

Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology By-Products

**Quarterly Report
December 30, 1996 - March 30, 1997**

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For
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EXECUTIVE SUMMARY

During the sixth quarter of Phase 2, work continued on conducting laboratory analyses and scholarly work, preparing for field work, proposing presentations, and making additional outside contacts.

Laboratory Analyses

Planning and preparatory work was initiated for Phase 2 laboratory work.

Scholarly Work

One graduate student completed her thesis and another joined the project team to begin hers.

Preparation for Field Work

MAX Environmental Technologies, Inc., was contacted to rejoin the project team and assign the field work to its Mill Service Yukon Plant. MAX Environmental responded positively and is examining the business and technical elements of taking this step.

Reports and Presentations

Two proposals were submitted to present the results of Phase 1 at technical meetings later in 1997.

Outside Contacts

Advice was provided to the Electric Power Research Institute on the presence of sodium in ash from several utility boilers.

Dravo Lime Company provided the project team with a paper describing the Carneys Point Generating Plant.

Plans for the Next Quarter

During the quarter from March 30, 1997 through June 30, 1997, work will continue on Tasks 4 and 5 of Phase 1.

Work on Task 1 of Phase 2 will continue. The principal investigator will maintain contact with MAX Environmental Technologies, Inc., to seek their formal return to the project team and to monitor their business and technical investigations leading to the preparation of the test plan for Phase 2. The test plan will include the detailed plan for the field work and related laboratory activities.

The new graduate student will continue scholarly work during this quarter. A new Graduate Student Researcher will be assigned part time to assist in the work of developing the test plan which is anticipated to begin this quarter.

INTRODUCTION

This tenth quarterly report describes work done during the tenth three-month period of the University of Pittsburgh's project on the "Treatment of Metal-Laden Hazardous Wastes with Advanced Clean Coal Technology By-Products."

This report describes the activities of the project team during the reporting period. The principal work has focussed upon continuing evaluation of aged samples from Phase 1, planning supportive laboratory studies for Phase 2, completing scholarly work, reestablishing MAX Environmental Technologies, Inc., as the subcontractor for the field work of Phase 2, proposing two presentations for later in 1997, and making and responding to several outside contacts.

LABORATORY AND FIELD WORK

Laboratory Analyses

Phase 2 laboratory work at the University of Pittsburgh was begun during this quarter. The work consisted of preparing for continued evaluation of aged samples from Phase 1 and planning supportive studies for Phase 2.

Solidification Testing of Treatment Residue

Laboratory work on this topic has been suspended until a test plan has been approved.

Metals Analysis of Treatment Residue

Jana Agostini, a graduate student in the Civil and Environmental Engineering Department, has begun to prepare the environmental laboratories on the ninth floor of Benedum Hall for resumption of TCLP leaching and leachate metals analysis of aged Phase 1 treatment residues. Ms. Agostini participated in Phase 1 of the project as an undergraduate student.

Scholarly Activity

Ms. Clifford completed her M.S. thesis, entitled "The Stabilization of a Hazardous Sandblast Waste with Advanced Clean Coal Technology By-Products." Professor Cobb served as the major advisor for this presentation.

Ms. Agostini has begun to structure her M.S. thesis activities, which will support work on Phase 2. Her initial directions include:

1. Set up a laboratory and protocol to shadow the evaluation and leaching of samples that may be provided by MAX Environmental Technologies, Inc. Leaching procedures will include ASTM-A, EPA-TCLP and the "synthetic precipitation procedure" [also outlined in the RCRA regulations but not often used except as mandated by Act-2 in Pennsylvania for determining leachable heavy metal levels in wastes that may exceed "statewide health standards."]
2. Conduct a literature review on the basic science of stabilization and solidification reactions.
3. Develop a table of chemical additives that may be used to enhance the stabilization of certain metals. For example, phosphates (in the form of TSP or phosphoric acid) are often used for lead.

4. Leach the treatment residues from Phase 1 and analyze the leachates. Examine long-term stabilization. Does sulfate interaction (ettringite) over time cause an increase in metal mobility from the solid to the liquid phase? Does the non-hazardous residue become hazardous over time?

Preparation for Field Work

In mid-January 1997 the principal investigator and the contracting officer's representative (COR) for this project discussed options for field work of Phase 2. After nine months of effort it had become apparent that a number of barriers were present to identifying a replacement for Mill Service, Inc., as the subcontractor for the field work:

- distance from and inexperience with the prime contractor
- lack of technical or economic incentives
- regulatory concerns
- press of competing projects.

The COR suggested recontacting Mill Service, Inc. The PI did so and the response was very encouraging. During the past year Mill Service, Inc., and its sister company, held by a sole proprietor, have reorganized and assumed a new corporate name, MAX Environmental Technologies, Inc. The "Mill Service" name has been maintained in the name of the treatment site at Yukon, Pennsylvania — the Mill Service Yukon Plant, and the "M" in the "MAX" acronym derives from "Mill Service." The business plan for the new corporation continues to call for adding treatment technologies utilizing dusty chemicals to the Mill Service Yukon Plant, and the permit modification application to allow this is still active with the Pennsylvania Department of Environmental Protection.

On February 11, 1997 the project team visited MAX Environmental Technologies, Inc. Philip Constantini, Vice President, and Hank Springer, Director of Engineering, represented MAX Environmental at the meeting. MAX Environmental is experiencing major shifts in the waste streams that are offered to them for treatment or that they might seek out for treatment. They also are always looking for new inexpensive treatment chemicals. A key handability property of clean coal technology by-products as treatment chemicals is their dustiness, but that is also a principal property of a growing percentage of wastes that may become available for treatment in the future. MAX Environmental is beginning an examination of this situation, because the permit application for the use of dusty chemicals has been under review for some time now and the permit should be issued soon. Mr. Constantini said that MAX Environmental would give careful consideration to returning to the project team. He expressed appreciation for this discussion, because it stimulated many good ideas about the direction their business might take.

Following the meeting on February 11, Mr. Springer sought and obtained several cost estimates for handling finely divided, dry chemicals and wastes. He also began to estimate the market in the surrounding ten states for treatment of finely divided, dry wastes. This information is necessary for MAX Environmental to make a decision on this new line of business and on rejoining the project. At the end of the quarter this decision remains in the future.

Anticipating a need to develop a task plan and to initiate field work, Wiles Elder, a graduate student in the Energy Resources Program, has been designated to spend part-time on the project in the coming months. Mr. Elder is a Graduate Student Researcher working on the project on "Wood/Coal Cofiring in Industrial Stokers in Pittsburgh," sponsored at the University by the U.S. Forest Service.

REPORTS AND PRESENTATIONS

Mr. Pritts and Ms. Clifford have begun drafting papers for publication in the open literature, describing their theses and the project topic in general.

Confirmation was received during this quarter of the publication of the paper which the coprincipal investigator presented in Singapore last year. Entitled "Hazardous Waste Stabilization with Clean-Coal Technology Ash Residuals," it appears in *Water Science and Technology*, volume 34, number 10, pages 179-185, 1996.

