operations were limited to water testing and Pitot tube traverses for determining the temperature profile in the duct and also gas velocities at different distances from the injection point. Tables 3-2a, 3-2b, 3-2c, and 3-2d show the data recorded on June 18, 1992 when the traverses were performed at the E-cross section, and Tables 3-2e, 3-2f, 3-2g, and 3-2h show data recorded when the traverses were performed at the outlet duct, downstream from the I.D. fan. The Pitot tube traverses at the E-cross section show the following results:

- The lowest flue gas temperatures were at the bottom of the duct, and the highest were at the top of the duct.
- Port 1 at the right side of the duct has higher temperatures than Port 4 at the left side of the duct.
- The average temperature of all the traverses was 295°F, and the lowest temperature was 287°F a decrease in temperature of 8°F.
- The calculated flue gas velocity is higher in the middle of the duct and lower on the sides. The average gas velocity is 52.7 ft/sec.
- A second set of Pitot tube traverses performed at the E-cross section (Table 3-2c), also on June 18, 1992, concluded with very similar results: the average temperature was 295.1°F and the average calculated flue gas velocity was 52.9 ft/sec.

On the same day, two Pitot tube traverses were performed at the I.D. fan outlet, downstream of the E.S.P. Tables 3-2e and 3-2g show very close results.

- The average Pitot temperature was 300.5°F and 300.6°F, respectively.
- The average calculated flue gas velocity was 68.6 ft/sec and 68.5 ft/sec, respectively.
- Flue gas velocities in the outlet duct varied from 107 ft/sec at Port 1 (at the bottom of the duct) to 86 ft/sec at Ports 3 and 4 (at the middle of the duct) to 50 ft/sec at Port 6 (at the top of the duct). Also, the flue gas velocities varied from 107 ft/sec on the left side (position 1) to 76 ft/sec at position 4 (on the right side).

On June 10 and 11, Pitot tube traverses were performed at the B-cross section and at the duct outlet (downstream of the I.D. fan). The results of these measurements are included in Appendix C. These results are close to those obtained on June 18, 1992.

In June 1992, in-duct operations were limited to water testing. The results of these tests show:

- Water injection tests were made at 30 gpm, 35 gpm, 40 gpm, 42 gpm, 45 gpm, and 47 gpm when the inlet gas temperature was 310°F. At this high temperature, the water injection rate of 47 gpm was too low because at the B-cross section the temperature was high above the adiabatic saturation temperature. To achieve a high percentage of SO₂ removal, the lime slurry flow rate should be above 55 gpm.
- The stack opacity during the water injection was less than 9%.

On June 1, the expectation was that the installation and facility construction would be completed by July 14, but the suppliers of the sump pumps, control valves, density meter, 4-way valves, etc., did not adhere to their delivery dates, causing a rescheduling of the completion for August 17, 1992.

Table 3-2a Pitot Tube Traverses Conducted on June 18, 1992

"E" SECTION -I

Date:	6/18/92	
Time:	????	
Boiler Load, MW	????	
Barometric Pressure, In. Hg.:	28.85	
Duct Pressure, In. H2O:	15.8	
Calculated Flue Gas Flow, ACFM:	278,103	
Calculated Flue Gas Flow, SCFM:	177,192	(@60 oF & 29.92 in. Hg)
Kurz Meter Reading, SCFM:	?	
Correction Factor:	?	

Traverse Data:

	Pitot Pressure In. Oil	Pitot Pressure In. H2O	Pitot Temperature Degrees F	Calculated Flue Gas Density Lb./ACF	Calculated Pitot Head Ft. Flue Gas	Calculated Flue Gas Velocity Ft/Sec
Port I - 5	0.540	0.45	293.0	0.0497	46.69	46.0
Port I - 4	0.670	0.55	296.4	0.0495	58.19	51.4
Port I - 3	0.730	0.60	298.4	0.0493	63.57	53.7
Port I - 2	0.450	0.37	298.8	0.0493	39.21	42.2
Port I - 1	0.680	0.56	298.2	0.0493	59.20	51.8
Port II - 5	0.720	0.59	292.6	0.0497	62.22	53.1
Port II - 4	0.650	0.54	294.6	0.0496	56.32	50.6
Port II - 3	0.760	0.63	298.4	0.0493	66.18	54.8
Port II - 2	0.740	0.61	299.8	0.0492	64.56	54.1
Port II - 1	0.870	0.72	299.6	0.0492	75.88	58.7
Port III - 5	0.740	0.61	287.8	0.0500	63.54	53.7
Port III - 4	0.720	0.59	291.0	0.0498	62.08	53.1
Port III - 3	0.810	0.67	295.0	0.0495	70.22	56.5
Port III - 2	0.720	0.59	297.6	0.0494	62.63	53.3
Port III - 1	0.800	0.66	297.8	0.0494	69.61	56.2
Port IV - 5	0.700	0.58	286.6	0.0501	60.01	52.2
Port IV - 4	0.630	0.52	291.8	0.0498	54.38	49.7
Port IV - 3	0.740	0.61	295.6	0.0495	64.20	54.0
Port IV - 2	0.735	0.61	297.2	0.0494	63.90	53.9
Port IV - 1	0.750	0.62	296.0	0.0495	65.10	54.4
Averages:			295.3			52.7

Table 3-2b Pitot Tube Traverses Conducted on June 18, 1992

52	59	56	54
42	54	53	54
54	55	56	54
51	51	53	50
46	53	54	52

DUCT VELOCITY PROFILE

Calculated Flue Gas Velocities in Feet per Second

Table 3-2c Pitot Tube Traverses Conducted on June 18, 1992

"E" SECTION - II

Date:	6/18/92	
Time:	????	
Boiler Load, MW	????	
Barometric Pressure, In. Hg.:	28.85	
Duct Pressure, In. H2O:	15.8	
Calculated Flue Gas Flow, ACFM:	279,542	
Calculated Flue Gas Flow, SCFM:	178,163	(@60 oF & 29.92 in. Hg)
Kurz Meter Reading, SCFM:	?	
Correction Factor:	?	

Traverse Data:

	Pitot Pressure In. Oil	Pitot Pressure In. H2O	Pitot Temperature Degrees F	Calculated Flue Gas Density Lb./ACF	Calculated Pitot Head Ft. Flue Gas	Calculated Flue Gas Velocity Ft/Sec
Port I - 5	0.550	0.45	292.8	0.0497	47.54	46.5
Port I - 4	0.680	0.56	296.4	0.0495	59.06	51.8
Port I - 3	0.760	0.63	298.6	0.0493	66.20	54.8
Port I - 2	0.490	0.40	299.0	0.0493	42.70	44.0
Port I - 1	0.710	0.59	298.0	0.0494	61.79	53.0
Port II - 5	0.725	0.60	292.2	0.0497	62.62	53.3
Port II - 4	0.650	0.54	294.2	0.0496	56.29	50.6
Port II - 3	0.760	0.63	297.8	0.0494	66.13	54.8
Port II - 2	0.720	0.59	299.6	0.0492	62.80	53.4
Port II - 1	0.850	0.70	299.2	0.0493	74.09	58.0
Port III - 5	0.760	0.63	287.8	0.0500	65.25	54.4
Port III - 4	0.720	0.59	291.2	0.0498	62.10	53.1
Port III - 3	0.810	0.67	295.2	0.0495	70.24	56.5
Port III - 2	0.720	0.59	297.6	0.0494	62.63	53.3
Port III - 1	0.810	0.67	297.4	0.0494	70.44	56.5
Port IV - 5	0.720	0.59	286.4	0.0501	61.70	52.9
Port IV - 4	0.630	0.52	291.4	0.0498	54.35	49.7
Port IV - 3	0.740	0.61	295.0	0.0495	64.15	54.0
Port IV - 2	0.720	0.59	296.6	0.0494	62.55	53.3
Port IV - 1	0.770	0.64	295.2	0.0495	66.77	55.1
Averages:			295.1			52.9

Table 3-2d Pitot Tube Traverses Conducted on June 18, 1992

53	58	57	55
44	53	53	53
55	55	56	54
52	51	53	50
46	53	54	53

DUCT VELOCITY PROFILE

Calculated Flue Gas Velocities in Feet per Second

Table 3-2e Pitot Tube Traverses Conducted on June 18, 1992

OUTLET SECTION - I

Date:	6/18/92	
Time:	?????	
Boiler Load, MW	?????	
Barometric Pressure, In. Hg.:	28.85	
Duct Pressure, In. H2O:	0.7434	
Calculated Flue Gas Flow, ACFM:	361,948	
Calculated Flue Gas Flow, SCFM:	238,197	(@60 oF & 29.92 in. Hg)
Outlet Kurz Meter Reading, SCFM:	???	Run Average
Ratio-Calculated F.G. / Kurz Meter (SCFM)	#VALUE!	

Traverse Data:

	Pitot Pressure In. Oil	Pitot Pressure In. H2O	Pitot Temperature Degrees F	Calculated Flue Gas Density Lb./ACF	Calculated Pitot Head Ft. Flue Gas	Calculated Flue Gas Velocity Ft/Sec
Port I - 1	3.000	2.48	302.0	0.0511	252.40	107.0
Port I - 2	2.950	2.44	301.8	0.0511	248.13	106.1
Port I - 3	1.750	1.45	301.2	0.0511	147.08	81.7
Port I - 4	1.500	1.24	300.0	0.0512	125.87	75.6
Port II - 1	2.500	2.07	300.6	0.0511	209.95	97.6
Port II - 2	2.300	1.90	301.6	0.0511	193.40	93.7
Port II - 3	1.350	1.12	301.2	0.0511	113.46	71.8
Port II - 4	0.640	0.53	300.2	0.0512	53.72	49.4
Port III - 1	2.000	1.65	301.6	0.0511	168.18	87.4
Port III - 2	2.400	1.98	302.4	0.0510	202.02	95.8
Port III - 3	1.750	1.45	302.0	0.0511	147.23	81.8
Port III - 4	0.640	0.53	300.6	0.0511	53.75	49.4
Port IV - 1	1.950	1.61	301.4	0.0511	163.93	86.3
Port IV - 2	2.350	1.94	301.8	0.0511	197.66	94.7
Port IV - 3	1.500	1.24	301.0	0.0511	126.03	75.6
Port IV - 4	0.590	0.49	298.0	0.0513	49.38	47.3
Port V - 1	0.835	0.69	300.4	0.0512	70.10	56.4
Port V - 2	0.660	0.55	300.8	0.0511	55.44	50.2
Port V - 3	0.330	0.27	300.4	0.0512	27.71	35.5
Port V - 4	0.170	0.14	292.6	0.0517	14.13	25.3
Port VI - 1	0.650	0.54	300.0	0.0512	54.54	49.8
Port VI - 2	0.410	0.34	300.2	0.0512	34.41	39.5
Port VI - 3	0.625	0.52	299.0	0.0513	52.38	48.8
Port VI - 4	0.390	0.32	300.1	0.0512	32.73	38.5
Averages:			300.5			68.6

Table 3-2f Pitot Tube Traverses Conducted on June 18, 1992

PORT VI	50 300.0	40 300.2	49 299.0	39 300.1
PORT V	56 300.4	50 300.8	35 300.4	25 292.6
PORT IV	86 301.4	95 301.8	76 301.0	47 298.0
PORT III	87 301.6	96 302.4	82 302.0	49 300.6
PORT II	98 300.6	94 301.6	72 301.2	49 300.2
PORT I	107 302.0	106 301.8	82 301.2	76 300.0
	POSITION 1	POSITION 2	POSITION 3	POSITION 4

DUCT VELOCITY PROFILE

Calculated Flue Gas Velocities in Feet per Second
Temperatures in Degrees Fahrenheit

Table 3-2g Pitot Tube Traverses Conducted on June 18, 1992

OUTLET SECTION - II

Date:	6/18/92	
Time:	?????	
Boiler Load, MW	?????	
Barometric Pressure, In. Hg.:	28.85	
Duct Pressure, In. H2O:	0.7434	
Calculated Flue Gas Flow, ACFM:	361,495	
Calculated Flue Gas Flow, SCFM:	237,869	(@60 oF & 29.92 in. Hg)
Outlet Kurz Meter Reading, SCFM:	????	Run Average
Ratio-Calculated F.G. / Kurz Meter (SCFM)	#VALUE!	

Traverse Data:

	Pitot Pressure In. Oil	Pitot Pressure In. H2O	Pitot Temperature Degrees F	Calculated Flue Gas Density Lb./ACF	Calculated Pitot Head Ft. Flue Gas	Calculated Flue Gas Velocity Ft/Sec
Port I - 1	2.900	2.40	300.0	0.0512	243.34	105.1
Port I - 2	2.800	2.31	301.8	0.0511	235.51	103.4
Port I - 3	1.750	1.45	301.4	0.0511	147.12	81.7
Port I - 4	1.400	1.16	299.8	0.0512	117.45	73.0
Port II - 1	2.450	2.02	300.8	0.0511	205.80	96.7
Port II - 2	2.300	1.90	301.8	0.0511	193.45	93.7
Port II - 3	1.350	1.12	301.4	0.0511	113.49	71.8
Port II - 4	0.570	0.47	300.0	0.0512	47.83	46.6
Port III - 1	2.100	1.73	300.8	0.0511	176.40	89.5
Port III - 2	2.400	1.98	301.8	0.0511	201.87	95.7
Port III - 3	1.750	1.45	301.8	0.0511	147.19	81.7
Port III - 4	0.680	0.56	300.2	0.0512	57.08	50.9
Port IV - 1	2.150	1.78	300.2	0.0512	180.46	90.5
Port IV - 2	2.100	1.73	301.4	0.0511	176.54	89.5
Port IV - 3	1.500	1.24	301.2	0.0511	126.07	75.7
Port IV - 4	0.640	0.53	298.6	0.0513	53.60	49.3
Port V - 1	0.840	0.69	300.2	0.0512	70.50	56.6
Port V - 2	0.640	0.53	300.6	0.0511	53.75	49.4
Port V - 3	0.340	0.28	300.4	0.0512	28.55	36.0
Port V - 4	0.180	0.15	296.2	0.0514	15.03	26.1
Port VI - 1	0.620	0.51	300.2	0.0512	52.04	48.6
Port VI - 2	0.470	0.39	300.8	0.0511	39.48	42.3
Port VI - 3	0.635	0.52	301.2	0.0511	53.37	49.2
Port VI - 4	0.420	0.35	300.6	0.0511	35.27	40.0
Averages:			300.6			68.5

Table 3-2h Pitot Tube Traverses Conducted on June 18, 1992

PORT VI	49 300.2	42 300.8	49 301.2	40 300.6
PORT V	57 300.2	49 300.6	36 300.4	26 296.2
PORT IV	91 300.2	90 301.4	76 301.2	49 298.6
PORT III	89 300.8	96 301.8	82 301.8	51 300.2
PORT II	97 300.8	94 301.8	72 301.4	47 300.0
PORT I	105 300.0	103 301.8	82 301.4	73 299.8
	POSITION 1	POSITION 2	POSITION 3	POSITION 4

DUCT VELOCITY PROFILE

Calculated Flue Gas Velocities in Feet per Second
Temperatures in Degrees Fahrenheit

3.5.3 July 1992

Lime injection testing was resumed during the week of July 6 using the new, heavy-duty lime slurry feed pumps. Since the lime preparation pit was under renovation, fresh-slaked calcitic lime was trucked daily from Conemaugh Station and unloaded into the lime feed tanks after passing through the vibrating screen.

The following tests were made and data compiled during the month of July 1992.

- Nine water and lime slurry injection tests were completed between July 2 and July 27, 1992.
- Lime slurry feed rates varied from 30 gpm to 56 gpm and the lime slurry concentration varied from 8.5% to 15%.
- The calculated percentage of SO₂ removal rates varied from an average of 40.9% to a maximum of 48.1% on July 17, with a 52.6 gpm lime slurry feed rate and 10.5% lime slurry concentration. With about the same lime slurry feed rate but with a lower lime slurry concentration of 8.5%, the average SO₂ removal was 31.8%. The maximum SO₂ removal was 39.3%.
- CZD testing with fresh-slaked calcitic lime showed that high SO₂ removal (over 50%) could be obtained. The only problem with this particular Ca(OH)₂ supply was the plugging of the lines and the inlet to the atomizers. During testing, 6 of the 18 atomizers were plugged at the same time by the unreactive materials in the lime slurry. To avoid plugging, the lime slurry was passed through a 60-mesh vibrating screen. A large amount of unreactive material was removed from the lime slurry, but a sufficient amount of fine particles remained and settled in the pipes, causing plugging. The chemical analysis of the Ca(OH)₂ showed that the available Ca(OH)₂ was only 86.13% instead of 93.5%, as was stated by the lime supplier. The high content of CO₂ (3.3% instead of maximum 1%) indicates that more than 7% of the Ca(OH)₂ is an unreactive product, mostly calcium carbonate, that is heavier and settles in the pipe and atomizers.
- During the lime slurry injection, the stack opacity percentage decreased and remained low. After the lime slurry injection, the low-rate water injection was maintained for some hours to keep the stack opacity percentage at a low level.

Relationship Between % SO₂ Removal with Lime Slurry Injection Rate and Ca(OH)₂ Concentration

The graphs in Figures 3-10a through 3-10c show the relationship between the percentage of SO₂ removal with the lime slurry injection rate and the Ca(OH)₂ concentration. The percentage of SO₂ removal increases with the increase in lime slurry injection rate and with the increased Ca(OH)₂ concentration.

Figure 3-10a Relationship Between Percentage of SO₂ Removal with the Lime Slurry Injection Rate and the Ca(OH)₂ Concentration

Figure 3-10c Relationship Between Percentage of SO₂ Removal with the Lime Slurry Injection Rate and the Ca(OH)₂ Concentration

Tables 3-3a through 3-3c show the variation in SO₂, CO₂, flue gas flow, flue gas temperature, temperature approach to saturation (the difference of the temperature at the C-section – at the turning vanes – and the adiabatic saturation temperature), percentage of lime slurry concentration, percentage of SO₂ removal and percentage of lime utilization (moles of lime injected per mole of SO₂ removed) on July 15, 1992.

Figure 3-11 shows the variation in SO₂ reduction with lime slurry flow rate, lime utilization and temperature approach to saturation on the July 15, 1992 test run from 10:40 a.m. to 12:00 noon with 10.5% concentration of fresh slaked calcitic lime.

Figure 3-12 shows the same process on the July 15, 1992, test run from 12:05 p.m. to 1:30 p.m., with a 15% concentration of fresh slaked calcitic lime.

Figure 3-13 shows the same process on the July 15, 1992, test run from 1:35 p.m. to 2:45 p.m. with a 12% concentration of fresh slaked calcitic lime.

Figure 3-14 shows the variation in SO₂ reduction with the lime slurry flow rate, lime slurry concentration, and temperature approach to saturation on the July 15, 1992 test run, from 10:40 a.m. to 2:45 p.m., with fresh slaked calcitic lime.

Figure 3-15 shows the SO₂/NO₂ removal trend between 11:56 a.m. and 1:41 p.m. on July 17, 1992.

Figure 3-16 shows the stack opacity recorded graph on July 15, 1992.

Table C-3 in Appendix C shows the operating conditions during the month of July 1992, with parametric testing and the calculated percentage of SO₂ removal and temperature approach to saturation.

