DOE/PC/89651--T25

INNOVATIVE CLEAN COAL TECHNOLOGY (ICCT)

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
Second Quarter 1995

DOE Contract Number
DE-FC22-90PC89651

SCS Contract Number
C-91-000027

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Cleared by DOE Patent Counsel on July 17, 1996

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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.

Following a one-month maintenance outage starting April 15, 1995, Hammond Unit 4 resumed operation on May 15, 1995. Among other efforts during the outage, damaged burners were repaired and mill maintenance was performed. Post-outage data continues to be retrieved from digital control system. This data will be concatenated with pre-outage data for use in model development which is now on-going. The digital control system has now been modified to facilitate implementation of GNOCIS recommendations automatically or via the operator. Three on-line carbon-in-ash monitors are being evaluated as part of the project. Two of these monitors are extractive systems and are in operation. A third system, a non-extractive type, is being fabricated and is scheduled to be operational mid-July. Open-and closed-loop testing of GNOCIS at Hammond Unit 4 is planned for summer 1995.

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acfm	actual cubic feet per minute
AMIS	All mills in service
AOFA	Advanced Overfire Air
ASME	American Society of Mechanical Engineers
C	carbon
CAA(A)	Clean Air Act (Amendments)
CEM	Continuous emissions monitor
CFSF	Controlled Flow/Split Flame
Cl	chlorine
CO	carbon monoxide
DAS	data acquisition system
DCS	digital control system
DOE	U.S. Department of Energy
ECEM	extractive CEM
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ETEC	Energy Technology Consultants
F	Fahrenheit
FC	fixed carbon
FWEC	Foster Wheeler Energy Corporation
Flame	Flame Refractories
GPC	Georgia Power Company
H	hydrogen
HHV	higher heating value
HVT	High velocity thermocouple
ICCT	Innovative Clean Coal Technology
KPPH	kilo pounds per hour
lb(s)	pound(s)
LNB	low NO_x burner
LOI	loss on ignition
(M)Btu	(million) British thermal unit
MOOS	Mills out of service
MW	megawatt
N	nitrogen
NO_x	nitrogen oxides
NSPS	New Source Performance Standards
O, O_2	oxygen
OFA	overfire air
PA	primary air
psig	pounds per square inch gauge
PTC	Performance Test Codes
RSD	relative standard deviation
S	sulfur
SCA	specific collection area
SCS	Southern Company Services
SO_2	sulfur dioxide
SoRI	Southern Research Institute
Spectrum	Spectrum Systems Inc.
THC	total hydrocarbons
UARG	Utility Air Regulatory Group
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 that 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 - 10/95*
5*	5*	Final Reporting and Disposition	
	5.1	Project Management and Reporting	9/95 - 12/95*
	5.2	Disposition of Hardware	12/95*

* Indicates change from original work breakdown structure.

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 Figures 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.

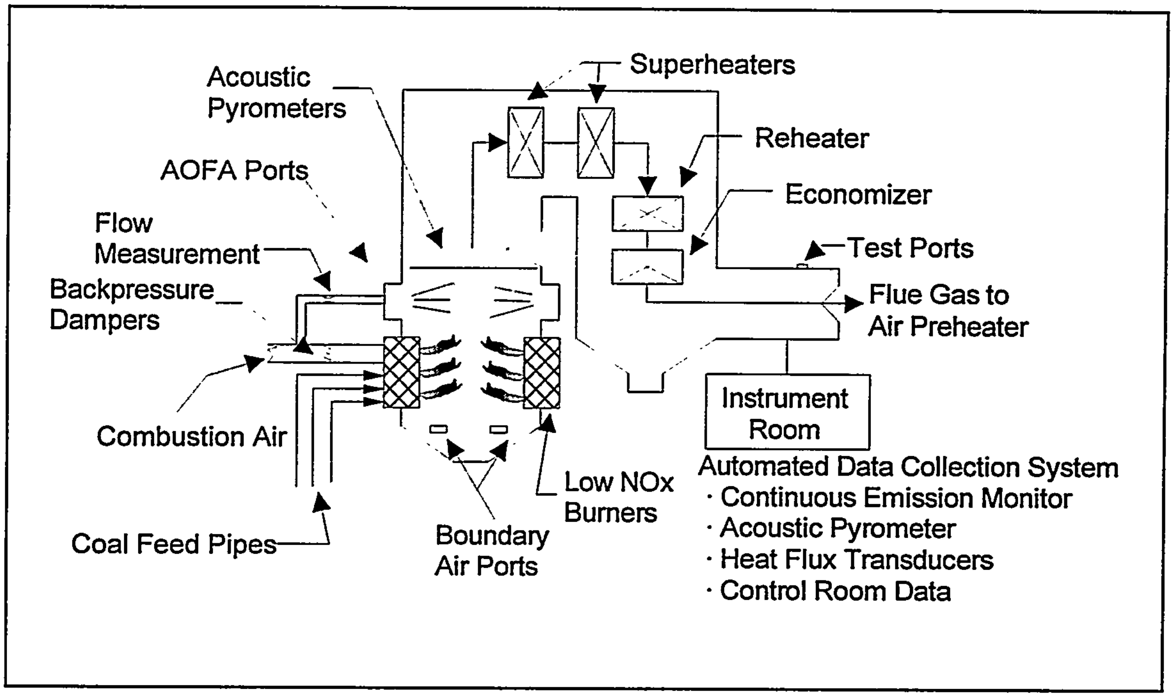

Figure 1: Plant Hammond Unit 4 Boiler

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 retrofitted 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 retrofitted 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 retrofitted 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.