On February 28, 1997, the principal investigator sent a proposal to present a paper at the 1997 Ash Utilization Symposium on October 20-22, 1997, in Lexington, Kentucky. The title of the paper is "Laboratory Evaluation and Commercial Demonstration of Hazardous Waste Treatment Using Clean Coal Technology By-Products." Its abstract is:

One element of the laboratory portion of this project was a standard hazardous waste treatability study. Several samples of three clean coal technology by-products were collected from commercial operations under steady state conditions. They were reacted at bench-scale with seven metal-laden hazardous wastes, which were presented to Mill Service, Inc., for commercial stabilization. Of the 15 heavy metals monitored, lead appeared as the element of significant concern. In addition, the unconfined compressive strength of the solidified stabilized products was continually measured over a 90-day period. Results show that certain types of hazardous wastes are highly amenable to chemical stabilization, while others are not. Certain by-products provided superior stabilization, but did not allow for strength generation over time.

Another element of the laboratory portion of this project was the evaluation of the microstructure of a spray dryer by-product, a sand-blast waste and the product of stabilization of the sand-blast waste with the spray dryer by-product. Both scanning electron microscopy and x-ray diffraction were used. The dominant mechanism responsible for stabilization of this system was discovered to be physical encapsulation.

The commercial demonstration of this technology is still to be launched. Several hazardous waste treaters have been approached. At the date of this abstract (March 1, 1997) one treatment plant operator is making a final determination of the feasibility of joining this effort. By the time of the presentation, the project team expects the demonstration to be in or nearing operation. The presentation will provide observations on the problems faced by hazardous waste treaters to make changes in their operations, and will present selected information obtained to that point during the demonstration, if it has begun.

On March 17, 1997, the principal investigator sent a proposal to present a paper at the 29th Mid-Atlantic Industrial & Hazardous Waste Conference on July 13-16, 1997, in Roanoke,

Virginia, entitled "Preparation of a Commercial Test of the Treatment of Metal-Laden Hazardous Wastes with Clean Coal Technology By-Products. Here is the abstract for this paper:

The University of Pittsburgh is conducting a program, sponsored by the U.S. Department of Energy, leading to a commercial test of the use of advanced clean coal technology by-products as treatment chemicals for the stabilization of metal-laden hazardous wastes. The first phase of the program, a treatability study at the bench-scale, has been completed. Seven wastes, whose principal element of concern was lead, and three by-products were examined. Results show that certain types of hazardous wastes are highly amenable to chemical stabilization, while others are not. Organizing the commercial test of successful treatments has proven difficult. Several hazardous waste treaters have been approached. At the date of this abstract (March 17, 1997) one treatment plant operator is making a final determination of the feasibility of joining this effort. Several types of barriers to commercialization have been found. They include concerns over long-term liability, public exposure during permitting, business competition, capital requirements, and long-term economic viability. These barriers will be discussed in detail.

OUTSIDE CONTACTS

American Society for Testing and Materials

The principal investigator informed the E50.03 subcommittee of the American Society for Testing and Materials (ASTM), that, because of other obligations and the delay in Phase 2 of this project, he will suspend his activity with the subcommittee until Phase 2 is underway.

Electric Power Research Institute

In response to a question from Dean Golden at the Electric Power Research Institute, regarding increased sodium content of ash from PSI Colorado, the principal and coprincipal investigators of the project informed EPRI of the practice of some utilities to add sodium carbonate to coal being fed to large boilers in order to extend the cycle time of the electrostatic precipitators. The addition of sodium may lower the melting point of the ash from the flame and create slagging conditions, fouling of boiler tubes and changes in the final ash properties. This might explain some of the prior experience the coprincipal investigator had with some Ohio Edison ash that was "mush-like" after being repeatedly exposed to water.

Miscellaneous Topics in Coal Combustion By-Product Utilization

Joel Beegly of Dravo Lime Company provided the project team with an article he obtained at the Twelfth International Symposium on Management & Use of Coal Combustion Byproducts, held by the American Coal Ash Association in late January in Florida. The paper, entitled "Trip Report on U.S. Generating Company Carneys Point Generating Plant Selective Catalytic Reduction and Lime/Spray Dryer FGD," is reproduced in Appendix A.

ADMINISTRATIVE ASPECTS

This section describes one special action and provides monthly highlights and a comparison of progress with the milestone chart.

Special Actions

The principal investigator received a request from Radian International to provide assistance in assembling materials for updating the Fossil Energy Waste Management (FE WM) Office's 1995 "Technology Status Report" to provide current information on the status, schedule, and findings of projects funded through FE WM. Radian has asked for any summary fact sheets, press releases, or papers for other purposes which the project team may want to link to the FETC webpage, or which Radian may be able to use to develop current materials for the status report. Radian has also asked for any information on revisions to the project's schedule and scope. Finally, Radian has asked for a current list of publications, patents, or other materials resulting from the project.

Monthly Highlights

Here are the highlights of the sixth three month period of the second phase of the project.

December 30, 1996 - January 30, 1997

- Ms. Clifford successfully defends her M.S. thesis, entitled "The Stabilization of a Hazardous Sandblast Waste with Advanced Clean Coal Technology By-Products."
- Jana Agostini rejoins the project team as a Graduate Student Researcher.
- Contracting Officer's Representative suggests contacting MAX Environmental Technologies, Inc., about rejoining the project team.

January 30 - February 28, 1997

- MAX Environmental Technologies, Inc., agrees to consider rejoining the project team.

February 28 - March 30, 1997

- Two proposals are submitted to present papers describing Phase 1 of the project at the 29th Mid-Atlantic Industrial & Hazardous Waste Conference and the 1997 Ash Utilization Symposium.

Comparison of Progress with Milestone Chart

The following task for Phase 2 had been scheduled for completion during the first quarter of Phase 2:

- Task 1 - Test Plan for Phase 2

Task 1 still was not completed during the sixth period of this phase. The decision in early April 1996 by METC that an environmental assessment of the Phase 2 project at the Yukon plant of Mill Service, Inc., would have to be conducted and the subsequent withdrawal in late April 1996 by MSI from Phase 2 necessitated a search for a new subcontractor to host and participate in the commercial test of Phase 2. MAX Environmental Technologies, Inc., has agreed to consider rejoining the project team and conducting Phase 2 at its Mill Service Yukon Plant. MAX Environmental is beginning to plan modifications at the Yukon Plant to enable it to enter this business area and carry out the field work on this project. The test plan for Phase 2 will be prepared when the "new" subcontractor is aboard and can provide the project team with specific information about the system ultimately to be employed in Phase 2.

Work continued on two tasks from Phase 1:

- Task 4 - Treatment of Metal-Laden Waste with CCT Solid By-Product
- Task 5 - Data Analysis

Work on Tasks 4 and 5 of Phase 1 will continue into the seventh quarter of Phase 2. The fourth by-product and the final three residues are no longer being actively sought. When the Phase 2 testing program is initiated, consideration will be given to reestablishing this activity.