Table 3-3a Variation in SO₂, CO₂, Lime Slurry Concentration and Lime Utilization on July 15, 1992

Time	Fresh Slaked Calcitic Lime				SO ₂				CO ₂				Flue Gas Flow				Flue Gas Temp			Comments
	gpm	% Conc.	Consumed lb-mol/ minute	% Utilization	In ppm	Out ppm	Absorbed lb-mol/ m. minute	Reduced %	In %	Out %	Dilution %	In KSCFM	Out KSCFM	Dilution %	In °F	C Section °F	Approach to Adiabatic Saturation °F			
10:35	32.2	10.5			849.1	651.6		10.8	11.5	9.9	16.2	188.0	220.3	17.2		210.0	90.0			
10:40	35.5	10.5	0.390	21.3	847.7	580.0	0.083	19.7	11.5	9.8	17.3	188.4	221.1	17.4		197.4	77.4			
10:45	37.3	10.5	0.410	23.7	850.9	560.0	0.097	22.8	11.5	9.8	17.3	188.9	222.0	17.5		203.4	83.4			
10:50	37.4	10.5	0.411	27.5	857.4	537.4	0.113	26.5	11.6	9.9	17.2	189.2	223.5	18.8		203.8	83.8			
10:55	39.6	10.5	0.435	27.4	855.0	532.5	0.119	27.8	11.6	10.0	16.0	189.4	222.9	17.7		190.0	70.0			
11:00	42.1	10.5	0.460	28.7	857.8	507.5	0.132	30.7	11.6	9.9	17.2	190.4	224.3	17.8		181.3	61.3			
11:05	44.4	10.5	0.488	30.0	851.0	478.0	0.146	34.1	11.5	9.8	17.3	191.0	224.8	17.7		170.4	50.4			
11:10	45.0	10.5	0.495	30.5	851.7	465.5	0.151	35.4	11.6	9.8	18.4	190.4	225.8	18.6		168.6	48.6			
* 11:15	45.0	10.5	0.495	34.9	858.9	431.8	0.173	40.0	11.7	9.8	19.4	190.6	226.9	19.0		166.5	46.5			
* 11:20	45.0	10.5	0.495	35.8	852.2	422.3	0.177	41.3	11.6	9.8	18.4	191.0	227.4	19.0		159.7	39.7			
* 11:25	45.0	10.5	0.495	35.4	850.4	422.2	0.175	40.8	11.6	9.9	17.2	191.2	227.6	19.0		156.8	36.8			
* 11:30	45.0	10.5	0.495	37.2	851.1	416.2	0.184	42.7	11.6	9.9	17.2	191.5	227.9	19.0		155.8	35.8			
* 11:35	45.2	10.5	0.497	37.8	855.2	406.3	0.188	43.4	11.6	9.9	17.2	192.0	228.9	19.2		159.0	39.0			
* 11:40	45.0	10.5	0.495	39.0	852.5	394.8	0.193	44.8	11.6	10.0	16.0	191.2	228.0	19.2		162.7	42.7			
* 11:45	45.0	10.5	0.495	40.4	851.7	394.6	0.200	46.7	11.5	10.0	15.0	190.9	226.5	18.6		163.9	43.9			
* 11:50	45.0	10.5	0.495	36.8	852.0	426.3	0.182	42.4	11.4	9.9	15.2	190.9	226.7	18.7		163.6	43.6			
* 11:55	36.4	10.5	0.400	43.5	856.2	438.1	0.174	40.5	11.5	9.9	16.2	191.0	227.3	19.0		185.3	65.3			
* 12:00	36.4	10.5	0.400	43.5	859.9	443.8	0.174	40.7	11.6	10.1	14.9	187.9	218.9	16.5		186.7	66.7			
85 Minutes Average	42.0	10.5		33.7				36.5									55.0°F			
30 Minutes Peak Average	43.3	10.5		38.4				42.3									45.6°F			

* Indicates the values included in the peak average.

Table 3-3b Variation in SO₂, CO₂, Lime Slurry Concentration and Lime Utilization on July 15, 1992

Time	Fresh Slaked Calcitic Lime				SO ₂			CO ₂			Flue Gas Flow			Flue Gas Temp			Comments	
	gpm	% Conc.	Consumed lb-mol/ minute	% Utilization	In ppm	Out ppm	Absorbed lb-mol/ minute	Reduction %	In %	Out %	Dilution %	In KSCFM	Out KSCFM	Dilution %	In °F	C Section °F		Approach to Adiabatic Saturation °F
12:05	39.0	15.0	0.624	27.2	859.7	50.6	0.170	39.8	11.6	10.1	14.9	188.5	222.0	17.8		162.5	42.5	
12:10	46.0	15.0	0.736	25.0	858.1	427.0	0.184	42.8	11.6	10.1	14.9	190.0	226.7	18.9		160.2	40.2	
* 12:15	46.0	15.0	0.736	31.1	861.1	352.7	0.229	52.9	11.6	10.1	14.9	190.8	227.6	19.3		158.8	38.8	
* 12:20	46.5	15.0	0.744	31.7	861.0	337.4	0.236	54.5	11.6	10.0	16.0	190.6	228.0	19.6		157.0	37.0	
* 12:25	43.8	15.0	0.700	32.3	867.9	354.8	0.226	52.3	11.6	10.0	16.0	190.2	227.6	19.7		160.3	40.3	
* 12:30	41.2	15.0	0.659	32.6	861.3	368.7	0.215	49.8	11.6	9.9	17.2	189.9	227.1	19.6		159.3	39.3	
* 12:35	41.9	15.0	0.670	30.6	853.1	378.2	0.205	48.0	11.6	9.9	17.2	189.5	226.2	19.4		158.6	38.6	
* 12:40	40.3	15.0	0.645	31.6	851.7	382.1	0.204	48.0	11.6	10.0	16.0	189.3	225.9	19.3		160.0	40.0	
* 12:45	38.6	15.0	0.618	34.5	860.9	373.6	0.213	49.7	11.6	10.0	16.0	189.1	226.2	19.6		164.9	44.9	
12:50	36.3	15.0	0.581	34.5	866.1	397.6	0.201	46.7	11.6	10.0	16.0	188.1	223.2	18.7		169.2	49.2	
12:55	35.3	15.0	0.565	35.9	876.9	400.5	0.203	46.6	11.7	10.0	17.0	188.5	224.1	18.9		172.5	52.5	
13:00	35.0	15.0	0.560	34.8	879.0	417.1	0.195	44.5	11.7	10.0	17.0	188.6	223.9	18.7		176.7	56.7	
13:05	34.5	15.0	0.552	32.8	877.1	443.1	0.181	41.5	11.7	10.1	15.8	188.6	224.2	18.9		179.2	59.2	
13:10	34.0	15.0	0.544	32.2	875.6	452.3	0.175	40.2	11.7	10.1	15.8	188.2	224.4	19.2		180.9	60.9	
13:15	34.0	15.0	0.544	31.3	872.6	458.4	0.170	39.2	11.7	10.1	15.8	188.0	224.0	19.1		181.6	61.6	
13:20	35.0	15.0	0.560	30.0	875.4	462.7	0.168	38.8	11.7	10.1	15.8	188.0	223.7	19.0		173.9	53.9	
13:25	37.2	15.0	0.595	28.6	873.9	456.5	0.170	38.8	11.6	9.9	17.2	189.5	225.5	19.0		174.9	54.9	
13:30	39.1	15.0	0.626	27.3	874.1	455.0	0.171	39.0	11.6	9.9	17.2	189.9	226.2	19.1		180.5	60.5	
90 Minutes Average	39.0	15.0		31.3	866.7	409.3		45.2									47.9°F	
35 Minutes Peak Average	42.6	15.0		32.0	858.9	364.0		50.7									39.8°F	

* Indicates the values included in the peak average.

Table 3-3c Variation in SO₂, CO₂, Lime Slurry Concentration and Lime Utilization on July 15, 1992

Time	Fresh Slaked Calcitic Lime				SO ₂				CO ₂			Flue Gas Flow				Flue Gas Temp		Comments
	gpm	% Conc.	Consumed lb-mol/ minute	% Utilization	In ppm	Out ppm	Absorbed lb-mol/ minute	Reduced %	In %	Out %	Dilution %	In KSCFM	Out KSCFM	Dilution %	In °F	C Section °F	Approach to Adiabatic Saturation °F	
13:35	39.1	12.0	0.495	36.4	872.9	443.9	0.180	40.9	11.5	9.9	16.2	190.9	227.7	19.3		173.2	53.2	
13:40	40.7	12.0	0.515	32.2	872.2	466.1	0.166	37.9	11.5	9.9	16.2	190.8	227.6	19.3		170.0	50.0	
13:45	42.5	12.0	0.538	28.0	864.4	488.6	0.151	34.9	11.4	9.9	15.2	190.3	227.2	19.4		167.8	47.8	
13:50	42.7	12.0	0.541	30.5	860.2	457.1	0.165	38.3	11.5	9.9	16.2	190.2	227.1	19.4		164.0	46.0	
* 13:55	42.8	12.0	0.542	31.7	857.2	441.0	0.172	40.2	11.5	9.9	16.2	189.3	227.3	20.0		163.3	43.0	
* 14:00	42.8	12.0	0.542	32.6	854.8	430.8	0.177	41.4	11.5	9.9	16.2	189.7	226.9	19.6		163.3	43.3	
* 14:05	42.8	12.0	0.542	32.5	859.8	437.9	0.176	40.8	11.5	9.9	16.2	190.2	226.9	19.3		157.7	37.7	
* 14:10	42.9	12.0	0.543	32.5	860.3	438.1	0.176	40.8	11.5	9.9	16.2	190.2	226.9	19.3		157.7	37.7	
* 14:15	42.9	12.0	0.543	32.6	862.5	438.2	0.177	41.0	11.5	9.9	16.2	189.5	225.7	19.1		157.7	37.7	
* 14:20	42.9	12.0	0.543	32.6	862.6	438.9	0.177	40.9	11.5	9.9	16.2	189.8	226.0	19.0		157.7	37.7	
14:25	42.9	12.0	0.543	29.5	862.2	465.6	0.160	37.3	11.5	9.9	16.2	189.1	225.8	19.4		157.7	37.7	
14:30	37.9	12.0	0.480	33.8	864.1	464.7	0.162	37.5	11.5	9.9	16.2	189.1	225.8	19.4		157.7	37.7	
14:35	36.6	12.0	0.467	35.5	869.1	466.9	0.166	38.2	11.5	10.0	15.0	189.1	225.2	19.1		158.0	38.0	
14:40	36.9	12.0	0.467	34.9	865.9	468.2	0.163	37.8	11.5	10.0	15.0	189.0	225.3	19.2		157.3	37.3	
14:45	39.4	12.0	0.499	33.3	872.6	470.0	0.166	38.1	11.5	10.0	15.0	188.9	225.3	19.3		153.4	33.4	
75 Minutes Average	41.0	12.0		32.6		454.4		39.0									41.2°F	
30 Minutes Peak Average	42.9	12.0		32.4		437.5		40.9									39.5°F	

* Indicates the values included in the peak average.

July 15, 1992 Test Run from 10:40 am TO 12:00 noon with 10.5% Concentration of Fresh Slaked Calcitic Lime

Figure 3-11 Variation in SO₂ Reduction with Lime Slurry Flow Rate, Lime Utilization, and Temperature Approach to Saturation

July 15, 1992 Test Run from 12:05 pm to 1:30 pm with 15% Concentration of Fresh Slaked Lime

Figure 3-12 Variation in SO₂ Reduction with Lime Slurry Flow Rate, Lime Utilization, and Temperature Approach to Saturation

July 15, 1992 Test Run from 1:35 pm to 2:45 pm with 12.0% Concentration of Fresh Slaked Lime

Figure 3-13 Variation in SO₂ Reduction with Lime Slurry Flow Rate, Lime Utilization, and Temperature Approach to Saturation

July 15, 1992 Test Run from 10:40 am to 2:45 pm with Fresh Slaked Lime

Figure 3-14 Variation in SO₂ Reduction with Lime Slurry Flow Rate, Lime Concentration, and Temperature Approach to Saturation

Figure 3-15 SO₂/NO_x Removal Trend Recorded between 11:56 a.m. and 1:41 p.m. on July 17, 1992

3.5.4 August 1-16, 1992

The following tests were made and data compiled between August 1-16, 1992:

- Four lime slurry injection tests were completed between August 5 and August 16, 1992.
- The lime slurry feed rate varied from 43 gpm to 51.5 gpm, and fresh-slaked calcitic lime slurry concentrations varied from 9.5% to 16.5%.
- The calculated percentage of SO₂ removal varied from an average of 32.4% to 45.5%, with a maximum of 52.1%.
- By increasing the lime slurry concentration from 9.5% to 15.7% – an increase in lime consumption of 65% – the maximum SO₂ removal increased from 44.9% to 52.1%, about a 16% increase in SO₂ removal. The substantial increase in the lime slurry concentration without a corresponding increase in the percentage of SO₂ removal, means that the lime utilization percentage is falling, causing a higher cost per ton of SO₂ removal.
- During the first part of August, the lime slurry sump, the sump pumps, the density control system, the level controls, etc., were under construction. For this reason, the tank dipping method was used to determine the amount of lime slurry injection into the duct.
- The lime slurry supplier delivered to Conemaugh Station a lower quality of lime. It contained about 7.5% CaCO₃ or uncalcined lime. These fine particles of uncalcined lime passed through the 60-mesh vibrating screen and moved with the lime slurry to the atomizers, plugging many of them. At one time, eight atomizers out of a total of 18 were plugged. Consequently, the flow rate of operating atomized slurry per atomizer had to be increased from 3 gpm to 5.4 gpm/atomizer. At that high flow rate, the atomized particles are much larger and require a longer residence time to evaporate. That time is not available. Therefore, to avoid the deposition of wet slurry on the turning vanes, the lime slurry injection rate must be reduced, but this results in lower SO₂ reduction. A solution to this problem could be to procure a higher lime quality or to replace the existing 60-mesh screen with a new 160-mesh screen.
- During the lime slurry injection, the stack opacity percentage decreased and remained low.

The testing with fresh-slaked calcitic lime that started on July 10, 1992 ended about one month later.

Table C-4 in Appendix C shows the operating conditions during the period August 1 to 16, 1992 with parametric testing and the calculated percentage of SO₂ removal and temperature approach to saturation.

3.6 OVERVIEW AT THE END OF CZD PARAMETRIC TESTING (WBS 1.3.2)

CZD parametric testing started on the last day of the month of September 1991 and ended on August 16, 1992, after about 10 1/2 months. Activities during this short period of time included:

- Testing different reagents (hydrated calcitic lime, pressure-hydrated dolomitic lime, and fresh-slaked calcitic lime)
- Testing different types of lime slurry atomizers (with a low and large consumption of compressed air)
- Testing different atomizer lance arrangements for the best mix of atomized lime slurry with the flue gas in the duct
- Testing different lime slurry concentrations and different lime slurry injection rates to achieve up to 50% SO₂ removal
- Testing different conditions that allowed maintenance of a low opacity percentage at the end of the lime slurry injection
- Experiments in how to transform a manually operated batch operation into a continuous, automated operation integrated with Seward Station's Boiler #15
- Use of CZD parametric testing for debugging and improving the automation system
- High-quality engineering, construction, and installation work that transformed, in an extremely short period of time, a batch operation into a continuous automated system, operated from the boiler control room

The 6-month CZD continuous demonstration will start on August 17, 1992. It was decided to use the pressure-hydrated dolomitic lime as a reagent for the CZD continuous demonstration because it is expected to help obtain a higher NO_x removal than the calcitic lime. A 2-week test with a higher sulfur coal is planned during the CZD continuous demonstration.

Section 4

PLANNED ACTIVITIES

During the next quarter (August 17 - November 17, 1992), the following work is planned:

4.1 PHASE 3b - OPERATION AND DISPOSITION

With the completion of parametric testing, the six-month continuous demonstration run will start on August 17, 1992. Total automation of the CZD has been completed, and the system has been integrated with the boiler operation of Unit 15.

To prepare the CZD system for winter operations, the final heat tracing and insulation requirements for piping and equipment will be developed so that the installation can be completed in October 1992.

4.2 PHASE 3 - PROJECT MANAGEMENT

Bechtel will provide overall management of the work required to complete Phase 3, including:

- Coordination with Penelec and the project financial assistance groups
- The planning and conducting of meetings with the DOE and the project team for review of the work
- Submittal of reports in accordance with the federal assistance reporting checklist

Appendix A

Description of Project and Work Breakdown Structure

Appendix A

DESCRIPTION OF PROJECT AND WORK BREAKDOWN STRUCTURE

A.1 PROJECT DESCRIPTION

To accomplish the objectives of this project, the test program contains two distinct periods:

- The first period, of six months duration, includes daily factorial runs to test different reagents, atomizers, additives, and slurry concentrations.
- The second period, of one year duration, will demonstrate the performance of the CZD system on a continuous basis under actual power plant operating conditions.

A detailed description of the Work Breakdown Structure for this project, is shown in Figure A-1 on page A-8. The work is scheduled to be accomplished in three phases as follows:

- Phase 1 work was completed on January 31, 1991. During this phase, Bechtel developed a process design, P&IDs, and performed detailed engineering for a new extended duct to be used in the CZD demonstration in Unit 15 at Penelec's Seward Station. Bechtel wrote all the specifications for equipment and instruments, and started procurement activities. Interface with the appropriate environmental agencies was accomplished through Penelec, with Bechtel providing assistance as needed.
- Phase 2 work was substantially completed by July 31, 1991. This phase included equipment acquisition and installation, facility construction, and start-up operations. Bechtel completed procurement of the equipment, instruments, materials, and fabrication of the new long duct. Penelec performed construction and installation of these items in accordance with specifications prepared by Bechtel. At completion of construction, using Penelec operating and maintenance personnel, Bechtel trained the operators, started all major elements of the CZD system, and verified that the installation and control system functioned according to requirements. During this phase, the installation of equipment and instrumentation was limited to that necessary for parametric testing to be accomplished in Phase 3.

- Phase 3 work will be conducted in two parts. Parametric testing, Phase 3a, was scheduled for the period from June 3, 1991 through November 29, 1991, but the start was delayed until early August. During this period, Bechtel planned to carry out a parametric test program to optimize the performance of the CZD process. The test program is designed to develop operating conditions that will achieve high reliability and low cost operation. Phase 3b was scheduled from December 2, 1991 to July 1, 1993, to complete this demonstration project. The initial program included a period of time from December 2, 1991 to July 1992 when no CZD testing was scheduled. With DOE's concurrence, this "no CZD testing" was modified by extending the CZD parametric testing until July 1992 for debugging and the training the Penelec operating and maintenance personnel, but the start of continuous operation was delayed until August 17, 1992, the start of the CZD demonstration.

Based on the results of the parametric tests, Bechtel was completing additional design, procurement, installation and facility construction as necessary to permit a 1-year continuous demonstration. At this time the CZD system is fully instrumented and integrated with the operation of Penelec's Unit #15. The goal is to demonstrate the performance of the CZD process for SO₂ removal without significantly affecting either the boiler operation or plant particulate emissions.

Bechtel will supervise the 1-year continuous demonstration, and will carry out various performance tests, data acquisition, and chemical analyses. After the demonstration is completed, the system may remain in operation or the test apparatus may be dismantled and the site restored to its former condition, depending on Penelec's wishes. In either case, the new long straight duct will remain in operation.

To promote the dissemination of technical information to industry during the CZD demonstration, technical papers will be presented at various conferences. These papers will provide non-proprietary technical and economic data, results, and conclusions. The technical papers will also be made available for publication in appropriate journals. Representatives of the utilities will be invited to visit the demonstration site to learn first hand how the CZD process handles SO₂ and NO_x removal from utility flue gas operations.

A.2 WORK BREAKDOWN STRUCTURE DESCRIPTION

The following tasks will be performed during the three phases of the project to demonstrate the cost effective control of SO₂ and NO_x emissions from the pre-NSPS coal-fired utility boiler No. 15 at Penelec's Seward Station:

Phase 1: Design and Permitting

WBS No. 1.1.2 *Design and Procurement*

- Prepare process flow diagrams for each of the two periods, including material balances and stream properties. Prepare technical specifications for process equipment.
- Prepare detailed designs for the fabrication of the duct extension and its associated construction and installation.
- Prepare site-specific detailed designs for installation of the compressed air system, lime feed system, and atomizers with their related headers and distribution piping, including instruments and controls.
- Prepare technical specifications for procurement of required support equipment, and its associated construction and installation.
- Issue bids for equipment with long delivery times.