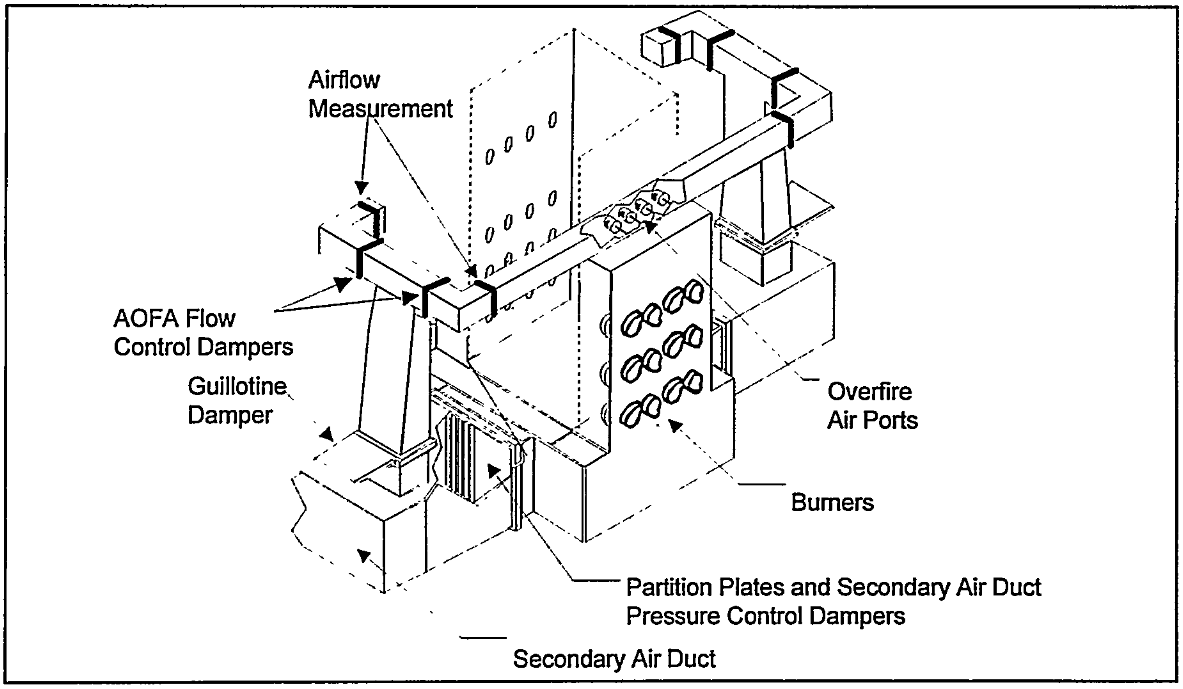

Figure 2: Advanced Overfire Air System

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.

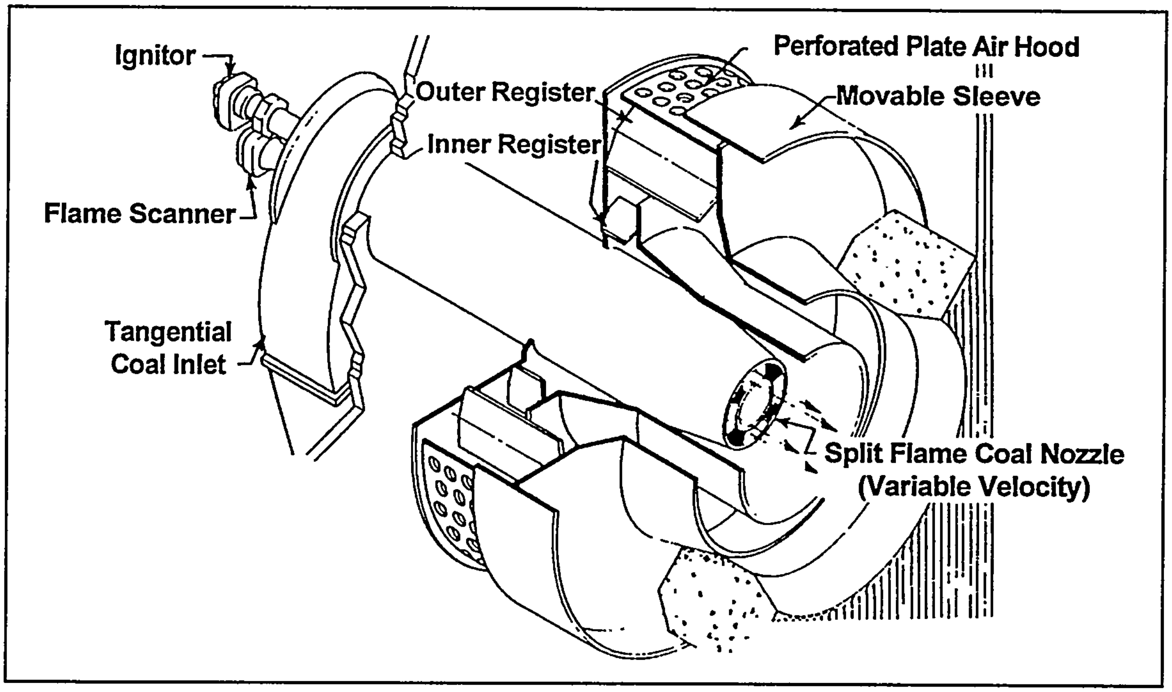

Figure 3: Low NO_x Burner Installed at Plant Hammond

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.

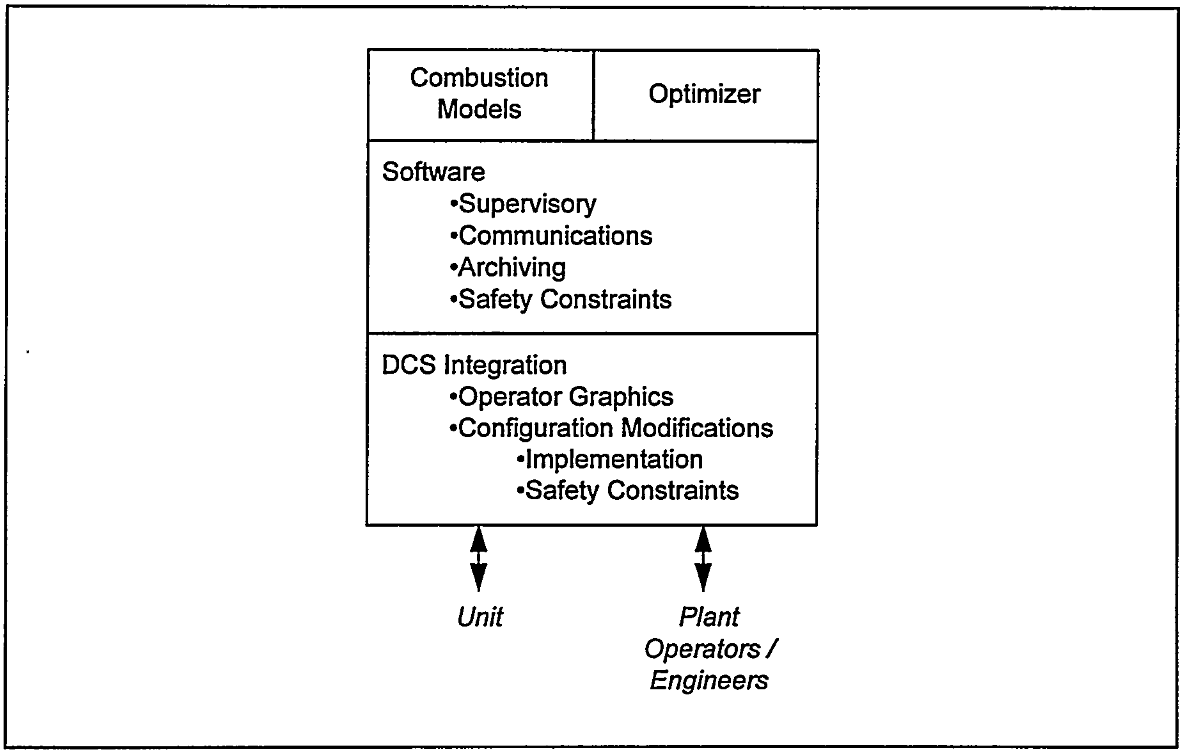

Figure 4: Major Elements of GNOCIS

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

Phase 4 of the project is in progress. During second quarter 1995, design of the advanced control and optimization software and strategies continued. Prototypes of the Generic NO_x Control Intelligent System (GNOCIS) continue to be tested at Alabama Power Company's Gaston Unit 4 and PowerGen's Kingsnorth Unit 1. Installation of the digital control system (DCS) installed as part of Phase 4 of the project has been completed and the system is fully operational. The GNOCIS host platform has been delivered to the site and networked to the Hammond Unit 4 Foxboro I/A digital control system.