PLAN FOR THE NEXT QUARTER

During the quarter from March 30, 1997 through June 30, 1997, work will continue on Tasks 4 and 5 of Phase 1.

Work on Task 1 of Phase 2 will continue. The principal investigator will maintain contact with MAX Environmental Technologies, Inc., to seek their formal return to the project team and to monitor their business and technical investigations leading to the preparation of the test plan for Phase 2. The test plan will include the detailed plan for the field work and related laboratory activities.

The new graduate student will continue scholarly work during this quarter. A new Graduate Student Researcher will be assigned part time to assist in the work of developing the test plan which is anticipated to begin this quarter.

APPENDIX A

TRIP REPORT ON U.S. GENERATING COMPANY CARNEYS POINT GENERATING PLANT SELECTIVE CATALYTIC REDUCTION AND LIME/SPRAY DRYER FGD

96FGT-2

TRIP REPORT

on

U.S. GENERATING COMPANY
CARNEYS POINT GENERATING PLANT
SELECTIVE CATALYTIC REDUCTION AND
LIME/SPRAY DRYER FGD

By: H. S. Rosenberg
J. Schlaechter

Date of Trip: August 13, 1996

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GUILD ASSOCIATES, INC.
4089 North Leap Road
Hilliard, Ohio 43026

Trip Number: 96FGT-2

Date of Trip: August 13, 1996

Purpose of Trip: To assess the SCR systems and the lime/spray dryer FGD systems on the Carneys Point Generating Plant, U.S. Generating Company, Carneys Point, NJ.*

Persons Interviewed: Nazre G. Adum, Environmental Superintendent, Carneys Point Generating Plant, U.S. Generating Company.

Summary: U.S. Generating Company installed Foster Wheeler/IHI SCR systems and Joy Environmental Technologies lime/spray dryer FGD systems on the Carneys Point Generating Plant at the time the plant was put into service. The plant consists of two 50 percent capacity boilers rated at a total of 224 MWe net, and provides up to 1×10^6 lb/hr of process steam to the Chambers Works of DuPont. The fuel is coal from Pennsylvania, and contains about 2.0 percent sulfur. The emission regulations are 100 ppm NO_x and 100 ppm SO_2 on a 3 hr rolling average. The particulate emission regulation is 52.4 lb/hr, or about 0.018 lb/ 10^6 Btu. The boiler has low NO_x burners and staged combustion to reduce the NO_x concentration to the SCR system to a design value of 196 ppm.

The SCR systems are located between the economizer and the air preheater on each boiler. Each system consists of one reactor containing an IHI ceramic honeycomb catalyst with a pitch of 7.4 mm. Aqueous ammonia (27 wt percent NH_3) is used to provide the reducing agent. The design NO_x removal efficiency is 63 percent at a space velocity of $4,000 \text{ hr}^{-1}$. The design NH_3 slip is ≤ 5 ppm after 56,000 hr of operation. The oxidation of SO_2 to SO_3 is designed to be ≤ 1.0 percent. The SCR system does not have a bypass. There is a bypass around the economizer to maintain the SCR inlet flue gas temperature above 610 F at reduced boiler loads.

The FGD system on each boiler consists of one spray dryer and a reverse air baghouse. Fly ash is removed in the baghouse together with the solids from the spray dryer. The gross air-to-cloth ratio is 1.6 ft/min, and the particulate removal efficiency is 99.9 percent. Each spray dryer has a single rotary atomizer from Joy. The overall SO_2 removal efficiency is 93 percent at a stoichiometric ratio of 1.5 moles of $\text{Ca}(\text{OH})_2$ per mole of inlet SO_2 , a solids recycle ratio of 5:1, and a 35 F approach to the adiabatic saturation temperature. The solids from the baghouse are trucked to central Pennsylvania where they are used for mine reclamation. The spray dryers do not have a bypass, but the baghouses do. To protect the flue, hot air from the outlet of the air preheater is used to reheat the flue gas to 180 F.

* The information contained in this report is based on information supplied to Guild Associates by U.S. Generating Company personnel and is believed to be substantially correct unless so noted in the text.

The plant began commercial operation with the SCR and FGD systems in March, 1994. The availability of the SCR systems is >99 percent and the availability of the FGD systems is >99 percent. Deposits on the spray dryer walls require periodic cleaning. The capital and operating costs of the SCR and FGD systems are proprietary.

Details:

The Carneys Point Generating Plant (refer to Figure 1) is located near the Delaware River in Carneys Point, New Jersey. The plant is fueled with high quality pulverized coal containing about 2.0 percent sulfur. Most of the plant's electric output is sold through Atlantic Electric. The plant is on the grounds of DuPont's Chambers Works, which buys up to 1×10^6 lb of process steam per hr and up to 40 MW of electricity. The Carneys Point cogeneration plant was developed, and is now managed, by U.S. Generating Company, a partnership of PG&E Enterprises (the non-utility subsidiary of Pacific Gas & Electric Company) and Bechtel Enterprises Inc. (a unit of Bechtel Group Inc.).

The Chambers Works gets all of its steam and electricity from Carneys Point, and all of the wastewater from Carneys Point is sent to the Chambers Works for treatment. Because the Chambers Works is totally dependent on Carneys Point for its steam and electricity, reliability was critical in the design of the cogeneration plant. Therefore, the cogeneration plant has two boilers, each rated at 1.2×10^6 lb steam/hr. Also, the plant is designed to run on fuel oil if there is an interruption in the coal supply. Both boilers feed a high pressure turbine and a low pressure turbine that drive a single generator. Each boiler has an SCR system for NO_x control, a spray dryer FGD system for SO_2 control, and a baghouse (fabric filter) for particulate control. There is zero liquid discharge from the plant. Wastewater is sent to the Chambers Works.

Carneys Point is the first coal-fired plant in the U.S. to use an SCR system on a fully commercial basis. The low NO_x burners coupled with overfire air systems were designed to minimize NO_x emissions from the boilers. Thus far, boiler NO_x emissions have exceeded the expected value of 0.27 lb/ 10^6 Btu. The actual value is in the range of 0.32 to 0.35 lb/ 10^6 Btu. The higher NO_x emissions required a higher NH_3 feed rate. The design removal efficiency of 63 percent is sufficient to meet the emission standard of 0.17 lb NO_x / 10^6 Btu. Even with the higher NH_3 feed rate, the Carneys Point air preheaters have experienced minimal problems with plugging. In addition, both SCR reactors were inspected and found in good condition. Catalyst samples were removed, but no tests were performed.

