INNOVATIVE CLEAN COAL TECHNOLOGY (ICCT)

DOE/PC/89651--T27

# 500 MW DEMONSTRATION OF ADVANCED WALL-FIRED COMBUSTION TECHNIQUES FOR THE REDUCTION OF NITROGEN OXIDE ($NO_x$) EMISSIONS FROM COAL-FIRED BOILERS

Technical Progress Report
Fourth Quarter 1995

DOE Contract Number
DE-FC22-90PC89651

SCS Contract Number
C-91-000027

Prepared by:

Southern Company Services, Inc.
P. O. Box 2625
Birmingham, Alabama 35202



Cleared by DOE Patent Counsel on July 17, 1996

## LEGAL NOTICE

## DISCLAIMER

## DISCLAIMER

## EXECUTIVE SUMMARY

This quarterly report discusses the technical progress of an Innovative Clean Coal Technology (ICCT) demonstration of advanced wall-fired combustion techniques for the reduction of nitrogen oxide ($NO_x$) emissions from coal-fired boilers. The project is being conducted at Georgia Power Company's Plant Hammond Unit 4 located near Rome, Georgia. The primary goal of this project is the characterization of the low $NO_x$ combustion equipment through the collection and analysis of long-term emissions data. The project provides a stepwise evaluation of the following $NO_x$ reduction technologies: Advanced overfire air (AOFA), Low $NO_x$ burners (LNB), LNB with AOFA, and advanced digital controls and optimization strategies. The project has completed the baseline, AOFA, LNB, and LNB+AOFA test segments, fulfilling all testing originally proposed to DOE.

Phase 4 of the project, demonstration of advanced control/optimization methodologies for $NO_x$ abatement, is now in progress. The methodology selected for demonstration at Hammond Unit 4 is the Generic $NO_x$ Control Intelligent System (GNOCIS), which is being developed by a consortium consisting of the Electric Power Research Institute, PowerGen, Southern Company, Radian Corporation, U.K. Department of Trade and Industry, and U.S. Department of Energy. GNOCIS is a methodology that can result in improved boiler efficiency and reduced $NO_x$ emissions from fossil fuel fired boilers. Using a numerical model of the combustion process, GNOCIS applies an optimizing procedure to identify the best set points for the plant on a continuous basis. GNOCIS is designed to operate in either advisory or supervisory modes. Prototype testing of GNOCIS is in progress at Alabama Power's Gaston Unit 4 and PowerGen's Kingsnorth Unit 1. The first commercial demonstration of GNOCIS will be at Hammond 4.

During fourth quarter 1995, Hammond 4 was off-line and on reserved standby the majority of the time. This was the result of (1) the relatively mild weather and the resultant low electricity demand and (2) relatively high cost (as compared to other units in the Southern electric system) of generation on this unit. In total, the unit operated approximately 30 days out of a total of 92 days this quarter. Installation of GNOCIS for open- and closed-loop operation is virtually complete. Final software checkout will begin upon resumption of consistent unit operation. Following checkout, testing of GNOCIS will commence. Also during this quarter, problems with the project's continuous emissions and carbon-in-ash monitors have compromised data collected. The recent extended outage of the unit likely contributed to the instrument problems. At the end of the quarter, repairs were underway on these instruments. Preparation of the project final report is continuing with approximately 50 percent completed to date. Results from Phase 4 of the project will be integrated into the report as it becomes available.

# TABLE OF CONTENTS

# LIST OF TABLES

## LIST OF FIGURES

## TABLE OF ABBREVIATIONS

| | | | |
|---|---|---|---|
| acfm | actual cubic feet per minute | ICCT | Innovative Clean Coal Technology |
| AMIS | All mills in service | KPPH | kilo pounds per hour |
| AOFA | Advanced Overfire Air | lb(s) | pound(s) |
| ASME | American Society of Mechanical Engineers | LNB | low $NO_x$ burner |
| | | LOI | loss on ignition |
| C | carbon | (M)Btu | (million) British thermal unit |
| CAA(A) | Clean Air Act (Amendments) | MOOS | Mills out of service |
| CEM | Continuous emissions monitor | MW | megawatt |
| CFSF | Controlled Flow/Split Flame | N | nitrogen |
| Cl | chlorine | $NO_x$ | nitrogen oxides |
| CO | carbon monoxide | NSPS | New Source Performance Standards |
| DAS | data acquisition system | O, $O_2$ | oxygen |
| DCS | digital control system | OFA | overfire air |
| DOE | U.S. Department of Energy | PA | primary air |
| ECEM | extractive CEM | psig | pounds per square inch gauge |
| EPA | Environmental Protection Agency | PTC | Performance Test Codes |
| EPRI | Electric Power Research Institute | RSD | relative standard deviation |
| ETEC | Energy Technology Consultants | S | sulfur |
| F | Fahrenheit | SCA | specific collection area |
| FC | fixed carbon | SCS | Southern Company Services |
| FWEC | Foster Wheeler Energy Corporation | $SO_2$ | sulfur dioxide |
| Flame | Flame Refractories | SoRI | Southern Research Institute |
| GPC | Georgia Power Company | Spectrum | Spectrum Systems Inc. |
| H | hydrogen | THC | total hydrocarbons |
| HHV | higher heating value | UARG | Utility Air Regulatory Group |
| HVT | High velocity thermocouple | VM | volatile matter |

## 1. INTRODUCTION

This document discusses the technical progress of a U. S. Department of Energy (DOE) Innovative Clean Coal Technology (ICCT) Project demonstrating advanced wall-fired combustion techniques for the reduction of nitrogen oxide ($NO_x$) emissions from coal-fired boilers. The project is being conducted at Georgia Power Company's Plant Hammond Unit 4 (500 MW) near Rome, Georgia.

The project is being managed by Southern Company Services, Inc. (SCS) on behalf of the project co-funders: Southern Company, U. S. Department of Energy (DOE), and Electric Power Research Institute. SCS is a subsidiary of the Southern Company that provides engineering, research, and financial services to other Southern Company subsidiaries.

The Clean Coal Technology Program is a jointly funded effort between government and industry to move the most promising advanced coal-based technologies from the research and development stage to the commercial marketplace. The Clean Coal effort sponsors projects that are different from traditional research and development programs sponsored by the DOE. Traditional projects focus on long-range, high-risk technologies with the DOE providing the majority of the funding. In contrast, the goal of the Clean Coal Program is to demonstrate commercially feasible, advanced coal-based technologies that have already reached the "proof of concept" stage. As a result, the Clean Coal Projects are jointly funded endeavors between the government and the private sector that are conducted as Cooperative Agreements in which the industrial participant contributes at least fifty percent of the total project cost.

The primary objective of the Plant Hammond demonstration is to determine the long-term effects of commercially available wall-fired low $NO_x$ combustion technologies on $NO_x$ emissions and boiler performance. Short-term tests of each technology are also being performed to provide engineering information about emissions and performance trends. Specifically, the objectives of the projects are:

1. Demonstrate in a logical stepwise fashion the short-term $NO_x$ reduction capabilities of the following advanced low $NO_x$ combustion technologies:

   ◊ Advanced overfire air (AOFA)
   ◊ Low $NO_x$ burners (LNB)
   ◊ LNB with AOFA
   ◊ Advanced Digital Controls and Optimization Strategies

2. Determine the dynamic, long-term emissions characteristics of each of these combustion $NO_x$ reduction methods using sophisticated statistical techniques.

3. Evaluate the cost effectiveness of the low $NO_x$ combustion techniques tested.

4. Determine the effects on other combustion parameters (e.g., CO production, carbon carryover, particulate characteristics) of applying the above $NO_x$ reduction methods.

## 2. PROJECT DESCRIPTION

### 2.1. Test Program Methodology

To accomplish the project objectives, a Statement of Work (SOW) was developed which included the Work Breakdown Structure (WBS) found in Table 1. The WBS is designed around a chronological flow of the project. The chronology requires design, construction, and operation activities in each of the first three phases following project award.