Following a one-month maintenance outage starting April 15,1995, Hammond Unit 4 resumed operation on May 15, 1995. Among other efforts during the outage, damaged burners were repaired and mill maintenance was performed. Post-outage data continues to be retrieved from digital control system. This data will be concatenated with pre-outage data for use in model development which is now on-going. The digital control system has now been modified to facilitate implementation of GNOCIS recommendations automatically or via the operator. Three on-line carbon-in-ash monitors are being evaluated as part of the project. Two of these monitors are extractive systems and are in operation. A third system, a non-extractive type, is being fabricated and is scheduled to be operational mid-July.

3.3. Burner Repairs

As mentioned above, burner repairs were performed during the April 15-May 15 outage. Repairs included: (1) burner BA - replaced damaged tip, (2) burner BD - repaired gasket, (3) burner EC - repaired gasket, (4) burner FB - repaired tile. In addition, the control settings of the burners were checked to insure that the settings were 0 inches, 50 percent, and 15 percent, for the inner barrel, outer register, and inner register respectively.

3.4. Short-Term Testing

No short-term testing was conducted this quarter. Pending availability of GNOCIS, testing of this technology should commence third quarter 1995. Also, testing of the carbon-in-ash analyzers will commence in July or August 1995.

3.5. Long-Term Generation and Emissions

Long-term data collection continued during this quarter. Unit generation is shown in Figures 5 and 6. As shown, the unit was run at minimum (approximately 200 MW) to maximum loads (approximately 540 MW) during this quarter. The unit was off-line approximately 39 percent of the period. Average load was approximately 185 and 302 MW when off-time was included and excluded, respectively. NO_x emissions for this period are shown in Figures 7 through 9. The average NO_x emission rate for the period was 0.44 lb/MBtu -- the emission rate during Phase 3B was approximately 0.40 lb/MBtu. The reason for the increase in emissions is at this time unknown. The emission limit for this unit is 0.50 lb/MBtu. As in prior phases, NO_x emissions were rather independent of unit load (Figure 9). The band around the mean represents ± two standard deviations. SO_2 emissions during this quarter are shown in Figures 10 through 12. SO_2 emissions show a general downward trend during the latter third of the quarter, apparently from some changes in coal sulfur content. The mean SO_2 emission rate for the quarter was approximately 4200 lb/hr with total emissions for the period being near 3000 tons. As shown in Figure 12, SO_2 emission rate is, as expected, linearly related to load. Stack gas mass flow rates for the period are depicted in Figures 13 through 15. As shown, mean gas flow rate is roughly linear with load.