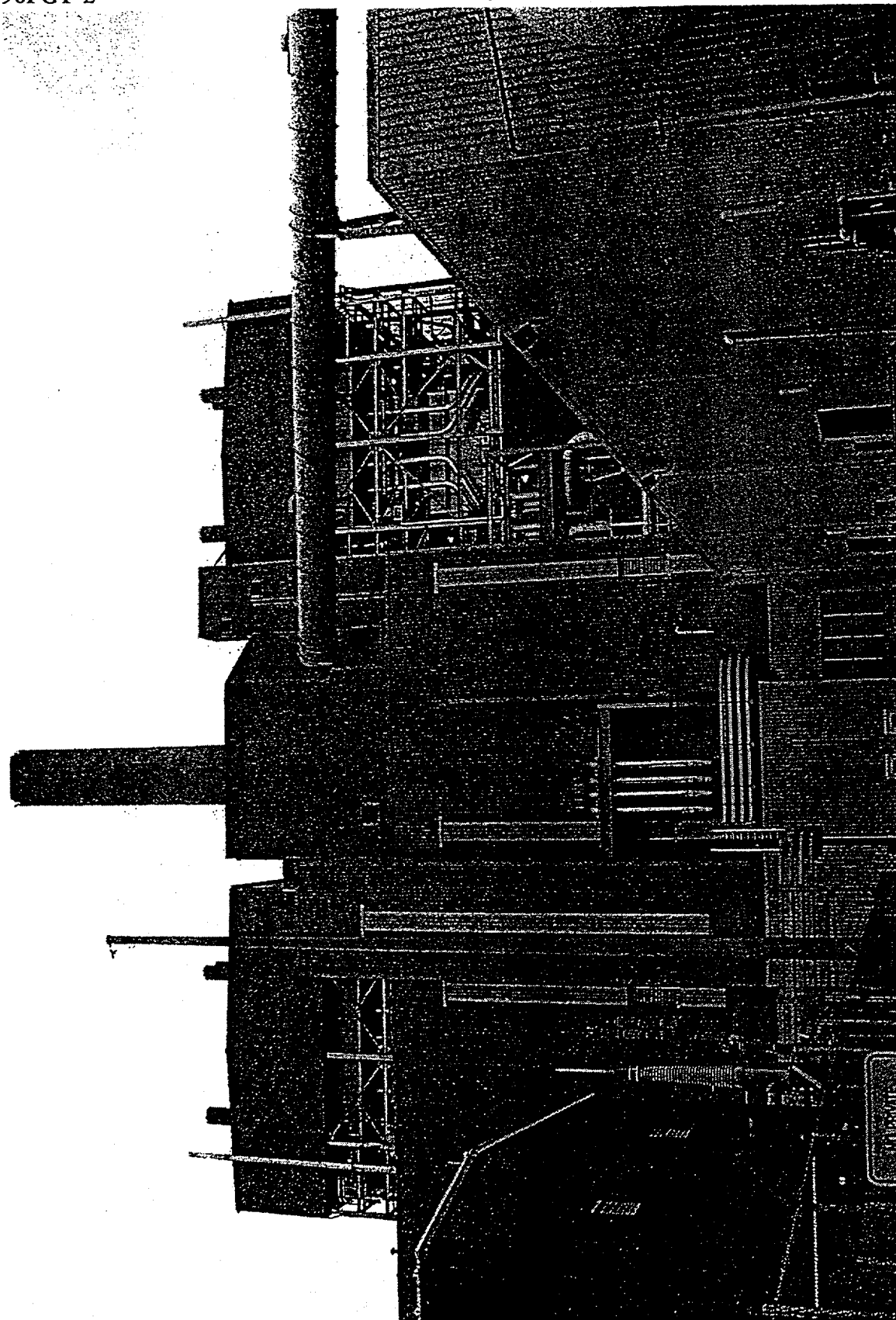


FIGURE 1. CARNEYS POINT GENERATING STATION

Data Sheets: U.S. Generating Company
Carneys Point Generating Plant
SCR and Lime/Spray Dryer FGD

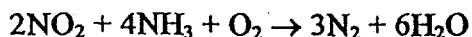
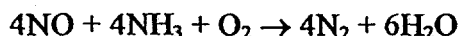
A. PLANT DESCRIPTION

1. Boiler Type - Two 50 percent capacity Foster Wheeler pulverized coal, front wall fired, natural circulation, dry bottom boilers; the cogeneration plant is rated at 245 MWe gross and provides up to 184 MWe to Atlantic Electric, and up to 1×10^6 lb/hr of process steam and up to 40 MWe to the DuPont Chambers Works; the steam capacity is 1.2×10^6 lb/hr per unit at 1,900 psig and 1005 F.
 - a. The plant heat rate is about 11,900 Btu/kWh based on 245 MW gross.
 - b. 20 percent excess air.
 - c. The capacity factor is about 57 percent.
2. Fuel - Eastern bituminous coal from Pennsylvania is delivered by rail; the coal contains about 2.0 percent sulfur, 6 to 10 percent ash, about 8 percent moisture, and about 0.1 percent chlorine; the heat content is about 13,100 Btu/lb; the boilers also can fire fuel oil.
3. Flue Gas Flow Rate - 657,000 acfm at 700 F at the economizer outlet; 453,000 acfm at 340 F at the air preheater outlet.
4. Flue Gas Composition - Design values are 0.27 lb $\text{NO}_x/10^6$ Btu (196 ppm at 3.6 percent oxygen) at the economizer outlet; 3.05 lb $\text{SO}_2/10^6$ Btu (1,520 ppm at 3.6 percent oxygen) at the air preheater outlet; and 0.10 lb $\text{NO}_x/10^6$ Btu (60 ppm at 7 percent oxygen), 0.21 lb $\text{SO}_2/10^6$ Btu (88 ppm at 7 percent oxygen), and 0.01 grains particulate/dscf at the stack; the actual inlet NO_x concentration is 0.33 lb/ 10^6 Btu.
5. In-Furnace Emission Controls -
 - a. Low NO_x burners from Foster Wheeler; each boiler has eight internal fuel staged burners with a split flame at six points; the furnace front wall has four rows of two burners each.
 - b. No flue gas recirculation.
 - c. Staged combustion with overfire air to four circular ports on the front wall of the furnace and four circular ports on the back wall.

- d. No reburning.
6. Unburned Carbon - 15 to 17 percent unburned carbon in the fly ash; the design value is 5 percent; the burners need to be tuned.
 7. Method of Particulate Removal - Particulate matter is removed in reverse air baghouses from Joy Environmental Technologies; one baghouse per boiler is located downstream of a spray dryer for SO₂ removal, and operates at a temperature of about 160 F; the baghouse can be bypassed using internal poppet dampers; each baghouse consists of 10 compartments, five on each side; each compartment has 312 Teflon®-coated fiberglass bags, about 12 in. in diameter by about 23 ft long; the air-to-cloth ratio is 1.6 ft/min with all of the compartments on line, 1.8 ft/min with one compartment off line, and 2.0 ft/min with two compartments off line; the baghouse is cleaned with reverse air based on the pressure drop; for 2.0 percent sulfur coal, the inlet loading is about 10 grains/dscf and the fly ash content is about 32 percent; the removal efficiency is 99.9 percent; the waste solids are sent back to the coal mine and used for reclamation; marketing of the waste solids is being investigated.
 8. Emission Regulations - 0.17 lb NO_x/10⁶ Btu, 0.22 lb SO₂/10⁶ Btu, and 0.018 lb particulate/10⁶ Btu; 100 ppm CO, 100 ppm NO_x, 10 ppm NH₃, and 100 ppm SO₂, all on a dry basis corrected to 7 percent oxygen, and on a 3 hr rolling average; the NH₃ standard is 5 ppm on a 30 day average; the particulate standard is 10 percent opacity on a 6 min block, and the emission regulation for particles <10 microns in diameter is 0.01 lb/10⁶ Btu.
 9. Stack - The stack was built by Continental-Heine and has two flues, one for each boiler, each flue has one breeching; the stack height is 490 ft, and the exit velocity is about 100 ft/sec; the stack has a concrete shell and a carbon steel flue except for the top 10 ft, which are stainless steel.