**Table 1: Work Breakdown Structure**

| Phase | Task | Description | Date |
|---|---|---|---|
| 0 | 0 | Phase 0 Pre-Award Negotiations | |
| 1 | 1 | Phase 1 Baseline Characterization | |
| | 1.1 | Project Management and Reporting | 8/89 - 4/90 |
| | 1.2 | Site Preparation | 8/89 - 10/89 |
| | 1.3 | Flow Modeling | 9/89 - 6/90 |
| | 1.4 | Instrumentation | 9/89 - 10/89 |
| | 1.5 | Baseline Testing | 11/89 - 4/90 |
| 2 | 2 | Phase 2 Advanced Overfire Air Retrofit | |
| | 2.1 | Project Management and Reporting | 4/90 - 3/91 |
| | 2.2 | AOFA Design and Retrofit | 4/90 - 5/90 |
| | 2.3 | AOFA Testing | 6/90 - 3/91 |
| 3 | 3 | Phase 3 Low $NO_x$ Burner Retrofit | |
| | 3.1 | Project Management and Reporting | 3/91 - 8/93* |
| | 3.2 | LNB Design and Retrofit | 4/91 - 5/91 |
| | 3.3 | LNB Testing with and without AOFA | 5/91 - 8/93* |
| 4* | 4* | Advanced Low $NO_x$ Digital Control System* | 8/93 - 4/96* |
| 5* | 5* | Final Reporting and Disposition | |
| | 5.1 | Project Management and Reporting | 9/95 - 6/96* |
| | 5.2 | Disposition of Hardware | 6/96* |

* Indicates change from original work breakdown structure. Final schedule dependent upon availability of unit.

The stepwise approach to evaluating the $NO_x$ control technologies requires that three plant outages be used to successively install: (1) the test instrumentation, (2) the AOFA system, and (3) the LNBs. These outages were scheduled to coincide with existing plant maintenance outages in the fall of 1989, spring of 1990, and spring of 1991. The planned retrofit progression has allowed for an evaluation of the AOFA system while operating with the existing pre-retrofit burners. As shown in Figure 1, the AOFA air supply is separately ducted from the existing forced draft secondary air system. Backpressure dampers are provided on the secondary air ducts to allow for the introduction of greater quantities of higher pressure overfire air into the boiler. The burners are designed to be plug-in replacements for the existing circular burners.

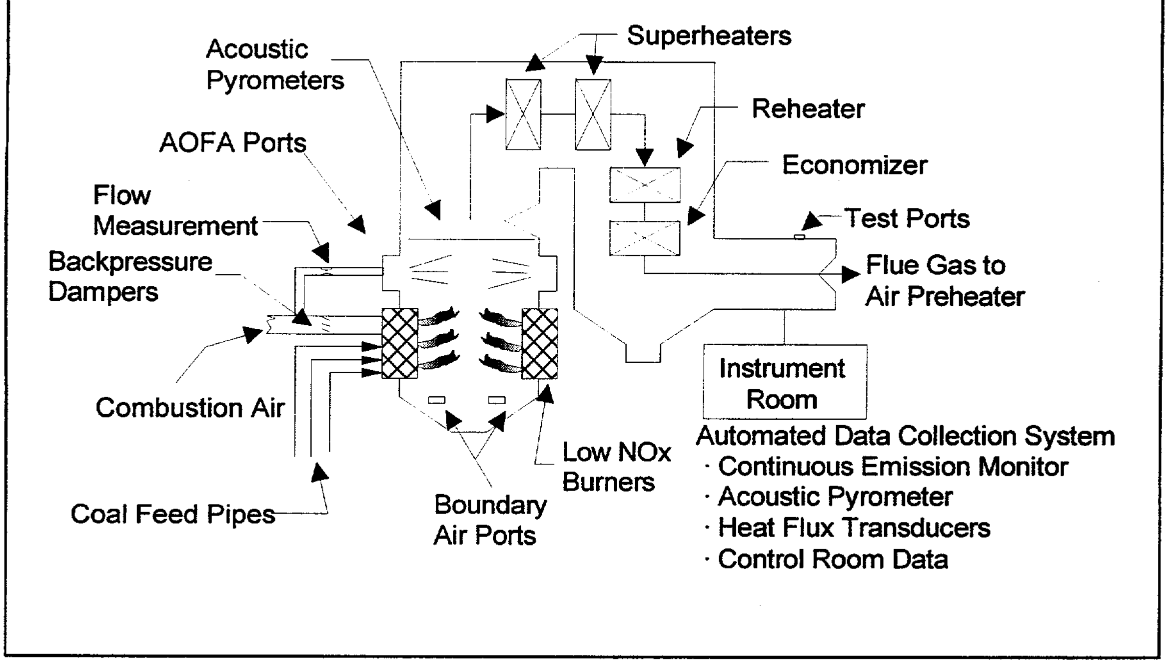


**Figure 1: Plant Hammond Unit 4 Boiler**

The data acquisition system (DAS) for the Hammond Unit 4 ICCT project is a custom-designed microcomputer-based system used to collect, format, calculate, store, and transmit data derived from power plant mechanical, thermal, and fluid processes. The extensive process data selected for input to the DAS has in common a relationship with either boiler performance or boiler exhaust gas properties. This system includes a continuous emissions monitoring system ($NO_x$, $SO_2$, $O_2$, THC, CO) with a multi-point flue gas sampling and conditioning system, an acoustic pyrometry and thermal mapping system, furnace tube heat flux transducers, and boiler efficiency instrumentation. The instrumentation system is designed to provide data collection flexibility to meet the schedule and needs of the various testing efforts throughout the demonstration program. A summary of the type of data collected is shown in Table 2.

During each test phase, a series of four groups of tests are conducted. These are: (1) diagnostic, (2) performance, (3) long-term, and (4) verification. The diagnostic, performance, and verification tests consist of short-term data collection during carefully established operating conditions. The diagnostic tests are designed to map the effects of changes in boiler operation on $NO_x$ emissions. The performance tests evaluate a more comprehensive set of boiler and combustion performance indicators. The results from these tests will include particulate characteristics, boiler efficiency, and boiler outlet emissions. Mill performance and air flow distribution are also tested. The verification tests are performed following the end of the long-term testing period and serve to identify any potential changes in plant operating conditions.

| Table 2: Inputs to Data Acquisition System | |
|---|---|
| Boiler Drum Pressure | Superheat Outlet Pressure |
| Cold Reheat Pressure | Hot Reheat Pressure |
| Barometric Pressure | Superheat Spray Flow |
| Reheat Spray Flow | Main Steam Flow |
| Feedwater Flow | Coal Flows |
| Secondary Air Flows | Primary Air Flows |
| Main Steam Temperature | Cold Reheat Temperature |
| Hot Reheat Temperature | Feedwater Temperature |
| Desuperheater Outlet Temp. | Desuperheater Inlet Temp. |
| Economizer Outlet Temp. | Air Heater Air Inlet Temp. |
| Air Heater Air Outlet Temp. | Ambient Temperature |
| BFP Discharge Temperature | Relative Humidity |
| Stack NOx | Stack SO2 |
| Stack O2 | Stack Opacity |
| Generation | Overfire Air Flows |

As stated previously, the primary objective of the demonstration is to collect long-term, statistically significant quantities of data under normal operating conditions with and without the various $NO_x$ reduction technologies. Earlier demonstrations of emissions control technologies have relied solely on data from a matrix of carefully established short-term (one- to four- hour) tests. However, boilers are not typically operated in this manner, considering plant equipment inconsistencies and economic dispatch strategies. Therefore, statistical analysis methods for long-term data are available that can be used to determine the achievable emissions limit or projected emission tonnage of an emissions control technology. These analysis methods have been developed over the past fifteen years by the Control Technology Committee of the Utility Air Regulatory Group (UARG). Because the uncertainty in the analysis methods is reduced with increasing data set size, UARG recommends that acceptable 30 day rolling averages can be achieved with data sets of at least 51 days with each day containing at least 18 valid hourly averages.

## 2.2. Unit Description

Georgia Power Company's Plant Hammond Unit 4 is a Foster Wheeler Energy Corporation (FWEC) opposed wall-fired boiler, rated at 500 MW gross, with design steam conditions of 2500 psig and 1000/1000°F superheat/reheat temperatures, respectively. The unit was placed into commercial operation on December 14, 1970. Prior to the LNB retrofit, six FWEC Planetary Roller and Table type mills provided pulverized eastern bituminous coal (12,900 Btu/lb, 33% VM, 53% FC, 1.7% S, 1.4% N) to 24 pre-NSPS, Intervane burners. During the LNB outage, the existing burners were replaced with FWEC Control Flow/Split Flame burners. The unit was also retrofit with six Babcock and Wilcox MPS 75 mills during the course of the demonstration (two each during the spring 1991, spring 1992, and fall 1993 outages). The burners are arranged in a matrix of 12 burners (4W x 3H) on opposing walls with each mill supplying coal to 4 burners per elevation. As part of this demonstration project, the unit was retrofit with an advanced overfire air system, to be described later. The unit is equipped with a cold-side

ESP and utilizes two regenerative secondary air pre-heaters and two regenerative primary air heaters. The unit was designed for pressurized furnace operation but was converted to balanced draft operation in 1977. The unit, equipped with a Bailey pneumatic boiler control system during the baseline, AOFA, LNB, and LNB+AOFA phases of the project, was retrofit with a Foxboro I/A distributed digital control system for Phase 4 of the project.