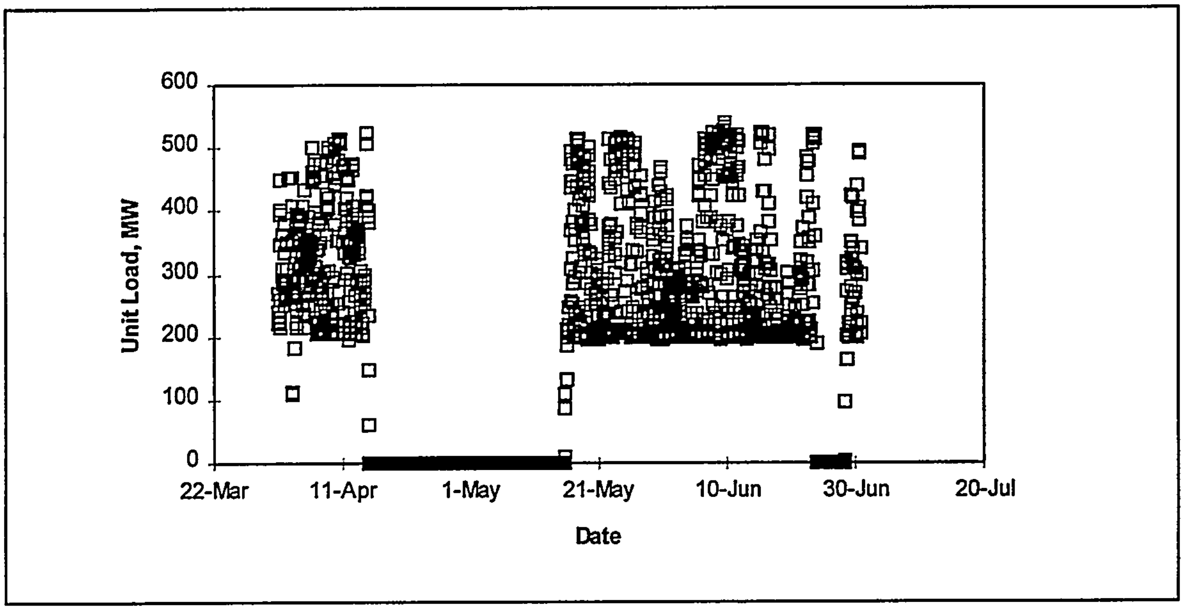

Figure 5: Second Quarter 1995 Generation

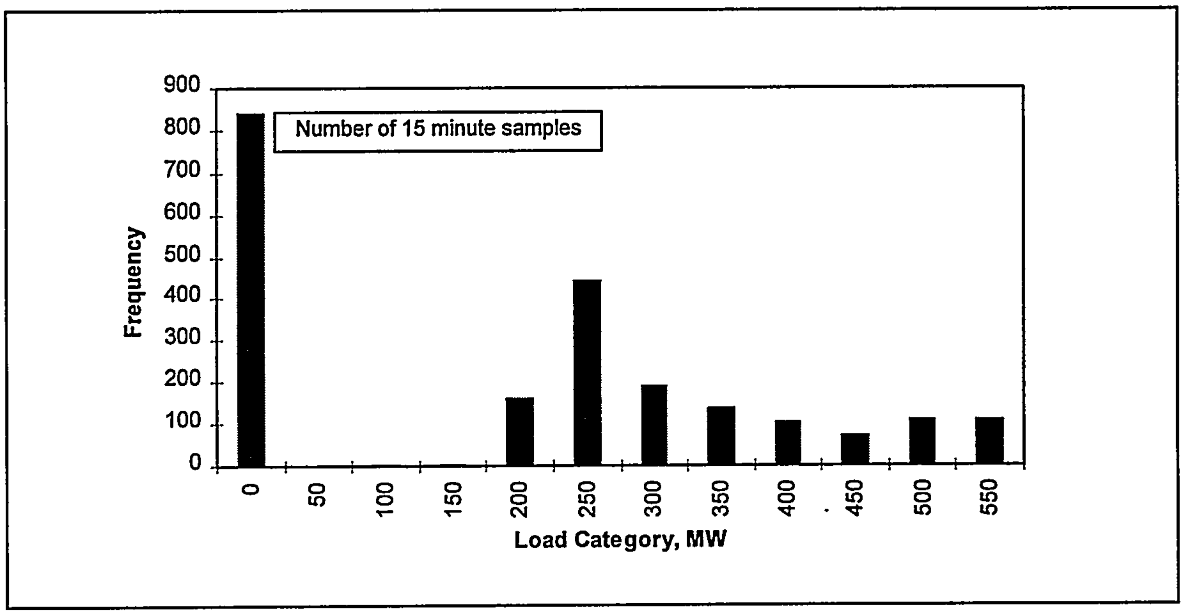

Figure 6: Second Quarter 1995 Generation Frequency

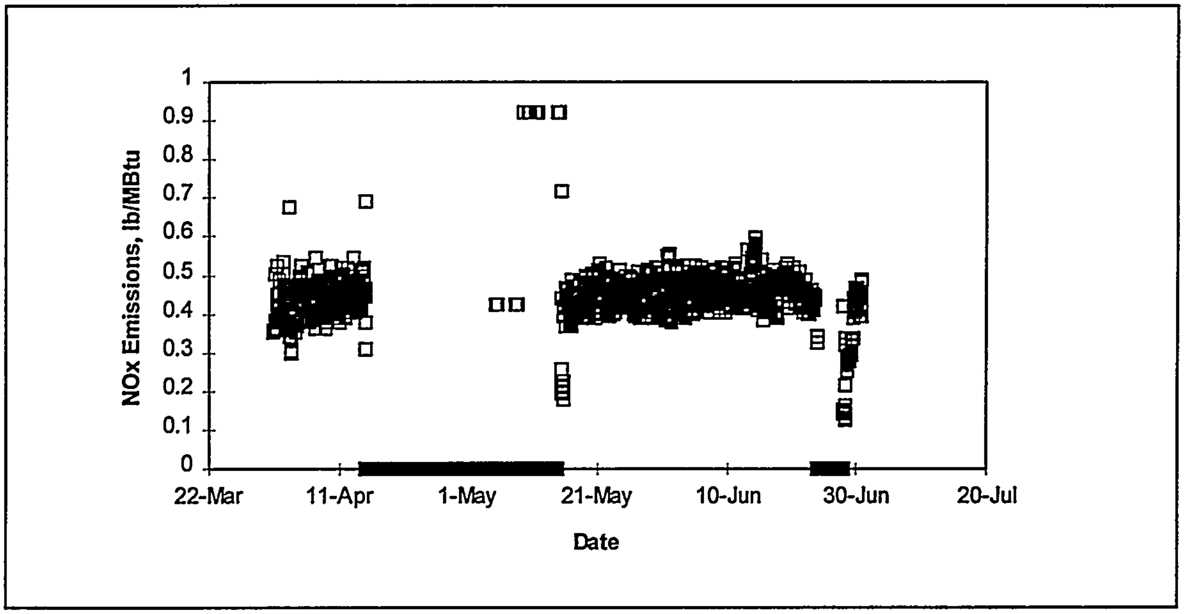

Figure 7: Second Quarter 1995 NO_x Emission Levels

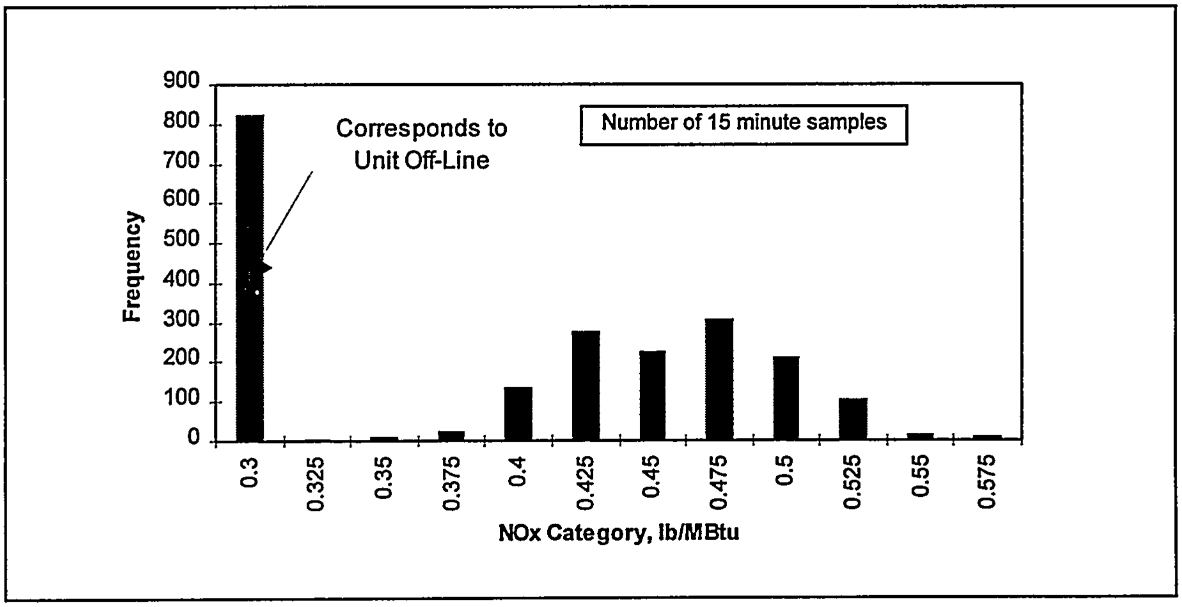

Figure 8: Second Quarter 1995 NO_x Emission Level Frequency

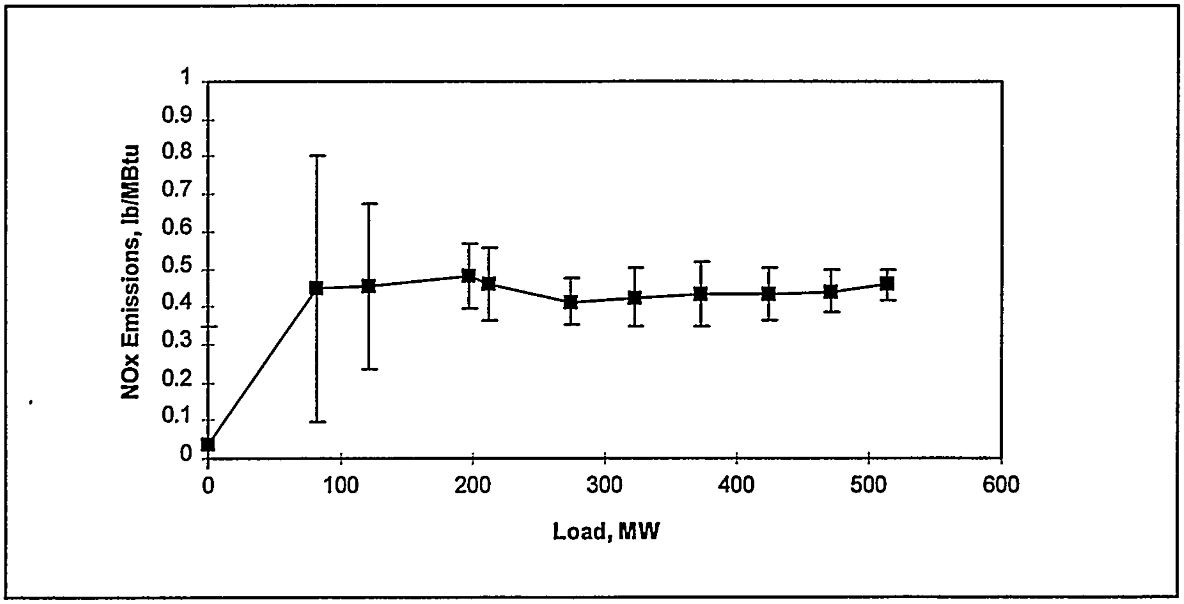

Figure 9: Second Quarter 1995 NO_x Emission vs. Load Characteristic

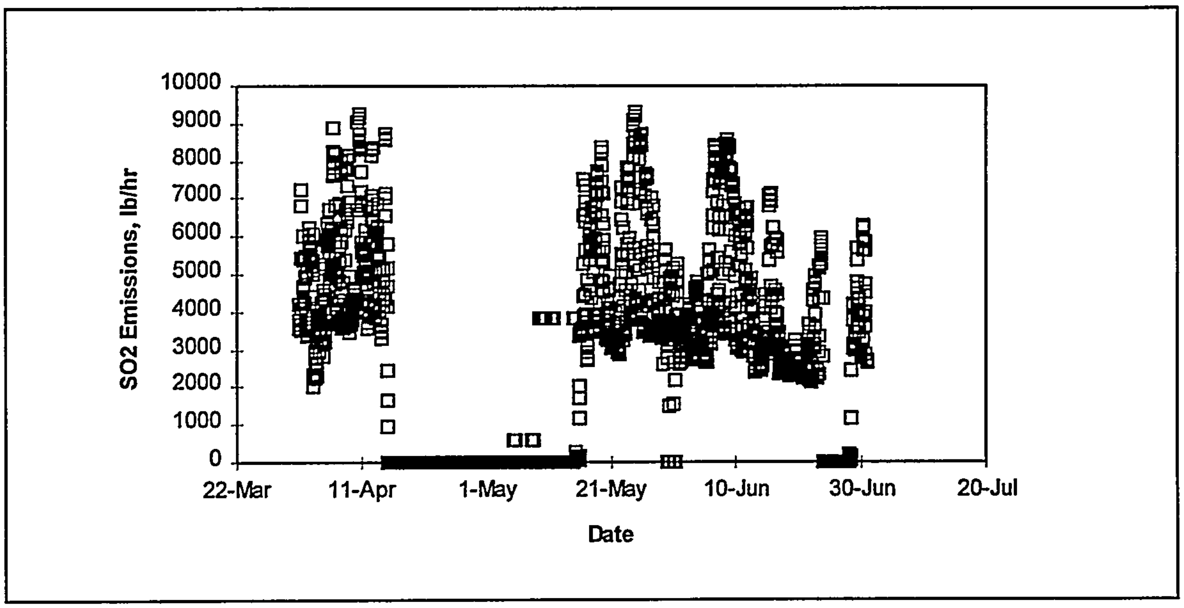

Figure 10: Second Quarter 1995 SO_2 Emission Levels

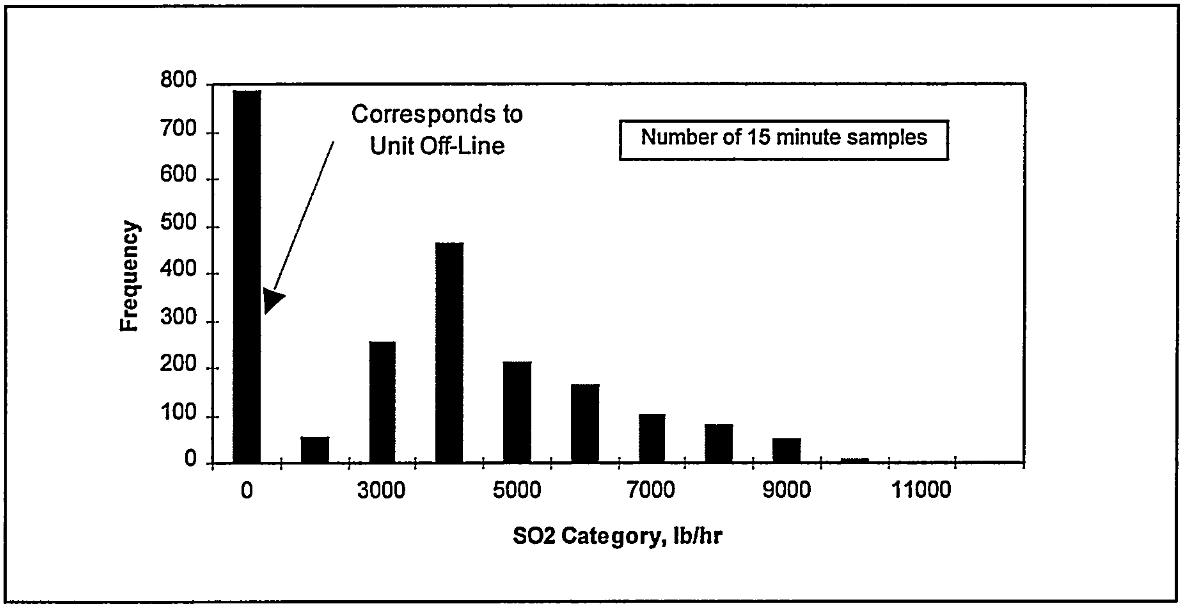

Figure 11: Second Quarter 1995 SO_2 Emission Frequency

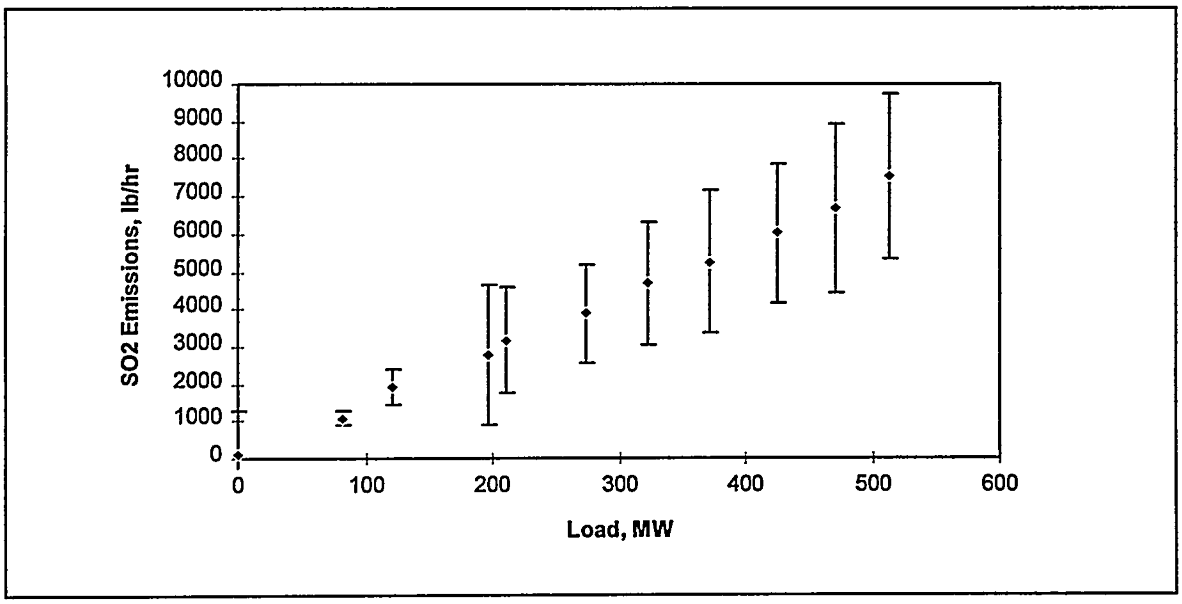

Figure 12: Second Quarter 1995 SO_2 Emissions vs. Load Characteristic

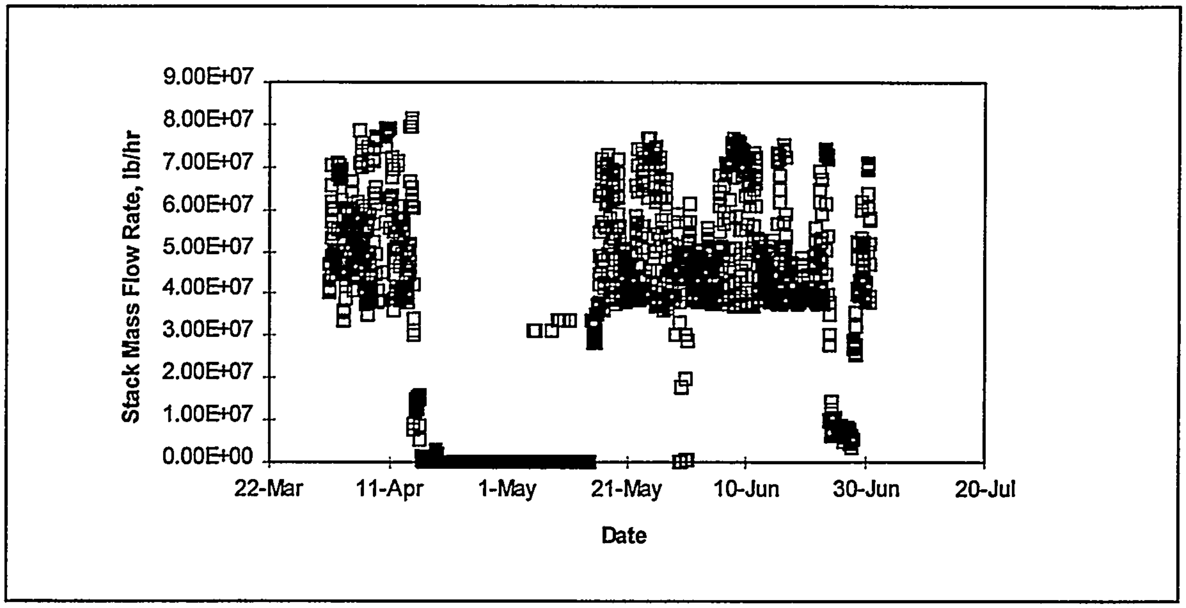

Figure 13: Second Quarter 1995 Stack Mass Flow Rate Levels

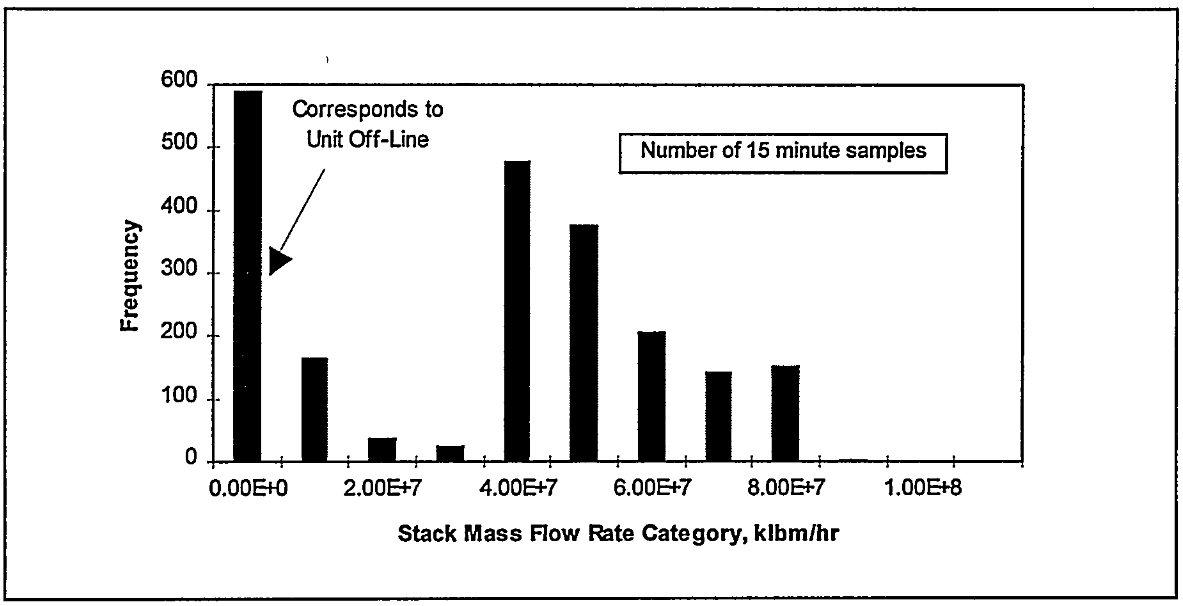

Figure 14: Second Quarter 1995 Stack Mass Flow Rate Frequency

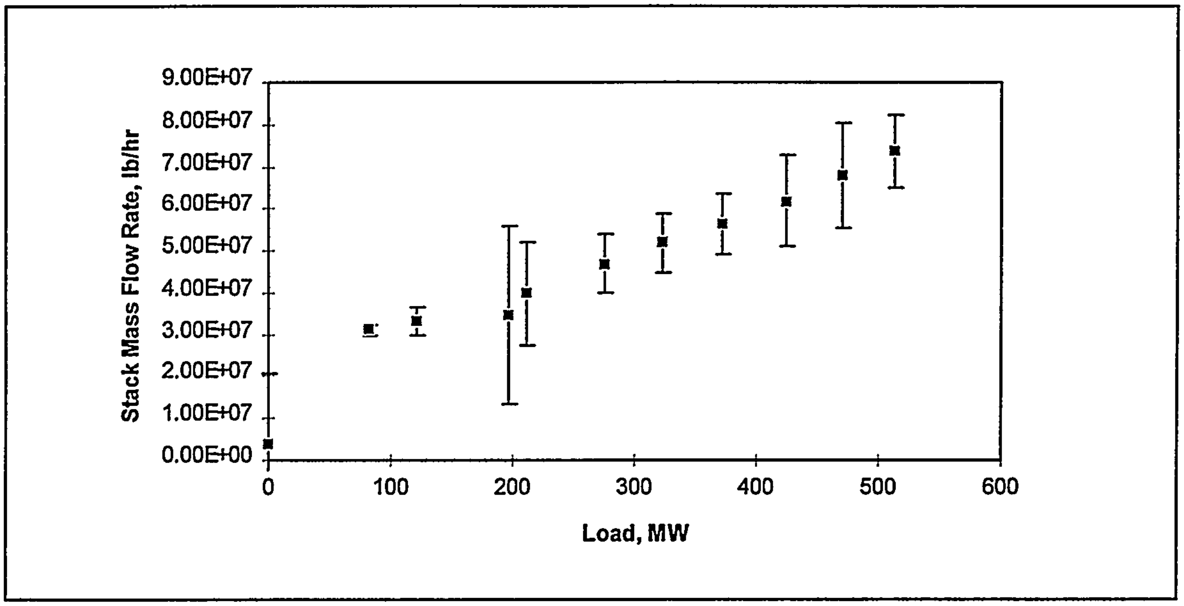

Figure 15: Second Quarter 1995 Stack Mass Flow Rate vs. Load Characteristic

3.6. 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]. The objective of the GNOCIS project is to develop an on-line enhancement to existing digital control systems that will result in reduced NO_x emissions, while meeting other operational constraints