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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
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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. A target of achieving fifty percent NO_X reduction using combustion modifications has been established for the project.

The project provides a stepwise retrofit of an advanced overfire air (AOFA) system followed by low NO_X burners (LNB). During each test phase of the project, diagnostic, performance, long-term, and verification testing will be performed. These tests are used to quantify the NO_X reductions of each technology and evaluate the effects of those reductions on other combustion parameters such as particulate characteristics and boiler efficiency.

Baseline, AOFA, and LNB without AOFA test segments have been completed. Analysis of the 94 days of LNB long-term data collected show the full-load NO_X emission levels to be approximately 0.65 lb/MBtu with flyash LOI values of approximately 8 percent. Corresponding values for the AOFA configuration are 0.94 lb/MBtu and approximately 10 percent. For comparison, the long-term, full-load, baseline NO_X emission level was approximately 1.24 lb/MBtu at 5.2 percent LOI. Comprehensive testing of the LNB plus AOFA configuration began in May 1993 and is scheduled to end during August 1993. As of June 30, the diagnostic, performance, chemical emissions tests segments for this configuration have been conducted and 29 days of long-term, emissions data collected. Preliminary results from the May-June 1993 tests of the LNB plus AOFA system show that the full load NOx emissions are approximately 0.42 lb/MBtu with corresponding fly ash LOI values near 8 percent. This is a substantial improvement in both NOx emissions and LOI values when compared to the results obtained during the February-March 1992 abbreviated testing of this system.

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AMIS	All mills in service
AOFA	Advanced Overfire Air
ASME	American Society of Mechanical Engineers
C	carbon
CEM	Continuous emissions monitor
CFSF	Controlled Flow/Split Flame
Cl	chlorine
CO	carbon monoxide
DAS	data acquisition system
DOE	United States Department of Energy
ECEM	extractive continuous emissions monitor
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
F	Fahrenheit
FC	fixed carbon
FWEC	Foster Wheeler Energy Corporation
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 NOx burner
LOI	loss on ignition
(M)Btu	(million) British thermal unit
MOOS	Mills out of service
MW	megawatt
N	nitrogen
NO_x	nitrogen oxides
O, O_2	oxygen
PA	primary air
psig	pounds per square inch gauge
PTC	Performance Test Codes
RSD	relative standard deviation
S	sulfur
SCS	Southern Company Services
SO_2	sulfur dioxide
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: The Southern Company, the U. S. Department of Energy (DOE), and the Electric Power Research Institute. In addition to SCS, The Southern Company includes five electric operating companies: Alabama Power, Georgia Power, Gulf Power, Mississippi Power, and Savannah Electric and Power. SCS provides engineering, research, and financial services to The Southern Company.

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 which are different from traditional research and development programs sponsored by the DOE. Traditional projects focus on long range, high risk, high payoff 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 which 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 which 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. A target of achieving fifty percent NO_X reduction using combustion modifications has been established for the project. 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:

a. Advanced overfire air (AOFA)
b. Low NO_X burners (LNB)
c. LNB with AOFA

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

3. Evaluate the progressive cost effectiveness (i.e., dollars per ton NO_X removed) 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 NO_X reduction methods listed above.

2. PROJECT DESCRIPTION

2.1. Test Program Methodology

In order 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

500 MW Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers

Phase	Task	Description	Date
0	1.0	Phase 0 Pre-Award Negotiations	
1	1.1	Phase 1 Baseline Characterization	8/89 - 4/90
	1.1.1	Project Management and Reporting	8/89 - 10/89
	1.1.2	Site Preparation	9/89 - 6/90
	1.1.3	Flow Modeling	9/89 - 10/89
	1.1.4	Instrumentation	11/89 - 4/90
	1.1.5	Baseline Testing	
2	1.2	Phase 2 Advanced Overfire Air Retrofit	4/90 - 3/91
	1.2.1	Project Management and Reporting	4/90 - 5/90
	1.2.2	AOFA Design and Retrofit	5/90 - 3/91
	1.2.3	AOFA Testing	
3	1.3	Phase 3 Low NO_x Burner Retrofit[1]	
	1.3.1	Project Management and Reporting	3/91 - 4/93
	1.3.2	LNB Design and Retrofit	3/91 - 5/91
	1.3.3	LNB Testing with and without AOFA	5/91 - 9/93
4	1.4	Final Reporting and Disposition[1,2]	
	1.4.1	Project Management and Reporting	9/93 - 12/93
	1.4.2	Disposition of Hardware	12/93

[1]Dates of these tasks reflects change from original project schedule.
[2]Final reporting and disposition will be renumbered to Task 5 upon final approval of the digital controls extension to this project.

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 and 2, 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.

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.

Table 2. Plant Data Points

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 NO_x	Stack SO2
Stack O2	Stack Opacity
Generation	Overfire Air Flows

Following each outage, a series of four groups of tests are planned. 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.

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 (Figure 1) 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 four Babcock and Wilcox MPS 75 mills during the course of the demonstration (two each during the spring 1991 and spring 1992 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 coldside ESP and utilizes two regenerative secondary air preheaters and two regenerative primary air heaters. The unit was designed for pressurized furnace operation but was converted to balanced draft operation in 1977.

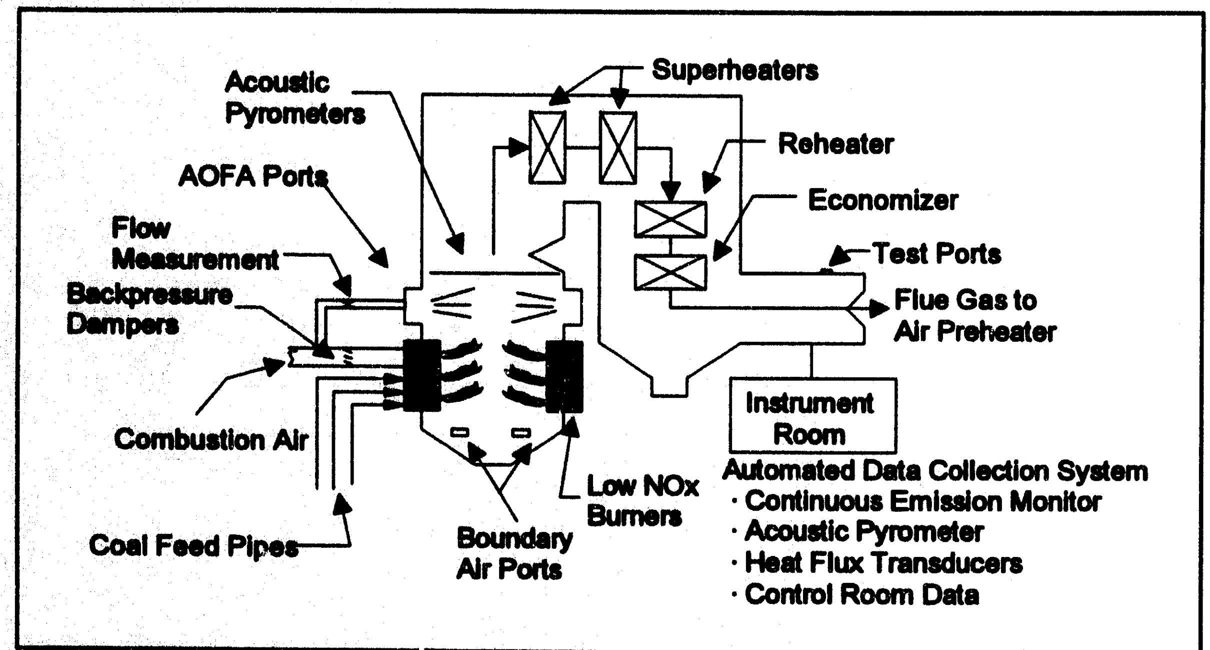

Figure 1. Plant Hammond Unit 4 Boiler

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. Due to 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 instead of the as-installed configuration of four per wall.

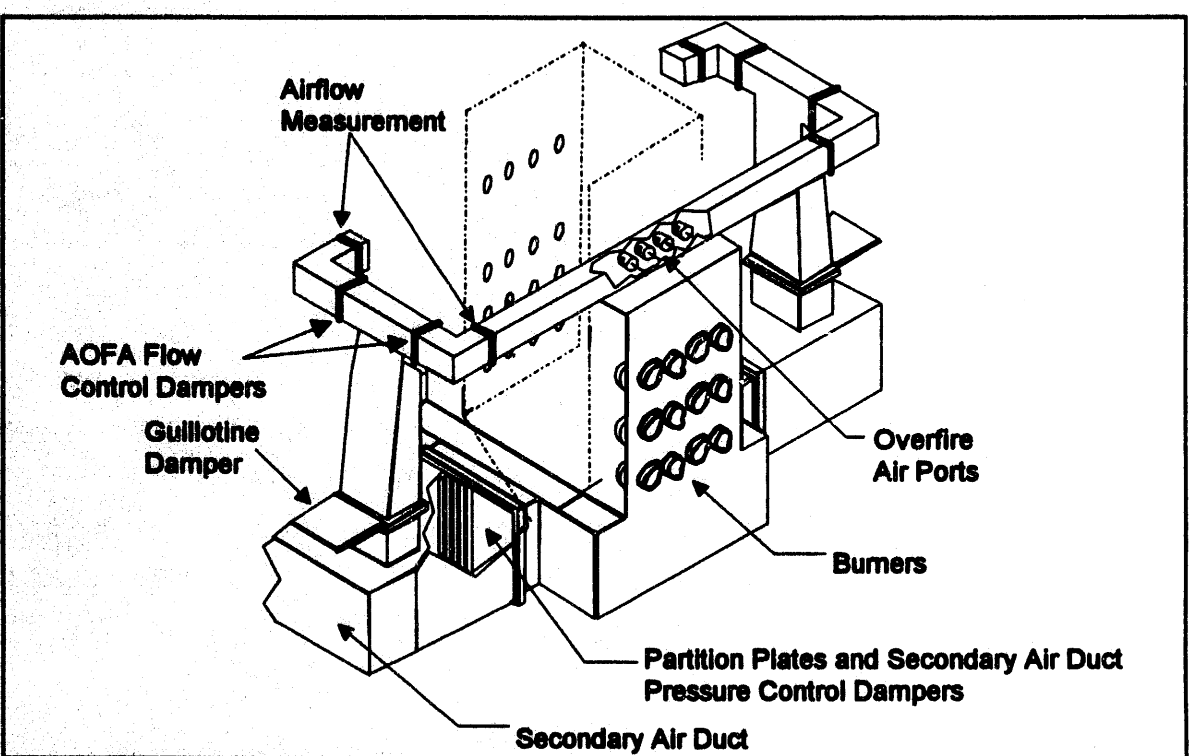

Figure 2. Advanced Overfire Air System

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.

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.