WBS No.1.1.3 *Management and Travel*

- Project Management. Provide overall management of the work required to complete this phase, including coordination with Penelec and the groups providing project financial assistance. Bechtel's project management plan includes provisions for meetings with the DOE and formal reviews of project work, as well as provisions for submitting reports in accordance with the Federal Assistance Reporting Checklist, Attachment C.
- Travel. Bechtel travel includes project management travel to the Penelec site and to DOE's offices for meetings, and travel by the project engineer and other members of the project team as required to complete the task activities. All travel and subsistence to be in accordance with Government regulations.

Phase 2: Construction and Start-up

WBS No. 1.2.1 *Equipment Acquisition and Installation*

- Procure air compressors and electric power supply.
- Procure atomizers.
- Procure instruments and controls.
- Procure lime feed system.
- Procure lime transfer system.
- Provide assistance to Penelec for installation of all process and support equipment, including drawings, specifications, design packages for bidding, and other related design information.

WBS No. 1.2.2 Facility Construction

- Approve shop drawings for fabrication of duct extension.
- Provide site engineering support and related assistance to Penelec as required for quality and schedule control.

WBS No. 1.2.3 Start-up (Checkout) and Operator Training for Parametric Testing

- Provide start-up engineer to supervise commissioning of all CZD components and systems.
- Train Penelec's operators to run the CZD system and perform the tasks required to conduct parametric testing.
- Establish procedures for coordination of test operations with Penelec's plant management and operations personnel.
- Finalize all elements of Test Plan.

WBS No. 1.2.4 Construction Management

- Provide construction management support to Penelec as requested. Penelec will have prime control and responsibility for all construction activities at Seward Station.

WBS No. 1.2.5 Management and Travel

- Project Management. Provide overall management of the work required to complete this phase, including coordination with Penelec and the groups providing project financial assistance. Plan and conduct meetings with the DOE and the project team for review of project work. Submit reports in accordance with the Federal Assistance Reporting Checklist, Attachment C.
- Travel. Bechtel travel includes project management travel to the Penelec site and to DOE's offices for meetings, and travel by the project engineer and other members of the project team as required to complete the task activities. All travel and subsistence to be in accordance with Government regulations.

Phase 3: Operation and Disposition

WBS No. 1.3.1 Lime Procurement

- Procure all types of lime and other reagents required to conduct parametric and continuous (one-year) test programs.

WBS No. 1.3.2 CZD Parametric Testing

- Perform wind tunnel tests on atomizers at the University of California at Davis to determine performance characteristics. Select atomizers to be used in the parametric test program.

- Evaluate performance of electrostatic precipitators (ESPs) during parametric tests. Consult with ESP experts, if necessary, to improve performance.
- Evaluate effects of process variables on emission control performance.
- Determine operating conditions for optimum overall performance.
- Evaluate effects of using alternative coals and reagents:
 - High and medium sulfur coals
 - Alternate reagents including pressure-hydrated dolomitic lime, hydrated calcitic lime, and fresh slaked calcitic lime.

WBS No. 1.3.3 Completion of Design, Procurement and Installation

- Based on the results of the parametric tests, complete the design packages and procure all process equipment needed to completely automate and integrate the operation of the CZD system with boiler No. 15 at Seward Station.
- Procure all instruments and controls needed for continuous operation, monitoring, and data collection.

WBS No. 1.3.4 Completion of Facility Construction

- Install facilities for lime unloading and storage to support the increased capacity required for continuous operation of the CZD system.
- Insulate piping and provide weather protection and enclosures as required to permit continuous, all-year operation of the CZD system.
- Provide construction management support to Penelec as requested. Penelec will have prime control and responsibility for all construction activities at Seward Station.

WBS No. 1.3.5 Start-up (Checkout) and Operator Training for Continuous Operation

- Provide start-up engineer to supervise commissioning of all new CZD components and systems.
- Train Penelec's operators to run the CZD system and perform the tasks required to conduct the one-year continuous demonstration.
- Establish procedures for coordination of data collection and reduction with Penelec's plant management and operations personnel.

WBS No. 1.3.6 CZD Demonstration with Continuous Operation

- Operate the CZD system under optimized conditions for one year completely integrated with the power plant operation.
- Measure emission control system performance:

- SO₂ and NO_x performance tests
- ESP performance tests
- ESP performance improvements, if required
- Chemical analysis of solid wastes
- Continuous data recording and acquisition
- Determine power plant impacts.

WBS No. 1.3.7 Duct and Hopper Cleaning

- Perform periodic inspection and cleaning, if necessary, during intervals when the boiler is not operating to determine the long-term extent of duct fouling resulting from CZD system operation.

WBS No. 1.3.8 Data Evaluation and Reporting

- Correlate and evaluate all data collected during the entire CZD test program, including parametric tests as well as continuous operation.
- Summarize key data and test results:
 - Inlet and outlet concentration of SO₂, NO_x, and oxygen
 - Amount of lime used and lime utilization
 - Variation in flue gas temperature during lime slurry injection
 - Variation in ESP recorded data
 - Variation in percent opacity at the stack
 - Lime deposition on duct surfaces
- Use technological, economic, environmental, and operating evaluations from the demonstration project to prepare Demonstration Test Reports and a Technology Performance and Economic Evaluation Report.

WBS No. 1.3.9 Disposition

- Disposition of the CZD system equipment installation:
 - The new long straight duct will remain in operation.
 - The disposition of all other equipment (continued operation or removal and storage) will be decided by Penelec.

WBS No. 1.3.10 Management and Travel

- Project Management. Provide overall management of the work required to complete this phase, including coordination with Penelec and the groups providing project financial assistance. Plan and conduct meetings with the DOE and the project team for review of project work. Submit

reports in accordance with the Federal Assistance Reporting Checklist, Attachment C.

- Travel. Bechtel travel includes project management travel to the Penelec site and to DOE's offices for meetings, and travel by the project engineer and other members of the project team as required to complete the task activities. All travel and subsistence to be in accordance with Government regulations.

Figure A-1 Work Breakdown Structure (WBS) Diagram

Appendix B

Report Distribution List

Appendix B
REPORT DISTRIBUTION LIST

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Appendix C

Summary of Phase 3a Activities

Appendix C

Summary of Phase 3a Activities

May 1992

- May 1** Parametric tests were made with 30 gpm of water and lime. The water injection was started at 9:20 a.m. with 20 gpm and then increased to 30 gpm.
- The lime slurry injection started at 10:00 a.m. with 30 gpm and then increased to 35 gpm. The lime injection was stopped at 12:35 p.m. and the water injection was stopped at 1:20 p.m.
- Stack opacity before the lime slurry injection was 10%; during the injection it was 10%; and after the injection it was 15%.
- May 4** The outlet duct traverses were taken with a Pitot tube. Because of the varied sizes of the cross sections at the sample ports, it was difficult to determine the exact flue gas flow rate to calibrate the mass Kurz flow meter for the outlet flue gas.
- May 5** The water injection varied from 18 gpm to 45 gpm; and the average and lowest temperatures were recorded at the B-, C-, D-, and E-cross sections. The attached graphs show the temperatures as a function of the water flow rates at different distances from the atomizers.
- May 6** Parametric tests were made with water and lime slurry injections to calibrate the lime slurry flow meter controller. The flow meter controller showed much lower flow rates of lime slurry injection than were anticipated. The measured SO₂ removal was 24%. During the lime slurry injection, the stack opacity remained constant at 7%.
- May 7** The parametric lime slurry injection was made from 1:30 p.m. to 3:00 p.m. with the injection flow rate varying from 37.6 to 42.3 gpm. The lime slurry concentration was 12%; the inlet flue gas temperature was 310°F. Since the average temperature at the B-cross section was 188°F (about 65°F above adiabatic saturation), the percent of SO₂ removal was limited to 24%. A higher lime slurry injection rate would substantially reduce the B-cross section average temperature and increase the percent of SO₂ removal. Stack opacity during the lime slurry injection was close to 8%. After the lime slurry injection was shut off, the stack opacity percentage increased, and it was necessary to continue the water injection for about 3 hours to limit opacity to 8%.

- May 11** The parametric lime slurry injection was made from 10:15 to 2:55 p.m. with the injection flow rate varying from 32 gpm to 47 gpm. SO₂ removal was 30%; the boiler load was 149 MW. The stack opacity before the injection was 7.63%; during the injection it was 6.09%.
- The flue gas inlet temperature was high at 314°F and therefore required a larger lime slurry flow rate. However, the new lime slurry flow meter gave a wrong reading of 55.5 gpm versus 42.3 gpm, a calculation based on tank dipping.
- There was also a problem with temperature distribution at the C-cross section where the variation between the average and lowest temperature was 15-20°F. An unsuccessful attempt was made to obtain a more uniform temperature at the C-cross section in the vicinity of the turning vanes by reducing the lime slurry flow rate at some of the atomizers. A new approach should be found to solve this problem. The lime slurry flow controller will be replaced with a more reliable one.
- May 12** The parametric lime slurry injection in the duct was made from 8:30 a.m. to 12:40 p.m. The flue gas inlet temperature of 310°F was not uniformly distributed. The lower temperature was in the lower side of the duct and also at the left side of the duct; the higher temperature was at the right side. To obtain a more uniform temperature, some adjustments were made in the flow rates of the lime slurry atomizers. The environmental monitors for SO₂, NO_x, and CO₂ were out of calibration; therefore, no measurements of SO₂ removal could be made. Stack opacity with the water injection at 11:09 a.m. was 5.81%; with the 40 gpm lime slurry injection at 2:39 p.m., it was 6.51%.
- May 14** The four additional soot blowers were not ready; therefore, the lime slurry injection was postponed, and only the water injection was made. The stack opacity at 9:55 a.m. before the water injection was 11.75%. At 1:46 p.m. with a 37 gpm water injection, it was lowered to 7.73%.

May 15 Water testing was carried out with a 45 gpm water injection after removing the back spacer. The temperature profile inside the duct showed the hot zone along the duct walls and the water-saturated flue gas inside the hot zone. The attached graphs show the temperature profile at the C-cross section and along the duct on the east and west walls all the way from the injection point to the turning vanes. These data demonstrate and verify the confined zone dispersion (CZD).

May 18 Water testing up to 49 gpm was carried out. The system worked well. The water flow meter was calibrated; the stack opacity was low and decreased as the water injection rate was increased.

The boiler was shut down for maintenance from May 19 through the end of May 1992.

Table C-1 summarizes CZD activities for May 1992.

Table C-1
CZD Activity Summary, May 1992

Day	Start	Stop	Lime Slurry Injection			SO ₂ Concentration			Flue Gas Temperature °F				Stack Opacity %	
			gpm	Gallons	% Lime Conc.	Inlet ppm by Volume	Outlet ppm by Volume	Percent Removal	Inlet °F	Outlet °F	At C-section ahead of Turning Vanes	Approach to Saturation	Before Injection	During Injection
5/1	09:20	10:00	30	1,200	Water				309	254	237	117	8	7
5/1	10:00	12:35	30-35	5,000	PHDL* 8.5%	947	792	8	309	244	225	105	7	10
5/1	12:35	13:20	30	1,350	Water				309	254	237	117	10	14
5/6	10:50	11:10	20	600	Water				307	272	259	139	8	7
5/6	11:10	14:41	30-45	7,300	PHDL 8.5%	966	637	26	307	222	199	79	7	7
5/7	13:30	15:00	38-42	3,600	PHDL 12%	947	642	24	300	221	199	79	12	7.7
5/11	10:15	14:55	32-47	11,200	PHDL 7%	868	542	30	314	225	201	81	7.6	6.1
5/12	08:30	11:02	20-40	4,500	Water				306	231	210	90		5.8
5/12	11:10	12:40	30-35	2,880	PHDL 7%	SO ₂ analyzer out of calibration.			306	241	222	102		6.5
5/14	11:15	14:20	35-42	7,000	Water	Soot blowers not ready yet for Lime Slurry injection.			300	221	199	79	11.7	7.7
5/15	11:26	14:51	10-45	7,800	Water				300	215	192	72	9.5	7.2
5/18	09:42	14:42	30-49	8,400	Water				300	207	182	62	9.9	8.2

* Pressure Hydrated Dolomitic Lime (PHDL)

June 1992

Lime injection test operations were shut down during the month of June 1992 to allow installation of the new lime transfer and feed pumps. In-duct operations during this period were limited to water testing and Pitot tube traverses to determine duct temperatures and flow.

- June 3** Pitot tube traverses were made at test ports (TPs): TP-1 through TP-10. TP-1, TP-3, TP-5, TP-7, and TP-9 are on the right side of the flue gas duct, and the even numbers are on the left side. TP-1, TP-5, and TP-9 are located 2 feet from the duct wall; TP-3 and TP-7 are only 6 in. from the duct wall. The same arrangement occurs with the even numbered TPs.
- The data show that flue gas temperatures on the right side of the flue gas duct are about 25°F higher than those on the left side and that the temperature on the left side, 6 in. from the duct wall, is substantially lower than that 2 ft from the wall. At about 70 ft from the injection point, the temperature difference between the right and left sides of the duct is still substantial. This variation in the flue gas temperature inside the flue gas duct requires a special distribution of the atomized lime slurry into the duct.
- June 4** The same Pitot tube traverses were made at TPs 1-10, but when the I.D. fans were raised from duct A to duct B, the data showed a larger difference in temperature between the right side and the left side. (About 5% more flue gas moved through duct B.)
- June 8** Environmental data were recorded without any in-duct injection. The instruments for SO₂ and NO_x concentration have to be recalibrated.
- June 10** Traverses were performed at the B-cross section. The instruments for SO₂ and NO_x concentration are in the process of recalibration.
- June 11** Traverses were performed at the outlet duct downstream of the I.D. fan.
- June 22** A water injection was made and tested at 30, 35, 40, 42, 45, and 47 gpm. The inlet gas temperature was 310°F. At this high temperature, the water injection rate of 47 gpm was too low, and the temperature at the B-cross section was too high above the adiabatic saturation temperature. The stack opacity during the water injection was less than 9%.

June 23

The water injection was tested at 30 and 35 gpm. Problems occurred when switching the Bailey flow controller from manual to auto, and vice versa. A correction should be made.

The stack opacity during the water injection was less than 6%.

Table C-2 summarizes CZD activities for June 1992.

Table C-2
CZD Activity Summary, June 1992

Day	Start	Stop	Lime Slurry Injection				SO2 Concentration			Stack Opacity %		
			Minutes	gpm	Gallons	Lime %	Inlet ppm by Volume	Outlet ppm by Volume	Percent removed	Before Injection	During Injection	After Injection
6/22	12:07	14:30	143	30-47	5,000	Water	865	742	-		8.23	
6/23	09:09	10:00	51	30-35	1,630	Water	808	691	-	6.9	5.44	

Lime injection test operations were shut down to allow installation of the new lime transfer and feed pumps. In-duct operations were limited to water testing and traverses for flue gas duct temperature and flow.

July 1992

Lime injection testing was resumed the week of July 6, using the new, heavy-duty, lime feed pumps. Since the lime preparation pit was being renovated, freshly slaked calcitic lime was trucked daily from Conemaugh Station to fill the lime slurry feed tanks, after passing through the vibrating screen.

July 2 In-duct water injection testing of 30-50 gpm was carried out between 9:30 a.m. and 11:30 a.m. The stack opacity varied from 14% at the start to 10% at the end of testing. The automatic water flow meter FT-22 indicated about 12 gpm less than that measured by the difference between the flue gas temperature at the inlet of the duct and that at the I.D. fan outlet. The FT-22 flow meter should be recalibrated.

The atomized water distribution was O.K. The average temperature at the C-cross section was 165°F at the 50 gpm water injection rate.

July 6 The Pitot tube traverses at the B-cross section were made to calibrate the flue gas Kurz flow meter. The inlet flue gas temperature (TE-R14B) was 284.23°F and the outlet flue gas temperature (TT-11B) was 280.7°F. The average temperature at B-cross section was 281.76°F; the second time it was 281.64°F. The temperature at the Kurz inlet flow meter (TT-11A) indicated 293°F, about 10°F more than the TE-R14B temperature of 283°F.

July 7 In-duct water injection testing was conducted from 30-40 gpm. However, the L&N chart recorders stopped updating so the water in-duct injection was stopped. Further testing was postponed until the Bailey people are able to put the L&N chart recorders back in operation.

July 8

In-duct water injection testing was conducted from 30-50 gpm. The inlet flue gas temperature (TE-R14B) was 313°F and the outlet flue gas (TT-11B) was 199°F at 1:12 p.m. with the injection rate of 50 gpm. The flue gas ΔT was at 114°F, about a 2.3°F temperature reduction for each 1 gpm.

The water injection was O.K. The temperature profile at the B-cross section indicated a saturation temperature (118-120°F) in the center of the duct and higher temperatures closer to the duct walls, with an average temperature of 149°F. The average temperature at the right side of the flue gas duct at the B-cross section (about one-half the distance between the injection point and the turning vanes) was 180°F; at the left side, 160°F; and in the center, 128°F. The temperature in the center was perfect, but the temperature on both sides should be lowered to an average of 140-145°F – that is, the temperature on the right side of the duct should be lowered 35-40°F and the temperature on the left side should be lowered 15-20°F.

The average temperature at the C-cross section was perfect at 163°F. The stack opacity was very good at about 6%.

July 10

Fresh-slaked calcitic lime for the in-duct lime slurry injection was trucked daily from Conemaugh Station a few miles from Seward Station. Today's injection was made at a rate of 23.5 gpm (FT-22). The measured SO₂ removal was 20.5% at 2:07 p.m. The inlet flue gas temperature was 301°F; the outlet temperature was 223°F.

At 2:48 p.m., the lime slurry flow rate was increased to 28.6 gpm (FT-22). The SO₂ removal increased to 33.3%. At that time, the inlet temperature was 307°F and the outlet flue gas temp (TT-11B) 215.7°F. Maybe the real lime slurry flow rate was 40 gpm and not 28.6 gpm.

At 3:33 p.m., the lime slurry flow rate was increased to 37.4 gpm (FT-22). The SO₂ removal increased to 42.7%. At that time, the inlet flue gas temperature was 313°F and the outlet temperature was 208°F. That means that the real lime slurry flow rate was about 45 gpm and not 37.4 gpm.

During the lime slurry injection, the stack opacity remained about constant at 12.4%. Measuring the flue gas temperature along the duct from the injection point to the turning vanes located 6 inches from the side walls, through the test ports (TPs), all the readings showed high temperatures except TP-62 and TP-102 on the left side of the flue gas duct – 35 ft. and 56 ft., respectively, from the injection point. The thermocouples at TP-62 and TP-102 indicated the lowest temperatures in the duct because the flue gas temperatures in the duct are not uniform.

July 13

The in-duct lime slurry injection was made with fresh-slaked calcitic lime trucked from Conemaugh Station. The lime was diluted to 10% in the feed tank after it was degrittied by the vibrating screen. Because of the large amount of sand in the lime slurry that passed through the 60-mesh vibrating screen, many of the 18 atomizers were plugged. With only 10 atomizers operating, the lime slurry flow had to be limited to 37 gpm to avoid deposition of wet solids on the turning vanes. In this condition, the SO₂ removal was 38%. To avoid plugging the atomizers, it was necessary to cause an overflow of a slip stream of lime slurry at the end of the distribution header to the vibrating screen. During the lime slurry injection, the stack opacity was at a low level of about 8%.

July 15

The in-duct lime slurry injection was made with fresh-slaked calcitic lime trucked from Conemaugh Station. The lime slurry was diluted to 10.5%, 15%, and 12%. Because the L&N chart recorders did not update the values, the data were taken by hand from the Bailey computer and attached to the daily test data. From 10:35 a.m. to 12:00 noon, the lime slurry concentration was 10.5%. The lime slurry flow rate, measured by FT-22, varied from 32.5 gpm to 42 gpm. The average SO₂ removal during this period was 35.3% with a peak of 46.3% from 11:40 to 11:45 a.m. when the lime slurry injection rate was about 42 gpm.

From noon to 1:30 p.m., when the lime slurry concentration was 15%, the lime slurry flow rate, measured by FT-22, varied from 35 gpm to 42 gpm., with an average SO₂ removal of 39% and a peak of 54.5% at 12:20 p.m., with an inlet SO₂ concentration of 861 ppm and an outlet concentration of 337.4 ppm at a 42 gpm lime slurry injection rate.