### 2.3. Advanced Overfire Air (AOFA) System

Generally, combustion $NO_x$ reduction techniques attempt to stage the introduction of oxygen into the furnace. This staging reduces $NO_x$ production by creating a delay in fuel and air mixing that lowers combustion temperatures. The staging also reduces the quantity of oxygen available to the fuel-bound nitrogen. Typical overfire air (OFA) systems accomplish this staging by diverting 10 to 20 percent of the total combustion air to ports located above the primary combustion zone. AOFA improves this concept by introducing the OFA through separate ductwork with more control and accurate measurement of the AOFA airflow, thereby providing the capability of improved mixing (Figure 2).

Foster Wheeler Energy Corporation (FWEC) was competitively selected to design, fabricate, and install the advanced overfire air system and the opposed-wall, low $NO_x$ burners described below. The FWEC design diverts air from the secondary air ductwork and incorporates four flow control dampers at the corners of the overfire air windbox and four overfire air ports on both the front and rear furnace walls. As a result of budgetary and physical constraints, FWEC designed an AOFA system more suitable to the project and unit than that originally proposed. Six air ports per wall were proposed, whereas four ports per wall were installed.

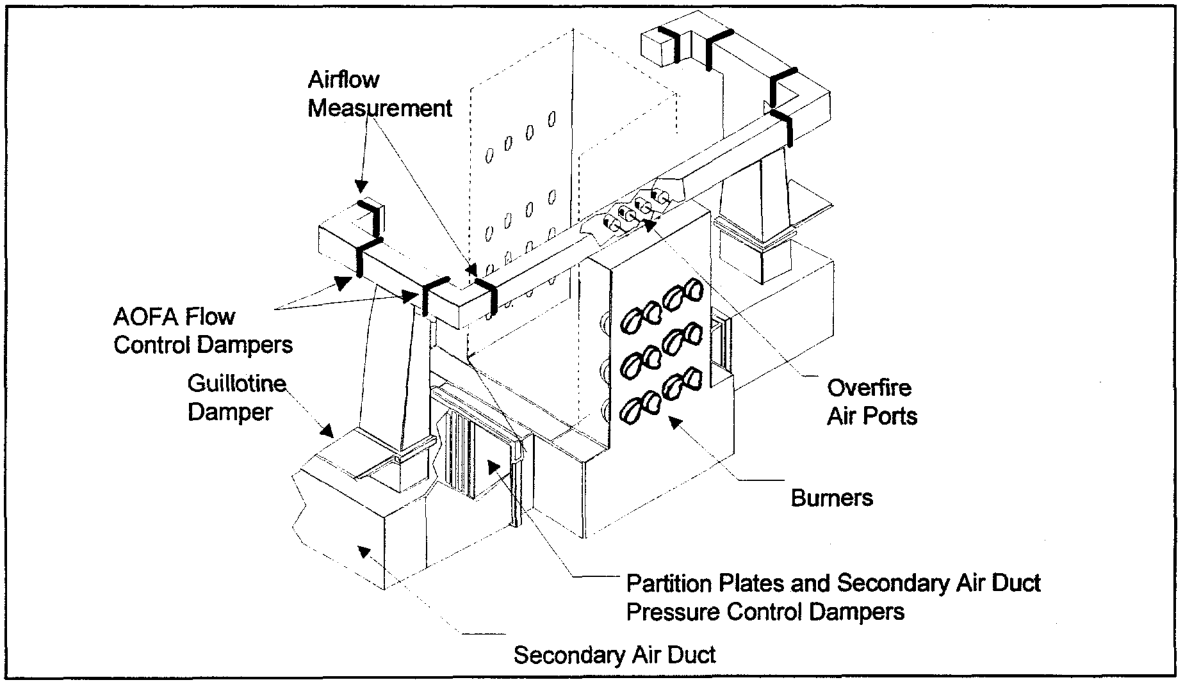


**Figure 2: Advanced Overfire Air System**

## 2.4. Low $NO_x$ Burners

Low $NO_x$ burner systems attempt to stage the combustion without the need for the additional ductwork and furnace ports required by OFA and AOFA systems. These commercially-available burner systems introduce the air and coal into the furnace in a well controlled, reduced turbulence manner. To achieve this, the burner must regulate the initial fuel/air mixture, velocities and turbulence to create a fuel-rich core, with sufficient air to sustain combustion at a severely sub-stoichiometric air/fuel ratio. The burner must then control the rate at which additional air, necessary to complete combustion, is mixed with the flame solids and gases to maintain a deficiency of oxygen until the remaining combustibles fall below the peak $NO_x$ producing temperature (around 2800°F). The final excess air can then be allowed to mix with the unburned products so that the combustion is completed at lower temperatures. Burners have been developed for single-wall and opposed-wall boilers.

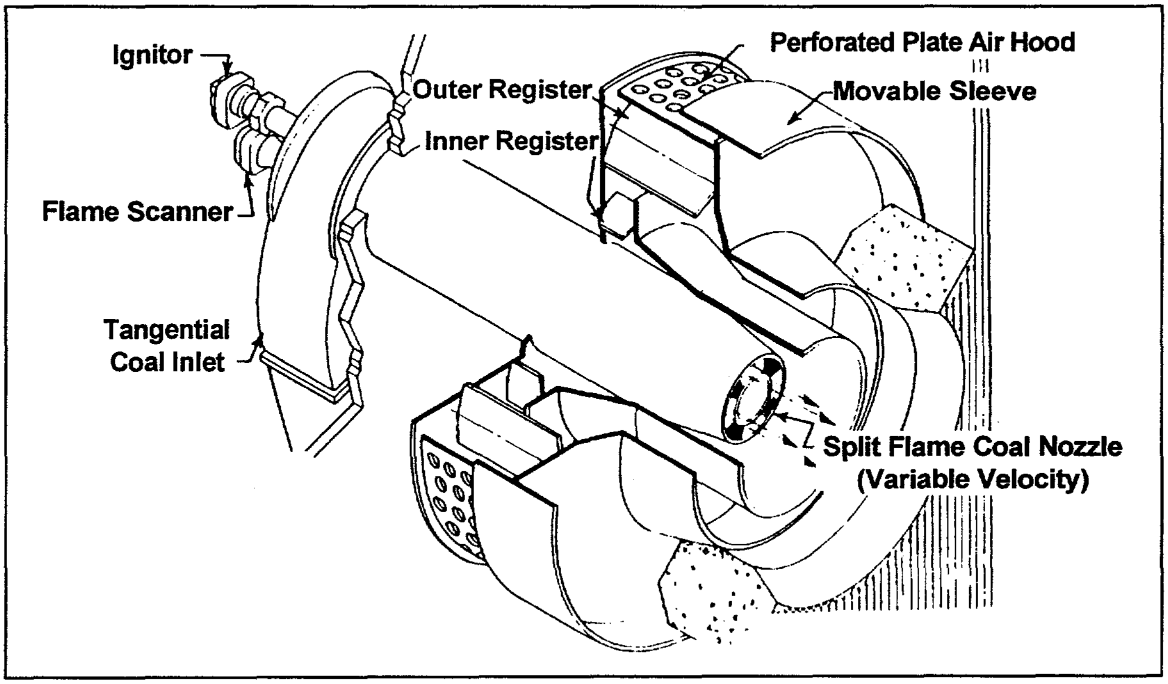


**Figure 3: Low $NO_x$ Burner Installed at Plant Hammond**

In the FWEC Controlled Flow/Split Flame (CFSF) burner (Figure 3), secondary combustion air is divided between inner and outer flow cylinders. A sliding sleeve damper regulates the total secondary air flow entering the burner and is used to balance the burner air flow distribution. An adjustable outer register assembly divides the burners secondary air into two concentric paths and also imparts some swirl to the air streams. The secondary air which traverses the inner path, flows across an adjustable inner register assembly that, by providing a variable pressure drop, apportions the flow between the inner and outer flow paths. The inner register also controls the degree of additional swirl imparted to the coal/air mixture in the near throat region. The outer air flow enters the furnace axially, providing the remaining air necessary to complete combustion. An axially movable inner sleeve tip provides a means for varying the primary air velocity while maintaining a constant primary flow. The split flame nozzle segregates the coal/air mixture into four concentrated streams, each of which forms an individual flame when entering the furnace. This segregation minimizes mixing between the coal and the primary air, assisting in the staged combustion process. The adjustments to the sleeve dampers, inner registers, outer registers, and tip position are made during the burner optimization process and thereafter remain fixed unless changes in plant operation or equipment condition dictate further adjustments.