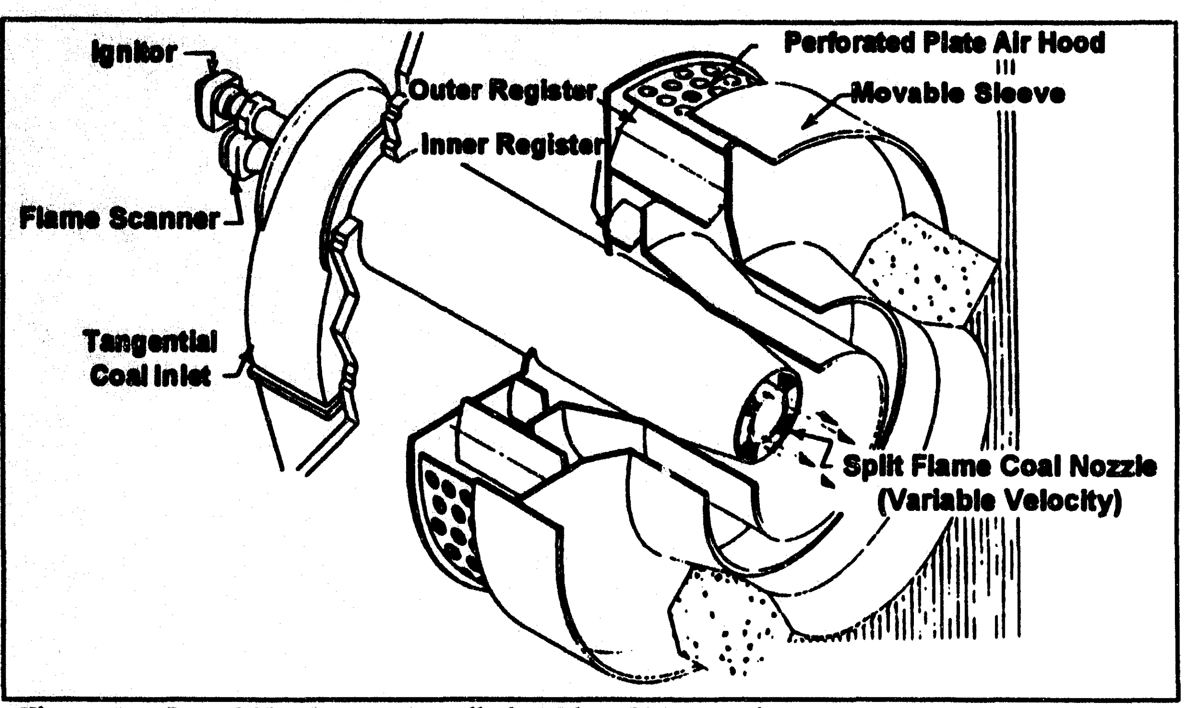

Figure 3. Low NO_X Burner Installed at Plant Hammond

3. PROJECT STATUS

3.1. Phase 1 - Baseline Characterization

3.1.1. Baseline Testing Summary

Phase 1 baseline testing ended in April 1990. During baseline testing, 52 days of long-term data were collected producing an average NO_X emission level of 1.12 lb/MBtu. NO_X emissions generally increased with load and ranged from 0.9 to 1.3 lb/MBtu. The long-term data demonstrates a full load, mean NO_X level of approximately 1.24 lb/MBtu.

3.2. Phase 2 - Advanced Overfire Air Retrofit and Characterization

3.2.1. AOFA Retrofit

The AOFA system was installed during a four week unit outage during spring 1990. For more information on the outage and installation see the *Second Quarter 1990 Technical Progress Report.*[1]

3.2.2. AOFA Testing Summary

Following optimization by FWEC, AOFA tests at Plant Hammond (with the pre-NSPS Intervane burners still in operation) were completed in March 1991. During the AOFA test phase, the unit was operated according to FWEC instructions provided in the design manuals. Eighty-six (86) days of long-term data were collected for which the average NO_X emission level was 0.92 lb/MBtu and the full load, mean, NO_X emission level was 0.94 lb/MBtu. As compared to the baseline characteristic, NO_X emissions were not highly dependent on load during the AOFA test phase.

3.3. Phase 3A - Low NO_x Burner Retrofit and Characterization

3.3.1. LNB Retrofit

The LNBs were installed during a seven week unit outage during spring 1991. For more information on the outage and installation see the *Second Quarter 1991 Technical Progress Report.*[2]

3.3.2. LNB Without AOFA Summary

Following optimization by FWEC, characterization of the low NO_x burner system began in June 1991 and ended in January 1992. Diagnostic testing was performed from July 9 to July 20, 1991 and performance testing began July 16, 1991. During the LNB test phase, the unit was operated according to FWEC instructions provided in the design manuals. This testing indicated that the low NO_x burners were not optimally configured and, therefore, testing was postponed for four days to allow FWEC personnel to make additional adjustments to the new burners and ancillary systems. Testing continued on July 22 and was completed July 28, 1991.

Long-term testing of the low NO_x burners began on August 7, 1991 and was completed on December 19, 1991. Ninety-four days of long-term data were collected for which the average NO_x emission level was 0.53 lb/MBtu and the full load, mean, NO_x emission level was 0.65 lb/MBtu. As in the baseline long-term test period, NO_x emissions generally increased with load; however, below approximately 275 MW, the converse is true and NO_x emissions rapidly increase with decreasing load. In contrast, NO_x emissions during the AOFA long-term test phase were not highly dependent on load.

3.4. Phase 3B - LNB with AOFA Characterization

Following completion of the LNB test phase during January 1992, testing in the low NOx burner and advanced overfire air configuration was to begin with completion scheduled for late March 1992. However, due to delays associated with increased stack particulate emissions following the LNB installation, it was not possible to complete testing in the LNB+AOFA configuration prior to the Spring 1992 outage during which two new mills were to be installed. To obtain operating data prior to this outage, abbreviated testing (designated 3B') in the LNB+AOFA configuration was performed during February and March 1992. In order to maintain stack particulate compliance, the unit ran at reduced loads (less than 450 MW) until Spring 1993. During this period, long-term data was collected and the NOx vs. LOI tests were performed. Hammond Unit 4 was given permission to resume full-load operation on March 26, 1993.

3.4.1. Optimization

Following resumption of full load operation on March 26, 1993, FWEC personnel reoptimized the unit for LNB+AOFA operation from March 30, 1993 through May 6, 1993. Burner settings, with the exception of the burner tips, are similar to that used for the NOx vs. LOI test segment (Table 3). The AOFA flow schedule is shown Figure 4. Since the AOFA is not automatically controlled, the operator must manually maintain not only the total overfire flow rate but also balance the flows to the four corners of the windbox. This task has proven difficult during long-term, normal unit dispatch. Operating instructions for the LNB+AOFA, as provided by FWEC, are found in Appendix A.

Table 3. LNB+AOFA Burner Settings

Burner Adjustment	Setting
Sleeve Damper	7" Outer burner columns
	4" Inner burner columns
Outer Register	~60%
Inner Register	15~20%
Burner Tip	+2 Inches

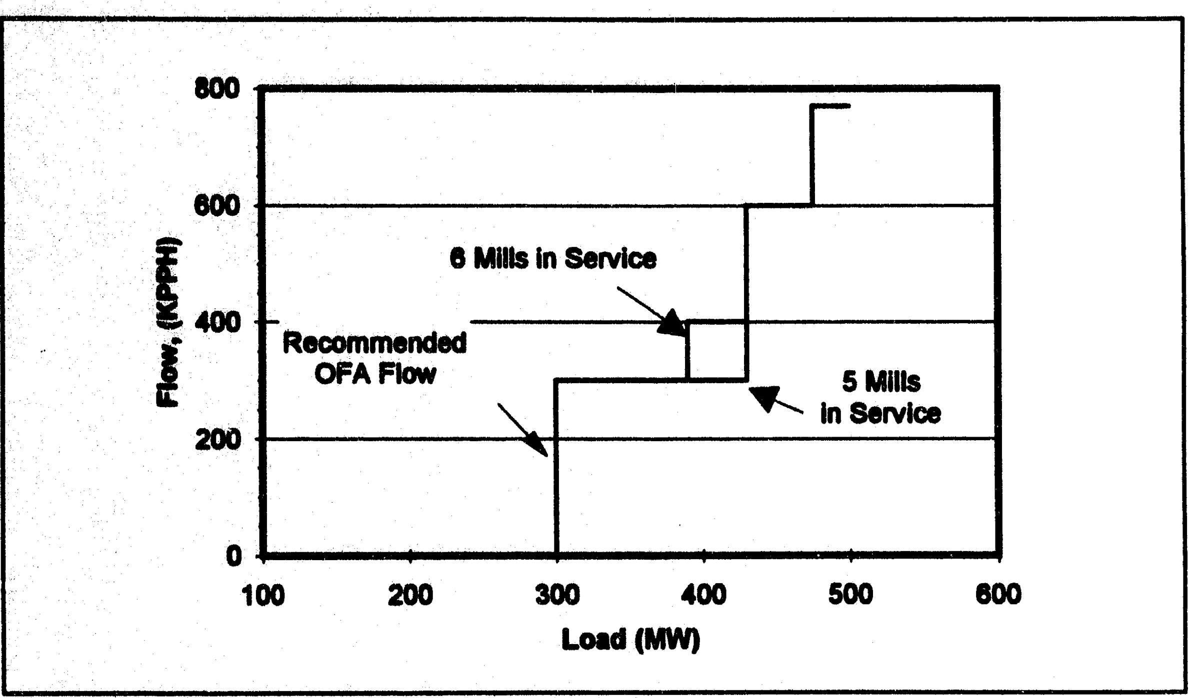

Figure 4. AOFA Flow Schedule as Function of Load

3.4.2. Diagnostic Testing

Subsequent to the March-May 1993 re-optimization, comprehensive testing using LNB plus AOFA began. The Phase 3B diagnostic effort consisted of characterizing emissions under normal operating conditions with the LNB's installed and the AOFA flow control dampers in the nominal, recommended, position. Fifty-four (54) tests were performed at nominal loads of 180, 300, 400 and 480 MW, a summary of which can be found in Appendix B. In order to accommodate intervening chemical emissions and performance testing, diagnostic testing was conducted during the following time frames: May 6-10, June 6-16, and June 24-25. Each test condition (load, excess oxygen overfire air, and mill configuration) was held steady for a period of from one to three hours depending upon the type of test performed. During this period, data were collected manually from the control room, automated boiler operational data were recorded on the DAS, and economizer exit and preheater exit species and temperatures were recorded utilizing the sample distribution manifold and were recorded on the DAS. When sufficient time permitted, furnace backpass ash grab samples were collected from the CEGRIT ash samplers and coal samples were collected from the individual mills.

Figure 5 shows graphically the NOx emissions for all diagnostic tests. These configurations represented the range of normal configurations that were believed to be the predominant modes of operation that might be experienced during the system load dispatch mode of operation during long-term testing. The data scatter is partially due to the fact the different operating conditions are represented.

Figure 6 shows the NOx vs. Excess O2 variation at full-load. With the exception of one outlier, the NOx shows a increasing, linear trend with excess O2 with a slope of approximately 0.05 lb/MBtu/Percent Excess O_2. As can be inferred from this figure, full load NOx emissions at the recommended excess O_2 level of approximately 3.7 percent is near 0.43 lb/MBtu. Comparisons were also made at the other loads tested with similar results (Figure 7). Also for comparison, the full load, NOx vs. Excess O_2 sensitivities for prior phases of the project are shown in Table 4.