on the unit (principally heat rate and other regulated emissions). The core of the system is a model of the combustion characteristics of the boiler, which will reflect both short-term and longer-term shifts in boiler emission characteristics. The software applies an optimizing procedure to identify the best set points for the plant. The recommended set points can be used for closed-loop control of the process or, at the plant's discretion, the set points can be conveyed to the plant operators via the DCS.

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 low 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 in a open-loop mode. If the results from the open-loop testing warrant, the advanced controls/optimization package will be operated in closed-loop mode with testing (short- and long-term). A brief review of the major developments during the current quarter pertaining to the GNOCIS project are provided below.

Gaston

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

- Archival and retrieval of Gaston Unit 4 process data are continuing. To date, the L&N archiver has been used as the primary mechanism by which process data has been archived and retrieved. The L&N archiver uses a custom device driver to communicate to a Write-Once-Read-Many (WORM) drive, which, at the current storage frequency and deadbands, requires replacement of the media every several days. However, as a result of difficulties in retrieving the data once archived, accommodations have also been made to archive the data on the GNOCIS host platform and remotely on SCS file servers in a format which is more flexible and easier to manipulate. The retrieval of data from the L&N system has been further complicated by the periodic failure of the WORM drive. The plant has a replacement drive on order.

- Modifications have been completed to the Gaston Unit 4 L&N DCS to allow communication between the DCS and GNOCIS host platform. The host platform is now being upgraded from the Process Insights Version 3 Beta to the commercial Version 3.1 release. Because of some changes in the procedure calls between the

Beta release and the commercial release, modifications to the wrapper code are required. In addition, because of enhancements in the handling of constraints in Version 3.1 as compared to the Beta release, modifications will be made in the way that the constraint functions are implemented at Gaston. Presently, the GNOCIS operator advisory graphics resides on the Windows NT platform using WonderWare's InTouch graphics software, and preliminary screens have been developed. These screens are being migrated to the L&N digital control system. However, because of limitations in the L&N display system, some ease-of-use features (such as the slide bars for constraints) will be implemented as text entry on the DCS.

- The commercial release of Pavilion's Process Insights Version 3 was received on May 25, 1995, however, because of problems with the license manager included with the distribution tape, a second issue was required and it was received on June 6, 1995. After testing, a further problem was found with the 3.0 release which made the product unusable for GNOCIS. This problem, which was not present in the Beta release, was associated with the optimizer and specifically to the parsing and evaluation of the derivative of the objective function(s). According to Pavilion, this problem is now resolved and distribution tapes containing a new version (Version 3.1) will be forwarded to PowerGen and SCS during the week of July 11, 1995.

- Baseline testing was conducted at Gaston 4 from November 11 through 17, 1994 and from February 2 through February 7, 1995. In total, forty-eight tests were conducted to: (1) determine emissions sensitivity to excess air, mill patterns, mill biasing, and flue gas recirculation, (2) explore possible alternative modes of operation, and (3) enhance the data set used to train the neural network models. At full load and normal operating excess O_2 levels, NO_x emissions and fly ash loss-on-ignition levels were near 0.38 lb/MBtu and 9 percent, respectively.