From 1:35 p.m. to 2:45 p.m. the lime slurry concentration was 12%. The lime slurry flow rate, measured by FT-22, varied from 38 gpm to 43 gpm with an average SO₂ removal of 39%. The peak SO₂ removal was 41.5% from 2:10 p.m. to 2:20 p.m., with an inlet SO₂ concentration of 862.5 ppm and an outlet concentration of 438.2 ppm at a 43 gpm lime slurry injection rate. One reason the temperatures on the C-cross section were low was that it rained very hard and the caps were not sufficiently tight over the thermocouples. Leaking water therefore contributed to the low temperatures.

July 16

The in-duct lime slurry injection was made with fresh-slaked calcitic lime trucked from Conemaugh Station. The lime slurry was diluted in Tank A to an 8.5% lime slurry concentration and in Tank B to an 11.5% to 12% lime concentration. Because the L&N chart recorders did not update the values, the data were taken by hand from the Bailey computer and attached to the daily test data.

From 10:25 a.m. to 11:50 a.m., the lime slurry was fed from Tank A with an 8.5% lime slurry concentration. Because the fresh-slaked calcitic lime contained a large concentration of fine sand that passed through the 60-mesh vibrating screen and risked plugging the lime slurry atomizers, a continuous stream of lime slurry (estimated at 5-7 gpm) was discharged at the end of the lime slurry distribution header through the vibrating screen into the other feed tank. This variable throughput made it very difficult to determine the exact lime slurry flow rate injected into the flue gas duct. In the future, it will be necessary to use a finer screen (perhaps a 160-mesh screen) to remove most of the fine sand from the lime slurry. This will avoid having to recirculate the lime slurry from the end of the distribution header.

The calculated SO₂ removal from 10:25 a.m. to 11:50 a.m. with an 8.5% lime slurry concentration averaged 30% with a peak of 34.5%. The calculated SO₂ removal from Tank B with an 11.5-12% lime concentration injected in the duct from 12:00 noon to 2:00 p.m. averaged 35% with a peak of 38.4%. At a maximum injection rate, the left duct wall was wet on the upper side, and the temperature at the C-cross section was unusually low. That means that the lime slurry injection rate should be reduced to a level that keeps the duct walls and the turning vanes dry. During the lime slurry injection, the stack opacity decreased to 8%.

July 17

The in-duct lime slurry injection was made with fresh-slaked calcitic lime trucked from Conemaugh Station. The lime slurry was diluted to 10.5% in Tank A and to 8.5% in Tank B. The lime slurry sump and the sump pump were not yet in operation.

The lime slurry flow meter had calibration problems. To determine the lime slurry injection rate, a dip stick was used to measure the tank's slurry level every 15 minutes. During the first hour (10:25 a.m. to 11:25 a.m.), the average SO₂ removal was 20%, with a maximum at 11:25 a.m. of 35.2%. During the next 75 minutes (11:30 a.m. – 12:40 p.m.), the average injection rate was 53.7 gpm and the average SO₂ removal was 40.9%. The maximum SO₂ removal was 48.1% at 12:40 p.m. The lime slurry from Tank A had a concentration of 10.5%. From Tank B, with a concentration of 8.5%, the average percentage of SO₂ removal was 32.8%; the maximum was 39.3%.

With the same lime slurry injection rate of 50-53 gpm, the percentage of SO₂ removal was higher with the higher lime slurry concentration of 10.5% versus the 8.5% concentration. During the lime injection, the stack opacity was lowered to about 10%.

July 27

The in-duct lime slurry injection was made with fresh-slaked calcitic lime trucked from the Conemaugh Station. The lime slurry was diluted to 9.7% lime concentration. The lime slurry injection started at 11:40 a.m. and was shut down at 2:40 p.m. The average injection rate was 37.5 gpm. The average SO₂ removal was 25%.

The low flow rate of lime slurry kept the percentage of SO₂ removal to an average of 25%. The inlet flue gas temperature was only 280°F. During the lime slurry injection, the stack opacity was maintained at about 8%.

Table C-3 summarizes CZD activities for July 1992.

Table C-3
CZD Activity Summary, July 1992

Day	Start	Stop	Lime Slurry Injection		SO ₂ Concentration			Flue Gas Temperature °F			Stack Opacity %			
			gpm	Gallons	% Lime Conc.	Inlet ppm by Volume	Outlet ppm by Volume	Percent Removal	Inlet °F	Outlet °F	At C-section ahead of Turning Vanes	Approach to saturation	Before Injection	During Injection
Tests with the New Feed Pumps														
7/2	09:42	11:47	30-50	5,000	Water	839	701							9.8
7/7	12:10	12:55	30-35	2,100	Water	950	813						12	9.1
7/8	08:38	13:42	30-47	11,800	Water	859	735						10	6.0
Testing with Fresh-Slaked Calcitic Lime:														
7/10	12:40	13:45	30-40	2,275	Water									
7/10	13:45	15:30	30-50	4,200	Calcitic Lime 10%	903	448	42.5	300	205	180	60	14	12.4
7/13	13:20	15:50	36-56	6,900	Calcitic Lime 10%	908	441	42.3	300	205	180	60	10	8
7/15	10:35	12:00	35-45	3,400	Calcitic Lime 10.5%	avg 853.4 max 854	avg 472.7 max 419.6	avg 36.5 max 42.3	283	avg 208 max 198	avg 175 max 165.6	avg 55 max 45.6	14	13
7/15	12:00	13:30	39-46	3,600	Calcitic Lime 15%	avg 867 max 859	avg 409.3 max 364	avg 45.2 max 50.7	283	avg 210 max 203	avg 168 max 160	avg 48 max 40	13	13
7/15	13:35	14:45	41-42.9	2,940	Calcitic Lime 12%	864	avg 454.4 max 437.5	avg 39 max 40.9	283	avg 216 max 202	avg 161.2 max 159.5	avg 41.2 max 39.5	13	13
7/16	10:25	11:50	46.6	3,960	Calcitic Lime 8.5%	884.8	avg 521.7 max 486.4	avg 30 max 34.5	290	202	178	58	12	8
7/16	12:00	14:00	50.6	6,072	Calcitic Lime 11.5-12%	avg 887 max 893	avg 478 max 455	avg 35 max 38.4	290	194	168	48	8	8

Table C-3
CZD Activity Summary, July 1992 (Cont'd)

Day	Start	Stop	Lime Slurry Injection			SO ₂ Concentration			Flue Gas Temperature °F				Stack Opacity %	
			gpm	Gallons	% Lime Conc.	Inlet ppm by Volume	Outlet ppm by Volume	Percent Removal	Inlet °F	Outlet °F	At C-section ahead of Turning Vanes	Approach to saturation	Before Injection	During Injection
7/17	10:25	11:25	44	2,640	Calcitic Lime 10.5%	avg 867.4	avg 579	avg 20.9	300	217	194	74	12	10
7/17	11:25	12:40	52.6	3,945	Calcitic Lime 10.5%	avg 866.4	avg 430	avg 40.9	300	200	174	54	10	10
7/17	13:10	15:00	48.7	5,357	Calcitic Lime 8.5%	avg 824.4	avg 473.8	avg 31.8	300	208	183	63	10	10
7/27	11:40	14:40	37.5	6,750	Calcitic Lime 9.7%	avg 878	avg 536	avg 25	280	230	210	90	12	8

August 1-16, 1992

August 5

The in-duct lime slurry injection was made with fresh-slaked calcitic lime trucked from the Conemaugh Station. The fresh-made lime slurry passes through a 60-mesh vibrating screen, and clean lime slurry is discharged into one of the two lime slurry feed tanks – A or B.

In Tank A the lime slurry was diluted to a 10.3% concentration, and in Tank B it was diluted to a 9.5% concentration. Because of the high content of fine sand in the clean lime slurry, a portion of the lime slurry was returned from the end of the distribution header back to the vibrating screen, and then to a lime feed tank.

During the injection from Tank A, the returning lime slurry was discharged to Tank A. By tank dipping and measuring the lime slurry level in Tank A, it was possible to determine the lime slurry flow rate in gpm that was atomized in the duct.

During the period when the slurry from Tank B was injected into the duct, a new truck of lime slurry was discharged through the vibrating screen into Tank A. Therefore, the lime slurry discharged from the end of the distribution header mixed with the lime slurry from the unloading truck and was directed to Tank A. The reading of Tank B's lime slurry did not include the returned lime slurry discharged into Tank A. For this reason, about 4 gpm were subtracted from the lime slurry flow rate injected into the duct during lime feeding from Tank B.

The lime slurry sump, sump pumps, density control, level controls, etc., were all under construction. For this reason, the tank dipping method was used to determine the lime slurry injection rate.

During the period from 12:55 p.m. to 2:51 p.m., the average lime slurry injected in the duct was 43 gpm. The average percentage of SO₂ removal was 32.4%, with a peak SO₂ removal of 40% from 2:45 to 2:50 p.m. The lime slurry concentration was 10.3%. During the period from 3:00 p.m. to 3:42 p.m., the average lime slurry injected in the duct was 49.71 gpm, the

lime slurry concentration was 9.5%, and the average SO₂ removal was 40.1% with a peak of 44.85% from 3:05 to 3:10 p.m. The atomized lime slurry was well distributed in the duct, maintaining a high temperature along the duct walls.

During the lime slurry in-duct injection, the stack opacity was lowered to 11%.

August 6

The in-duct lime slurry injection was made with fresh slaked calcitic lime trucked from the Conemaugh Station. The lime slurry had been diluted to a 10.5% concentration in Tank A and in Tank B. The lime slurry injection started at 11:05 a.m. from Tank B. The average lime slurry injection was 47.11 gpm, with an average of 39.65% SO₂ removal and a peak of 42%.

From 1:00 p.m. to 2:15 p.m., the lime slurry from Tank A was injected at an average rate of 51.8 gpm with an average SO₂ removal of 39.84% and a peak of 41.8%.

At the beginning of the lime injection, the stack opacity was 14.1%; at the end of the lime slurry injection, it decreased to 9.51%.

August 7

The in-duct lime slurry injection was made with fresh-slaked calcitic lime trucked from the Conemaugh Station. The lime slurry had been diluted to 10%. The boiler operated at a lower load, and the flue gas flow rate and temperature were also lower, allowing the lime slurry to be injected at a lower rate. Some lime atomizers were plugged with fine sand contained in the lime slurry. There were also problems with the L&N chart recorders that failed to continuously update the temperature at the C-cross section. From 2:00 p.m. to 2:31 p.m. we operated blindly. It is expected that all these difficulties will be eliminated shortly.

The lime slurry injection rate varied from 32.6 gpm to 52.8 gpm with an average of 42 gpm. The average SO₂ removal was 42%. As described above, the low boiler load and low flue gas temperature in the duct limited the lime slurry injection rate.

August 10

The in-duct lime slurry injection was made with fresh-slaked calcitic lime tracked from the Conemaugh Station. The test was done in two time periods:

- The first period was from 2:20 p.m. to 3:20 p.m., with the lime slurry diluted to a 16.5% lime concentration. The average lime slurry injection rate was 44.65 gpm, based on tank dipping, with a maximum flow rate of 56.1 gpm between 3:05 p.m. and 3:20 p.m. The average SO₂ removal at about 54 gpm was 47.1% with a maximum SO₂ removal of 47.5% at a 54.6 gpm lime slurry injection rate.
- The second period was from 4:45 p.m. to 7:12 p.m. with the lime slurry diluted to a 15.7% lime concentration. The average lime slurry injection rate was 51.5 gpm from 5:30 p.m. to 7:12 p.m., based on tank dipping, with the maximum flow rate of 61.1 gpm. The average SO₂ removal was 45.5% (between 5:10 p.m. and 7:12 p.m.) with a peak of 52.1% SO₂ removal at 5:50 p.m. when the lime slurry flow rate injection was 56.4 gpm.

The test data show that at an injection rate of 51.7 gpm (measured by tank dipping) with a 15.7% lime concentration, the SO₂ removal varies from 48% to 52%. When the lime slurry concentration was decreased from 16.5% to 15.7% at the same injection flow rate, no detrimental effect on the percentage of SO₂ removal could be detected.

The testing with fresh-slaked calcitic lime that started on July 10, 1992 has come to an end. This completes the parametric testing and signals the beginning of the CZD demonstration with a continuous operation, automated and integrated with the power plant operation.

The parametric testing was very useful because it defined the optimum parameters of the Bechtel-developed lime slurry atomizers when operating with hydrated calcitic lime, pressure-hydrated dolomitic lime, and fresh-slaked calcitic lime. Most of the installation for the automated operation has now been debugged and operator training for the continuous operation is nearly completed. Start of the continuous operation phase is planned for August 17, 1992.

Table C-4 summarizes CZD activities for August 1-16, 1992.

Table C-4
CZD Activity Summary, August 1-16, 1992

Day	Start	Stop	Lime Slurry Injection			SO ₂ Concentration			Flue Gas Temperature °F				Stack Opacity %	
			gpm	Gallons	% Lime Conc.	Inlet ppm by Volume	Outlet ppm by Volume	Percent Removal	Inlet °F	Outlet °F	At C-section ahead of Turning Vanes	Approach to saturation	Before Injection	During Injection
8/5	12:55	14:51	43	4,998	Calcitic Lime 10.3%	850	464	avg 32.4 max 40.0	297	216	194	74	14	12
8/5	15:00	15:42	49.7	2,088	Calcitic Lime 9.5%	848	420	avg 40 max 44.9	297	203	178	58	12	12
8/6	11:05	14:45	49.5	10,890	Calcitic Lime 10.3%	870	432	avg 39.7 max 41.8	305	211	186	66	14	11.3
8/7	13:10	15:05	44	5,060	Calcitic Lime 10%	885	404	avg 42	300	217	194	74		
8/10	14:20	15:20	44.7	2,680	Calcitic Lime 16.5%	928	406	avg 47.1	300	216	193	73		
8/10	16:45	19:12	51.5	7,570	Calcitic Lime 15.7%	928	409	avg 45.5 max 52.1	300	202	176	56		

Appendix D

Updated Project Schedule for Phase 3a – June to August, 1992

Table D-1a
Updated Project Schedule for Phase 3a - June 1, 1992

DATE	TESTING	LINE FEED	MMT	LINE PIT	MMT	S.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
1-Jun	MONDAY	Install pumps	165	Sieve pumps	134	Install line transfer line	133	Star valve motor & gear reducer on site	138	Install Bailey Mini-90	169
				Survey foundations	136	Install root blower air line	133				
2-Jun	TUESDAY	Install pumps	165	Reinforce foundations	137	Install line transfer line	133			Install Bailey Mini 90	169
		Install piping	165			Install root blower air line	133				
		Order MCC feeder	166								
3-Jun	WEDNESDAY	Install seal water	165	Reinforce foundations	137	Install line transfer line	133			Install Bailey Mini-90	169
		Install piping	165			Install root blower air line	133				
		Run MCC conduit	166								
4-Jun	THURSDAY	Install seal water	165	Add foundation bolts	137	Install line transfer line	133			Install mini-90 power & ground wiring	169
		Install piping	165			Install root blower air line	133				
		Run MCC conduit	166								
		Install motor starter	166								
5-Jun	FRIDAY	Install seal water	165	Install level probe	159	Install line transfer line	133			Install mini-90 wiring	169
		Install piping	165			Install root blower air line	133			Wire pit level probe	169
		Install motor starter	166			Review platform drawings	163				
		Install MCC feeder	166								
6-Jun	SATURDAY										
7-Jun	SUNDAY										
8-Jun	Monday	Install starter wiring	166			Install line transfer line	133	Install star valve motor & gear box	138	Terminate fiber optics	169
		Install piping	165			Install root blower air line	133				

Table D-1b
Updated Project Schedule for Phase 3a - June 1, 1992

DATE	TESTING	LINE FEED	MMT	LINE PIT	MMT	S.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
9-Jun		Install MCC feeder	166			Fabricate platform	163				
	Tuesday	Install wiring	166			Fabricate platform	163	Install star valve motor & gear reducer	138		
		Terminate MCC feeder	166								
		Install motor breaker	166								
		Checkout piping	166								
10-Jun	Wednesday	Calibrate MCC source breaker	166			Fabricate platform	163	Install feed rate controller	138		
11-Jun	Thursday	Checkout system		Install pump & cover	137	Install platform	163	Install Bailey loop controller	167		
12-Jun	Friday	Checkout system		Install pump & cover	137	Install platform	163	Wire Bailey loop controller	167		
13-Jun	SATURDAY										
14-Jun	SUNDAY										
15-Jun	HOLIDAY										
16-Jun	Factorial test - fresh sliced			Install instrumentation	140	Install platform	163			Connect density gauge controller	
				Fabricate piping	167						
17-Jun	Factorial test - fresh sliced			Install instrumentation	140	Install platform	163	Connect water valves to controller	168		
				Fabricate piping	167						
18-Jun	Factorial test - fresh sliced			Install header	167	Install platform	163	Program & checkout Bailey		Calibrate density gauge	

Table D-1c
Updated Project Schedule for Phase 3a - June 1, 1992

DATE	TESTING	LIME FEED	MMT	LIME PIT	MMT	B.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
19-Jun	Factorial test-fresh slaked			Install header	167	Initial RB-11	162	Program & checkout Bailey			
20-Jun	SATURDAY										
21-Jun	SUNDAY										
22-Jun	Factorial test-fresh slaked					Wired RB-12	162				
23-Jun	Factorial test-fresh slaked					Wire RB-11	162				
24-Jun	Factorial test-fresh slaked					Initial RB-13	162				
25-Jun	Factorial test-fresh slaked					Wire RB-12	162				
26-Jun	Factorial test-fresh slaked					Pipe RB-11	162				
27-Jun	Factorial test-fresh slaked					Initial RB-14	162				
28-Jun	Factorial test-fresh slaked					Wire RB-13	162				
29-Jun	Factorial test-fresh slaked					Pipe RB-12	162				
30-Jun	Factorial test-fresh slaked					Checkout RB-11	162				
1-Jul	Factorial test-fresh slaked					Wire RB-14	162				
2-Jul	Factorial test-fresh slaked					Pipe RB-13	162				
3-Jul	Factorial test-fresh slaked					Checkout RB-12	162				
4-Jul	Factorial test-fresh slaked					Pipe RB-14	162				
5-Jul	Factorial test-fresh slaked					Checkout RB-13	162				
6-Jul	Factorial test-fresh slaked						162				

CZD SCHEDULE by TAS

Table D-1d
Updated Project Schedule for Phase 3a - June 1, 1992

DATE	TESTING	LIME FEED	MMT	LIME PIT	MMT	S.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
29-Jun	Factorial test-didactic					Checkout RB-14	162			Transfer enclosure to site	170
30-Jun	Factorial test-didactic									Refurbish enclosure	170
1-Jul	Factorial test-didactic									Refurbish enclosure	170
2-Jul	Factorial test-didactic									Refurbish enclosure	170
3-Jul	HOLIDAY										
4-Jul	SATURDAY										
5-Jul	SUNDAY										
6-Jul	Factorial test-calcific									Install equipment in enclosure	170
7-Jul	Factorial test-calcific									Install equipment in enclosure	170
8-Jul	Factorial test-calcific										
9-Jul	Factorial test-calcific										
10-Jul	Factorial test-calcific										
11-Jul	SATURDAY									Transfer equipment	170
12-Jul	SUNDAY										
13-Jul	Factorial test-calcific									Checkout & test	170
14-Jul	Factorial test-calcific										
15-Jul	Factorial test-calcific										
16-Jul	Factorial test-calcific										
17-Jul	Factorial test-calcific										
18-Jul	SATURDAY										