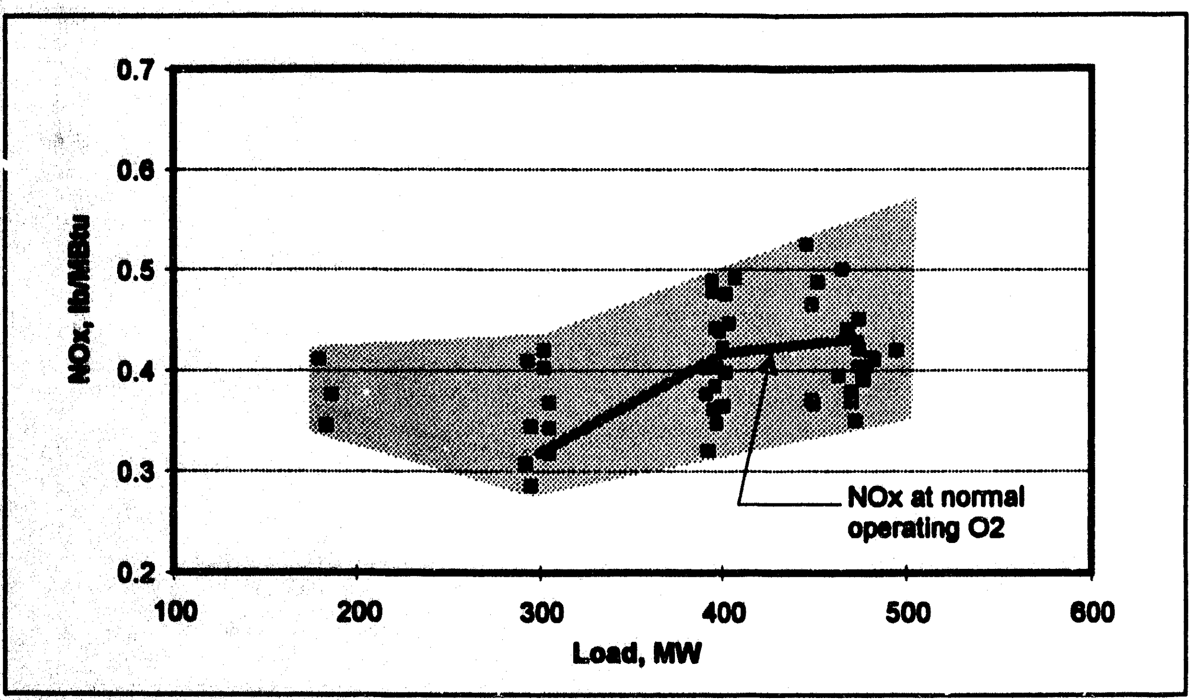

Figure 5. LNB+AOFA Diagnostic Tests - NOx Emissions

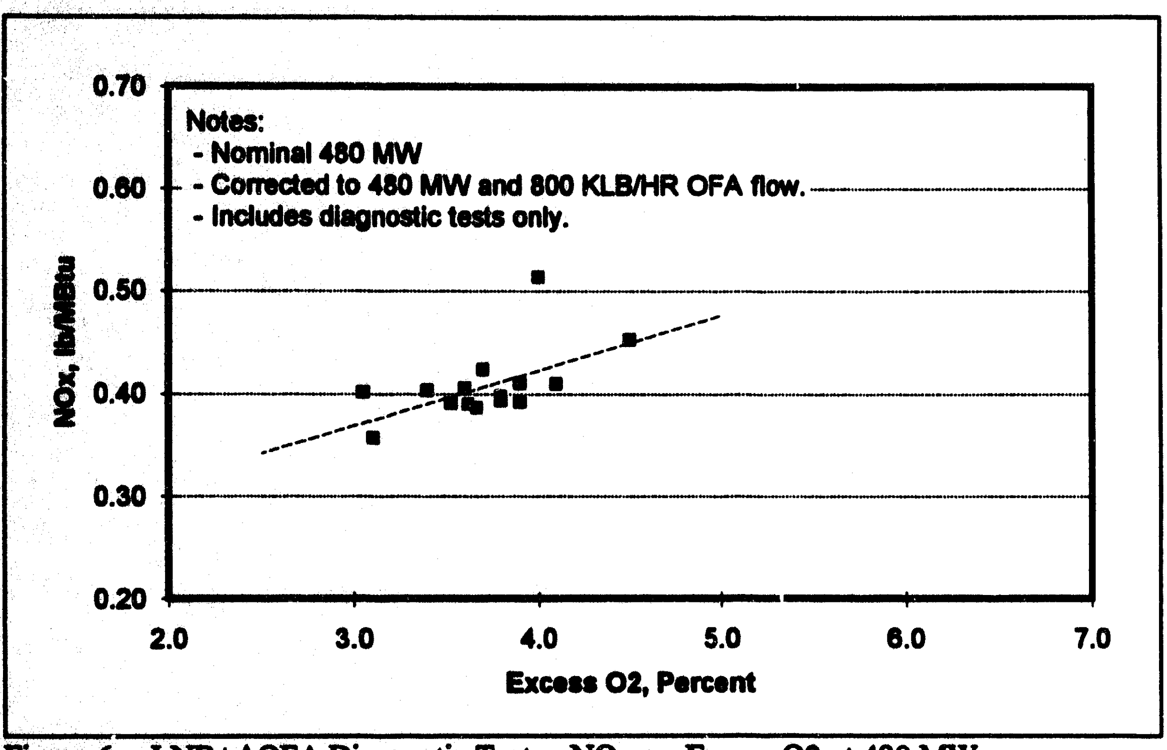

Figure 6. LNB+AOFA Diagnostic Tests - NOx vs. Excess O2 at 480 MW.

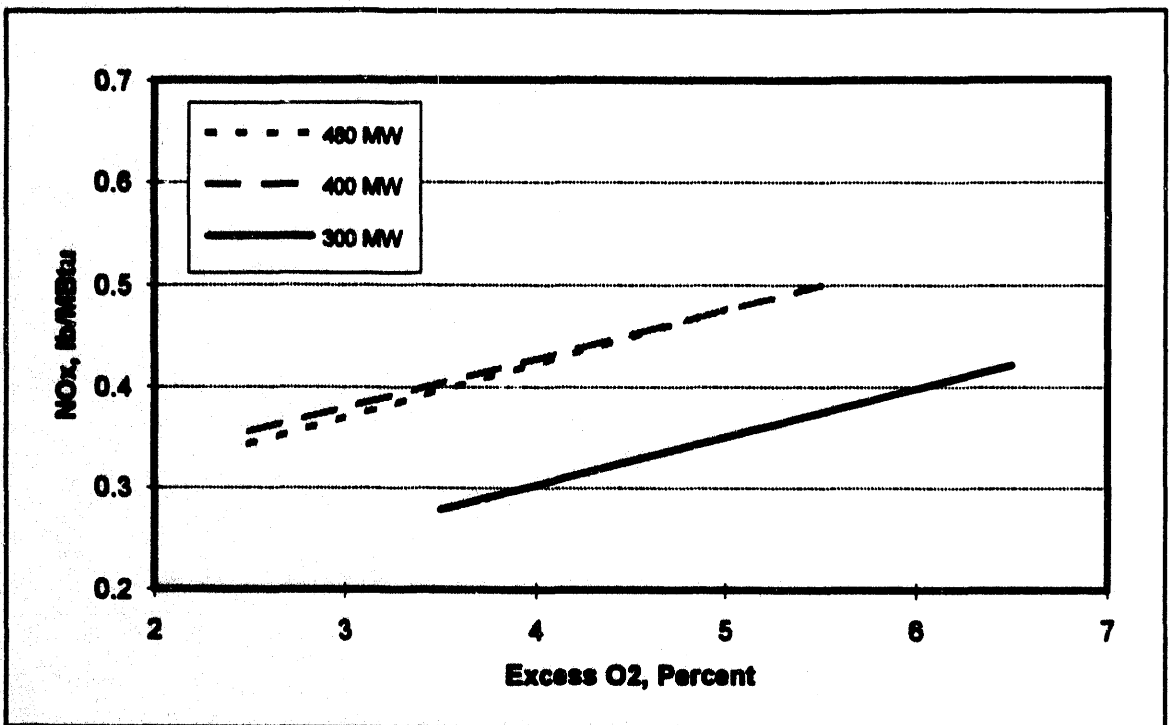

Figure 7. LNB+AOFA Diagnostic Tests - NOx vs. Excess O2.

Table 4. Sensitivity of NOx Emissions to Excess O2 Levels at Full Load	
Test Phase	Sensitivity lb/MBtu/% Excess Air
Baseline	>0*
AOFA	0.08
LNB	0.05
LNB / NOx vs. LOI Tests (450 MW)	0.07
LNB+AOFA	0.05

*As described in the Phase 1 Baseline Tests Report, a reliable estimate of the sensitivity could not be obtained.

On the final day of diagnostic testing (June 24, 1993 - Test Numbers 121-1, 2, 3, & 4), high volume fly ash sampling was conducted in tandem with isokinetic fly ash sampling to compare the two techniques. This testing was performed at 480 MW with normal O2 levels while varying the AOFA flow rate. Samples collected were size fractionated into +200 mesh (74 μm) and -200 mesh components and analyzed for loss-on-ignition and carbon content. The +200 mesh and -200 mesh results were then mass averaged to obtain overall LOI and carbon results.

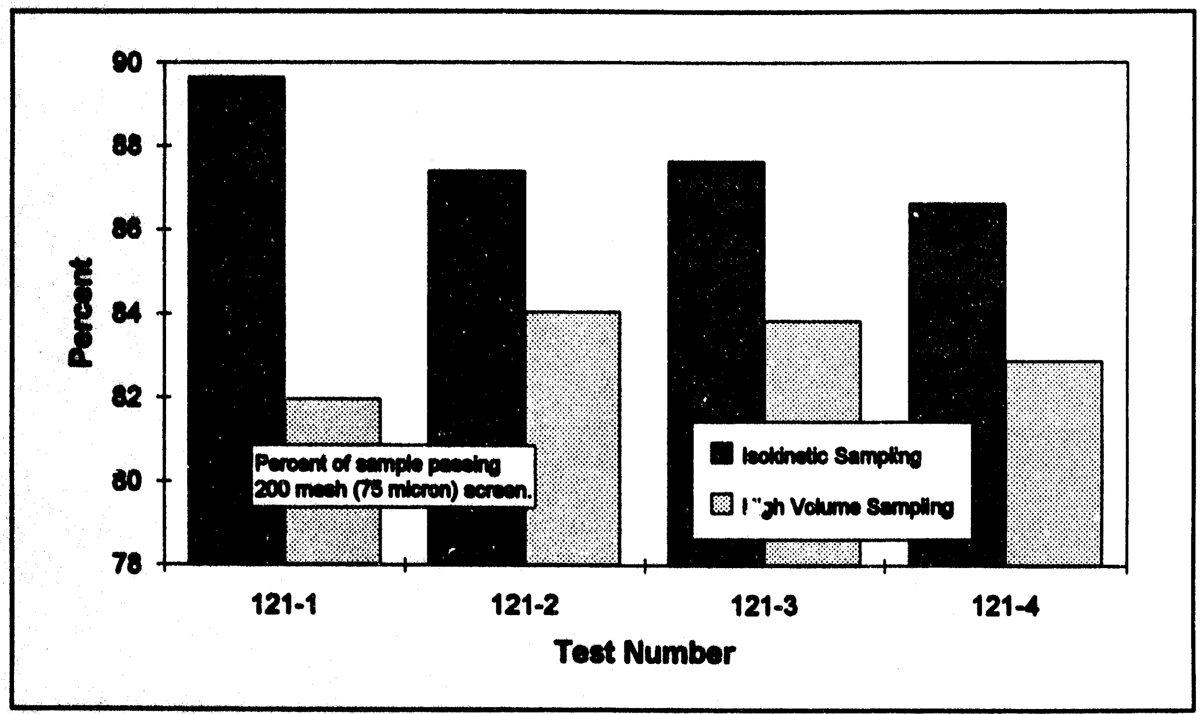

Figure 8. LNB+AOFA Diagnostic Tests - Comparison of Percent of Fly Ash Sample Passing Through 200 Mesh Screen for Isokinetic and High Volume Sampling Methods.