## 2.5. Application of Advanced Digital Control Methodologies

The objective of Phase 4 of the project is to implement and evaluate an advanced digital control/optimization system for use with the combustion $NO_x$ abatement technologies installed on Plant Hammond Unit 4. The advanced system will be customized to minimize $NO_x$ production while simultaneously maintaining and/or improving boiler performance and safety margins. This project will provide documented effectiveness of an advanced digital control /optimization strategy on $NO_x$ emissions and guidelines for retrofitting boiler combustion controls for $NO_x$ emission reduction. The methodology selected for demonstration at Hammond Unit 4 during Phase 4 of the project is the Generic $NO_x$ Control Intelligent System (GNOCIS). The major elements of GNOCIS are shown in Figure 4.

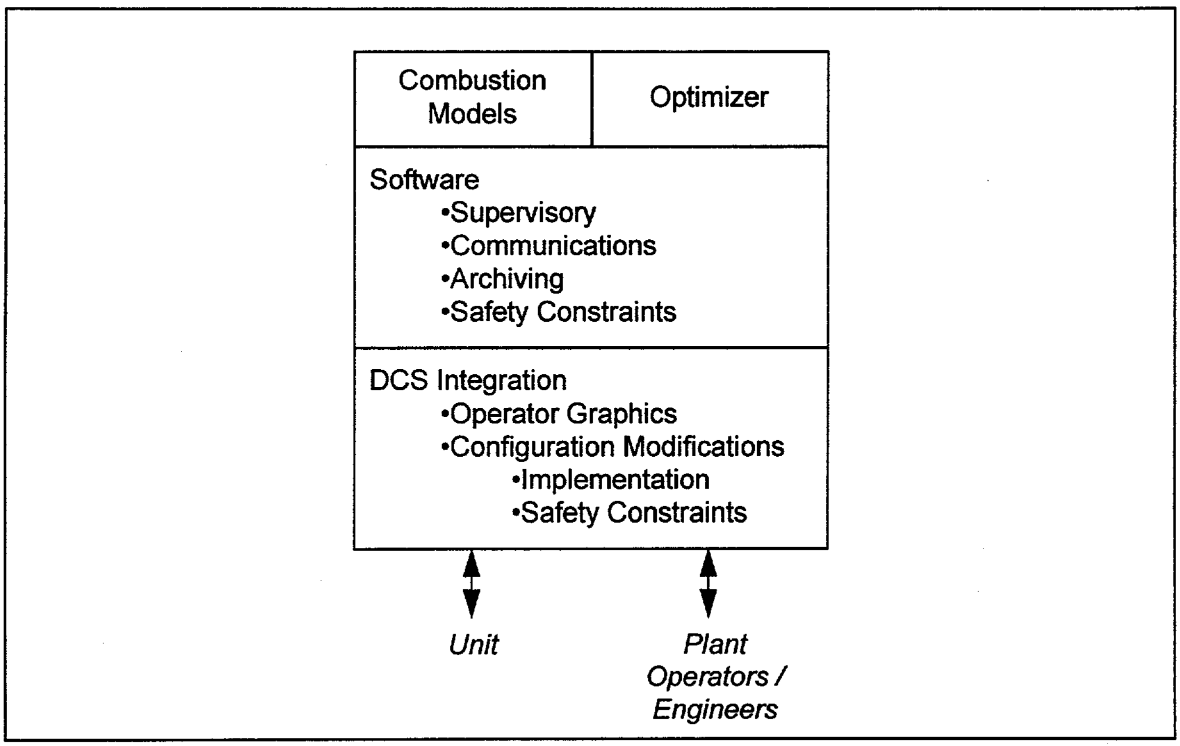


**Figure 4: Major Elements of GNOCIS**

# 3. PROJECT STATUS

## 3.1. Project Summary

Baseline, AOFA, LNB, and LNB+AOFA test phases have been completed. Details of the testing conducted during each phase can be found in the following reports:

- Phase 1 Baseline Tests Report [1],
- Phase 2 AOFA Tests Report [2],
- Phase 3A Low $NO_x$ Burner Tests Report [3], and
- Phase 3B Low $NO_x$ Burner plus AOFA Tests Report [4].

Chemical emissions testing was also conducted as part of the project and the results have been previously reported [5]. Phase 4 of the project -- evaluation of advanced digital optimization / controls strategies as applied to $NO_x$ abatement -- is now in progress. A list of the current activities and their current status can be found in Table 3.

**Table 3: Phase 4 Milestones / Status**

| Milestone | Status |
|---|---|
| Digital control system design, configuration, and installation | Completed |
| Digital control system startup | Completed |
| Instrumentation upgrades | Completed |
| Characterization of the unit pre- activation of advanced strategies | Completed |
| Advanced controls/optimization design | In Progress |
| Characterization of the post- activation of advanced strategies | 6/95 - 9/95 |

## 3.2. Summary of Current Quarter Activities

During fourth quarter 1995, Hammond 4 was off-line and on reserved standby the majority of the time. This was the result of (1) the relatively mild weather and the resultant low electricity demand and (2) relatively high cost (as compared to other units in the Southern electric system) of generation on this unit. In total, the unit operated approximately 30 days out of a total of 92 days this quarter. Installation of GNOCIS for open- and closed-loop operation is virtually complete. Final software checkout will begin upon resumption of consistent unit operation. Following checkout, testing of GNOCIS will commence. Also during this quarter, problems with the project's continuous emissions monitor and carbon-in-ash monitor have compromised some of the data collected. The recent extended outage of the unit likely contributed to the instrument problems. At the end of the quarter, repairs were underway on these instruments. Preparation of the project final report is continuing with approximately 50 percent completed to date. Results from Phase 4 of the project will be integrated into the report as it becomes available.

### 3.3. Short-Term Testing

Because of unavailability of the unit, no short-term testing was conducted this quarter. Pending availability of the unit, GNOCIS testing will commence first quarter 1996. Also, further testing of the carbon-in-ash analyzers will be conducted next quarter.

### 3.4. Long-Term Generation and Emissions

Long-term data collection continued during this quarter. Unit generation is shown in Figures 8 and 9. As shown, the unit was run at minimum (approximately 200 MW) to maximum loads (approximately 540 MW) during this quarter. The unit operated at a capacity factor of near 20 percent and was off-line approximately 65 percent of the time this quarter. Average load was approximately 114 and 320 MW when off-time was included and excluded, respectively. $NO_x$ emissions for this period are shown in Figures 10 through 12. The average $NO_x$ emission rate for the period was 0.41 lb/MBtu -- the emission rate during Phase 3B was approximately 0.40 lb/MBtu. The emission limit for this unit is 0.50 lb/MBtu. $NO_x$ emissions exhibited more dependence on unit load than in prior phases (Figure 13). The band around the mean represents ± two standard deviations. $SO_2$ emissions during this quarter are shown in Figures 13 through 15. $SO_2$ emissions were generally consistent during this quarter. The mean $SO_2$ emission rate for the quarter was approximately 2020 lb/hr with total emissions for the period being near 2000 tons. As shown in Figure 15, the $SO_2$ emission rate is, as expected, linearly related to load. Stack gas mass flow rates for the period are depicted in Figures 16 through 18. As shown, mean gas flow rate is roughly linear with load.