6/3/92

Table D-2a
Updated Project Schedule for Phase 3a - June 3, 1992

Task No.	Panel No.	WBS	Description	Est. Mh's	Act Mh's	Material cost	Labor cost	Total	STATUS
100		1.3.2	Inspect water supply adjacent to booster pump				\$0	\$0	COMP
101		1.3.2	Install a new backflow preventer				\$0	\$0	COMP
102		1.3.2	Install water lines for the eyewash station				\$0	\$0	COMP
103		1.3.2	Install an automatic shutdown circuit on FV-20				\$0	\$0	COMP
104		-----	Replace the hose leading from the Grits screen to the Lime slurry tanks				\$0	\$0	COMP
105		1.3.2	Printer flush cover, Bailey printer installed in the control room				\$0	\$0	COMP
106		1.3.2	Install two sinks with their faucet assemblies				\$0	\$0	COMP
107		1.3.2	Install ground wires for spray fences				\$0	\$0	COMP
108		1.3.2	Wash down the entire system				\$0	\$0	COMP
109		1.3.2	Fabricate and install covers over the fill ports				\$0	\$0	COMP
110		1.3.2	Fabricate and install a cover over the agitators on the lime slurry feed tanks				\$0	\$0	COMP
111		1.3.2	Remove for inspection one of the 1/2" ball valves that are used for throttling lime slurry				\$0	\$0	COMP
112		1.3.3.2	Relocate the sensor for the Kurz flowmeter				\$0	\$0	COMP
113		1.3.3.2	Install recycle line from the end of the lime slurry header to the vibrating screen				\$0	\$0	COMP
114		1.3.2	Install replacement flow indicators in the test stand area				\$0	\$0	COMP
115	C3531	1.3.4.1	Install water filters at each eye wash station		32		\$1,280	\$1,280	COMP
116		1.3.2	Fabricate and install a cover for the vibrating screen overflow tank				\$0	\$0	COMP
117		1.3.2	Fabricate and install a cover for the vibrating screen				\$0	\$0	COMP
118	C3406	1.3.4.1	Estimate for installation a 2 1/2" lime slurry line		16	\$189	\$640	\$829	COMP
119		1.3.3.2	Install fiber optic cable from the weather enclosure to the control room				\$0	\$0	COMP
120	C3427	1.3.3.2	Check Kurz flowmeter for calibration		32		\$1,280	\$1,280	COMP
121	C3407	1.3.3.2	Install fiberglass insulation in skin thermocouples		24		\$960	\$960	COMP
122		1.3.4.1	Investigate and report on the operational condition of aeration blower				\$0	\$0	COMP
123		1.3.4.1	Inspect the beghouses at the top of the lime silo and report general condition				\$0	\$0	COMP
124		1.3.3.2	Remove all of the pressure gauges, calibrate using a deadweight tester				\$0	\$0	COMP
125	C3401	1.3.7	Fabricate and install devices		114	\$130	\$4,160	\$4,290	COMP
126	C3402	1.3.3.2	Fabricate and install 2 pipe spools		164	\$115	\$6,160	\$6,275	COMP
127	C3403	1.3.3.2	Dilution water flow control		36	\$38	\$1,440	\$1,478	COMP
128	C3404	1.3.3.2	Temperature replacement and flow meter installation		74	\$111	\$2,160	\$2,271	COMP
129	-----	-----	Measure distant from the lime pit control panel				\$0	\$0	COMP
130	C3408	1.3.3.2	Measure distant from lime pit control line sump area to control room for fiber optic cable		52		\$2,080	\$2,080	COMP
131	C3409	1.3.3.2	Remove ACCO solenoid valve, install drain lines on the strainers, reassemble the ACCO valve		28		\$1,20	\$1,120	COMP
132		1.3.3.2	Install fiber optic cable from lime sump area to control room				\$0	\$0	COMP
133	C3408	1.3.4.1	Install socket fittings from lime pit area to the vibrating screen				\$0	\$0	COMP
134	C3410	1.3.4.1	In lime sump area remove C2D piping, wiring, form C2D pump, remove pump, store		32		\$1,280	\$1,280	COMP
135	C3414	1.3.3.2	Remove level controller, install new one, store old one		16		\$640	\$640	COMP

6/3/92

Table D-2b
Updated Project Schedule for Phase 3a - June 3, 1992

Task No.	Penal No.	WBS	Description	Est. Mh's	Act Mh's	Material cost	Labor cost	Total	STATUS
136	C3428	1.3.4.1	Clean sump area, remove cover of sump, remove pumps, survey for new pumps		45		\$1,800	\$1,800	COMP
137	C3429	1.3.4.1	Adapt sump foundations, install new sump pumps, reinstall sump cover		5		\$200	\$200	
138	C3415	1.3.4.1	Replace star valve motor and gear reducer with new, store old unit				\$0	\$0	
139	C3416	1.3.4.1	Replace motor starters for sump pumps, remove electrical feeders, install new feeder, reroute				\$0	\$0	
140	C3406	1.3.4.1	Install piping and valve form sump pumps, install density gauge on recirculation line				\$0	\$0	
141		-----	Install 2 1/2" port, finish, install valves on each of the flanges				\$0	\$0	COMP
142	C3417	1.3.4.1	Remove top line chips, replace with slurry mixture, install drains in floor, remove line feed pump bed		64		\$2,560	\$2,560	
143		1.3.4.1	Install fiber optic cable		52		\$2,080	\$2,080	COMP
144	C3418	1.3.4.1	Install level sensors inside the lime slurry feed tanks		120.5		\$4,820	\$4,820	
145	C3411	1.3.4.1	Checkout interlock		49		\$1,960	\$1,960	COMP
146	C3412	1.3.4.2	Remove temporary insulation from top of duct		16		\$640	\$640	COMP
147	C3413	1.3.4.1	Furnish and install handrails around lance openings		48		\$1,920	\$1,920	
148	C3419	1.3.3.2	Rewire Kurz unit		95		\$3,800	\$3,800	COMP
150	C3421	1.3.3.2	Full cables for FE-22, FT-22 Bailey R10 and new Bailey controllers		20	\$129	\$800	\$929	COMP
151	C3420	1.3.3.2	Install end checkout instrument air to the lime slurry control valve		8	\$29	\$320	\$349	COMP
152	C3422	1.3.3.2	Mount the two Bailey controllers		32		\$1,280	\$1,280	COMP
153		1.3.3.2	Set Bailey R10				\$0	\$0	COMP
154		1.3.3.2	Wire PSL-19 to solenoid on lime slurry control valve				\$0	\$0	COMP
155	C3424	1.3.7	Maintenance on soot blowers		207.5		\$8,300	\$8,300	COMP
156	C3426	1.3.7	Trouble shoot and repair thermal drain valve		8		\$320	\$320	COMP
157A	C3423	1.3.7	Install 2" air line from test station to soot blowers						
157B	C3427	1.3.3.2	Install FE-12		32		\$1,280	\$1,280	COMP
158	C3441	1.3.3.2	Install 10' x 12' concrete pad for environmental enclosure				\$0	\$0	
159	C3435	1.3.3.2	Install level indicator				\$0	\$0	
160	C3432	1.3.4.1	Install hose on outlet from vibrating screen, install hose to lime slurry inlet pipe				\$0	\$0	
161	C3433	1.3.4.1	Install nozzle top of lime slurry tank, install nozzle vibrating screen				\$0	\$0	
162	C3400	1.3.7	Install RB-7 thru RB-14		629		\$25,160	\$25,160	
163	C3442	1.3.7	Install platforms				\$0	\$0	
164	C3440	1.3.4.1	Remove lime tank pumps and piping				\$0	\$0	COMP
165	C3436	1.3.4.1	Install pumps and piping in the lime tank area				\$0	\$0	
166	C3437	1.3.4.1	Install electrical feeders To the lime tank area				\$0	\$0	
167	C3437	1.3.4.1	Fabricate and install piping in the lime pit area				\$0	\$0	
168	C3439	1.3.3.2	Install wiring to the lime slurry pit level valve				\$0	\$0	
169	C3434	1.3.3.2	Install Bailey mini-90				\$0	\$0	
170		1.3.3.2	Environmental enclosure				\$0	\$0	
							\$0	\$0	

Table D-3a
Updated Project Schedule for Phase 3a - June 16, 1992

DATE	TESTING	LIME FEED	MMT	LIME PIT	MMT	B.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
16-Jun	TUESDAY	Install motor starter	166	Install pump & cover	137	Fabricate platform	163			Connect density gauge controller	
		Order ready/standby piping	171			Smooth tank area floor					
17-Jun	WEDNESDAY	Install motor starter	166	Install pump & cover	137	Fabricate platform	163			Terminate Fiberoptics	169
18-Jun	THURSDAY	Install starter wiring	166			Fabricate flatform	163			Calibrate density gauge	
		Receive ready standby materials									
19-Jun	FRIDAY	Install starter wiring	166	Fabricate piping	167	Install platform	163				
		Start ready /standby piping fabrication	171			Seal tank area floor					
		Install pump motor circuit breaker	166								
20-Jun	SATURDAY										
21-Jun	SUNDAY										
22-Jun	MONDAY			Fabricate piping	167	Install platform	163	Install Bailey loop controller	167		
23-Jun	TUESDAY	Checkout piping	165	Install header	167	Install platform	163	Wire Bailey loop controller	167		
24-Jun	WEDNESDAY	Checkout system		Install header	167	Install platform	163	Connect water valve to controller	168		
25-Jun	THURSDAY	Start R/S piping installation	171	Checkout & Test		Install platform	163	Program & checkout Bailey			
26-Jun	FRIDAY	Install R/S piping	171					Program & checkout Bailey			
27-Jun	SATURDAY										
28-Jun	SUNDAY										
29-Jun	MONDAY	Install R/S piping	171			Install RB-11	162			Transfer enclosure to site	170
30-Jun	TUESDAY	Install R/S piping	171			Install RB-12	162			Refurbish enclosure	170
						Wire RB-11	162				
1-Jul	WEDNESDAY	Install R/S piping	171			Install RB-13	162			Refurbish enclosure	170
						Wire RB-12	162				

Table D-3b
Updated Project Schedule for Phase 3a - June 16, 1992

DATE	TESTING	LIME FEED	MMT	LIME PIT	MMT	B.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
2-Jul	THURSDAY	Install R/S piping	171			Pipe RB-11	162			Refurbish enclosure	170
						Wire RB-13	162				
						Pipe RB-12	162				
						Checkout RB-11	162				
3-Jul	HOLIDAY										
4-Jul	SATURDAY										
5-Jul	SUNDAY										
6-Jul	MONDAY	Test R/S piping	171			Wire RB-14	162			Install equipment in enclosure	170
						Pipe RB-13	162				
						Checkout RB-12	162				
7-Jul	TUESDAY	Test R/S piping	171			Pipe RB-14	162			Install equipment in enclosure	170
						Checkout RB-13	162				
						Checkout RB-14	162				
8-Jul	Factorial test-fresh slaked										
9-Jul	Factorial test-fresh slaked										
10-Jul	Factorial test-fresh slaked										
11-Jul	SATURDAY									Transfer equipment	170
12-Jul	SUNDAY										
13-Jul	Factorial test-fresh slaked									Checkout & test	170
14-Jul	Factorial test-fresh slaked										
15-Jul	Factorial test-fresh slaked										
16-Jul	Factorial test-fresh slaked										

Table D-4a
Updated Project Schedule for Phase 3a - July 8, 1992

DATE	TESTING	LIME FEED	MMT	LIME PIT	MMT	B.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
6-Jul	MONDAY	Test R/S piping	171	Install header	167	Install platform	163	Inst. Feedback,MCC-Bailey	180	Install equipment in enclosure	170
7-Jul	TUESDAY	Test R/S piping	171	Install header	167	Install platform	163	Inst. Feedback,MCC-Bailey	180	Install equipment in enclosure	170
8-Jul	Factorial test-fresh slaked	Install LV-25	182	Install header	167	Install platform	163	Inst. Feedback,MCC-Bailey	180	Modify Lime silo cont. pnl.	184
9-Jul	Factorial test-fresh slaked	Install LV-25	182	Install header	167	Install RB-11	162	Inst. Feedback,MCC-Bailey	180	Modify Lime silo cont. pnl.	184
10-Jul	Factorial test-fresh slaked	Install LV-25	182	Install header	167	Install RB-12	162	Inst. Feedback,MCC-Bailey	180	Wire Clarifier MCC to Mini-90	183
11-Jul						Wire RB-11	162	Wire water control valve to Mini-90	188	Modify Lime silo cont. pnl.	184
12-Jul	SATURDAY										
13-Jul	SUNDAY										
13-Jul	Factorial test-fresh slaked			Connect Header to xfer	167	Install RB-13	162	Install RB wiring from cont rm to end of duct	178	Recieve K-Ray	186
						Wire RB-12	162			Wire Lime Silo cont pnl to Mini-90	184
						Pipe RB-11	162			Wire Clarifier MCC to Mini-90	183
14-Jul	Factorial test-fresh slaked			Install R/S valves	167	Install RB-14	162	Install RB wiring from cont rm to end of duct	178	Install K-ray	186
						Wire RB-13	162			Wire Clarifier MCC to Mini-90	183
						Pipe RB-12	162				
						Checkout RB-11	162				
15-Jul	Factorial test-fresh slaked			Install R/S valves	167	Wire RB-14	162	Install RB wiring from cont rm to end of duct	178	Install K-Ray	186
						Pipe RB-13	162				
						Checkout RB-12	162				
16-Jul	Factorial test-fresh slaked			C/O & Test R/S	167	Pipe RB-14	162	Install RB wiring from cont rm to end of duct	178	Wire K-Ray	186
						Checkout RB-13	162				

Table D-4b
Updated Project Schedule for Phase 3a - July 8, 1992

DATE	TESTING	LIME FEED	MMT	LIME PIT	MMT	B.O.P.	MMT	CONTROLS	MMT	INSTRUMENTATION	MMT
17-Jul	Factorial test-fresh slaked			C/O & Test R/S	167	(Checkout RB-14	162	Ship Bailey MFPO1 & MFPO2		Checkout K-Ray	186
18-Jul								Checkout RB wiring	178		
19-Jul	SATURDAY										
20-Jul	SUNDAY										
20-Jul	Factorial test-fresh slaked							Install MFPO1 & MFPO2			
21-Jul	Factorial test-fresh slaked							Install MFPO1 & MFPO2			
22-Jul	Factorial test-fresh slaked							Install MFPO1 & MFPO2			
23-Jul	Factorial test-dolomitic							Install MFPO1 & MFPO2			
24-Jul	Factorial test-dolomitic							Install MFPO1 & MFPO2			
25-Jul											
26-Jul	SATURDAY										
27-Jul	SUNDAY										
27-Jul	Factorial test-dolomitic					Install AC	185				
28-Jul	Factorial test-dolomitic					Install AC	185				
29-Jul	24 Hour Test					Install AC	185				
30-Jul	24 Hour Test					Install AC	185				
31-Jul	24 Hour Test					Install AC	185				
1-Aug											
2-Aug	SATURDAY										
3-Aug	SUNDAY										
3-Aug	8 Hour run										
4-Aug	8 Hour run										
5-Aug	8 Hour run										
6-Aug	8 Hour run										

Table D-5a
Mobile Maintenance Tasks - August 19, 1992

Task No.	Penelec No.	WBS	Description	Act Mh's	Material cost-bechtel	Material cost-penelec	Labor cost	Total	STATUS
100		1.3.2	Inspect water supply adjacent to booster pump				\$0	\$0	COMP
101		1.3.2	Install a new backflow preventer				\$0	\$0	COMP
102		1.3.2	Install water lines for the eyewash station				\$0	\$0	COMP
103		1.3.2	Install an automatic shutdown circuit on FV-20				\$0	\$0	COMP
104		-----	Replace the hose leading from the Grits screen to the Lime slurry tanks				\$0	\$0	CANC
105		1.3.2	Printer Hush cover, Bailey printer installed in the control room				\$0	\$0	COMP
106		1.3.2	Install two sinks with their faucet assemblies				\$0	\$0	COMP
107		1.3.2	Install ground wires for spray lances				\$0	\$0	COMP
108		1.3.2	Wash down the entire system				\$0	\$0	COMP
109		1.3.2	Fabricate and install covers over the fill ports				\$0	\$0	COMP
110		1.3.2	Fabricate and install a cover over the agitators on the lime slurry feed tanks				\$0	\$0	
111		1.3.2	Remove for inspection one of the 1/2" ball valves that are used for throttling lime slurry				\$0	\$0	COMP
112		1.3.3.2	Relocate the sensor for the Kurz flowmeter				\$0	\$0	COMP
113		1.3.3.2	Install recycle line from the end of the lime slurry header to the vibrating screen				\$0	\$0	COMP
114		1.3.2	Install replacement flow indicators in the test stand area				\$0	\$0	COMP
115	C3431	1.3.4.1	Install water filters at each eye wash station	32	\$121		\$1,280	\$1,401	COMP
116		1.3.2	Fabricate and install a cover for the vibrating screen overflow tank				\$0	\$0	COMP
117		1.3.2	Fabricate and install a cover for the vibrating screen				\$0	\$0	COMP
118	C3406	1.3.4.1	Estimate for installation a 2 1/2" lime slurry line	16		\$777	\$640	\$1,417	COMP
119		1.3.3.2	Install fiber optic cable from the weather enclosure to the control room				\$0	\$0	COMP
120	C3427	1.3.3.2	Check Kurz flowmeter for calibration	32			\$1,280	\$1,280	COMP
121	C3407	1.3.3.2	Install fiberglass insulation in skin thermocouples	24			\$980	\$980	COMP
122		1.3.4.1	Investigate and report on the operational condition of aeration blower				\$0	\$0	COMP
123		1.3.4.1	Inspect the baghouse at the top of the lime silo and report general condition				\$0	\$0	COMP
124		1.3.3.2	Remove all of the pressure gauges, calibrate using a deadweight tester				\$0	\$0	COMP
125	C3401	1.3.7	Fabricate and install davits	112		\$136	\$4,480	\$4,616	COMP
126	C3402	1.3.3.2	Fabricate and install 2 pipe spools	164	\$635	\$115	\$6,580	\$7,310	COMP
127	C3403	1.3.3.2	Dilution water flow control	36		\$38	\$1,440	\$1,478	COMP
128	C3404	1.3.3.2	Temperature replacement and flow meter installation	74		\$111	\$2,960	\$3,071	COMP
129		-----	Measure distant from the lime pit-control-panel				\$0	\$0	COMP
130	C3408	1.3.3.2	Measure distant from lime pit control lime sump area to control room for fiber optic cable	68		\$56	\$2,720	\$2,776	COMP
131	C3409	1.3.3.2	Remove ACCO solenoid valve, install drain lines on the strainers, reassemble the ACCO valve	44	\$153		\$1,760	\$1,913	
132	C3408	1.3.3.2	Install fiber optic cable from lime sump area to control room		\$1,469		\$0	\$1,469	COMP
133		1.3.4.1	Install socket fittings from lime pit area to the vibrating screen				\$0	\$0	COMP
134	C3410	1.3.4.1	In lime sump area remove C2D piping, wiring, form C2D pump, remove pump, store	32			\$1,280	\$1,280	COMP
135	C3414	1.3.3.2	Remove level controller, install new one, store old one	16		\$50	\$640	\$690	COMP