As shown in Figure 8, the high volume sampling method consistently over sampled the large particle fraction of the fly ash. As a result of high volume sampling being super-isokinetic, it can be inferred that the larger fraction is the less dense of the two. The size bias will affect the overall carbon and LOI estimate because the +/- 200 mesh size fractions have significantly different carbon contents and LOI values (Figure 9). Figure 10 illustrates the overall results obtained by the two methods. As can be seen, the high volume sampling method leads to a consistent 1 to 2 percent over estimation of the amount of carbon in the fly ash. Also, for the isokinetic sampling method, the carbon percentage is always less than the LOI percentage as expected. However for the high volume samples, in some instances, *the carbon percentage is greater than the LOI percentage*. This result, which also occurred in one prior isokinetically collected fly ash samples (AOFA Performance Test / Test 45), is contrary to normal expectations and could be the result of a number of factors including:

- Non-Representative Samples - The small sample sizes (~10 mg) used in the Carbon/Hydrogen/Nitrogen analysis tend to exacerbate problems with obtaining representative samples of the collected fly ash. This is less of a problem with the fly ash used in the LOI analysis since sample sizes on the order of 1 gram are required.

- **Trapped Carbon** - Some carbon may be bound to the fly ash such that it is not combusted during the processing of the fly ash samples at 800°C for the LOI analysis.

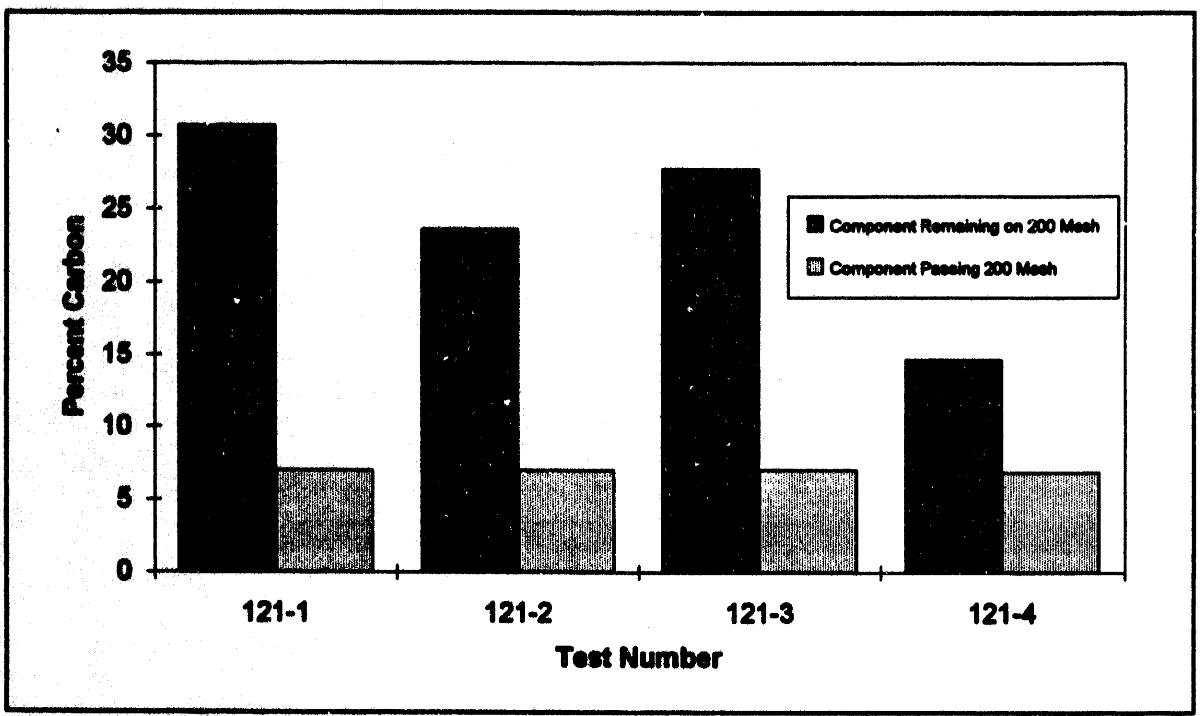

Figure 9. LNB+AOFA Diagnostic Tests - Comparison of Carbon Content for +200 Mesh and -200 Mesh Components of Fly Ash.

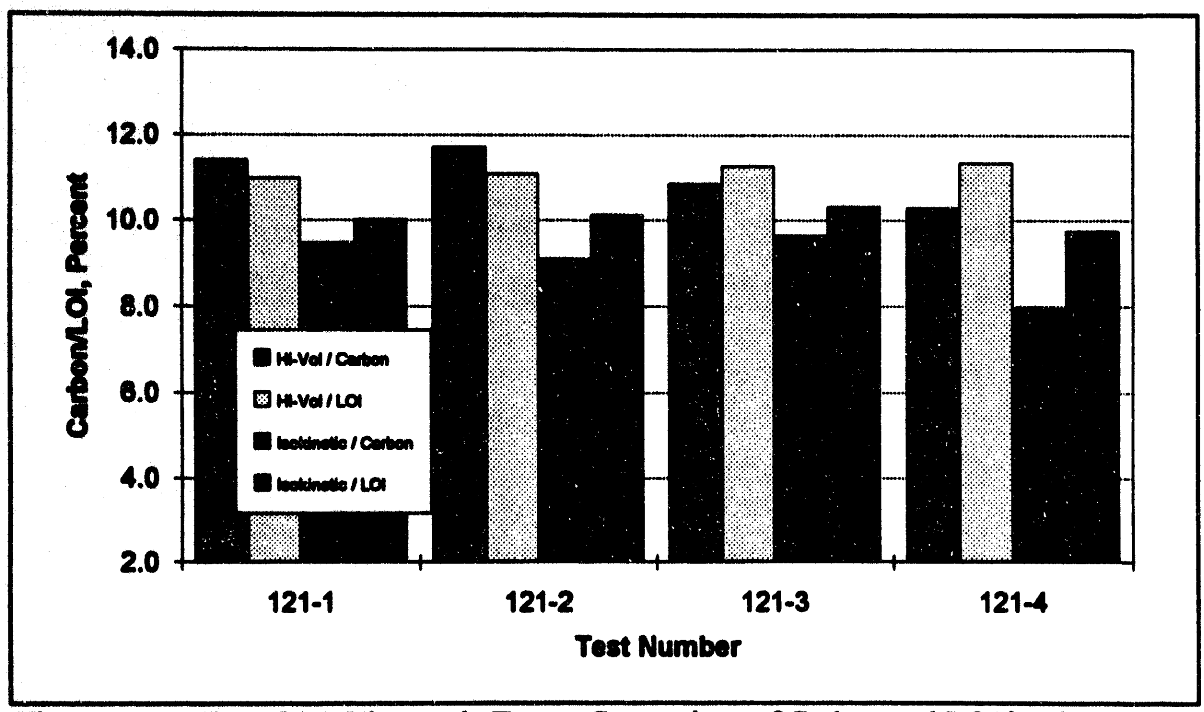

Figure 10. LNB+AOFA Diagnostic Tests - Comparison of Carbon and LOI in Fly Ash.

3.4.3. Performance Testing

Performance testing was performed June 17-23, 1993. A summary of the performance tests activities is shown in Table 5. To date, not all analyses of the samples have been completed including ESP mass loading, coal ultimate analysis, fly ash particle size and resisitivity, therefore the results reported within this report should be considered preliminary.

Table 5. LNB+AOFA Performance Tests Activities

Date ⇒	17 June	18 June	19 Jun	20 Jun	21-22 Jun	22-23 Jun
Test Number ⇒	115	116	117	118	119	120
Activity ⇓ / Nominal Load ⇒	480 MW	480 MW	300 MW	300 MW	400 MW	400 MW
Pulverizer Isokinetic Sampling	X	X	X		X	
Pulverizer Dirty Air Flow				X		X
Primary Air Flow	X	X	X	X	X	X
Total Secondary Air Flow	X	X	X	X	X	X
Secondary Air to Front Windbox	X	X		X	X	
OFA Flow	X	X	X	X	X	X
Furnace HVT	X	X	X	X	X	X
ESP TSP	X		X		X	
Fluegas Resistivity	X	X	X	X	X	X
Flyash Particle Size		X		X		X
Coal Sampling	X	X	X	X	X	X
Fluegas Sampling	X	X	X	X	X	X

X - Conducted

Testing at each load point required two consecutive days to complete sampling of all the parameters in the sampling matrix. At each nominal load, the coal firing rate was kept as constant as possible and generation allowed to swing slightly as affected by coal variations, boiler ash deposits, ambient temperature, etc. Each performance test day covered a period of from ten to twelve hours during which boiler operating data were recorded, fuel and ash samples acquired, gaseous and solid emissions measurements made, and fly ash resisitivity measured in-situ. For each performance tests, the desired conditions were established and allowed to stabilize at least one hour prior to commencement of testing. To the extent possible, the active mills were balanced with respect to the coal flow rates as displayed in the control room. When the desired operating conditions were established, some controls were placed in manual mode to minimize fluctuations in the units firing rate. Soot blowing was performed only when particulate sampling was suspended so as to include only particulate matter actually generated by the combustion during the time of testing.

Table 6 summarizes the results of each of the performance tests. As shown in this table and graphically in Figures 11 and 12, full load NOx emissions are approximately 0.43 lb/MBtu with corresponding fly ash loss-on-ignition (LOI) values of 8 percent. At low loads (300 MW), NOx emissions and LOI are approximately 0.32 lb/MBtu and 5½ percent, respectively. Also shown in these figures are the results from the February-March 1992 testing. NOx emissions for the latest round of testing are considerably below the NOx levels found in the earlier tests. However, it is believed that a substantial portion of the incremental change in NOx emissions between the LNB and LNB+AOFA configurations is the result of additional burner tuning and other operational adjustments and is not the result of improved performance of the AOFA system.