B. SCR SYSTEM

1. Process Supplier - Foster Wheeler was the process designer and vendor; Bechtel Construction was the contractor and the A/E firm; Ishikawajima-Harima Heavy Industries (IHI) supplied the catalyst; new installation.
2. Process Chemistry -



- a. Stoichiometry - 1.00 to 1.02 moles of NH₃ per mole of NO_x removed.

3. Process Flow Sheet - Refer to Figure 2..

4. Process Variables -

- a. Flue gas flow rate is about 629,000 acfm at 650 F; 100 percent of the flue gas is treated; there is no bypass.
- b. Flue gas inlet temperature is 650 F.
- c. Reactor outlet temperature is 700 F.
- d. Fly ash inlet loading to the reactor is about 3.2 grains/dscf
- e. Design NH_3 slip is ≤ 5 ppm at 7 percent oxygen after 56,000 hr; current value is ≤ 0.2 ppm.
- f. Oxidation of SO_2 to SO_3 is designed to be < 1.0 percent; the actual value ranges from 0.4 percent at minimum load, to 0.8 percent at full load.

5. Process Instrumentation -

- a. Automatic process control is not used; the NH_3 feed rate is based on the NO_x concentration in the stack
- b. There are no gas flow meters; they are not required for Subpart Db.
- c. NO_x analyzers are located at the outlet of the SCR systems; Enviroplan continuous emission monitors (CEMs) measure NO_x and NH_3 at the stack.

6. Removal Efficiency - The design NO_x removal efficiency is 63 percent.

7. Reactor Design - One reactor per boiler (refer to Figure 3) is located between the economizer and the air preheater; the reactor has space for three layers of catalyst, but the bottom layer is empty; the catalyst is Type CH-2A, a homogeneous extruded ceramic honeycomb with a TiO_2 base for V_2O_5 and WO_3 ; each catalyst layer contains 72 modules of catalyst elements arranged in a 12 by 6 array; each module is 1,350 mm (53 in.) long by 900 mm (35 in.) wide by about 700 mm (27.6 in.) high, and contains 54 elements arranged in a 6 by 9 array; each element is 150 mm (5.9 in.) by 150 mm (5.9 in.) by 700 mm (27.6 in.) high and contains 400 square openings with a pitch of 7.5 mm and a wall thickness of 1.5 mm; the reactor is about 10.8 m (35 ft) by 8.1 m (27 ft) in cross section, with a height of about 18 m (60 ft); the space velocity is about $4,000 \text{ hr}^{-1}$ based on the measured flue gas flow rate under standard conditions; the specific surface area of the catalyst is about $427 \text{ m}^2/\text{m}^3$, which yields an area velocity of about 9.4 m/hr; the gas flow