Table D-5b
Mobile Maintenance Tasks - August 19, 1992

Task No.	Penelec No.	WBS	Description	Act Mh'a	Material cost-bechtel	Material cost-penelec	Labor cost	Total	STATUS
136	C3428	1.3.4.1	Clean sump area, remove cover of sump, remove pumps, survey for new pumps	208		\$0	\$8,320	\$8,320	COMP
137	C3429	1.3.4.1	Adapt sump foundations, install new sump pumps, reinstall sump cover	160		\$37	\$6,400	\$6,437	COMP
138	C3415	1.3.4.1	Replace star valve motor and gear reducer with new, store old unit	80	\$474	\$44	\$3,200	\$3,718	COMP
139	C3416	1.3.4.1	Replace motor starters for sump pumps, remove electrical feeders, install new feeder, reroute	146		\$149	\$5,840	\$5,989	COMP
140		1.3.4.1	Install piping and valve form sump pumps, install density gauge on recirculation line				\$0	\$0	CANC
141	-----	-----	Install 2 1/2" port, finish install valves on each of the flanges				\$0	\$0	COMP
142	C3417	1.3.4.1	Remove top lime chips, replace with slurry mixture, install drains in floor, remove lime feed pumps bed	64			\$2,560	\$2,560	COMP
143	C3408	1.3.4.1	Install fiber optic cable	52			\$2,080	\$2,080	COMP
144	C3418	1.3.4.1	Install level sensors inside the lime slurry feed tanks	480.5	\$213	\$220	\$19,220	\$19,653	COMP
145	C3411	1.3.4.1	Checkout interlock	49			\$1,960	\$1,960	COMP
146	C3412	1.3.4.2	Remove temporary insulation from top of duct	16			\$640	\$640	COMP
147	C3413	1.3.4.1	Furnish and install handrails around lance openings	95.5		\$55	\$3,820	\$3,875	COMP
148	C3419	1.3.3.2	Rewire Kurz unit	24			\$960	\$960	COMP
150	C3421	1.3.3.2	Pull cables for FE-22, FT-22 Bailey R10 and new Bailey controllers	20		\$135	\$800	\$935	COMP
151	C3420	1.3.3.2	Install and checkout instrument air to the lime slurry control valve	16.5		\$29	\$680	\$689	COMP
152	C3422	1.3.3.2	Mount the two Bailey controllers	32		\$890	\$1,280	\$1,970	COMP
153		1.3.3.2	Set Bailey R10				\$0	\$0	COMP
154		1.3.3.2	Wire PISL-19 to solenoid on lime slurry control valve				\$0	\$0	COMP
155	C3424	1.3.7	Maintenance on soot blowers	417	\$344	\$1,131	\$16,680	\$18,155	COMP
156	C3426	1.3.7	Trouble shoot and repair thermal drain valve	8			\$320	\$320	COMP
157A	C3423	1.3.7	Install 2" air line from test station to soot blowers			\$534		\$534	COMP
157B	C3427	1.3.3.2	Install FE-12	32			\$1,280	\$1,280	COMP
158	C3441	1.3.3.2	Install 10' x 12' concrete pad for environmental enclosure				\$0	\$0	COMP
159	C3435	1.3.3.2	Install level indicator	44.5	\$245	\$125	\$1,780	\$2,150	COMP
160	C3432	1.3.4.1	Install hose on outlet from vibrating screen, install hose to lime slurry inlet pipe	80	\$140	\$7	\$3,200	\$3,347	COMP
161	C3433	1.3.4.1	Install nozzle top of lime slurry tank, install nozzle vibrating screen				\$0	\$0	COMP
162	C3400	1.3.7	Install RB-7 thru RB-10	1459		\$2,255	\$58,360	\$60,615	COMP
163	C3442	1.3.7	Install platforms	16		\$8	\$640	\$648	COMP
164	C3440	1.3.4.1	Remove lime tank pumps and piping	32		\$40	\$1,280	\$1,320	COMP
164A	C3425	1.3.4.1		30			\$1,200	\$1,200	COMP
165	C3436	1.3.4.1	Install pumps and piping in the lime tank area	334	\$1,195	\$81	\$13,360	\$14,636	COMP
166	C3437	1.3.4.1	Install electrical feeder To the lime tank area	406	\$1,749	\$593	\$16,240	\$18,582	COMP
167	C3449	1.3.4.1	Fabricate and install piping in the lime pit area	57		\$31	\$2,280	\$2,311	COMP
168	C3439	1.3.3.2	Install wiring to the lime slurry pit level valve	73	\$127	\$28	\$2,920	\$3,075	COMP
169	C3434	1.3.3.2	Install Bailey mint-90	191		\$145	\$7,640	\$7,785	COMP
170	C3443	1.3.3.2	Environmental enclosure				\$0	\$0	CANCEL
171	C3446	1.3.4.1	Ready standby piping	310		\$249	\$12,400	\$12,649	COMP

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Appendix E

Baseline Testing

Appendix E Baseline Testing

The results of sampling the incoming coal for Seward Station boiler #15 during the months of May, June, and July and for August 1-16, 1992 are presented on pages E-2 through E-5.

Reports for the daily tons of coal burned, the percentage of ash, and daily tons of ash at Seward Station during the months of May, June, and July and for August 1-16, 1992 are presented on pages E-6 through E-9.

During completion of construction and installation in the lime preparation area at Seward Station, we used fresh-slaked calcitic lime from Conemaugh Station, located about 3 miles from Seward Station. Conemaugh Station purchased the lime from American Lime and Stone Company in Pennsylvania.

The chemical and physical test results for the hydrated lime made by the GPUN System Laboratory are presented on pages E-10 through E-13. A comparison between the Conemaugh purchasing specifications, the vendor specifications, and the laboratory test results shows that instead of 96.07% available calcium hydroxide, as requested in their purchase specifications, the vendor supplied a much lower quality with only 86.13% calcium hydroxide – a difference of more than 10% impurities. We had a lot of difficulty with this low-quality lime slurry because of the excess of fine unreactive materials that frequently plugged our pipes and lime slurry atomizers.

SEWARD STATION HEAT RATE QUALITY MAY - 1992

DATE	# 12 TONS	# 14 TONS	# 15 TONS	% MOIST	% ASH	% SULFER	BTU	# SUL/ 10E6 BTU	% VOL
1	271	362	1292	5.74	13.97	1.63	12325	1.33	21.27
2	252	288	1344	5.95	14.62	1.57	12179	1.29	22.24
3	216	267	1202	6.34	13.40	1.52	12264	1.24	22.44
4	221	255	1261	5.39	15.28	1.53	12154	1.27	21.72
5	353	252	1353	5.21	14.59	1.50	12315	1.22	22.22
6	275	247	1336	6.60	13.83	1.55	12196	1.27	21.87
7	348	253	1305	6.03	13.49	1.55	12308	1.27	22.69
8	321	258	1376	5.18	14.74	1.64	12249	1.35	21.71
9	361	265	1261	6.99	13.20	1.58	12198	1.30	21.87
10	264	187	1176	6.25	12.17	1.51	12459	1.21	22.58
11	309	277	1228	6.24	13.55	1.53	12214	1.26	22.36
12	323	191	1288	6.20	13.88	1.55	12243	1.27	20.67
13	332	245	1227	6.00	13.50	1.41	12329	1.15	21.55
14	299	247	1324	5.92	13.75	1.57	12321	1.28	21.34
15	358	270	1231	5.85	12.76	1.40	12542	1.13	21.07
16	301	250	1220	5.55	13.21	1.47	12507	1.18	21.07
17	244	251	1162	5.50	14.50	1.46	12251	1.19	21.35
18	302	275	1021	5.62	13.66	1.57	12381	1.28	21.13
19	113	193	0	5.42	13.61	1.62	12444	1.31	20.63
20	153	172	0	4.68	15.54	1.55	12272	1.26	20.46
21	274	233	444	5.36	14.22	1.48	12300	1.21	21.71
22	267	229	348	4.84	15.40	1.53	12218	1.26	20.92
23	330	252	510	4.90	17.36	1.88	11830	1.59	20.92
24	336	212	185	4.42	14.93	1.46	12348	1.18	20.92
25	243	227	0	5.35	12.72	1.44	12566	1.15	20.92
26	312	223	1279	4.83	14.65	1.57	12305	1.28	21.26
27	285	192	1340	4.55	15.54	1.63	12154	1.34	21.48
28	322	216	1359	5.61	14.45	1.60	12151	1.32	20.97
29	296	261	1377	4.74	15.58	1.65	12218	1.36	20.89
30	219	197	1185	4.74	15.86	1.81	12133	1.49	20.97
31	192	195	1211	6.60	11.75	1.42	12556	1.13	21.40
TOTAL-12	8692			5.59	14.18	1.55	12283	1.27	21.46
TOTAL-14		7442		5.60	14.18	1.55	12286	1.27	21.47
TOTAL-15			31845	5.69	14.10	1.56	12279	1.27	21.57

NOTE: WEEKENDS AND HOLIDAYS BASED ON GRAB SAMPLES

NOTE: VOLATILE MATTER NOT RUN FOR GRAB SAMPLES, AVERAGE OF PREVIOUS DAYS USED

NOTE: STOCKPILE AS OF 5/31/92 93358.94 TONS

SEWARD STATION HEAT RATE QUALITY JUNE - 1992

DATE	# 12 TONS	# 14 TONS	# 15 TONS	% MOIST	% ASH	% SULFER	BTU	# SUL/ 10E6 BTU	% VOL
1	266	219	1242	6.12	12.43	1.54	12417	1.25	21.74
2	323	254	1258	5.50	13.27	1.51	12429	1.22	21.70
3	273	260	1234	4.81	14.30	1.65	12336	1.35	22.06
4	230	268	1238	6.30	12.26	1.41	12443	1.14	21.13
5	358	177	1235	6.17	13.98	1.49	12181	1.22	21.82
6	221	242	1207	6.46	12.78	1.51	12365	1.22	21.82
7	233	171	1231	6.16	14.13	1.56	12157	1.28	21.29
8	61	71	1274	6.29	12.79	1.61	12407	1.30	22.10
9	0	0	1373	6.49	12.63	1.52	12393	1.23	21.91
10	0	26	1225	5.90	13.00	1.51	12365	1.23	22.50
11	0	0	1238	5.40	14.54	1.53	12204	1.26	22.17
12	0	0	1255	5.19	12.64	1.37	12559	1.09	22.80
13	0	0	1168	5.63	11.56	1.28	12681	1.01	22.80
14	0	0	1212	5.11	12.00	1.29	12700	1.02	22.80
15	0	11	1227	5.31	12.01	1.36	12612	1.08	22.19
16	36	304	1292	4.68	14.17	1.42	12403	1.15	21.99
17	279	343	1234	5.75	13.40	1.42	12277	1.16	21.99
18	290	261	1220	5.28	14.89	1.49	12191	1.23	22.76
19	319	339	1286	6.05	13.01	1.49	12426	1.20	22.89
20	337	347	1230	4.98	13.37	1.41	12477	1.13	22.85
21	197	244	1162	4.85	13.01	1.57	12514	1.25	22.52
22	173	193	1244	6.26	12.51	1.48	12413	1.20	23.08
23	206	247	1136	5.88	13.93	1.46	12194	1.21	23.70
24	150	230	0	5.44	14.74	1.50	12162	1.24	23.91
25	280	249	146	5.25	14.44	1.53	12257	1.25	21.59
26	185	220	694	5.30	13.45	1.40	12362	1.14	25.37
27	162	231	1209	6.85	12.53	1.41	12257	1.15	25.37
28	211	190	1129	5.63	12.64	1.48	12501	1.18	23.13
29	156	213	1221	5.11	14.07	1.61	12289	1.32	25.46
30	211	270	1252	4.94	14.80	1.47	12239	1.21	23.99
<hr/>									
TOTAL-12	5157			5.66	13.53	1.50	12332	1.22	22.65
TOTAL-14		5580		5.60	13.54	1.49	12339	1.21	22.78
TOTAL-15			34072	5.66	13.22	1.48	12385	1.20	22.65

NOTE: WEEKENDS AND HOLIDAYS BASED ON GRAB SAMPLES

NOTE: VOLATILE MATTER NOT RUN FOR GRAB SAMPLES, AVERAGE OF PREVIOUS DAYS USED

NOTE: STOCKPILE AS OF 6/30/92 119904.64 TONS

SEWARD STATION HEAT RATE QUALITY JULY - 1992

DATE	# 12 TONS	# 14 TONS	# 15 TONS	% MOIST	% ASH	% SULFER	BTU	# SUL/ 10E6 BTU	% VOL
1	236	211	1346	5.42	13.78	1.32	12163	1.09	27.97
2	234	365	1307	5.99	13.51	1.57	12126	1.30	24.60
3	177	239	1249	6.23	13.83	1.68	12014	1.40	24.80
4	239	268	126	5.16	16.38	1.51	11845	1.27	25.10
5	192	154	41	6.38	13.79	1.59	12121	1.31	25.46
6	351	0	967	5.68	15.01	1.58	12036	1.32	24.92
7	283	0	1331	6.15	13.69	1.53	12026	1.27	20.55
8	378	0	1229	5.70	13.03	1.57	12383	1.27	24.68
9	231	184	1315	5.70	13.85	1.62	12285	1.33	23.96
10	268	274	1217	6.12	13.40	1.52	12339	1.24	22.34
11	306	392	1391	6.46	13.13	1.49	12248	1.22	23.55
12	253	201	1285	6.18	12.67	1.51	12390	1.22	25.21
13	361	14	1337	6.13	13.94	1.59	12134	1.32	25.44
14	244	305	1285	6.12	13.93	1.59	12198	1.31	24.14
15	351	395	1384	5.80	13.42	1.57	12262	1.28	24.56
16	234	265	1258	6.76	13.57	1.50	12175	1.24	25.43
17	338	374	1338	6.12	13.94	1.51	12199	1.24	22.15
18	257	537	1057	5.98	13.34	1.51	12318	1.23	23.01
19	153	219	520	6.21	12.91	1.58	12351	1.28	22.34
20	179	264	100	5.82	14.67	1.59	12108	1.32	24.96
21	252	216	148	5.77	13.48	1.61	12287	1.32	26.07
22	197	227	0	4.93	12.32	1.63	12589	1.30	23.41
23	195	247	0	6.17	13.95	1.43	12088	1.19	21.45
24	214	283	729	6.74	14.20	1.56	12134	1.29	22.90
25	183	186	821	7.15	14.24	1.44	11976	1.20	22.42
26	162	188	1190	6.75	13.02	1.48	12269	1.21	23.03
27	73	89	1289	7.49	14.46	1.65	11986	1.38	23.47
28	54	0	1293	6.31	14.58	1.56	12154	1.29	24.09
29	0	339	843	6.10	14.07	1.61	12221	1.32	21.27
30	189	331	0	7.26	13.51	1.57	12102	1.30	22.34
31	228	269	0	6.95	13.57	1.47	12167	1.21	22.34
TOTAL-12	7012			6.11	13.74	1.54	12192	1.27	23.95
TOTAL-14		7036		6.19	13.71	1.54	12199	1.27	23.66
TOTAL-15			27396	6.20	13.72	1.54	12189	1.27	23.92

NOTE: WEEKENDS AND HOLIDAYS BASED ON GRAB SAMPLES

NOTE: VOLATILE MATTER NOT RUN FOR GRAB SAMPLES, AVERAGE OF PREVIOUS DAYS USED

NOTE: STOCKPILE AS OF 7/31/92 122045.14 TONS

SEWARD STATION HEAT RATE QUALITY AUGUST - 1992

DATE	# 12 TONS	# 14 TONS	# 15 TONS	% MOIST	% ASH	% SULFER	BTU	# SUL/ 10E6 BTU	% VOL
1	212	236	0	6.73	13.40	1.56	12214	1.28	22.34
2	199	167	0	6.91	13.36	1.65	12187	1.35	22.34
3	170	327	756	5.97	16.17	1.65	11939	1.39	20.56
4	147	140	1152	6.59	12.85	1.56	12188	1.29	21.09
5	176	252	1179	5.94	14.14	1.53	12177	1.27	22.19
6	0	284	1221	5.93	12.27	1.42	12548	1.14	22.68
7	0	326	1141	6.32	14.98	1.56	12018	1.30	22.06
8	141	344	1165	6.79	13.66	1.77	12109	1.46	22.41
9	108	218	1121	5.40	12.59	1.49	12509	1.19	21.40
10	246	311	1197	6.71	13.19	1.51	12165	1.25	22.48
11	319	298	1380	6.99	12.49	1.52	12144	1.25	24.29
12	298	260	1280	6.35	14.14	1.59	12080	1.33	23.28
13	346	161	1333	5.77	14.03	1.51	12170	1.25	26.34
14	370	25	1271	6.36	13.71	1.63	12113	1.35	21.49
15	159	176	1236	5.37	13.31	1.47	12373	1.19	22.24
16	163	189	1149	6.18	11.98	1.46	12466	1.17	24.78
17	147	191	947	5.09	14.95	1.56	12138	1.29	26.55
18	292	399	210	5.20	12.62	1.59	12524	1.27	27.03
19	198	252	158	6.27	12.32	1.57	12253	1.29	22.85
20	184	237	736	5.48	13.84	1.56	12253	1.28	25.63
21	159	164	1184	5.05	13.78	1.51	12388	1.22	24.60
22	141	183	1150	5.03	14.21	1.54	12321	1.25	24.62
23	136	188	1174	4.93	14.10	1.54	12302	1.25	25.63
24	258	291	1201	5.19	12.96	1.51	12453	1.21	26.02
25	300	154	1324	5.63	13.71	1.55	12239	1.27	24.48
26	312	338	1299	6.10	13.54	1.50	12205	1.23	22.29
27	246	287	1368	5.82	14.22	1.75	12162	1.44	23.96
28	430	261	1371	5.51	15.05	1.62	12133	1.34	23.50
29	175	263	1278	5.56	13.01	1.55	12407	1.25	23.66
30	174	252	1382	6.74	13.25	1.45	12165	1.19	23.02
31	159	220	1263	5.78	15.00	1.56	12024	1.30	26.69
TOTAL-12	6365			5.95	13.67	1.56	12222	1.28	23.75
TOTAL-14		7394		5.95	13.64	1.56	12237	1.28	23.64
TOTAL-15			32626	5.89	13.69	1.55	12233	1.27	23.65

NOTE: WEEKENDS AND HOLIDAYS BASED ON GRAB SAMPLES

NOTE: VOLATILE MATTER NOT RUN FOR GRAB SAMPLES, AVERAGE OF PREVIOUS DAYS USED

NOTE: STOCKPILE AS OF 8/31/92 130873.06 TONS

SEWARD STATION
ASH REPORT

MAY 1992

DATE	DAILY TONS BURNED	PERCENT ASH	DAILY TONS ASH
1	1925	13.97	268.92
2	1884	14.62	275.44
3	1685	13.40	225.79
4	1737	15.28	265.41
5	1958	14.59	285.67
6	1858	13.83	256.96
7	1906	13.49	257.12
8	1955	14.74	288.17
9	1887	13.20	249.08
10	1627	12.17	198.01
11	1814	13.55	245.80
12	1802	13.88	250.12
13	1804	13.50	243.54
14	1870	13.75	257.13
15	1859	12.76	237.21
16	1771	13.21	233.95
17	1657	14.50	240.27
18	1598	13.66	218.29
19	306	13.61	41.65
20	325	15.54	50.50
21	951	14.22	135.23
22	844	15.40	129.98
23	1092	17.36	189.57
24	733	14.93	109.44
25	470	12.72	59.78
26	1814	14.65	265.75
27	1817	15.54	282.36
28	1897	14.45	274.12
29	1934	15.58	301.33
30	1601	15.86	253.92
31	1598	11.75	187.77
TOTAL	47979	14.18	6778.26

BEWARD STATION
ABH REPORT

JUNE 1992

DATE	DAILY TONS BURNED	PERCENT ABH	DAILY TONS ABH
1	1727	12.43	214.67
2	1835	13.27	243.50
3	1767	14.30	252.68
4	1736	12.26	212.83
5	1770	13.98	247.45
6	1670	12.78	213.43
7	1635	14.13	231.03
8	1406	12.79	179.83
9	1373	12.63	173.41
10	1251	13.00	162.63
11	1238	14.54	180.01
12	1255	12.64	158.63
13	1168	11.56	135.02
14	1212	12.00	145.44
15	1238	12.01	148.68
16	1632	14.17	231.25
17	1856	13.40	248.70
18	1771	14.89	263.70
19	1944	13.01	252.91
20	1914	13.37	255.90
21	1603	13.01	208.55
22	1610	12.51	201.41
23	1589	13.93	221.35
24	380	14.74	56.01
25	675	14.44	97.47
26	1099	13.45	147.82
27	1602	12.53	200.73
28	1530	12.64	193.39
29	1590	14.07	223.71
30	1733	14.80	236.48
TOTAL	44809	13.31	5958.63