Table 6. LNB+AOFA - Summary of Performance Testing

Test No.	Date	Load MWe	Feedwater Flow klb/hr	Mills Out of Service	Overfire Air Flow klb/hr	CO ppm	Economizer O2 Percent	NOx lb/MBtu
115-1A	06/17/93	480	3535	NONE	790	31	3.8	0.433
115-1B	06/17/93	467	3447	NONE	784	29	4.0	0.441
115-1C	06/17/93	462	3373	NONE	774	38	3.9	0.427
116-1A	06/18/93	476	3461	NONE	787	54	3.9	0.421
116-1B	06/18/93	472	3437	NONE	805	300	3.8	0.412
117-1A	06/19/93	303	2036	B	311	62	4.0	0.320
117-1B	06/19/93	299	1990	B	297	40	4.1	0.320
118-1A	06/20/93	302	2035	B	321	37	4.3	0.317
118-1B	06/20/93	298	1981	B	308	41	4.3	0.315
119-1A	06/21/93	400	2679	B	427	105	4.5	0.413
119-1B	06/22/93	400	2725	B	409	123	4.5	0.424
120-1A	06/22/93	401	2705	B	421	87	4.5	0.415
120-1B	06/23/93	401	2796	B	424	91	4.6	0.419

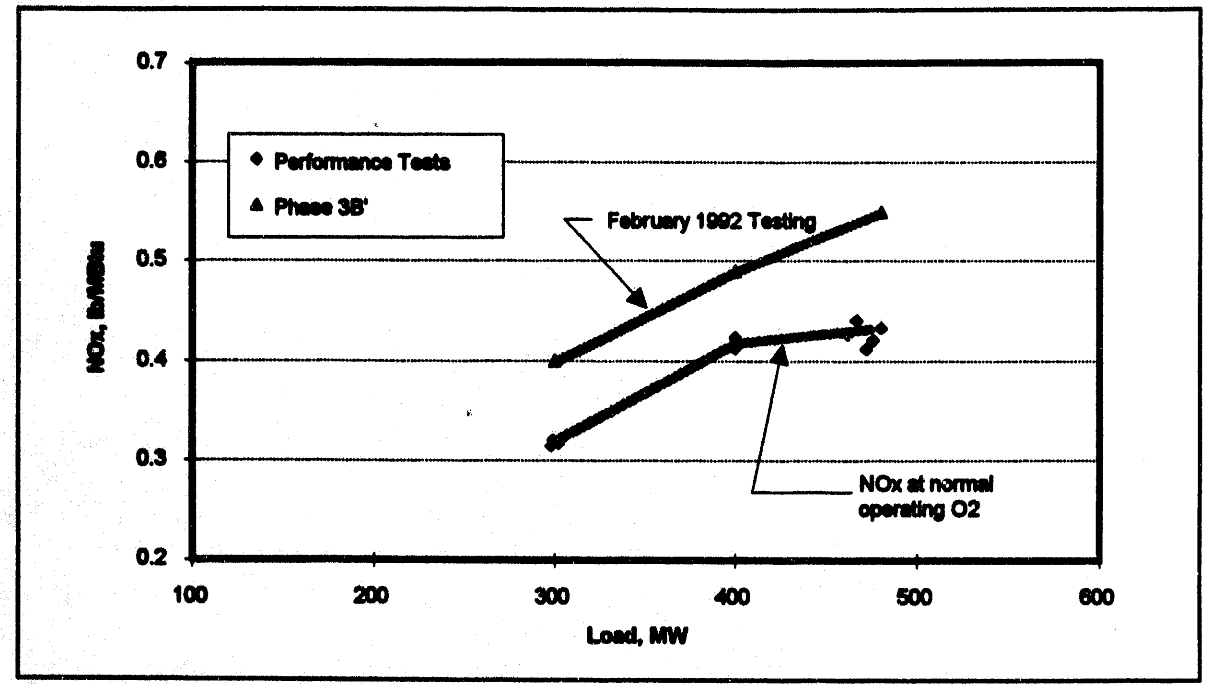

Figure 11. LNB+AOFA Performance Tests - NOx Emissions

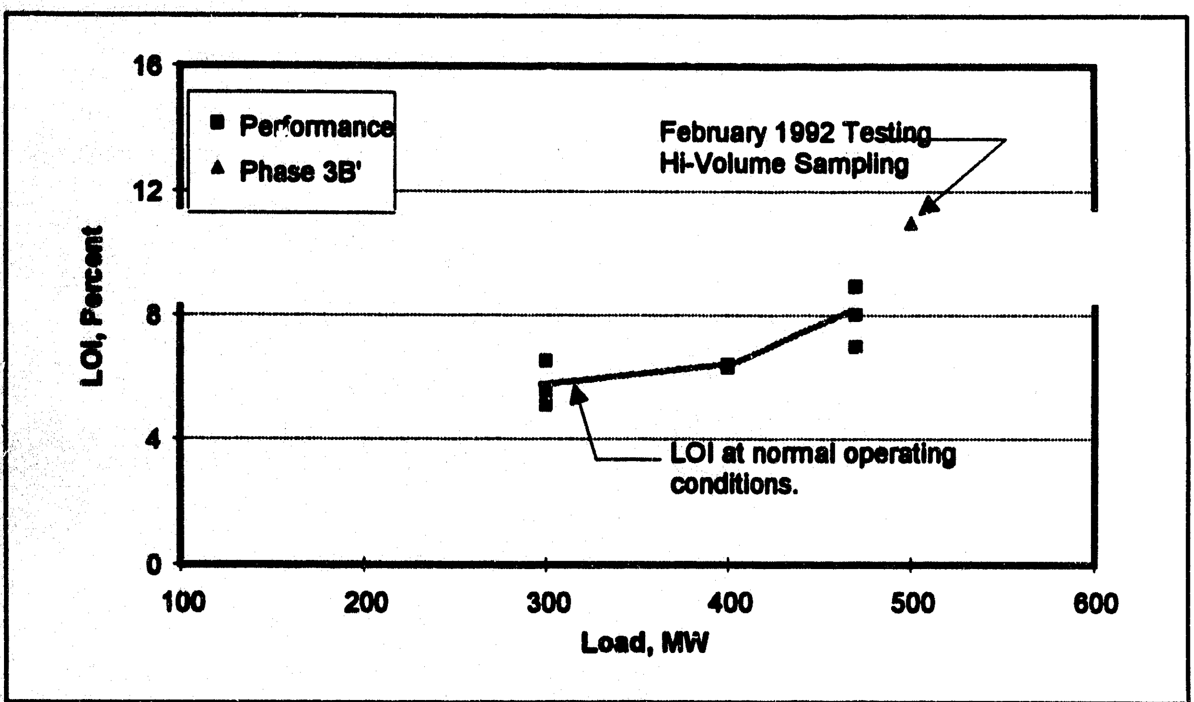

Figure 12. LNB+AOFA Performance Tests - Fly Ash Loss-On-Ignition

Pulverizer testing addressed the following parameters:

- Coal Fineness through 50, 100 and 200 Mesh Screens
- Dirty air flow and distribution, as measured in the fuel lines
- Fuel flow and distribution observed by isokinetic sample
- Air to Fuel Ratios
- Primary air as measured at the pulverizer inlet
- Temperature and static pressure of fuel air mixture in the fuel lines

Coal samples extracted for coal fineness, fuel flow, and fuel distribution were collected utilizing the Flame Refractories, Inc. (FRI) Air to Fuel Ratio Sampler. FRI personnel performed coal sieve analyses utilizing Plant Hammond's laboratory facilities and equipment. The FRI Dirty Air Probe facilitated measurement of fuel line air flow. Measurement of primary air flow at the pulverizer inlet was facilitated by use of a standard Pitot tube.

The Babcox and Wilcox (B&W) MPS pulverizers (A, C, E and F pulverizers) produced fineness levels ranging from 74 to 80 percent passing 200 mesh and less than 0.75 percent remaining on 50 mesh. The originally installed Foster Wheeler MB pulverizers (B and D pulverizers) produced fineness levels ranging from 63 to 67 percent passing 200 Mesh and 2 to 3 percent remaining on 50 Mesh. The average coal fineness for the performance tests are summarized in Table 7.

Table 7. Average Coal Fineness

	Rem. on 50 (300 μm)	Passing 100 (150 μm)	Passing 200 (74 μm)
Test 115	0.79	94.69	73.50
Test 116	0.98	94.69	74.19
Test 117	0.43	96.38	75.99
Test 119	0.61	95.38	74.04

Furnace High Velocity Thermocouple (HVT) traverses were completed on the 7th (Elevation 724') and 8th (Elevation 694') floors. A total of (8) ports on the 8th floor and (2) ports on the 7th floor were traversed. Figure 13 illustrates the location of test ports to boiler components.

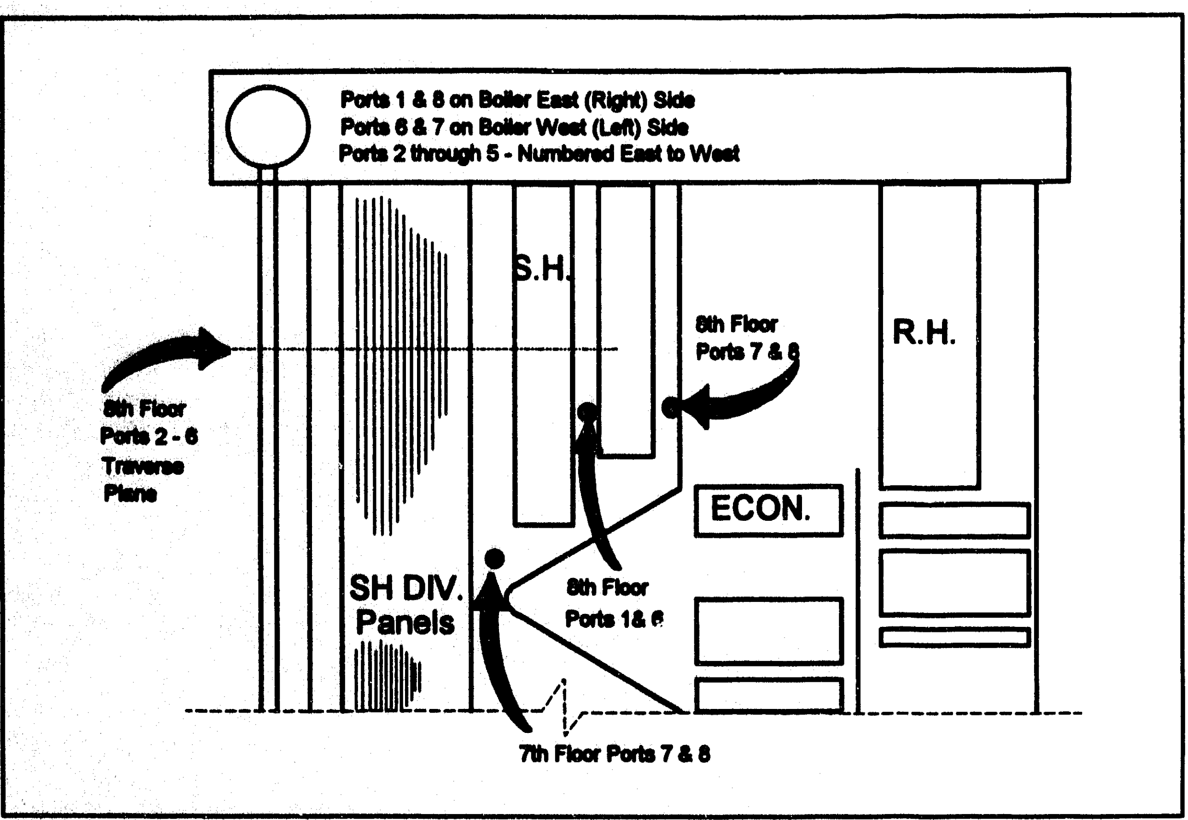

Figure 13. HVT Sampling Locations

Average furnace gas temperature on the 8th floor ranged between 1887°F and 1907°F at full load (Table 8). The average oxygen level was 2.8 percent but was very stratified from port to port. Large fluctuations in temperature and oxygen level were observed across the furnace. Oxygen levels from port to port fluctuated from 0 percent (reducing) to 5.6 percent.

Table 8. Average HVT Temperatures and Oxygen						
Parameter⇓ \ Test Number ⇒	115	116	117	118	119	120
7th Flr. %Oxygen	0.8	2.6	1.2	2.0	1.2	0.4
8th Flr. %Oxgen	2.8	2.8	2.4	3.3	3.4	3.3
7th Flr. Temperature (°F)	2287	2163	2232	2095	2222	2302
8th Flr. Temperature (°F)	1887	1907	1650	1616	1827	1853

Total unit air flow, as defined in this report, is the sum of secondary air (combustion air flow to burners including under fire air), overfire air and total pulverizer primary air. Total dirty air flow is considered total pulverizer primary air. Dirty air includes seal air introduced to the pulverizer and feeders that would not be observed by measuring primary air at the inlet of the pulverizer. During low and intermediate load tests, off-line pulverizer air flow measured at the inlet of the pulverizer was included when tabulating total unit air flow. The test methodologies for determining these flows are described in this project's *Phase 1 Baseline Tests Report*.[3]

The average of multiple test runs of secondary air and overfire air flows were used to obtain total unit air flow. Total unit air flow, at full load, was 6 to 10 percent higher than observed during previous tests. Figure 14 summarizes total unit air flow for the LNB+AOFA performance tests and compares the flows to previous tests.