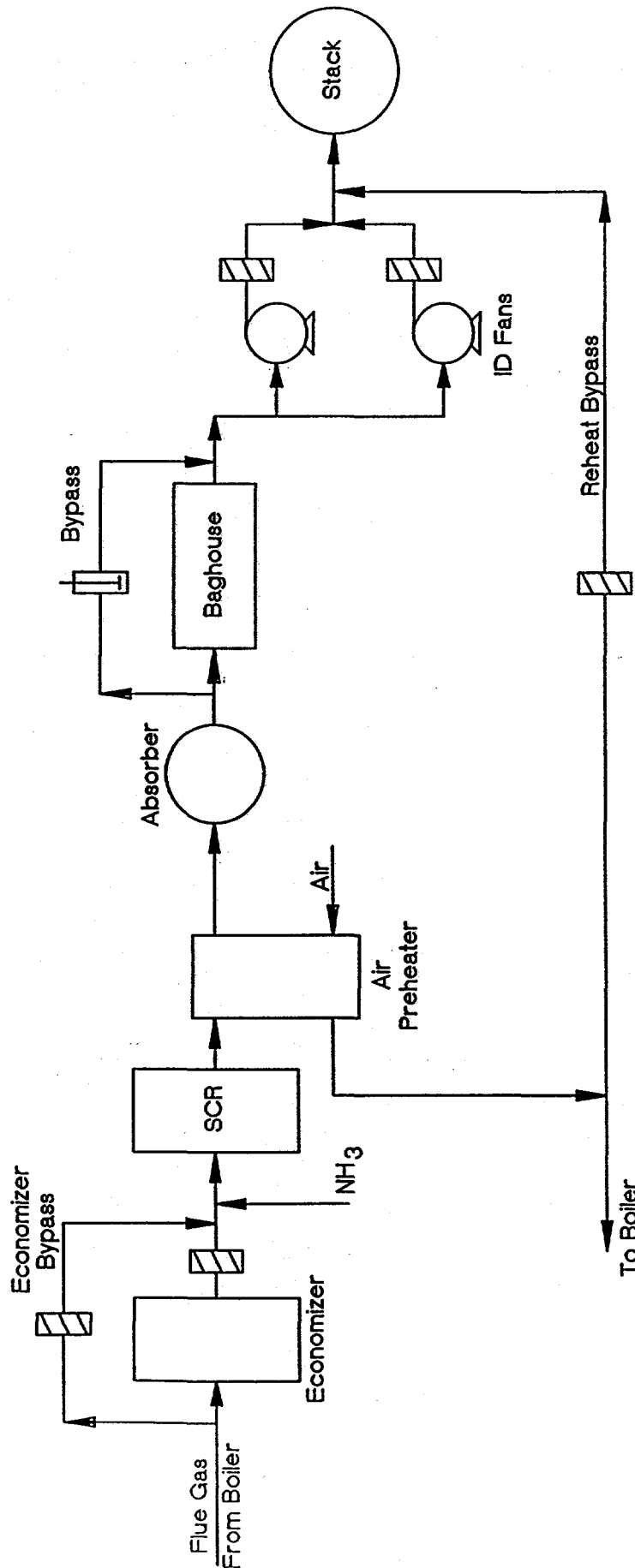


FIGURE 2. SIMPLIFIED GAS FLOW DIAGRAM FOR CARNEY'S POINT UNIT 1 OR 2

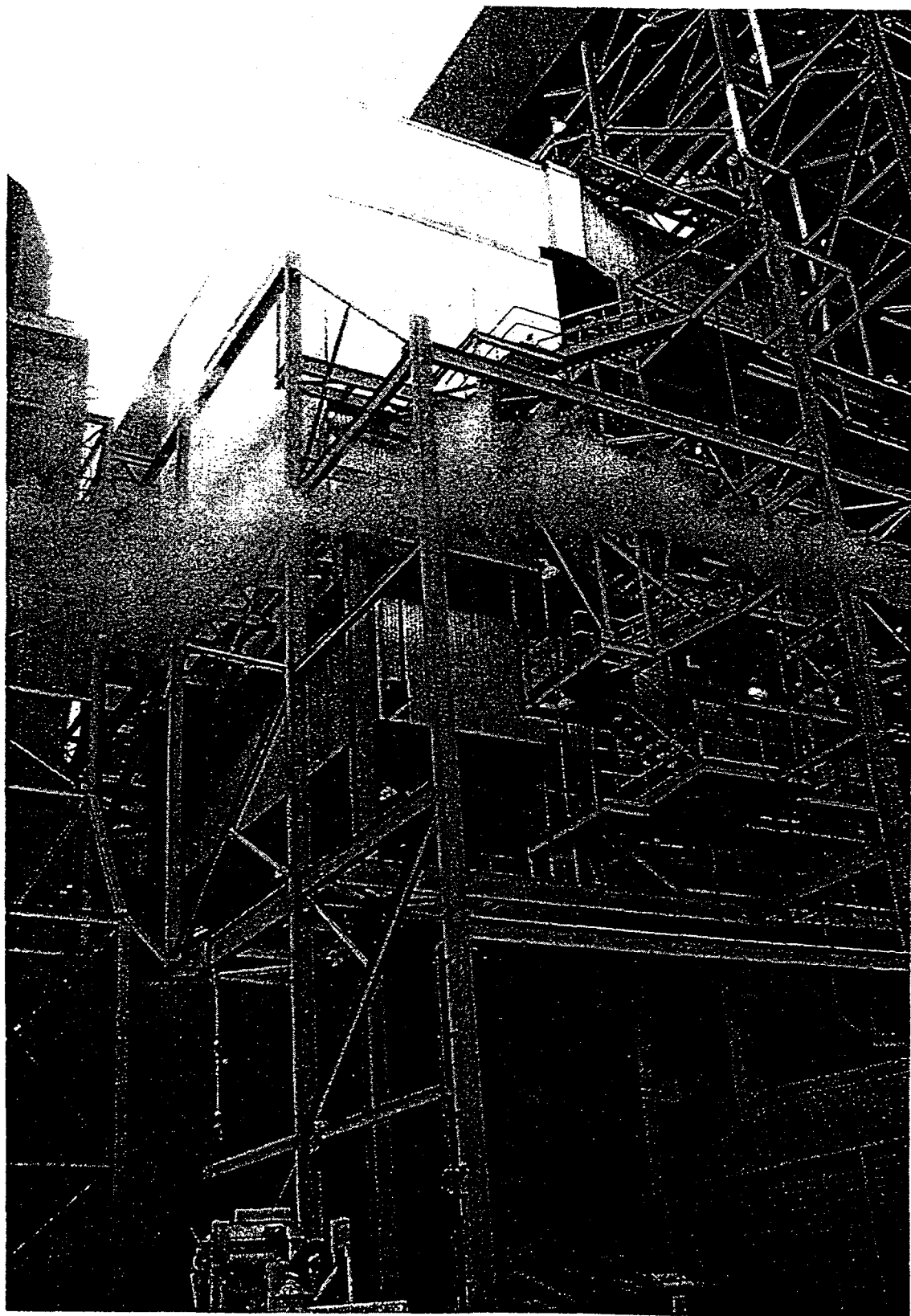


FIGURE 3. SCR REACTOR

is downward at a superficial velocity of 12 ft/sec and a linear velocity of 20 ft/sec in the channels; the turndown ratio is limited by the minimum boiler load, which is 35 percent of the maximum rated capacity.

8. Pressure Drop - The pressure drop across the SCR reactor is 2.2 to 2.7 in. H₂O.
9. NH₃ Injection - Aqueous NH₃ (27 wt percent NH₃) from a 19,800 gal storage tank is vaporized with atomizing air, mixed with heated dilution air, and injected into the flue gas in the duct upstream of the reactor; the duct has a grid to distribute the NH₃ over the entire cross section; the NH₃ is injected into 12 flue gas zones, which are individually controllable in either the horizontal or vertical plane; each zone is fed with NH₃ through a common supply manifold and controlled using a flow meter and valve; individual injection pipes, branching from the common supply manifold, contain circular injection holes on the side of the pipe for NH₃ injection into the flue gas; during initial operation, these zones were fine-tuned to provide proper distribution of the NH₃; a set of turning vanes is installed at the 90 degree duct bend to provide good flow distribution while minimizing pressure drop in the duct.
10. Catalyst Life - The catalyst is under warrantee for a ten-year period, with up to 50 percent of the initial catalyst charge to be added/replaced during each of the first and second five-year periods; the plan is to add a third layer of catalyst after seven years of operation.
11. Methods for Catalyst Protection - A flow rectifier made of square tubes is installed above the first catalyst layer; the flow rectifier straightens the gas flow; steam sootblowers are installed upstream of the catalyst layers; the sootblowers are sequentially operated from top to bottom of the successive layers.
12. Type of Reheat - For operation at 35 to 50 percent load, part of the flue gas is bypassed around a portion of the economizer to maintain the flue gas temperature above 610 F; a damper in the bypass duct and a damper in the economizer outlet duct operate in unison to automatically control the temperature between 610 and 710 F.
13. Dampers - A louver damper is located in the economizer bypass duct and in the economizer outlet duct.
14. Energy Requirements - <0.2 percent of the unit output is required for fan power to overcome the pressure drop across the SCR system.
15. Space Requirements - The reactor vessel is about 35 ft long by 27 ft wide by 60 ft high; the area occupied by the NH₃ storage tank and the area occupied by the NH₃ vaporization skid were not provided.
16. Type of Operating and Maintenance Staff - No extra staff is required for the SCR system.

17. Reliability -

- a. The boilers and SCR systems started up in late 1993, and went commercial in March, 1994.
- b. The availability of the SCR systems is >99 percent.
- c. The longest continuous run is about 8 months.
- d. The SCR systems have accumulated about 20,000 operating hours.
- e. The NH₃ feed rate cannot be automatically controlled.

The NO_x analyzers require a high amount of maintenance.

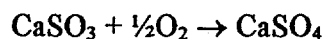
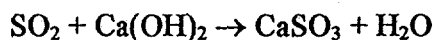
Minimal problems with plugging of the air preheater baskets; the air preheaters are washed once per year during the annual boiler outage.