- Testing of GNOCIS continued at Gaston Unit 4 during June 1995. On June 8, 1995, full load testing was conducted. The combustion model used during this test was based on training data collected during October and November 1994 and February 1995. It was evident from these tests that the models need to be retrained using more recent plant data. This need was most pronounced in the prediction of CO. Although the reason for the discrepancy between the predicted and actual parameters is unknown, possible factors include the result of ongoing mill maintenance or a change in coal characteristics. Also, as a result of this testing, enhancements to the GNOCIS operator interface are being incorporated including the display of current model predictions and direction arrows to aid the operator in determining the direction to move the controllable parameters. Further testing was conducted on June 30, 1995. The results from these tests confirmed the need to retrain the models with more recent data. All testing during June 1995 was conducted with Process Insights Version 3.0 Beta.

Kingsnorth

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

Hammond

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

- Data from both prior short- and long-term tests are being used to assess the combustion characteristics of the unit and provide training data for the combustion models. Approximately 60 days of long-term data have been collected to date for use in model training and this information has been transmitted to Radian for model development. Currently, predictive models have been developed that predict NO_x emissions with R^2 of 0.73. Although the R^2 is not as high as demonstrated earlier, it is felt that it would be satisfactory for the current application. Also, the data used for training purposes is being reviewed for invalid data and work will continue to improve the predictive capabilities of the models. Control models are also being developed. Based on (1) an analysis of the data collected to date and (2) potential control parameters, the following controllable parameters will likely be used at Hammond 4:
    - ◊ Individual fuel flow demands,
    - ◊ Overfire air flows, and
    - ◊ Overall excess O_2.
- Delays in the completion of GNOCIS (see Gaston discussion above) software has adversely impacted its implementation at Hammond. Current plans are to wait for a fully functional package to be developed before installation at Hammond. Current estimates are that the package will be available third quarter 1995.

3.7. On-Line Carbon-in-Ash Monitors

A subsidiary goal of the Wall-Fired project is the evaluation of advanced instrumentation as applied to combustion control. Based on this goal, three on-line carbon-in-ash (CIA) monitors have been procured for this project and are being evaluated as to their:

- Reliability and maintenance,
- Accuracy and repeatability, and
- Suitability for use in the control strategies being demonstrated at Hammond Unit 4.

A Clyde-Sturtevant SEKAM monitor samples from two fixed locations at the economizer outlet. The outputs (carbon-in-ash and system alarm) have been connected to the DCS for archival purposes and incorporation into the control logic. This monitor was commissioned during November 1994. A CAMRAC Corporation CAM monitor, installed February 1995, samples from a single movable location at the precipitator inlet. These two monitors were described previously in the *Third Quarter 1994 Technical Progress Report.*

The third monitor is manufactured by Applied Synergistics. The Applied Synergistic's FOCUS™ Unburned Carbon Module is a non-intrusive real-time device which provides a timely, continuous on-line indication of unburned carbon in fly ash. The device is based on the premise that unburned carbon particles and carbon laden ash particles exiting the furnace will be hotter than the surrounding background gases, carbon-free ash particles, and support structures, and therefore the carbon-laden particles will be higher emitters of radiant energy, especially in the infrared range. The primary sensing elements are one or more near infrared video cameras installed on the furnace. The hotter particles will be seen as white spots traversing the camera(s) field of view and these images are processed to determine the number of traverses in counts per minute. The assumption is then made that the carbon-in-ash (on a percent basis) is a function of these counts and unit load. Two cameras are utilized at Hammond 4. A sketch of the system is shown in Figure 16.

The FOCUS Unburned Carbon Module is to be installed during July 1995 after which testing of this device for calibration and verification purposes will begin.

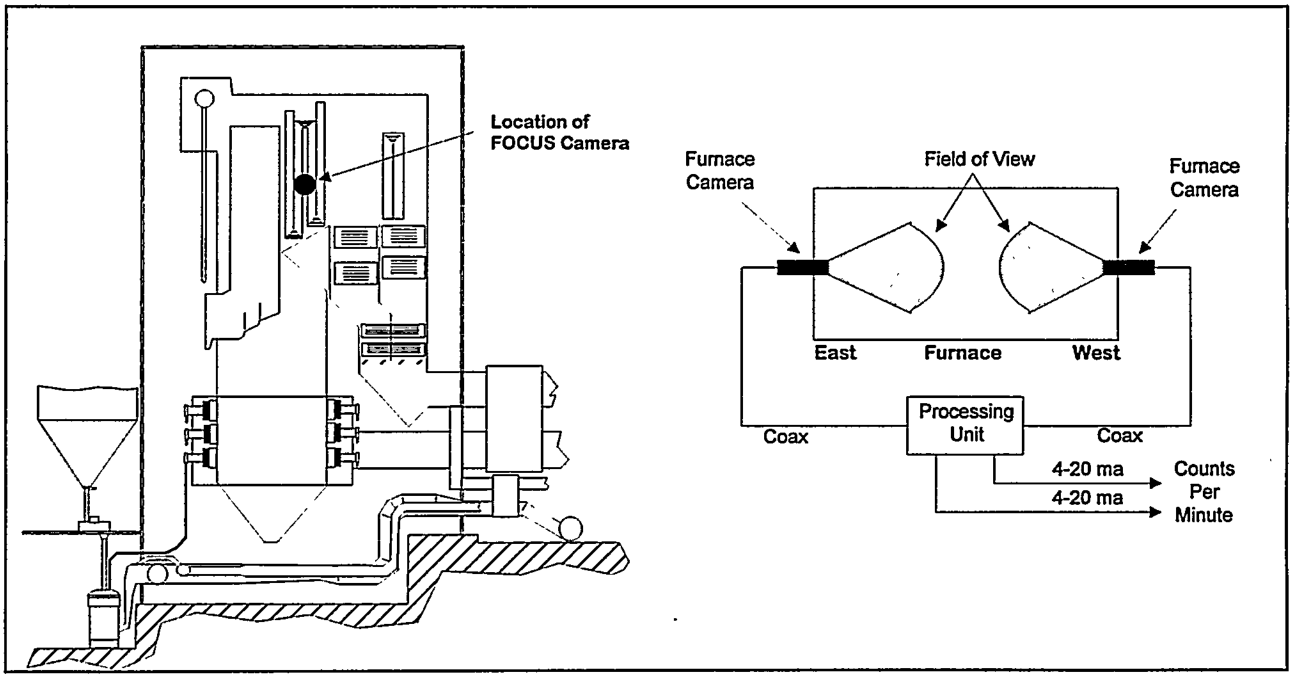

Figure 16: FOCUS General Arrangement

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
Third Quarter 1995	• LOI Monitor Testing • Advanced Controls Testing • Final Reporting & Disposition
Fourth Quarter 1995	• Final Reporting & Disposition

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