	Test Number	Total Unit Air Flow	%Dev. From Average
Phase IIIb	115-1	4,182,883	+7.61%
	116-1	4,263,429	+9.68%
Phase III	65-1	3,957,904	+1.82%
	66-1	3,933,419	+1.19%
	70-1	4,133,784	+6.34%
	71-2	3,889,088	+0.05%
	72-1	3,746,518	-3.62%
Phase II	37-1	3,447,972	-11.30%
	38-1	3,684,285	-5.22%
	43-1	3,849,933	-0.96%
	44-1	3,988,251	+2.60%
	45-1	3,850,147	-0.95%
Phase I	12-1	3,888,690	+0.04%
	17-1	3,605,196	-7.26%
Average of All Tests		3,887,250	

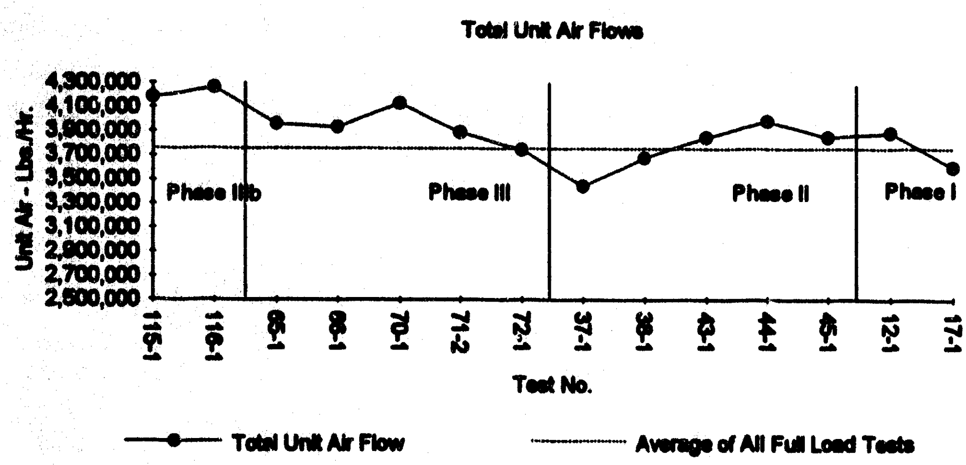

Figure 14. Total Unit Air Flows at Full Load

During full load tests (480 MW), total unit air flow (Figure 15) was distributed as follows: approximately 21 percent (894 klb/hr) was primary air, 58 percent (2464 klb/hr) was secondary air to burners and 21 percent (864 klb/hr) was overfire air. During intermediate load tests (400 MW), total unit air flow was distributed as follows: approximately 22 percent was primary air flow, 64 percent was secondary air to burners, 13 percent was overfire air and 2 percent was air flow to 'B" pulverizer that was off-line. During low load tests (300 MW), total unit air flow was distributed as follows: approximately 27 percent was primary air, 60 percent was secondary air to burners, 11 percent was overfire air and 2 percent was air flow to "B" pulverizer that was off-line.

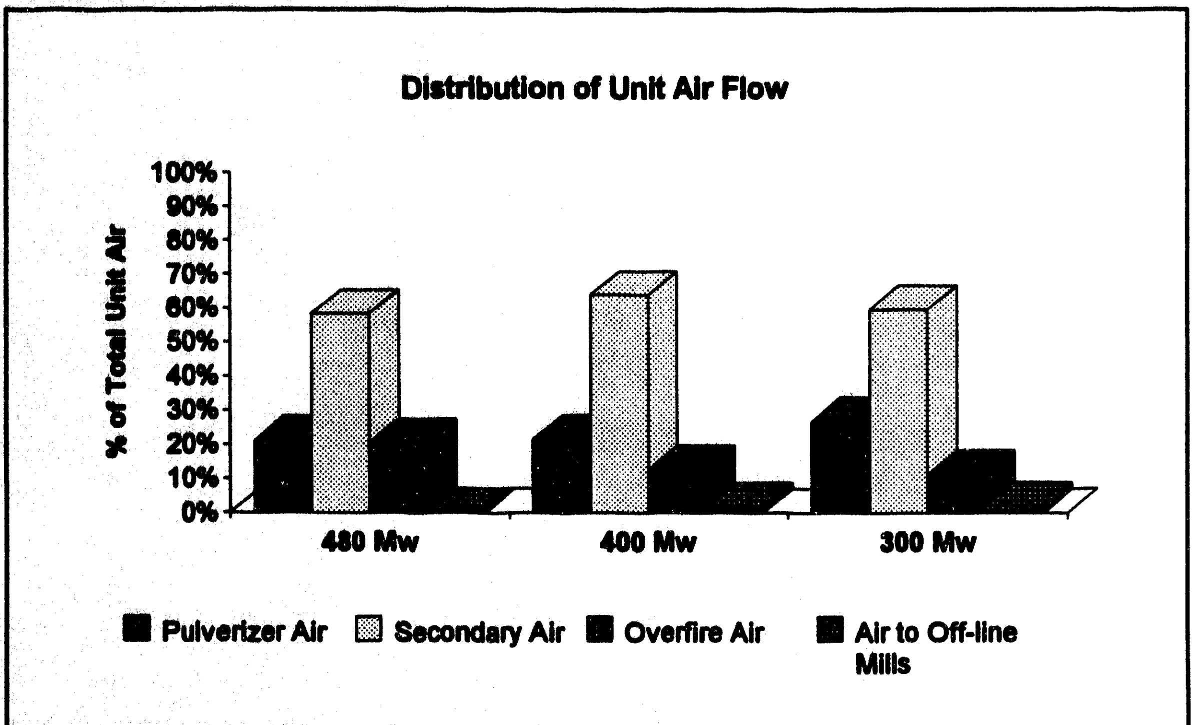

Figure 15. Distribution of Unit Air Flow

3.4.4. Long-Term Testing

Long-term testing of the LNB+AOFA is in progress and is scheduled to continue until August 1993. Appendix C contains a summary of the NO_X emissions and load from May to June 1993. As of June 30, 1993, twenty-nine (29) days of valid long-term have been collected. Full load, long-term NOx emissions are approximately 0.42 lb/MBtu which is consistent with that found during the performance testing (Figure 16). However, at 300 MW, long-term NOx emissions are near 0.37 lb/MBtu, nearly 0.05 lb/MBtu higher than the short-term emissions at the same load with approximately the same excess air and AOFA flow rate. The cause of this disparity is unknown. Despite this difference, the short-term data lies within the 90^{th} percentile range of the long-term data. The spread of the NOx emissions data is similar to that seen during the Phase 3A LNB test phase and substantially smaller than the baseline and AOFA phases, especially at high loads. As with the short-term data, there is substantial difference between the current long-term NOx emissions and that previously reported for the abbreviated LNB+AOFA tests. However, it is believed that a substantial portion of the improvement in NOx emissions is the result of additional burner tuning and other operational adjustments and is not the result of improved performance of the AOFA system. Approximately 60 days of long-term data will be collected in this configuration, therefore the final results may change substantially when the complete data set is analyzed.

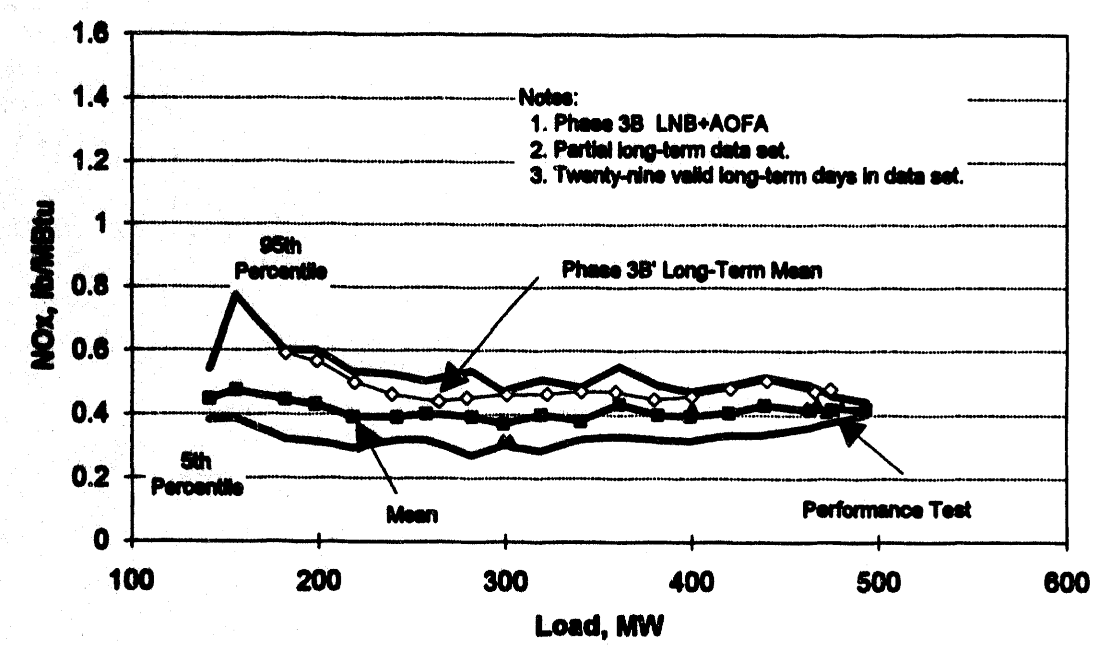

Figure 16. LNB+AOFA Long-Term NOx Emissions Through June 30, 1993.

In contrast to the long-term NOx emissions, the 90 percentile band width of LNB+AOFA stack O_2 levels (Figure 17) is similar to the baseline and AOFA test phases and exceeds that of the LNB phase. This increase in data spread may be an artifact of the reduced data set from which the calculations are performed. Also, the "dips" in the stack O2 curves at 300 MW and 400 MW, especially for the 5th percentile curve, are likely due to mill transition points and the AOFA operating instructions calling for step changes in AOFA flow rate at these load points. At this time, it is not known why these O_2 variations did not result in similar variations in NOx emissions.