18. Economics -

- a. The capital cost of the SCR system is proprietary.
- b. The operating cost is proprietary.

C. FGD SYSTEM

1. Process Supplier - Joy Environmental Technologies was the process designer and vendor; Bechtel Construction was the contractor and the A/E firm; new installation.
2. Absorber Reactant - High calcium lime containing >90 percent CaO is slaked on site in a ball mill slaker.
3. Process Chemistry (Simplified) - SO₂ is absorbed by an atomized slurry and the following reactions occur:



- a. Stoichiometry - 1.5 moles fresh lime per mole of inlet SO₂ based on 2.0 percent sulfur coal; the internal stoichiometry is much higher because of recycle of solids from the baghouse; the recycle ratio is about 5 lb of recycled solids per lb of fresh Ca(OH)₂.

4. Process Flow Sheet - Refer to Figure 4.

5. Process Variables -

- a. Design flue gas flow rate is 548,000 acfm at 340 F; 100 percent of the flue gas is scrubbed.
- b. There is no bypass.
- c. The flue gas inlet temperature to the absorbers is 340 F.
- d. Absorber outlet temperature is 160 F, which is about a 35 F approach to the adiabatic saturation temperature.
- e. Fly ash inlet loading to the absorbers is about 3.2 grains/dscf.
- f. pH of the scrubbing liquor is not relevant for a spray dry FGD system.

6. Process Instrumentation -

- a. The outlet temperature from the spray dryer controls the slurry flow to the atomizer; the outlet SO₂ concentration controls the fresh lime and recycle solids feed rates.
- b. pH probes are not needed.
- c. There are no gas flow meters.
- d. TECO ultraviolet SO₂ analyzer are located at the inlet of the spray dryers; Enviroplan continuous emission monitors (CEMs) measure SO₂ at the stack.

7. Removal Efficiency - 93 percent SO₂ removal.

8. Process Design - There is one spray dryer absorber per boiler; the spray dryers are about 46 ft in diameter by about 72 ft high, including about a 36 ft cone section at the bottom (refer to Figure 5); each spray dryer is followed by a baghouse for particulate removal (fly ash and solids from the spray dryer); each spray dryer has a single 900 hp rotary atomizer from Joy; the atomizers rotate at 10,000 rpm and have nozzles in the wheel; a spare atomizer is kept on site; about 60 percent of the flue gas enters the spray dryers through a roof gas disperser counter to the atomizer wheel rotation, and about 40 percent enters through a central disperser that is directed upward; practically all of the solids exit the spray dryers with the flue gas; the superficial gas velocity is about 4.5 ft/sec; the turndown ratio is limited by the minimum boiler load, which is 35 percent of the maximum rated capacity.