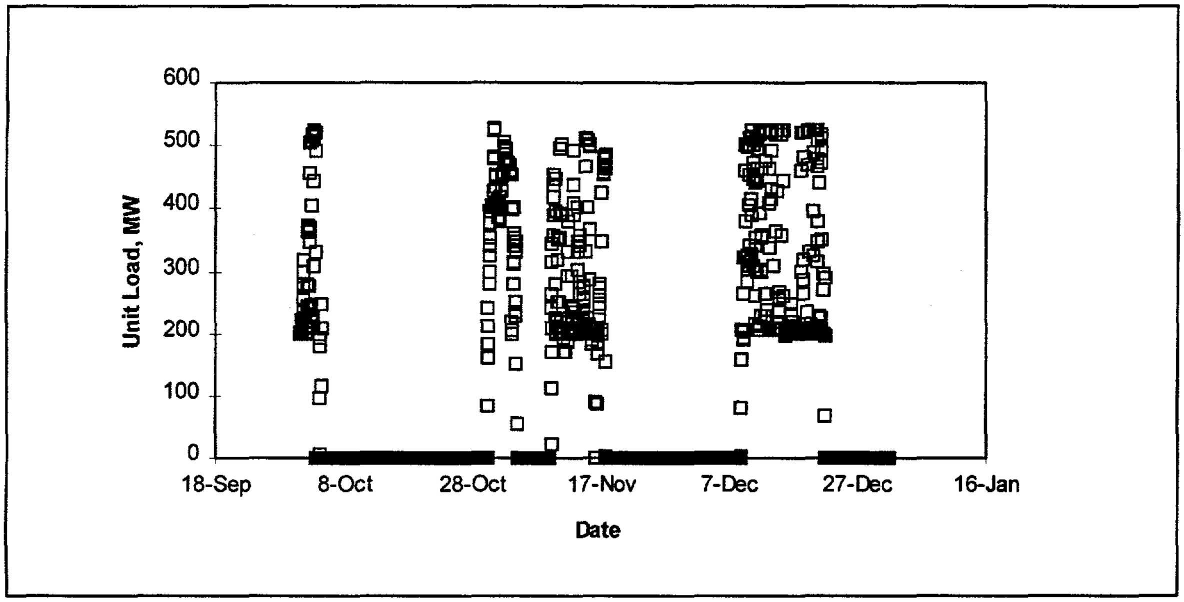


**Figure 5: Fourth Quarter 1995 Generation**

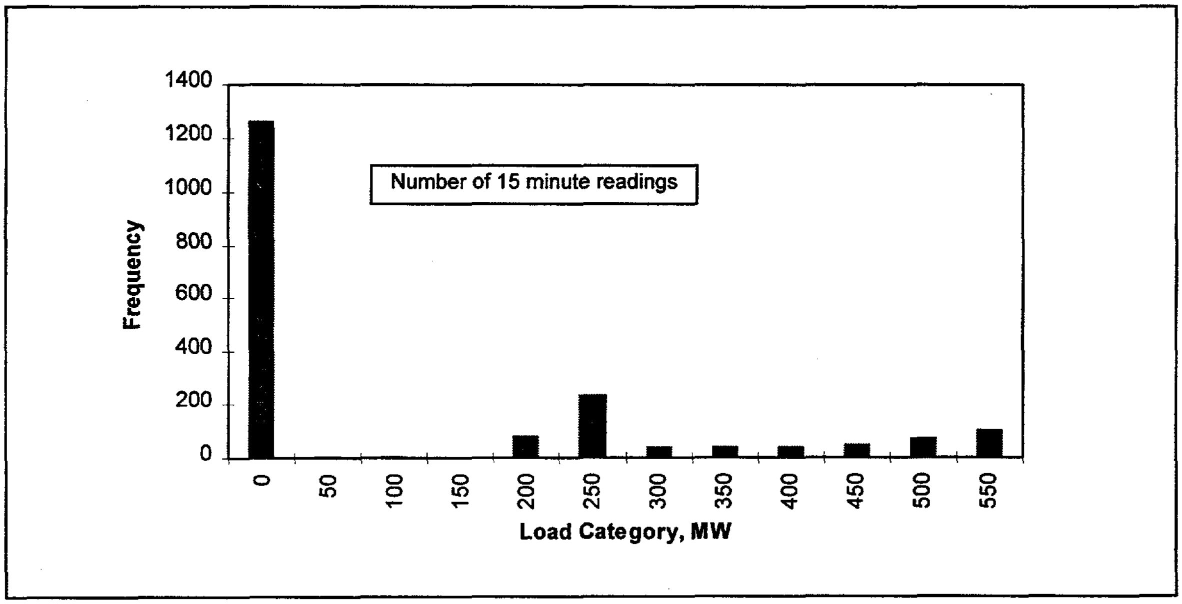


**Figure 6: Fourth Quarter 1995 Generation Histogram**

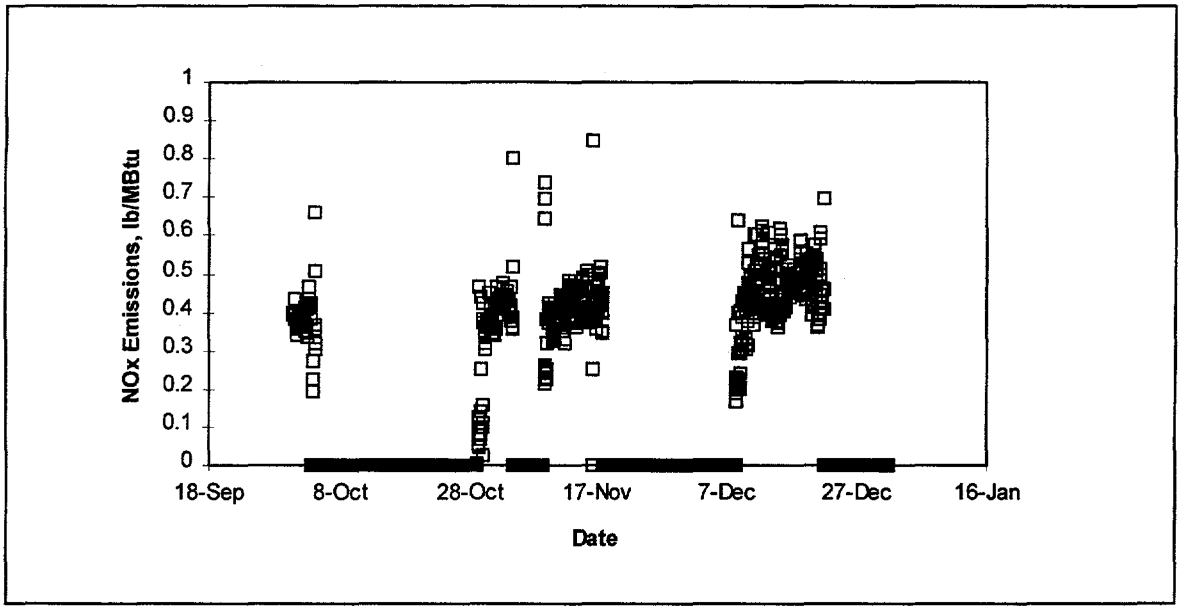


**Figure 7: Fourth Quarter 1995 $NO_x$ Emission Levels**

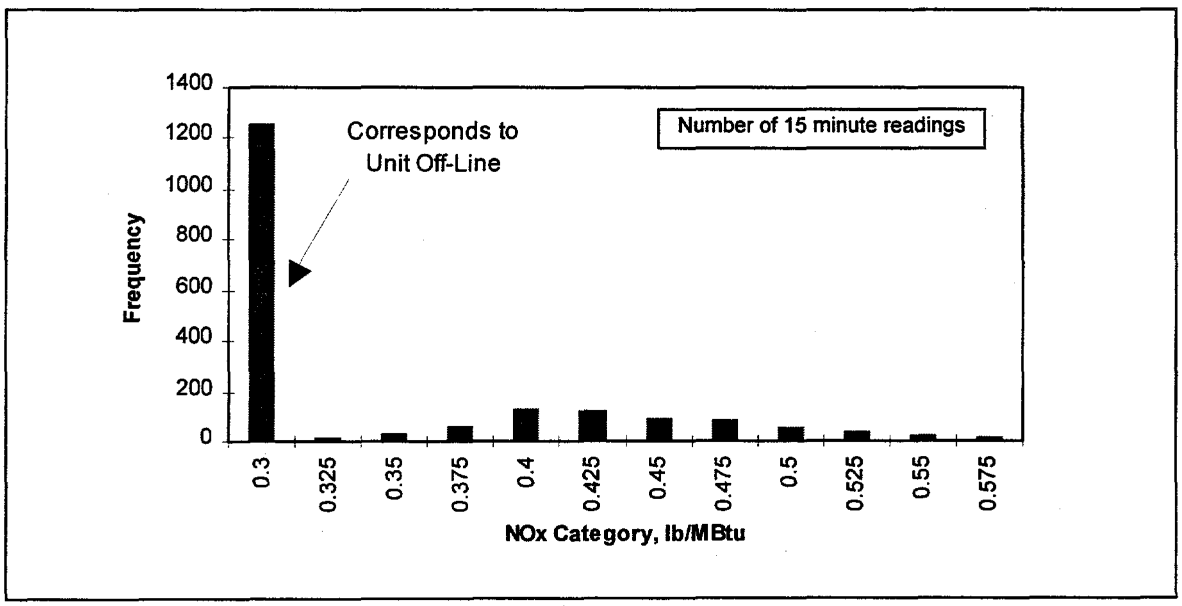


**Figure 8: Fourth Quarter 1995 $NO_x$ Emission Level Histogram**

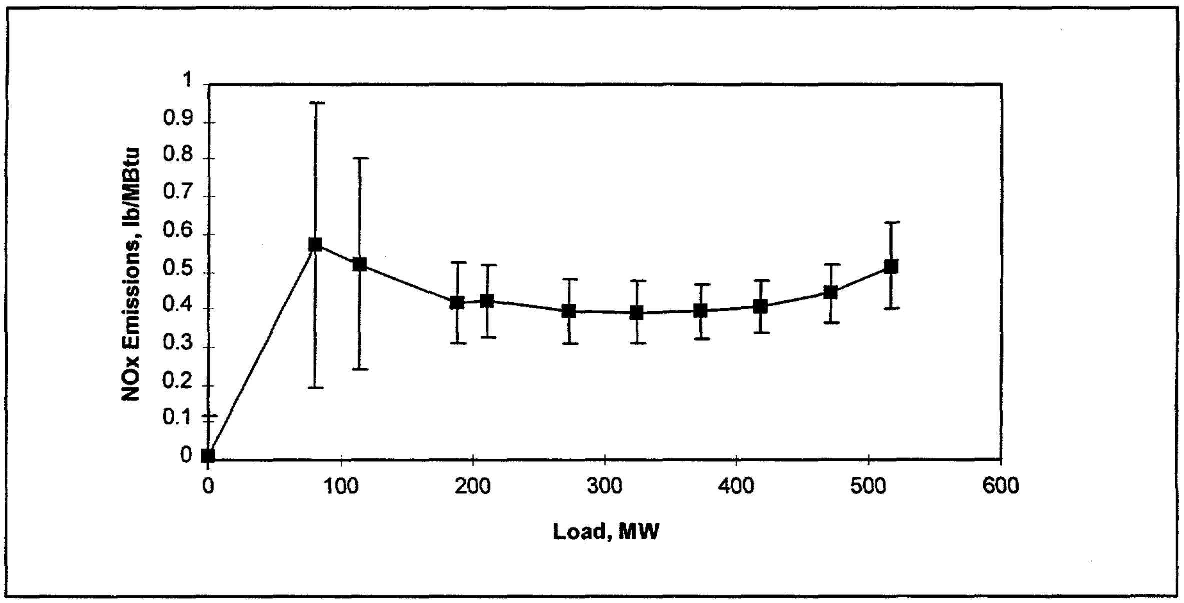


**Figure 9: Fourth Quarter 1995 $NO_x$ Emission vs. Load Characteristic**

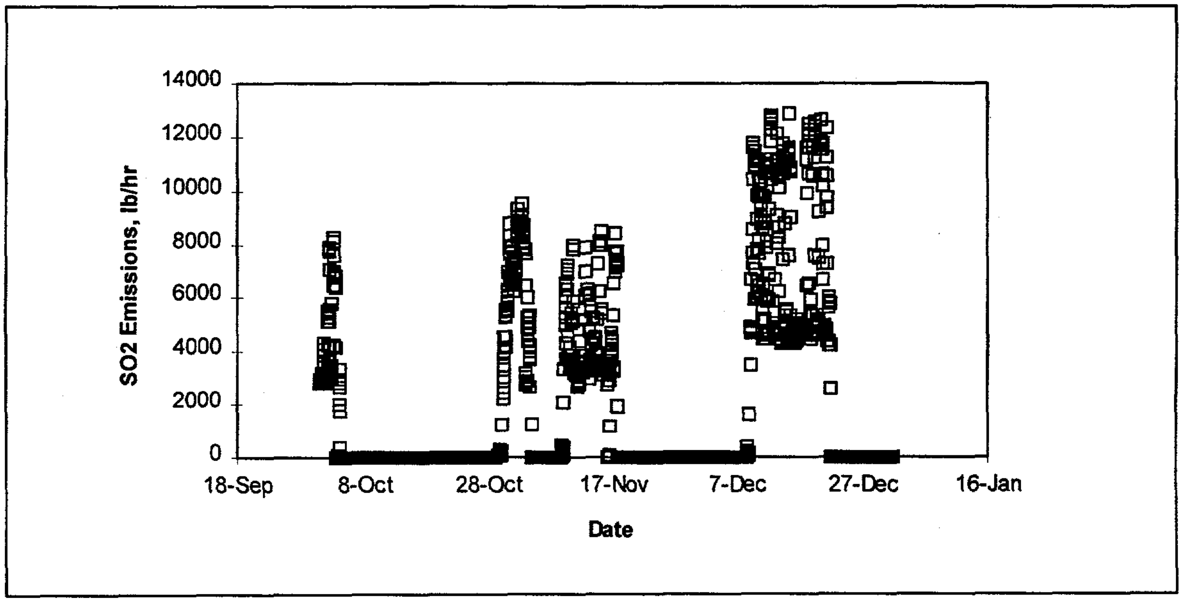


**Figure 10: Fourth Quarter 1995 $SO_2$ Emission Levels**

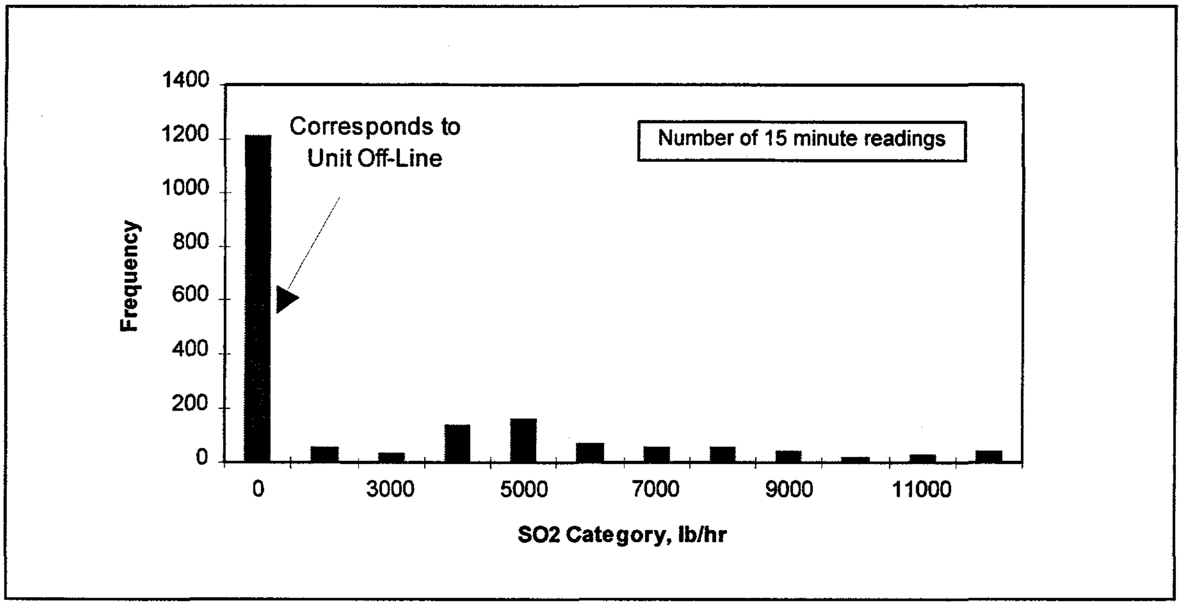


**Figure 11: Fourth Quarter 1995 $SO_2$ Emission Histogram**

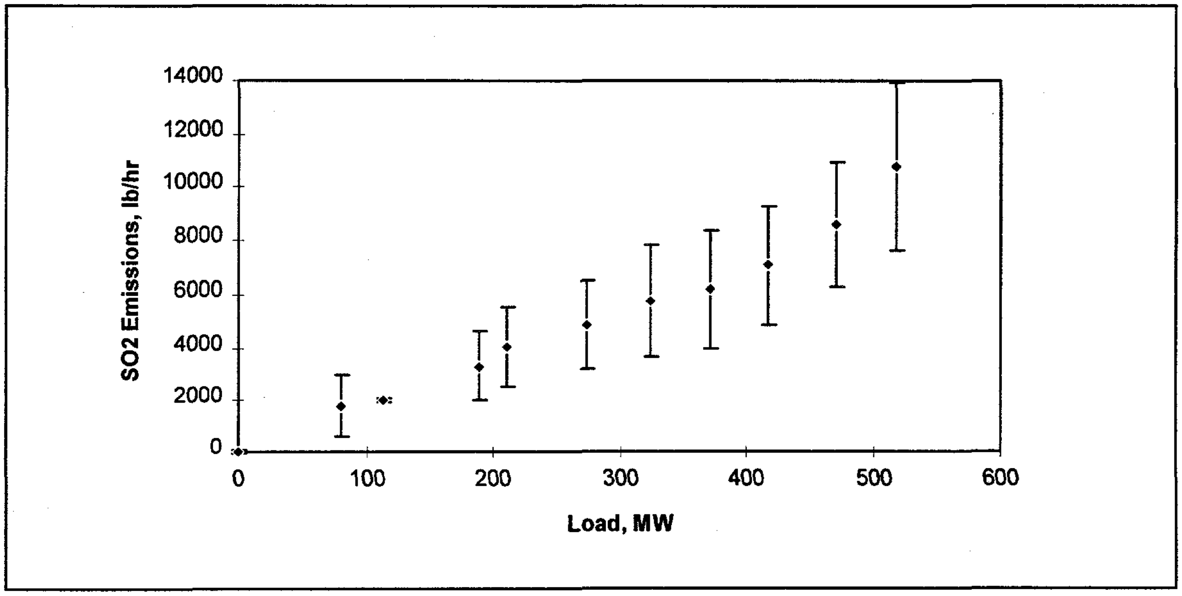


**Figure 12: Fourth Quarter 1995 $SO_2$ Emissions vs. Load Characteristic**

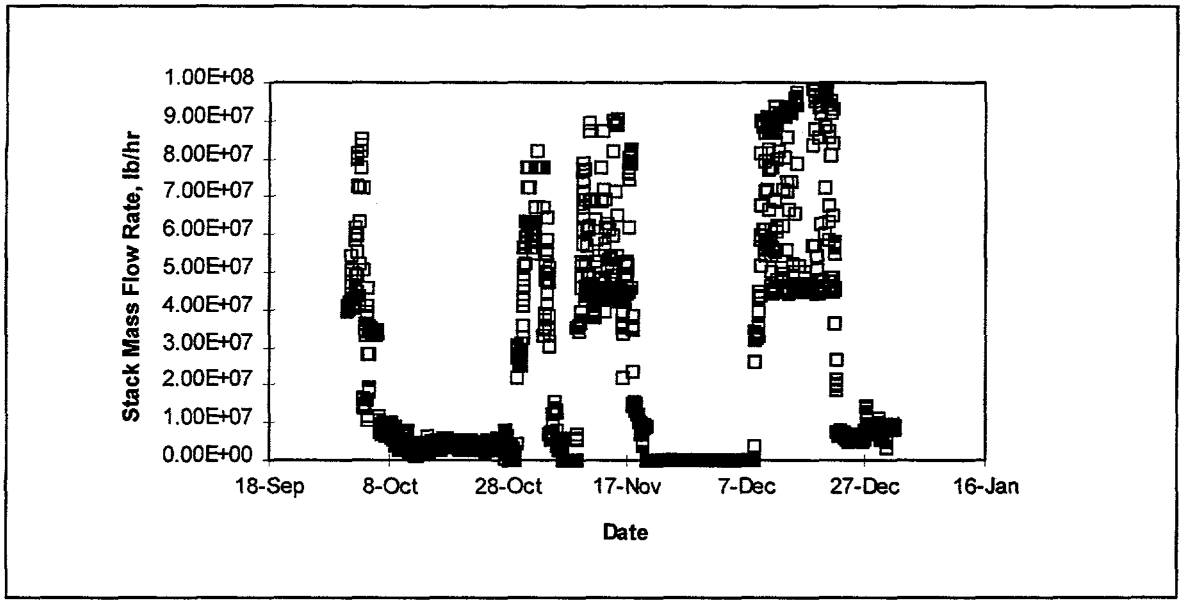


**Figure 13: Fourth Quarter 1995 Stack Mass Flow Rate Levels**

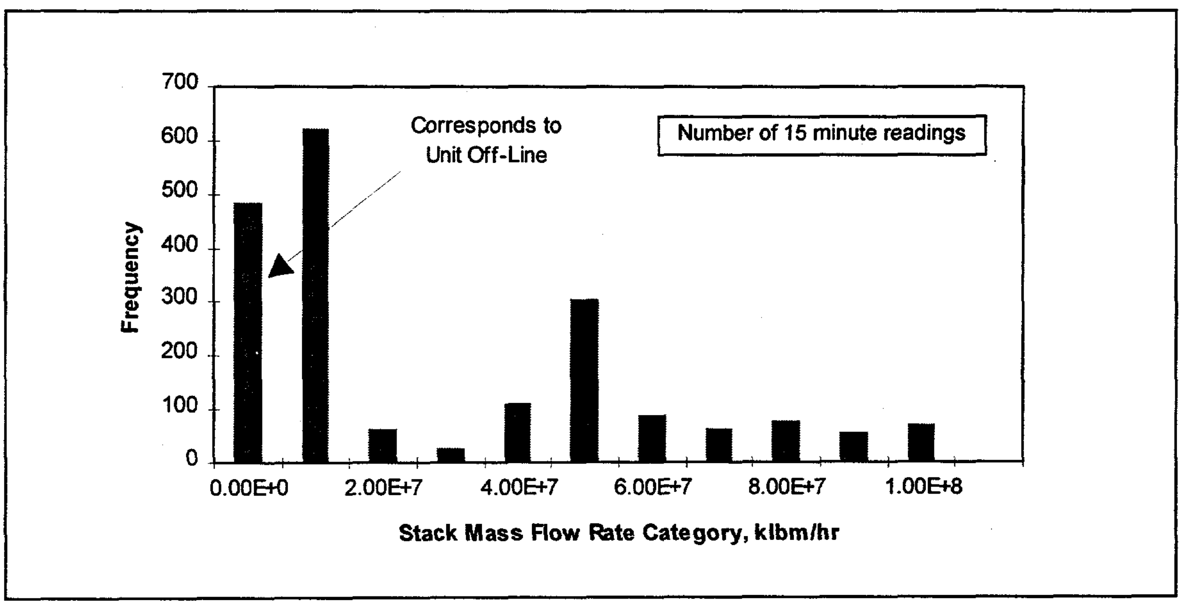


**Figure 14: Fourth Quarter 1995 Stack Mass Flow Rate Histogram**

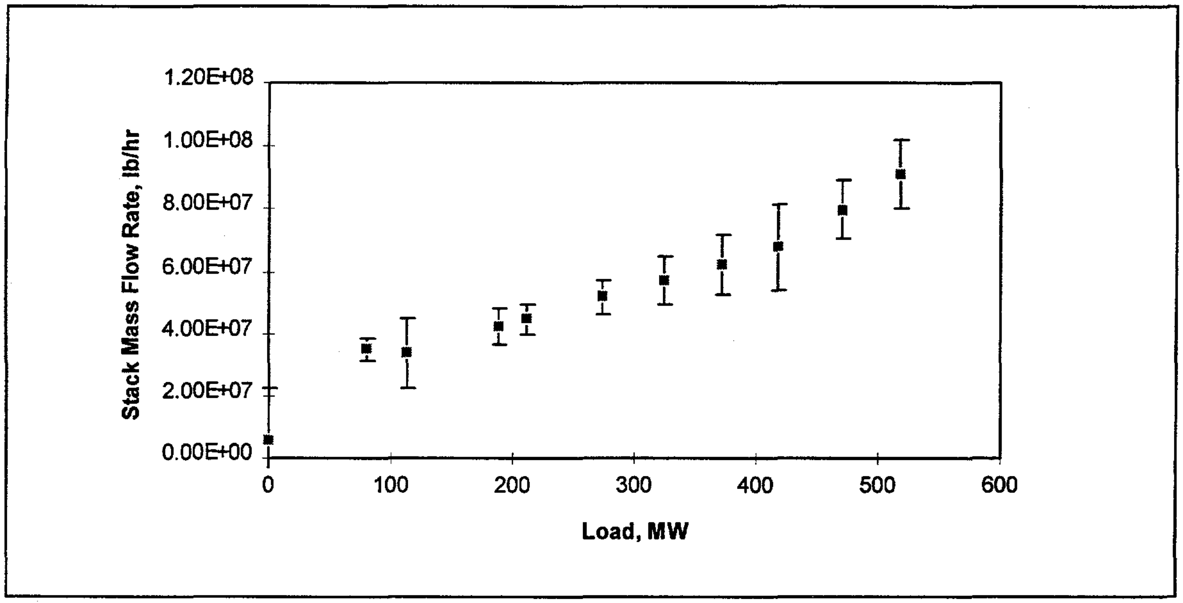


**Figure 15: Fourth Quarter 1995 Stack Mass Flow Rate vs. Load Characteristic**

### 3.5. Advanced Controls and Optimization

The software and methodology to be demonstrated at Hammond Unit 4 is the Generic $NO_x$ Control Intelligent System (GNOCIS) whose development is being funded by a consortium consisting of the Electric Power Research Institute, PowerGen (a U.K. power producer), Southern Company, U.K. Department of Trade and Industry, and U.S. Department of Energy [6]. GNOCIS is a methodology that can result in improved boiler efficiency and reduced $NO_x$ emissions from fossil fuel fired boilers. Using a numerical model of the combustion process, GNOCIS applies an optimizing procedure to identify the best set points for the plant on a continuous basis. The optimization occurs over a wide range of operating conditions. Once determined, the recommended set points can be implemented automatically without operator intervention (closed-loop), or, at the plant's discretion, conveyed to the plant operators for implementation (open-loop). GNOCIS is designed to run on a stand-alone workstation networked to the digital control system, or internally on some digital control systems.