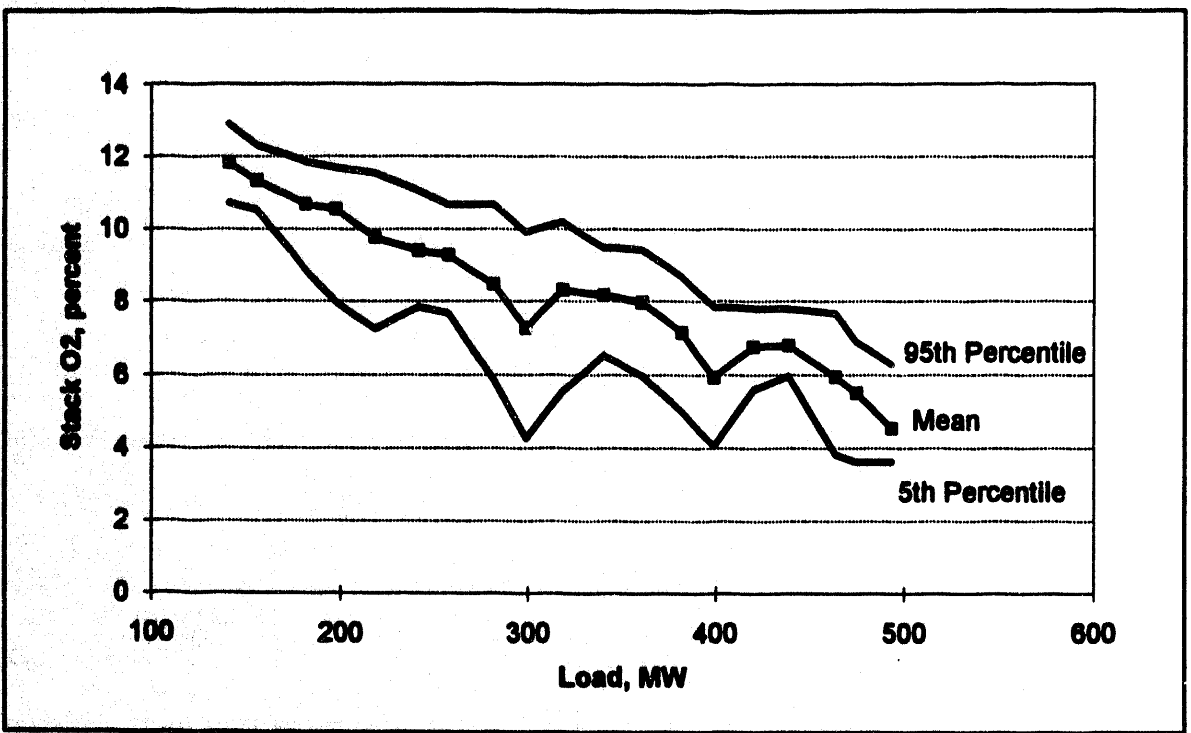

Figure 17. LNB+AOFA Long-Term Stack O2 Levels Through June 30, 1993.

3.4.5. Verification Testing

Verification testing in the LNB+AOFA configuration is scheduled for August 1993. Table 9 shows the preliminary test matrix for this testing.

Table 9. Test Matrix for LNB+AOFA Verification Testing (Preliminary)

Load, MWe	Mills in Service	OFA	Excess O_2
300	A,C,D,E,F	NOMINAL	NOMINAL
			HIGH
			LOW
			NOMINAL
	A,C,E,F	NOMINAL	NOMINAL
400	A,C,D,E,F	NOMINAL	NOMINAL
			HIGH
			LOW
	ALL	NOMINAL	NOMINAL
480	ALL	NOMINAL	NOMINAL
			HIGH
			LOW
			NOMINAL
		HIGH	NOMINAL
		LOW	NOMINAL
500	ALL	NOMINAL	NOMINAL

3.4.6. Chemical Emissions

Chemical emissions testing was conducted in the LNB+AOFA configuration this quarter. The purpose of this characterization was to compare emissions of potentially hazardous air pollutants (HAPs) during operation with low NOx burners with emissions measured prior to the low NOx burner retrofit. The baseline test was run in March 1990. Categories of HAPs tested included inorganic metals and anions, volatile organic compounds, semivolatile organic compounds, and aldehydes. Speciation of mercury of chromium was also performed at the stack.

Samples were collected for stream characterization, process stream flow rates were measured, and process operating data were gathered with the following objectives:

- To quantify emissions of target substances from the stack,
- To determine the efficiency of the ESPs for removing the target substances, and
- To determine the environmental fate of the target substances in the various plant discharge streams.

The target substances are a subset of those identified in Title III of the Clean Air Act Amendments of 1990. The process sampling matrix for this testing is shown in Table 10.

Testing at the ESP inlet was conducted May 11-12, 1993, prior to the start of the chemical emissions testing. The purpose of this testing was to determine the flow profile and particulate loading at this location, to compare EPA Method 5 and 17 sampling techniques, and identify possible sampling problems. Chemical emissions testing was performed by Radian personnel from May 18-21, 1993. Results from this testing will be reported in a topical report scheduled for draft release during the forth quarter of 1993.

Table 10. Chemical Emissions Sampling Matrix					
Analyses	Coal[a]	Bottom Ash[a]	ESP Fly Ash[b]	ESP Inlet Flue Gas	Stack Gas
Particulate Loading (pre-test)				X	
Bulk Particulate					X
Mercury Speciation					X
Chrome VI					X
Volatile Organics (VOST)					X
Semivolatile Organics				X	X
Formaldehyde, Gas Phase					X
Metals, Solid/Liquid Phase	X	X	X	X	X
Metals, Gas Phase				X	X
Particle Size Distribution					X[c]
Anions, Gas/Solid/Liquid	X	X	X	X	X
Heating Value	X				
Moisture Content	X	X	X		
Ultimate/Proximate	X				

[a]Analysis will be performed on composite samples only.
[b]One sample per hopper per day, held for possible future analysis.
[c]Selected fractions for three PSD samples will be analyzed for metals.

3.5. Data Comparison

3.5.1. NOx Reductions

Figure 18 compares the baseline, AOFA, LNB, and LNB+AOFA (May-June 1993 only) long-term NOx emissions data for Hammond Unit 4. Baseline testing was performed in an "as found" condition and the unit was not tuned for NOx emissions for this test phase. For the AOFA, LNB, and LNB+AOFA test phases, following optimization of the unit by FWEC personnel, the unit was operated according to FWEC instructions provided in the design manuals. As shown, the AOFA and LNBs provide a long-term, *full load*, NOx reduction of 24 and 48 percent, respectively. For the LNBs, the NOx reduction was consistent over the load range, averaging approximately 50 percent; however, the effectiveness of the AOFA system decreased with decreasing load. For the baseline, AOFA, and LNB phases, the NOx vs. load characteristic is based on normal operation of the unit in excess of 51 days. Long-term NOx emissions reduction in the LNB+AOFA configuration *with the partial data set* is approximately 65 percent at full load. Since data collection in this configuration is continuing, the LNB+AOFA results may change substantially when the complete data set is analyzed.

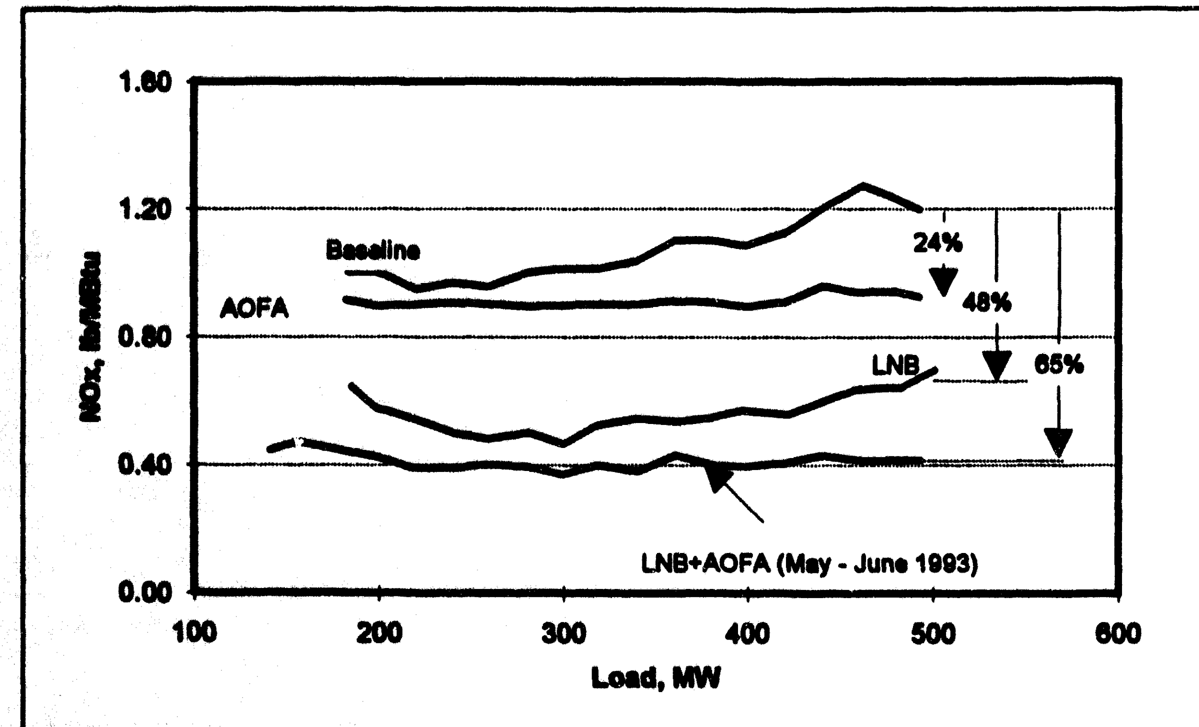

Figure 18. Long-Term NOx Emissions

The NOx emissions averaged over the baseline, AOFA, and LNB test phases are shown in Table 11. Since NOx emissions are generally dependent on unit load, the NOx values shown in this table are influenced by the load dispatch of the unit during the corresponding test frame. Results from the LNB+AOFA test phase will be determined at the end of it's long-term data collection period.

Table 11. Long-Term NOx Emissions

Unit Configuration -->	Baseline		AOFA		LNB	
	Mean	RSD,%	Mean	RSD,%	Mean	RSD,%
Number of Daily Averaged Values	52	-	86	-	94	-
Average Load (MW)	407	9.4	386	17.9	305	17.7
Average NOx Emissions (lb/MBtu)	1.12	9.5	0.92	8.6	0.53	13.7
Average O2 Level (percent at stack)	5.8	11.7	7.3	12.6	8.4	7.7
NOx 30 Day Achievable Emission Limit (lb/MBtu)	1.24	-	1.03	-	0.64	-
NOx Annual Achievable Emission Limit (lb MBtu)	1.13	-	0.93	-	0.55	-

3.5.2. LOI Performance

The fly ash loss-on-ignition (LOI) values increased significantly for the AOFA and LNB test phases and similar increases have been experienced in the abbreviated LNB+AOFA testing (Figure 19). These LOI increases were evident over the load range. The LOI