SEWARD STATION
ASH REPORT

JULY 1992

DATE	DAILY TONS BURNED	PERCENT ASH	DAILY TONS ASH
1	1793	13.78	247.08
2	1906	13.51	257.50
3	1665	13.83	230.27
4	633	16.38	103.69
5	387	13.79	53.37
6	1318	15.01	197.83
7	1614	13.69	220.96
8	1607	13.03	209.39
9	1730	13.85	239.61
10	1759	13.40	235.76
11	2089	13.13	274.29
12	1739	12.67	220.33
13	1712	13.94	238.65
14	1834	13.93	255.46
15	2130	13.42	285.85
16	1757	13.57	238.41
17	2050	13.94	285.86
18	1851	13.34	246.92
19	892	12.91	115.16
20	543	14.67	79.66
21	616	13.48	83.04
22	424	12.32	52.24
23	442	13.95	61.66
24	1226	14.20	174.09
25	1190	14.24	169.46
26	1540	13.02	200.51
27	1451	14.46	209.81
28	1347	14.58	196.39
29	1182	14.07	166.31
30	520	13.51	70.25
31	497	13.57	67.44
TOTAL	41444	13.78	5687.22

SEWARD STATION
ASH REPORT

AUGUST 1992

DATE	DAILY TONS BURNED	PERCENT ASH	DAILY TONS ASH
1	448	13.40	60.03
2	366	13.36	48.90
3	1253	16.17	202.61
4	1439	12.85	184.91
5	1607	14.14	227.23
6	1505	12.27	184.66
7	1467	14.98	219.76
8	1650	13.66	225.39
9	1447	12.59	182.18
10	1754	13.19	231.35
11	1997	12.49	249.43
12	1838	14.14	259.89
13	1840	14.03	258.15
14	1666	13.71	228.41
15	1571	13.31	209.10
16	1501	11.98	179.82
17	1285	14.95	192.11
18	901	12.62	113.71
19	608	12.32	74.91
20	1157	13.84	160.13
21	1507	13.78	207.66
22	1474	14.21	209.46
23	1498	14.10	211.22
24	1750	12.96	226.80
25	1778	13.71	243.76
26	1949	13.54	263.89
27	1901	14.22	270.32
28	2062	15.05	310.33
29	1716	13.01	223.25
30	1808	13.25	239.56
31	1642	15.00	246.30
TOTAL	46385	13.64	6345.23

Subject: BULK HYDRATED LIME SAMPLE -
CONEMAUGH STATION

Date: January 23, 1990

From: D. A. Reed - Chemist, Chemistry Support

Location: Reading
5343-90-0036

To: P. W. Johnson - Engineer, Station (Conemaugh)

Attached is the GPUN System Lab analysis report on a hydrated lime sample sent from Conemaugh Station. The station was experiencing lime slurry line pluggage problems and asked for an assay against Penelec purchasing specs and those issued by the vendor, American Lime and Stone Company. Generally, the sample assay compared well with both specs. As pointed out in the report, calcium hydroxide - $\text{Ca}(\text{OH})_2$ and calcium oxide - CaO results were below stated specs by ~8%. Carbon levels (noted as CO_2) and free moisture were also reported to be elevated but should not impact the quality of the lime. CO_2 and moisture entrainment could easily have occurred while waiting for analysis.

My first concern would be to question the vendor on his ability to meet the calcium hydroxide and calcium oxide purchase spec. They were obviously lower than what they even publish. Second, ensure yourself that the proper concentration of lime slurry is being made (normally 10%). GPUN Chemistry Support generated a lime slurry concentration chart which can be found in Conemaugh's water lab. Also, what is the frequency of flushing the slurry lines? This may need to be done on a periodic basis to avoid line pluggage.

If there are any questions, contact me in Reading.

D. A. Reed
Ext. 5143

/ida

cc: S. L. Christy - Station Engineer, Chemical (Conemaugh)
F. S. Giacobbe - Manager Matl's. Eng./Chem. Sup.
J. E. Gritzer - Gen. Station Director (Conemaugh)
A. N. Hewing - Chemistry Support Manager
D. J. Seign - Engineer, Generation (Penelec)

Report No: 5393-90-0152

Revision Date: 01/17/90

Page 1 of 1

Revision No: 0

Prepared for: Chemist, Chemistry Support - ~~XXXXXXXXXX~~

Distribution

File

Title:

ASR No. 176380 - Analysis of Hydrated Lime
for Conemaugh Station

Summary:

Recent excessive I.D. build-up in the slurry line at Conemaugh Station prompted analysis of the high calcium hydrated lime compound used for incoming river water pretreatment.

Attached are the chemical and physical test results obtained from a sample of the hydrated lime used at Conemaugh. Also attached is a report from American Lime and Stone Company listing a typical assay for high calcium hydrated lime. Our test results show some deviation from the reported "typical" values. The available calcium hydroxide - $\text{Ca}(\text{OH})_2$ and calcium oxide - CaO results were found to be approximately 8% lower than the "typical" and carbon dioxide and moisture (free H_2O) were found to be somewhat higher than the reported results.

WJJ/el1

Attachments:

2 Laboratory Data Figures

Prepared by:

Sr. Tech.-Matls./Deposit Laboratory
T. A. Laughlin

Reviewed by:

Supv.-Matls./Deposit Laboratory
W. J. Jeitner

Approved by:

Manager-System Laboratory
G. L. Carlson

The chemical and physical test results for hydrated lime (ASR-176380) were obtained following ASTM Procedure C-25 or C-184 except where noted.

<u>Chemical (ASTM C-25)</u>		<u>Penelec</u> <u>Spec #6</u>	<u>AL & S</u> <u>Co. Spec</u>
Available Calcium Hydroxide ($\text{Ca}(\text{OH})_2$)	86.13	96.07	93.50%
Calcium Oxide (CaO)	65.20	73.63	73.00%
¹ Magnesium Oxide (MgO)	0.71	0.61	0.70%
Silica and Insolubles (SiO_2)	0.43	0.70	1.20%
² Iron Oxide (Fe_2O_3)	0.17	0.13	0.20%
³ Alumina Oxide (Al_2O_3)	0.64	0.19	0.50%
Sulfur (S)	0.038		0.03%
Sulfur Trioxide (SO_3)	0.095		0.08%
Carbon Dioxide (CO_2)	3.30		1.00%
Free Water (H_2O)	1.71	0.34	0.60%
Loss on Ignition (L.O.I.)	22.85	23.75	24.50%

<u>Physical (ASTM C-184)</u>		<u>Penelec</u> <u>Spec #6</u>	<u>AL & S</u> <u>Co. Spec</u>
<u>Mesh Size</u>	<u>% Passing</u>		
50	100	100.0	100%
100	99.3	100.0	99%
200	94.4	99.9	96%
325	94.8	99.2	93%

- 1 & 2 - atomic absorption/stoichiometric conversion
 3 - ICP/stoichiometric conversion

AMERICAN LIME AND STONE COMPANY

SUITE 3-B • 110 WEST STREETSBOBO STREET • HUDSON, OHIO 44236 (216) 636-4200

HIGH CALCIUM HYDRATED LIME

BELLEFONTE, PENNSYLVANIA

TYPICAL ANALYSIS

CHEMICAL

AVAILABLE CALCIUM HYDROXIDE ($\text{Ca}(\text{OH})_2$)	93.50%
CALCIUM OXIDE (CaO)	73.00%
MAGNESIUM OXIDE (MgO)	0.70%
SILICA & INSOLUBLES (SiO_2)	1.20%
IRON OXIDE (Fe_2O_3)	0.20%
ALUMINA OXIDE (Al_2O_3)	0.50%
SULPHUR (S)	0.03%
SULPHUR TRIOXIDE (SO_3)	0.08%
CARBON DIOXIDE (CO_2)	1.00%
FREE WATER (H_2O)	0.60%
LOSS ON IGNITION (L.O.I.)	24.50%

PHYSICAL

<u>MESH SIZE</u>	<u>% PASSING</u>
50	100
100	99
200	96
325	93

*Test To see how chose hydrated Lime
is To this specification sheet.*

Appendix F

Procedures for Calculating SO₂ and NO_x Removal and the Percentage of Lime Utilization

ESTIMATES OF SO₂ AND NO_x REMOVAL

Bases: Measured Quantities are:

- SO₂, NO_x and O₂ concentrations in inlet and outlet flue gas
- Flue gas flow at the discharge from the test duct
- Inlet and outlet gas temperatures
- Barometric pressure
- Flue gas pressure
- Lime usage
- Lime concentration
- Atomizing air usage
- Dilution water usage

Estimated Quantities are:

- Flue gas flows in and out
- SO₂ and NO_x removal
- Lime utilization
- Solid waste requiring disposal

Flue Gas Flow Measurements

The flue gas flow meter is located at the end of the test duct, just upstream of the second stage Buell ESP. When nothing is being injected into the flue gas, it indicates the instantaneous gas flow in SCFM on a mass flow basis. During the injection of water or of a lime slurry, this meter will be used to indicate the flow of treated flue gas without correction for the effects of changed gas properties on the accuracy of these readings.

Figure 1 contains the planar arrangement of the test duct with the locations of the flue gas flow meter, the lime atomizers and the upstream and downstream SO₂, NO_x and O₂ analyzers indicated on it.

Figure 2 contains the flue gas flow diagram showing the location of ESPs, atomizers and instrumentation required for the determination of SO₂ removal and lime utilization.

Figures 3 and 4 contain the laboratory correlation of lime slurry concentrations with their specific gravities at 40°F, 60°F and 72°F.

Figure 1. Test Duct Arrangement

FIGURE - 1
TEST DUCT ARRANGEMENT
 SHOWING RELATIVE LOCATIONS
 OF FLUE GAS FLOW METER,
 LIME SLURRY ATOMIZERS AND
 UPSTREAM AND DOWNSTREAM
 SO₂, NO_x, & O₂ ANALYZERS

Figure 2. Seward CZD System, Test Duct, Flue Gas Flow Diagram

1.3/1.2

"N" Line (HIGH CALCIUM) SPECIFIC GRAVITIES at 72° 60° & 40° F

Figure #4
Correlation of specific gravity of
calcium lime slurry
with lime concentration
and % lime slurry
at different lime slurry
temperatures

lime concentration
lb/gal

lime concentration in lb/gal of slurry

% concentration (wt %)

CZD TESTING AT SEWARD - ESTIMATING PROCEDURE

In order to understand the operation and performance of CZD system we must know:

- The inlet and outlet flue gas flows and their compositions
- The atomizing air usage
- Lime slurry and dilution water injection rates
- Lime slurry concentration

The inlet and outlet flue gas flows are estimated from the flue gas flow meter reading located downstream of the atomizing nozzles at the inlet to the second stage ESP, from the atomizing air and water usage and from inlet and outlet flue gas analysis (SO_2 , NO_x and O_2).

Atomizing air usage is indicated by a flow indicator. Water usage is estimated from measured lime slurry usage and its water content and from the dilution water usage.

Plant air leakage is based on the oxygen mass balance.

In all, there is a set of 5 linear equation to be solved to estimate the actual SO_2 and NO_x removal.

Lime usage and utilization are based on the measured volumes and specific gravities of the lime slurries injected into the flue gas stream and the above estimates of the associated SO_2 and NO_x removals.

MATHEMATICAL PROCEDURE NOMENCLATURE

<u>Description</u>	<u>Symbol</u>	<u>Units</u>
Inlet flue gas flow	F.G. IN	SCFM
Outlet flue gas flow	F.G. OUT	SCFM
Flue gas flow meter reading	F.G.	SCFM
Atomizing air flow meter reading	A.A.	SCFM
Water content of atomized lime slurry (This is estimated from the flow of lime slurry and dilution water and expressed as the flow of water vapor in SCFM)	W.C.	SCFM
SO ₂ absorbed from flue gas	XSO ₂	SCFM
NO _x absorbed from flue gas	YNO _x	SCFM
Air leakage	Z _{al}	SCFM
Oxygen concentration in inlet flue gas	OX _{IN}	Vol %
Oxygen concentration in outlet flue gas	OX _{OUT}	Vol %
SO ₂ concentration in inlet flue gas	SO ₂ IN	$\frac{\text{ppm}}{10^6}(\text{Vol})$
SO ₂ concentration in outlet flue gas	SO ₂ OUT	$\frac{\text{ppm}}{10^6}(\text{Vol})$
NO _x concentration in inlet flue gas	NO _x IN	$\frac{\text{ppm}}{10^6}(\text{Vol})$
NO _x concentration in outlet flue gas	NO _x OUT	$\frac{\text{ppm}}{10^6}(\text{Vol})$

MASS BALANCE EQUATIONS

1. Inlet Flue Gas (FG_{IN}) = Flue gas flow meter reading (FG) less atomizing air meter reading (AA) less water content of lime slurry used (WC) plus SO₂ absorbed (X_{SO2}) plus NO_x absorbed (Y_{NOx}).

$$(FG_{IN}) = (FG) - (AA) - (WC) + (X_{SO2}) + (Y_{NOx})$$

2. Outlet Flue Gas (FG Discharged from ID fan) = Flue gas flowmeter reading (FG) plus air leakage (Z_{AL})

$$(FG_{OUT}) = (FG) + (Z_{AL})$$

3. Oxygen Balance

$$\text{Inlet Flue Gas (FG}_{IN}) \times \frac{\text{Measured O}_2 \text{ Conc. (OX}_{IN})}{100} + \text{Atom. Air} \times 0.21 + Z_{AL} \times 0.21$$

$$= \text{Outlet Flue gas (FG}_{OUT}) \times \frac{\text{Measured O}_2 \text{ Conc. (OX}_{OUT})}{100}$$

$$(FG_{IN}) \times \frac{(OX_{IN})}{100} + (AA) \times 0.21 + (Z_{AL}) \times 0.21 = (FG_{OUT}) \times \frac{(OX_{OUT})}{100}$$

4. SO₂ Balance

$$\text{SO}_2 \text{ absorbed (X}_{SO2}) = \frac{\text{Inlet Flue Gas (FG}_{IN}) \times \text{measured SO}_2 \text{ concentrate (SO}_2 \text{ ppm)}}{\text{Outlet Flue Gas (FG}_{OUT}) \times \text{measured SO}_2 \text{ concentrate (SO}_2 \text{ ppm)}}$$

$$(X_{SO2}) = (FG_{IN}) \times \frac{(SO2_{IN})}{10^6} - (FG_{OUT}) \times \frac{(SO2_{OUT})}{10^6}$$

5. NO_x Balance

$$\begin{aligned} \text{NO}_x \text{ absorbed (Y}_{NOx}) = & \text{inlet flue gas (FG}_{IN}) \times \text{measured NO}_x \text{ concentrate } \frac{\text{NO}_x}{10^6} \\ & - \text{outlet flue gas (FG}_{OUT}) \times \text{measured NO}_x \text{ concentrate } \frac{\text{NO}_x}{10^6} \end{aligned}$$

$$Y_{NO_x} = (FG_{IN}) \times \left(\frac{NO_{x IN}}{10^6} \right) - (FG_{OUT}) \times \left(\frac{NO_{x OUT}}{10^6} \right)$$

There are 5 mass balance equations from which the 5 unknowns (FG_{IN}, FG_{OUT}, X_{SO2}, NO_x, and Z_{AL}) can be estimated. These equations are:

$$(1) \quad (FG_{IN}) = (FG) - (AA) - (WC) + (X_{SO2}) + (Y_{NOx})$$

$$(2) \quad (FG_{OUT}) = (FG) + (Z_{AL})$$

$$(3) \quad (FG_{IN}) \times \frac{(OX_{IN})}{100} + AA \times 0.21 + Z_{AL} \times 0.21 = (FG_{OUT}) \times \frac{(OX_{OUT})}{100}$$

$$(4) \quad (X_{SO_2}) = (FG_{IN}) \times \frac{(SO_2 IN)}{10^6} - (FG_{OUT}) \times \frac{(SO_2 OUT)}{10^6}$$

$$(5) \quad (Y_{NO_x}) = (FG_{IN}) \times \frac{(NO_x IN)}{10^6} - (FG_{OUT}) \times \frac{(NO_x OUT)}{10^6}$$

To eliminate Z_{AL} (air leakage) multiply equation (2) by 0.21 and add it to equation (3)

$$0.21 (FG_{OUT}) = 0.21 (FG) + 0.21 (Z_{AL})$$

$$+ \frac{(FG_{IN}) \times \frac{(OX_{IN})}{100} + 0.21 (AA) = FG_{OUT} \frac{OX_{OUT}}{100} - Z_{AL} \times 0.21}{0.21 (FG_{OUT}) - 0.21 (FG) + (FG_{IN}) \frac{(OX_{IN})}{100} + 0.21 (AA) = (FG_{OUT}) \frac{(OX_{OUT})}{100}}$$

$$(FG_{OUT}) \left[0.21 - \frac{(OX_{OUT})}{100} \right] = -0.21 AA + 0.21 (FG) - (FG_{IN}) \frac{(OX_{IN})}{100}$$

Substituting X_{SO_2} and Y_{NO_x} in Equation (1) by their values from equations (4) and (5) we will get:

$$FG_{IN} = (FG) - (AA) - (WC) + (FG_{IN}) \times \frac{SO_2 IN}{10^6} - FG_{OUT} \times \frac{SO_2 OUT}{10^6}$$

$$+ (FG_{IN}) \frac{NO_x IN}{10^6} - (FG_{OUT}) \frac{NO_x OUT}{10^6}$$

$$FG_{IN} \left(1 - \frac{SO_2 IN}{10^6} - \frac{NO_x IN}{10^6} \right) = FG - AA - WC - \frac{SO_2 OUT}{10^6} + \frac{NO_x OUT}{10^6}$$

$$FG_{IN} \times \frac{OX_{IN}}{10^6} = 0.21 AA + 0.21 FG - FG_{OUT} \left[0.21 - \frac{OX_{IN}}{10^6} \right]$$

$$\frac{1 + \frac{SO_2 IN}{10^6} - \frac{NO_x IN}{10^6}}{\frac{OX_{IN}}{100}} = \frac{FG - AA - WC - (FG_{OUT}) \left[\frac{SO_2 OUT}{10^6} + \frac{NO_x OUT}{10^6} \right]}{-0.21 AA + 0.21 FG - (FG_{OUT}) \left[0.21 - \frac{OX_{OUT}}{100} \right]}$$

$$= \frac{FG - AA - WC - (FG_{OUT}) \left[\frac{SO_2 OUT}{10^6} + \frac{NO_x OUT}{10^6} \right]}{-0.21 (AA + FG) - FG_{OUT} \left[0.21 - \frac{OX_{OUT}}{100} \right]}$$

$$\begin{aligned}
& \frac{1 - \frac{SO_2 IN}{10^6} + \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} [0.21(AA + FG)] = \frac{1 - \frac{SO_2 IN}{10^6} - \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} FG_{OUT} \left(0.21 - \frac{OX_{OUT}}{100} \right) \\
& + FG - AA - WC - FG_{OUT} \left[\frac{SO_2 OUT}{10^6} + \frac{NO_x OUT}{10^6} \right] \\
& FG_{OUT} \left[\frac{1 + \frac{SO_2 IN}{10^6} + \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} \left(0.21 - \frac{OX_{OUT}}{100} \right) - \frac{SO_2 OUT}{10^6} - \frac{NO_x OUT}{10^6} \right] \\
& = \left[\frac{1 - \frac{SO_2 IN}{10^6} - \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} \times [0.21(AA + FG)] - FG + AA + WC \right] \\
& = FG \left[0.21 \frac{1 - \frac{SO_2 IN}{10^6} - \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} - 1 \right] - 0.21 \frac{1 - \frac{SO_2 IN}{10^6} - \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} AA + AA + WC \\
& FG_{OUT} = \frac{FG \left[0.21 \frac{1 - \frac{SO_2 IN}{10^6} + \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} - 1 \right] - 0.21 \frac{1 + \frac{SO_2 IN}{10^6} - \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} + AA + AA + WC}{\frac{1 - \frac{SO_2 IN}{10^6} + \frac{NO_x IN}{10^6}}{\frac{OX IN}{100}} \left(0.21 - \frac{OX_{OUT}}{100} \right) + \frac{SO_2 OUT}{10^6} + \frac{NO_x OUT}{10^6}}
\end{aligned}$$

$$FG_{IN} = \frac{FG - AA - WC - FG_{OUT} \left[\frac{SO_2_{OUT}}{10^6} + \frac{NO_x_{OUT}}{10^6} \right]}{1 - \frac{SO_2_{IN}}{10^6} - \frac{NO_x_{IN}}{10^6}}$$

$$Z_{AL} = FG_{OUT} - FG$$

$$X_{SO_2} = FG_{IN} \times \frac{SO_2_{IN}}{10^6} - FG_{OUT} \times \frac{SO_2_{OUT}}{10^6}$$

$$X_{NO_x} = FG_{IN} \times \frac{NO_x_{IN}}{10^6} - FG_{OUT} \times \frac{NO_x_{OUT}}{10^6}$$

$$\% SO_2 \text{ REMOVAL} = \frac{X_{SO_2}}{FG_{IN} \times SO_2_{IN}} \times 100$$

$$\% NO_x \text{ REMOVAL} = \frac{Y_{NO_x}}{FG_{IN} \times NO_{x_{IN}}} \times 100$$

$$\text{Flue Gas Humidity} = \frac{\text{Lb } H_2O \text{ Vap}}{\text{Lb of Dry Air Equivalent of Flue Gas}} = W$$

$$\text{Relative Humidity} = \frac{P}{P_s} \times 100$$

where:

W = Flue gas humidity

P = Water vapor partial pressure
in flue gas

P_s = Saturated steam pressure at flue
gas temperature

$$P = \frac{\text{Relative Humidity} \times P_s}{100}$$

$$W = \frac{18.016 p}{18.967 (P - p)}$$

DETERMINING LIME USAGE

Basis:

There is no data available for correlating the specific gravity of dolomitic hydrate slurries with their hydrate content. Local laboratory will measure specific gravities of dolomitic lime slurries and their hydrate contents at 40°F, 60°F and 80°F and prepare a chart showing the dependence of specific gravity on hydrate concentration at the above temperatures.