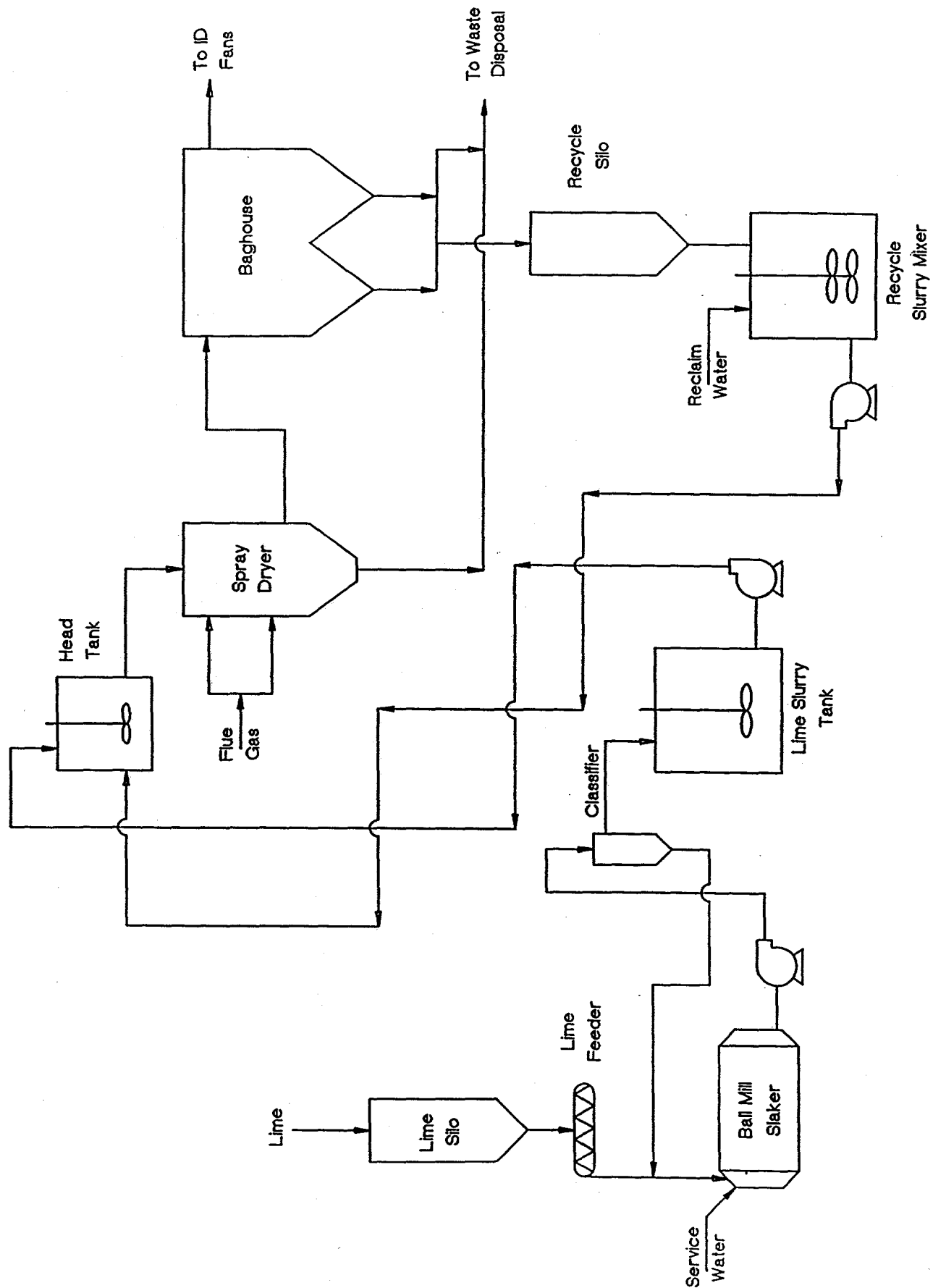


FIGURE 4. SIMPLIFIED FLOW DIAGRAM FOR FGD SYSTEM ON CARNEY'S POINT UNIT 1 OR 2

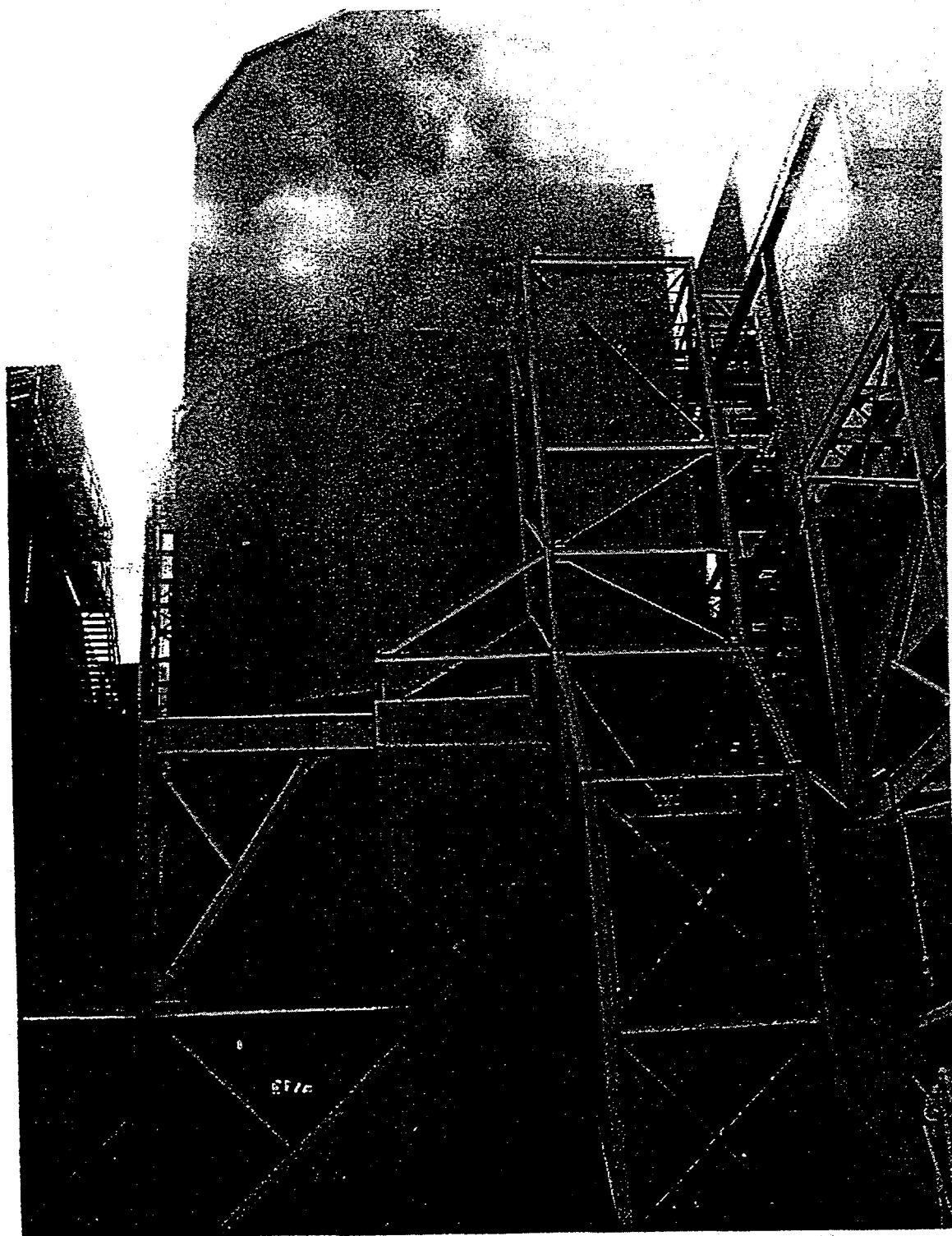


FIGURE 5. SPRAY DRYER ABSORBER

9. Liquid-to-Gas Ratio - About 0.39 gal/10³ scf.
10. Oxidation - The oxidation of sulfite to sulfate is was not provided.
11. Pressure Drop - The total pressure drop across the FGD system was not provided.
12. Solids Level - 22 percent solids in the fresh lime slurry, 45 percent solids in the ash recycle slurry, and 38 percent solids in the atomizer feed slurry.
13. Reactant Addition - Fresh lime slurry is added to the atomizer head tanks together with the ash recycle slurry.
14. Reactant Feed Rate - About 11,000 lb CaO per hr for both boilers based on 2.0 percent sulfur coal.
15. Retention Time - The flue gas residence time in the spray dryers is about 14 sec.
16. Mist Eliminator - None required.
17. Plugging and Scaling - Plugging and scaling are minimized by shutting down and backflushing the FGD system when necessary; a recent change from a 1 hr averaging time to a 3 hr averaging time for SO₂ compliance has allowed more time to fix problems.
18. Reheat - There is a bypass duct from the hot air side of the air preheater to the outlet duct downstream of the ID fans; hot air at 500 F is used to reheat the flue gas to 180 F; this is done to protect the flue from corrosion.
19. Waste Disposal - Waste solids from the baghouse are trucked to the coal mine in central Pennsylvania where they are mixed with water in a pug mill and used for mine reclamation; bottom ash is used for construction materials; pneumatic transport is used to convey solids from the baghouse; the Carneys Point Generating Plant has zero liquid discharge; wastewater is sent to the Chambers Works for treatment..
 - a. Primary makeup water to the FGD system is filtered river water, which is used for lime slaking; secondary makeup water is concentrated wastewater brines, which is used for preparation of the ash recycle slurry.
20. Materials of Construction - Most of the components are carbon steel; the atomizer wheels have upper and lower wear plates of an erosion-resistant material; the nozzles have silicon carbide inserts, which are rotated periodically to obtain even wear.
21. Fans - Two ID fans per boiler are located downstream of the baghouse.

22. Dampers - There are no dampers on the spray dryers; the baghouses have internal poppet dampers for bypass; there is a louver damper downstream of each ID fan and in the bypass reheat duct.
23. Energy Requirements - The total energy required to operate the FGD system was not provided.
24. Space Requirements - The land area occupied by the FGD system was not provided; the baghouses occupy about 12,000 ft².
25. Type of Operating and Maintenance Staff - The total plant staff consists of 70 people; there are five shifts with five operators per shift; the maintenance staff consists of 9 mechanics, three instrument and electrical technicians, and three supervisors; the rest of the staff is for administrative functions; the same operation and maintenance personnel are responsible for the plant and the FGD systems.
26. Reliability -
 - a. The boilers and FGD systems started up in late 1993, and went commercial in March, 1994.
 - b. The availability of the FGD systems is >99 percent; one boiler is sufficient to supply the steam required by DuPont.
 - c. The longest continuous run for one boiler was not provided.
 - d. The FGD systems have accumulated about 20,000 operating hours.
 - e. Deposits on the spray dryer walls; the averaging time for SO₂ compliance was recently increased from 1 hr to 3 hr; this has significantly improved operation because more time is available to fix problems before the unit would be out of compliance.

Corrosion of baghouse rings throughout the baghouse.

27. Economics -
 - a. The capital cost of the FGD system is proprietary.
 - b. The operating cost is proprietary.