GNOCIS is currently under development and has been or is scheduled to be implemented at PowerGen's Kingsnorth Unit 1 (a 500 MW tangentially-fired unit with ICL separated and close-coupled overfire air $NO_x$ combustion system) and Alabama Power's Gaston Unit 4 (a 250 MW B&W unit with B&W XCL low $NO_x$ burners) prior to comprehensive testing at Hammond. Following "re-characterization" of Hammond 4, the advanced controls and optimization strategies will be activated and run open-loop. If the results from the open-loop testing warrant, the advanced controls/optimization package will be operated closed-loop with testing (short- and long-term). A brief review of the major developments during fourth quarter 1995 regarding the GNOCIS activities at Gaston, Kingsnorth, and Hammond are provided below.

<u>Gaston</u>

A summary of the activities and status of the GNOCIS project at Gaston Unit 4 follows:

- Following a November 1995 maintenance outage, Gaston Unit 4 resumed operation on December 7, 1995. The unit was on-line for approximately 20 days during December 1995 and there is high likelihood that there will be sufficient opportunity to conduct GNOCIS testing during first quarter 1996.
- As originally conceived and proposed to the project funders, the Gaston 4 implementation of GNOCIS was to be open-loop only. Although GNOCIS can be used in this manner, to obtain the full-benefit of GNOCIS, a closed-loop implementation is required. During fourth quarter 1995, modifications were begun to the Unit 4 DCS to enable closed-loop operation. Closed-loop implementation of GNOCIS involves modification of the DCS configuration to accept and implement the recommendations without operator intervention. These enhancements are being implemented within the existing budget.
- Because of unit outages and load cuts, no on-site testing of GNOCIS was conducted at Gaston during fourth quarter 1995. Testing of the unit is now expected to resume