During the test runs the actual dolomitic lime usage will be determined by:

- measuring the specific gravity and temperature of the lime slurry in the feed tank
- using the laboratory correlation of the specific gravity with the hydrate concentration to determine the hydrate content of this slurry
- dipping the lime feed tank to determine the volume of the lime slurry and, hence, the amount of lime hydrate used

DETERMINATION OF SPECIFIC GRAVITY OF THE DOLOMITIC LIME SLURRY IN THE LIME FEED TANK

This tank handles up to 20 WT% of lime slurries which are too viscous for determining their specific gravity with a simple hydrometer. However, a hydrometer could be used to determine specific gravity of 20% lime slurry after threefold dilution with water.

Method

Take 100 ml sample of concentrated slurry, weigh it and dilute it with 200 ml of water to a total volume of 300 ml. Measure its specific gravity and then calculate the specific gravity of original sample as follows:

Calculations:

Suppose that 100 ml of original sample weight equals 112.5 gm and that after mixing it with 200 ml of water it has specific gravity equals 1.04 at 80°F.

This specific gravity (from the graph of concentrated vs specific gravity) corresponds to the lime concentrate of 7.3%.

$$\therefore \frac{\text{Lime content of original sample}}{\text{WT of 100 ml of original sample} + 200} \times 100 = 7.3$$

Lime content of original sample = 0.073 (weight of original sample + 200)

Concentration of lime in original sample: =

$$\begin{aligned} &= \frac{0.073 (\text{Wt. of original sample} + 200)}{\text{WT of original sample}} \times 100 \\ &= \frac{0.073 (112.5 + 200)}{112.5} \times 100 = 20.28 \text{ Wt. \%} \end{aligned}$$

Lime concentrated below 10 Wt. % can be measured using hydrometer to determine their specific gravity and then a chart of specific gravity vs. concentrate. To determine slurry concentrate, the lime feed pumps will recirculate 100 GPM of 20 Wt% lime slurry of which about 20 GPM will be fed to the atomizers and about 80 GPM returned to the feed tank. The two lime slurry feed pumps will use up to 1-1/2 GPM of seal water, 80% of which will enter the lime feed tank resulting in progressive dilution of its content. In order to account for it the concentrate of lime slurry in the feed tank should be checked at least twice for each test. The first check should be when lime injection starts and the second check when it stops.

"N" LINE (HIGH CALCIUM) SPECIFIC GRAVITIES at 72° 60° & 40° F

Lime concentration in lbs/gal of slurry

LIME CONCENTRATION
lb/gal

CONCENTRATION (wt %)

Lime Usage = (Content of lime feed tank at the start of test run in gallon) x 8.328 x (its specific gravity) x (corresponding slurry concentrate) - content of lime feed tank at the end of test run in gallon) x 8.326 x (FLS specific gravity) x (corresponding slurry concentrate)

Example: Estimate of lime content of the lime slurry in the lime feed tank at the start of test:

Tank diameter = 12'-0"
Slurry Depth = 10'-0" (by tank dipping)

$$\therefore \text{Volume of slurry} = \frac{12^2 \pi}{4} \times 10 = 1,130^4 \text{ cu. ft.}$$

$$= 8,455.4 \text{ GAL.}$$

Specific gravity of slurry = 1.125 (at 60°F, measured)

Corresponding lime concentrate = 19.5 wt % (from the chart relating specific gravity to concentrate)

$$\therefore \text{Lime content of the feed tank at the start of test} = 8,455.4 \times 8.328 \times 1.125 \times 0.195 = 15,447.6 \text{ lbs.}$$

Estimate of lime content of the lime slurry in the lime feed tank at the end of test:

Slurry Depth = 5'9 $\frac{3}{8}$ " (by tank dipping)

$$\therefore \text{Volume of Slurry} = \frac{12^2 \pi}{4} \times 5.7792 \times 7.48 = 4,961.4 \text{ Gal.}$$

Specific gravity of slurry = 1.12

Corresponding lime concentrate = 18.9 WT %

$\therefore$ Lime content of the feed tank at the end of test

$$= 4,961.4 \times 8.328 \times 1.12 \times 0.189 = 8,614.3 \text{ lbs.}$$

$$\text{Hence lime used} = 15,447.6 - 8,614.3 = 6,833 \text{ lbs.}$$

Average concentration of lime slurry used

$$= \frac{6,833}{8,455.4 - 4,886.5 + 307.5}$$

Estimated volume of seal water used by P-102A and P-102B during the test.

$$= 1,7627 \text{ lbs of lime hydrate/gallon of slurry corresponding to slurry concentrate of 18.9 WT\% from the chart.}$$

$$\text{Lime utilization} = \frac{\text{Mols SO}_2 \text{ ABS} = \frac{1}{2} \text{ Mols NO}_x \text{ ABS}}{\text{Mols of lime used}}$$

$$\text{Mols SO}_2 \text{ ABS} = \frac{X_{\text{SO}_2}}{379.5}$$

$$\text{Mols NO}_x \text{ ABS} = \frac{Y_{\text{NO}_x}}{379.5}$$

Mols of lime used

$$= \frac{\text{WT of lime hydrate} \times 0.385}{58} + \frac{\text{WT of lime hydrate} \times 0.57}{74}$$

$$= \text{WT of lime hydrate used} (0.0066 + 0.0077)$$

$$= \text{WT of lime hydrate used} \times 0.0143$$

TEST DATA
10/10/91

Flue gas flow meter reading = 260,000 SCFM = FG = C
 Atomizing air flow meter reading = 1,350 SCFM = AA = D
 Water content of lime slurry = 5,180 SCFM = WC = E

Concentrate = 3.4 WT%
 Specific Gravity = 1.018 at 60°F
 Flow = 30 gpm

$$WC = 30 \times 8.328 \times 1.018 \times 0.966 = 245.7 \text{ lb/mid} = 5,180 \text{ SCFM}$$

Inlet SO₂ concentrate in ppmv = 905.81 ppmv = SO₂ IN = F
 Outlet SO₂ concentrate in ppmv = 703.87 = SO₂ OUT = G
 Inlet NO_x concentrate in ppmv = 383.25 = NO_x IN = H
 Outlet NO_x concentrate in ppmv = 313.87 = NO_x OUT = I
 Inlet O₂ concentrate in Vol. % = 6.16 = O₂ IN = J
 Outlet O₂ concentrate in Vol. % = 7.41 = O₂ OUT = K

$$FG_{OUT} = \frac{FG \left[.21 \frac{1 + SO_2 IN + NO_x IN}{\frac{O_x IN}{100}} - 1 \right] + AA \left[1 - 0.21 \frac{1 + SO_2 IN + NO_x IN}{\frac{O_x IN}{100}} \right] + WS}{\frac{1 + SO_2 IN + NO_x IN}{\frac{O_x IN}{100}} \left(0.21 - \frac{O_x OUT}{100} \right) + SO_2 OUT + NO_x OUT}$$

$$= \frac{260,000 \left[.21 \frac{1.0012891}{0.0616} - 1 \right] + 1,350 \left[1 - 0.21 \frac{1.0012891}{0.0616} \right] + 5,180}{\frac{1.0012891}{0.0616} (0.21 - 0.0741) + 0.00070387 + 0.000313851}$$

$$= \frac{627,506.2 + 3,258.2 + 5,180}{2.2090 + 0.00101774} = \frac{629,428}{2.2100} = 284,809 \text{ SCFM}$$

$$\text{Inlet FG} = FG_{IN} = \frac{FG - AA - WC - FG_{OUT} (SO_2 OUT + NO_x OUT)}{1 + SO_2 IN - NO_x IN}$$

$$= \frac{260,000 - 1,350 - 5,180 - 284,809 (0.00070367 + 0.00031387)}{1 - 0.00090581 - 0.00038325}$$

$$= \frac{253,470 - 289.9}{0.9987109}$$

$$= 253,506 \text{ SCFM}$$

$$\begin{aligned}
 \text{Air Leakage} &= Z_{AL} = FG_{OUT} - FG \\
 &= 284,809 - 260,000 \\
 &= 24,809 \text{ SCFM}
 \end{aligned}$$

$$\begin{aligned}
 SO_2 \text{ Removed} &= FG_{IN} \times SO_2 \text{ IN} - FG_{OUT} \times SO_2 \text{ OUT} \\
 &= 253,506 \times 0.00090581 - 284,809 \times 0.00070387 \\
 &= 229.63 - 200.47 \\
 X_{SO_2} &= 2916 \text{ SCFM}
 \end{aligned}$$

$$\begin{aligned}
 NO_3 \text{ Removed} &= FG_{IN} \times NO_{xIN} - FG_{OUT} \times NO_{xOUT} \\
 &= 253,506 \times 0.00038325 - 284,809 \times 0.00031387 \\
 Y_{NOx} &= 97.16 - 89.39 + 7.76 \text{ SCFM}
 \end{aligned}$$

$$\% SO_2 \text{ Removal} = \frac{X_{SO_2}}{FG_{IN} \times SO_2 \text{ IN}} \times 100 = \frac{29.16}{229.56} \times 100 = 12.7\%$$

$$\% NO_x \text{ Removal} = \frac{Y_{NO_x}}{FG_{IN} \times NO_{xIN}} \times 100 = \frac{7.76}{97.13} \times 100 = 8.00\%$$

Estimate of lime usage:

30 gpm of 3.4 WT% lime slurry

$$\text{SP GT at } 60^\circ\text{F} = 1.018$$

$$\begin{aligned}
 \text{Ca(OH)}_2 \text{ Used} &= 30 \times 8.328 \times 1.018 \times 0.034 \\
 &= 8.6475 \text{ lb/minute}
 \end{aligned}$$

Assume 95.5% purity

$$= \frac{8.6475 \times 0.955}{74}$$

$$= 0.1116 \text{ lb Mol/minute}$$

$$SO_2 \text{ Removed} = \frac{29.16}{379} = 0.0769 \text{ Lb Mol/minute}$$

$$NO_x \text{ Removed} = \frac{7.76}{379} = 0.0204 \text{ Lb Mol/minute}$$

$$\text{Lime Utilization} = \frac{0.0769 \times \frac{0.0204}{2}}{0.1116} \times 100 = 78.07\%$$

TEST DATA
10/11/91

Flue gas Flow Meter Reading = 268,000 SCFM

Atomizing Air Meter Reading = 1,350 SCFM

Water Content of Lime Slurry = 5,127 SCFM

Concentrate = 5.5 WT %

Sp Gr = 1.03 at 60° F

Flow = 30 gpm

W.C. = $30 \times 8.328 \times 1.03 \times 0.945 = 243.18 \text{ Lb/Min}$
= 5,127 SCFM

Inlet SO₂ Concentrate = 868.56 ppm

Outlet SO₂ Concentrate = 660.49 ppm

Inlet NO_x Concentrate = 400.23 ppm

Outlet NO_x Concentrate = 328.05 ppm

Inlet O₂ Concentrate = 6.32%

Outlet O₂ Concentrate = 7.38%

$$\begin{aligned}
 FG_{OUT} &= \frac{268,000 \times \left[\frac{1.0012688}{0.0623} - 1 \right] + 1,350 \left[1 - .21 \times \frac{1.0012688}{0.0623} \right] + 5,127}{\frac{1.0012688}{0.0623} (.21 - 0.0738) + 0.00066049 + 0.000328.05} \\
 &= \frac{636,517.0 - 3,206.3 + 5,127}{2,1890 + 0.0009885} = \frac{638,437.7}{2.1900} \\
 &= 291,524 \text{ SCFM}
 \end{aligned}$$

$$\begin{aligned}
 FG_{IN} &= \frac{FG - AA - WC + FG_{OUT} (SO_{2\ OUT} + NO_{x\ OUT})}{1 + SO_{2\ IN} + NO_{x\ IN}} \\
 &= \frac{268,000 - 1,350 - 5,127 + 295,690.7 (0.00066049 + 0.00032805)}{1 + 0.00086856 + 0.00040023} \\
 &= \frac{261,523 + 292.3}{0.9987312} \\
 &= 261,562 \text{ SCFM}
 \end{aligned}$$

$$\begin{aligned}
 \text{Air Leakage} = Z_{AL} &= FG_{OUT} - FG \\
 &= 241,524 - 268,000 \\
 &= 23,524 \text{ SCFM}
 \end{aligned}$$

$$\begin{aligned}
 \text{SO}_2 \text{ Removed} &= FG_{IN} \times \text{SO}_2 \text{ IN} - FG_{OUT} \times \text{SO}_2 \text{ OUT} \\
 &= 261,562 \times 0.00086856 - 291,524 \times 0.0006604 \\
 &= 227.18 - 192.55 \\
 &= 34.63 \text{ SCFM}
 \end{aligned}$$

$$\begin{aligned}
 \text{NO}_x \text{ Removed} &= 261,562 \times 0.00040023 - 291,524 \times 0.00032805 \\
 &= 104.68 - 95.63 \\
 &= 9.05 \text{ SCFM}
 \end{aligned}$$

$$\% \text{ SO}_2 \text{ REMOVAL} = \frac{34.63}{227.18} 100 = 15.24\%$$

$$\% \text{ NO}_x \text{ REMOVAL} = \frac{9.05}{104.68} 100 = 8.65\%$$

Estimate of Lime Usage

30 gpm of 5.5 WT% lime slurry

Sp Gr = 1.03

$$\begin{aligned}
 30 \times 8.328 \times 1.03 \times 0.55 &= 14.15 \text{ Lb/Hr} \\
 &= 13.5 \text{ Lb of pure Ca (OH)}_2 \\
 &= 0.1827 \text{ Lb Mol/Minute}
 \end{aligned}$$

$$\text{SO}_2 \text{ Removed} = \frac{34.63}{379.5} = 0.0913 \text{ Lb Mol/Minute}$$

$$\text{NO}_x \text{ Removed} = \frac{9.05}{379.5} = 0.0238 \text{ Lb Mol/Minute}$$

$$\begin{aligned}
 \text{Lime Utilization} &= \frac{0.0913 + \frac{0.0238}{2}}{0.1827} 100 \\
 &= 56.50\%
 \end{aligned}$$

TEST DATA
10/14/91

$$\text{FG} = 252,000 \text{ SCFM}$$

$$\text{AA} = 1,350 \text{ SCFM}$$

$$\text{Water Content of Lime Slurry} = 5,054 \text{ SCFM}$$

$$\begin{aligned}\text{Concentrate} &= 8 \% \\ \text{Sp Gr} &= 1.043\text{F} \\ \text{Flow} &= 30 \text{ gpm}\end{aligned}$$

$$\begin{aligned}\text{W.C.} &= 30 \times 8.328 \times 1.03 \times 0.92 = 239.74 \text{ Lb/Min} \\ &= 5,054 \text{ SCFM}\end{aligned}$$

$$\text{Inlet SO}_2 \text{ Concentrate} = 891.1 \text{ ppm}$$

$$\text{Outlet SO}_2 \text{ Concentrate} = 665.9 \text{ ppm}$$

$$\text{Inlet NO}_x \text{ Concentrate} = 423.9 \text{ ppm}$$

$$\text{Outlet NO}_x \text{ Concentrate} = 326.6 \text{ ppm}$$

$$\text{Inlet O}_2 \text{ Concentrate} = 6.2\%$$

$$\text{Outlet O}_2 \text{ Concentrate} = 7.52\%$$

$$\text{FG}_{\text{OUT}} = \frac{252,000 \left[.21 \times \frac{1.001315}{0.062} - 1 \right] + 1,350 \left[1 - .21 \times \frac{1.001315}{0.062} \right] + 5,000}{\frac{1.001315}{0.062} (0.21 - 0.0738) + 0.000659 + 0.0003266}$$

$$= \frac{602,670.8 - 3,228.6 + 5,054}{2.1771 + 0.0009925} = \frac{604,496.2}{2.1781}$$

$$= 277,534.7 \text{ SCFM}$$

$$\text{FG}_N = \frac{252,000 - 1,350 - 5,054 + 277,534.7 (0.0006659 + 0.0003266)}{1 + 0.000891.1 - 0.000423.9}$$

$$= \frac{245,320}{0.9987} = 245,643 \text{ SCFM}$$

$$\text{Air Leakage} = Z_{AL} = \text{FG}_{\text{OUT}} - \text{FG}$$

$$= 277,534 - 252,000$$

$$= 25,534 \text{ SCFM}$$

$$\text{SO}_2 \text{ Removed} = \text{FG}_{\text{IN}} \times \text{SO}_2 \text{ IN} - \text{FG}_{\text{OUT}} \times \text{SO}_2 \text{ OUT}$$

$$= 245,643 \times 891.1 - 277,535 \times 665.9$$

$$= 218.89 - 184.81$$

$$= 34.08 \text{ SCFM}$$

$$\text{NO}_x \text{ Removed} = 245,643 \times 423.9 - 277,535 \times 326.6$$

$$= 104.13 - 10.64$$

$$= 13.49 \text{ SCFM}$$

$$\% \text{ SO}_2 \text{ REMOVAL} = \frac{34.08}{218.89} 100 = 15.57\%$$

$$\% \text{ NO}_x \text{ REMOVAL} = \frac{13.49}{104.13} 100 = 12.95\%$$

Estimate of Lime Usage

30 gpm of 8 WT% lime slurry

$$\text{Sp Gr} = 1.043$$

$$\text{Purity} = 95.5\%$$

$$30 \times 8.328 \times 1.043 \times 0.08 \times 0.955 = 19.9 \text{ Lb/Min} = 0.269 \text{ Lb Mol/Minute}$$

$$\text{SO}_2 \text{ Removed} = \frac{34.08}{379.5} = 0.0898$$

$$\text{NO}_x \text{ Removed} = \frac{13.49}{379.5} = 0.0355$$

$$\text{Lime Utilization} = \frac{0.0898 + \frac{0.0355}{2}}{0.259} = 40\%$$

END

**DATE
FILMED**

10 / 13 / 93