in mid-January 1996. Approximately thirty parametric tests are planned at full, intermediate, and low loads. Closed-loop testing will also be conducted.

- Prior GNOCIS models at this site relied on the project's temporary continuous emissions monitor (CEM). In consideration of reliability problems of this monitor and long-term deployment of GNOCIS at Gaston, the combustion models are being revised to make use of the Unit 3-4 compliance CEM. Preliminary indications are that satisfactory models can be built using this CEM. Also, modifications are being made to the Unit 3 DCS to enable monitoring and archiving of data from that unit for use in the GNOCIS models.
- Arrangements have been made for the installation of a Mark & Wedell (M&W) on-line carbon-in-ash monitor at Gaston 4. The M&W system is an extractive system and the Gaston 4 installation will have two sample probes located at the economizer outlet. The installation should be completed by late January 1996. When available, the LOI data from this instrument will be incorporated into the GNOCIS models.

*Kingsnorth*

Testing of GNOCIS at Kingsnorth has been completed and GNOCIS is now being used in a production mode at the plant, however, further ad hoc testing of GNOCIS may be conducted at Kingsnorth in the future. The current GNOCIS installation at Kingsnorth is based on a linear model and constrained linear optimization routines. This installation may be modified to incorporate the non-linear models, such as those used at Gaston and Hammond.

*Hammond*

Because of unavailability of the unit, testing of GNOCIS was not conducted this quarter. Installation of GNOCIS for open- and closed-loop operation is virtually complete. Final software checkout will begin upon resumption of consistent unit operation and prior to testing. Predictive and control models have been developed. New data will be incorporated into the models as the data becomes available.

## 4. FUTURE PLANS

The following table is a quarterly outline of the activities scheduled for the remainder of the project:

**Table 4: Future Plans**

| Quarter | Activity |
|---|---|
| First Quarter 1996 | • LOI Monitor Testing<br>• Advanced Controls Testing<br>• Final Reporting & Disposition |
| Second Quarter 1996 | • Final Reporting & Disposition |

## BIBLIOGRAPHY


1. *500 MW Demonstration Of Advanced Wall-Fired Combustion Techniques For The Reduction Of Nitrogen Oxide ($NO_X$) Emissions From Coal-Fired Boilers - Phase 1 Baseline Tests Report.* Southern Company Services, Inc., Birmingham, AL: 1992.

2. *500 MW Demonstration Of Advanced Wall-Fired Combustion Techniques For The Reduction Of Nitrogen Oxide ($NO_X$) Emissions From Coal-Fired Boilers - Phase 2 Advanced Overfire Air Tests Report.* Southern Company Services, Inc., Birmingham, AL: 1992.

3. *500 MW Demonstration Of Advanced Wall-Fired Combustion Techniques For The Reduction Of Nitrogen Oxide ($NO_X$) Emissions From Coal-Fired Boilers - Phase 3A Low* $NO_x$ *Burner Tests Report (Draft).* Southern Company Services, Inc., Birmingham, AL: 1993.

4. *500 MW Demonstration Of Advanced Wall-Fired Combustion Techniques For The Reduction Of Nitrogen Oxide ($NO_X$) Emissions From Coal-Fired Boilers - Phase 3B Low* $NO_x$ *Burner Tests & Advanced Overfire Air Report.* Southern Company Services, Inc., Birmingham, AL: 1995.

5. *500 MW Demonstration Of Advanced Wall-Fired Combustion Techniques For The Reduction Of Nitrogen Oxide ($NO_X$) Emissions From Coal-Fired Boilers - Field Chemical Emissions Monitoring: Overfire Air and Overfire Air/Low* $NO_x$ *Burner Operation Final Report.* Southern Company Services, Inc., Birmingham, AL: 1993.

6. Holmes, R., Squires, R., Sorge, J., Chakraborty, R., McIlvried, T., "Progress Report on the Development of a Generic $NO_x$ Control Intelligent System (GNOCIS)," EPRI 1994 Workshop on $NO_x$ Controls for Utility Boilers, May 11-13, 1994, Scottsdale, Arizona.

7. Holmes, R., Squires, R., Sorge, J., Chakraborty, R., McIlvried, T., "Progress Report on the Development of a Generic $NO_x$ Control Intelligent System (GNOCIS)," EPRI 1994 Workshop on $NO_x$ Controls for Utility Boilers, May 11-13, 1994, Scottsdale, Arizona.