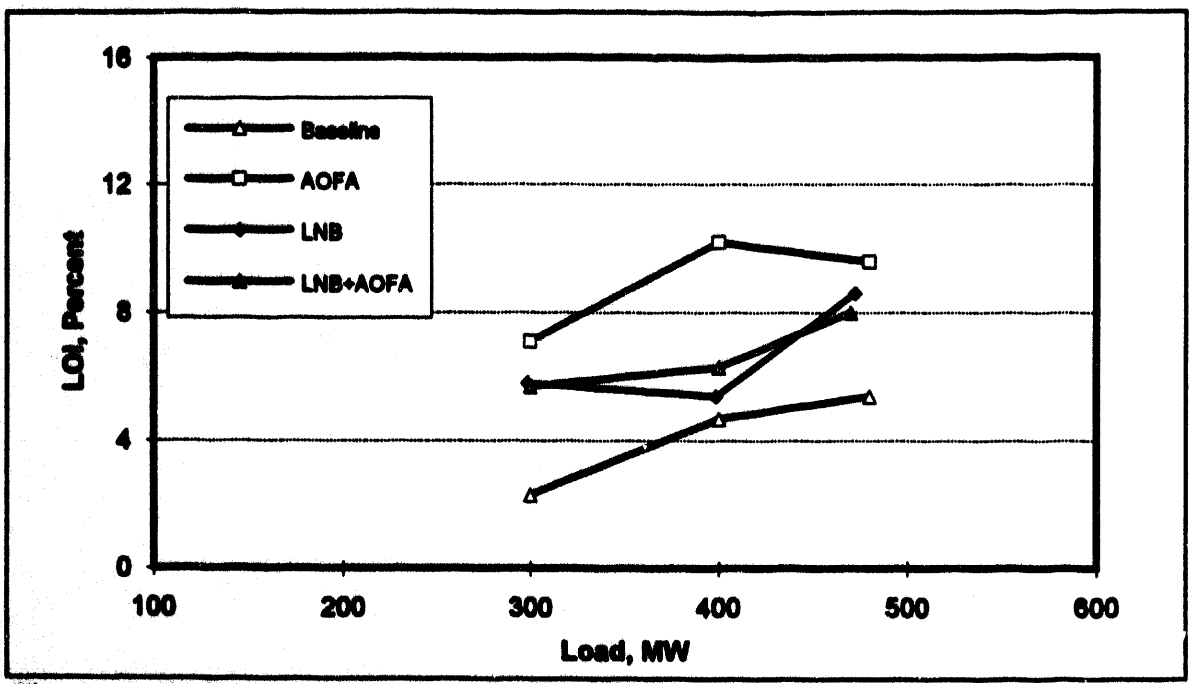

Figure 19. Performance Tests Fly Ash LOI

Table 12. Mill Performance Summary		
	Coal Fineness	
Technology	Passing 200 Mesh Percent	Remaining 50 Mesh Percent
Baseline	63	2.8
AOFA	67	2.6
LNB	67	1.4
LNB+AOFA	74	0.6

measurements were made during each performance test using EPA's Method 17 at the secondary air heater outlet.[4] As shown in Table 12, mill performance was generally better in the AOFA, LNB, and LNB+AOFA test phases than during baseline. The improvement in coal fineness was likely responsible for the reduction in fly ash LOI levels during the May-August 1993 LNB+AOFA test phase. Although it is commonly recognized that fuel fineness can have a pronounced affect on fly ash LOI, results from Plant Smith, Plant Gaston, and other sources indicate the direct impact of fuel fineness on NOx emissions is small.[5,6,7] As previously reported, the post LNB retrofit increase in fly ash LOI along with increases in combustion air requirements and fly ash loading to the precipitator, has had an adverse impact on the unit's stack particulate emissions.

3.5.3. Excess O2 Levels

Long-term, economizer outlet O_2 levels for the AOFA, LNB, and LNB+AOFA test phases were generally higher than the corresponding baseline values (Figure 20). This change in O_2 level for these configurations is mostly attributable to an increase in combustion air requirements for the low NOx combustion configurations, however, factors unrelated to the retrofits, such as leakage in the furnace backpass, can also affect these levels. The impact of this leakage and varying O_2 levels on emissions and unit performance will be investigated and discussed in future reports. The "cusp" of the LNB+AOFA curve at 300 MW and 400 MW seen in stack O_2 levels (Figure 17) is also evident in Figure 20.

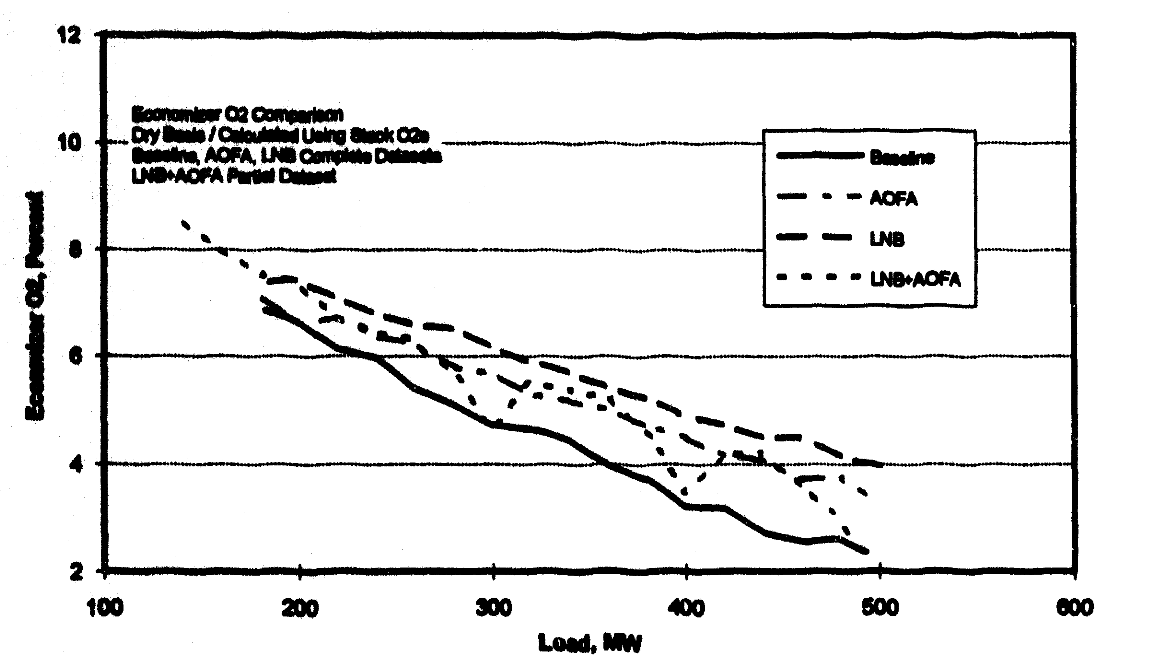

Figure 20. Long-Term Economizer Exit Excess O_2

3.6. Advanced Low NOx Digital Controls

The objective of this proposed addition to the ICCT project at Plant Hammond Unit 4 is to evaluate and demonstrate the effectiveness of advanced digital control methods as applied to NOx abatement technologies in coal-fired power plants. The advanced low NOx control system project will provide documented effectiveness of advanced digital controls on NOx emissions and guidelines for retrofitting boiler combustion controls for NOx emission reduction. The work breakdown structure for this proposed extension is shown in Table 13.

The following are the major activities during the second quarter 1993:

- Verification of input/output (I/O) list,
- Allocation of I/O to controllers and I/O cards,
- Foxboro digital control system powered up and system defined,
- Development of elementary wiring diagrams,
- Development of functional control diagrams and ladder logic,
- Cable tray and conduit layout design,
- Operator console / bench board design,
- Start of digital control system configuration.

Table 13. Digital Control System Work Breakdown Structure

Task	Description	Date
4.1	Project Management and Reporting	1/94 - 4/95
4.1.1	SCS R&EA Management and Reporting	
4.1.2	Environmental Reporting	
4.2	Design & Retrofit	
4.2.1	Preliminary Design - SCS Engineering	
4.2.2	Detail Design - SCS Engineering	
4.2.3	Digital Control System Hardware Design	
4.2.4	Configuration - SCS Engineering	
4.2.5	Installation & Checkout - SCS Engineering	
4.2.6	Materials	
4.3	Advanced Low NOx Digital Control System Testing	6/94 - 4/95
4.3.1	Test Coordination	
4.3.2	Long-Term Statistical Analysis	
4.3.3	Environmental Testing	
4.3.4	Performance Testing	
4.3.5	On-Site Technical Support	
4.3.6	Laboratory Analysis	
4.3.7	Other Testing	
4.3.8	Miscellaneous	
4.4	Advanced Controls	1/94 - 4/95
4.4.1	Advanced Hardware and Software Customization	

4. FUTURE PLANS

The following table is a quarterly outline of the activities scheduled for the remainder of the project *not including* the task associated with the proposed Advanced Low NOx Digital Control System scope:

Table 14. Future Plans

Quarter	Activity
Third Quarter 1993	• Complete LNB+AOFA Long-Term Test • Verification Tests of the LNB+AOFA • Start Final Reporting • Start Disposition
Forth Quarter 1993	• Complete Final Reporting • Complete Disposition • Project Completion

Notes:

1. Does not reflect proposed digital control system to the project. Table will be updated when final approval of scope addition is obtained.

5. CONCLUSIONS

In conclusion, the results to date at Plant Hammond indicate:

- NOx emissions have been reduced to near 50 percent of baseline values by using low NOx burners alone. These reductions were sustainable over the long-term test period and were consistent over the entire load range. The full load short-term NOx reductions in this configuration were approximately 55 percent. Furnace waterwall slagging has been significantly reduced, leading to a reduction in soot-blowing frequency. Unit operation was approximately the same or slightly better than that experienced during baseline testing.

- Preliminary results show that AOFA used in conjunction with the LNBs provide only incremental NOx reduction benefits averaged less than 15 percent over the load range. When compared to baseline, the full load long-term and short-term NOx reductions in this configuration were approximately 65 percent and 69 percent, respectively. The long-term, full load NOx reduction using AOFA alone was approximately 24 percent. Operation of the unit was characterized by plant operators as being more difficult when using the AOFA system.

- In the AOFA, LNB, and LNB+AOFA configurations, the unit experienced significant performance impacts including increases in excess air and carbon in fly ash.

- The LNBs are susceptible to tip cracking and melting. These problems will impact reliability and may affect performance as it relates to NOx production and LOI. The cause of these failures is at this time undetermined. Future work should address these challenges and the controls necessary to maintain performance and reliability.

- Auxiliary systems can be adversely impacted by the installation of these combustion technologies. Precipitator mass loading and gas flow rates have increased. Excess air requirements and, therefore, fan power requirements have also increased.

6. ACKNOWLEDGMENTS

The following project participants are recognized for their dedicated efforts toward the success of the wall-fired low NO_X demonstration: Mr. Ernie Padgett, Georgia Power Company, and Mr. Mike Nelson, Southern Company Services, for their coordination of the design and retrofit efforts and Mr. Jose Perez, full-time Instrumentation Specialist from Spectrum Systems, Inc. Also Messrs Jim Witt and Jimmy Horton of Southern Company Services for design, procurement, and installation of the instrumentation systems. The following companies have provided outstanding testing and data analysis efforts: Energy Technology Consultants, Inc., Flame Refractories, Inc., Southern Research Institute, W. S. Pitts Consulting, and Radian Corporation. Finally, the support from Mr. Art Baldwin, DOE ICCT Project Manager, and Mr. David Eskinazi, EPRI Project Manager, is greatly appreciated.

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APPENDIX A
AOFA Operating Instructions

ADVANCED OVERFIRE AIR SYSTEM
OPERATING INSTRUCTIONS[1]

1 PROCEDURE PRIOR TO STARTING FD, PA AND ID FANS

1.1 Checks to be Performed

a. Check that all overfire air pressure control dampers CD-F1, CD-F2, CD-R1 and CD-R2 are in the 0% open position.

b. Open the overfire isolation (guillotine) dampers and confirm that the open-lights are illuminated.

2 START-UP (AFTER REACHING STABLE OPERATION AT 300 MEGAWATTS OR ABOVE)

2.1 Overfire Air Pressure Control Damper Initial Settings

a. Slowly open air pressure control dampers CD-F1, CD-F2, CD-R1 and CD-R2 as indicated below:

(1) Open all four dampers, one at a time, an additional 15%.

(2) Wait five minutes. Open all four dampers, one at a time another 15%.

(3) Repeat again until all four dampers are at the 50% open position.

3 NORMAL LOAD CONTROL OPERATION

3.1 Damper and Excess Oxygen Settings

a. The following procedure is conservative in that NOx emission levels will be reduced with relatively little or no CO levels being experienced.

---

[1]Source: FWEC OPERATING INSTRUCTIONS, April 1992.

b. However, if high CO levels are encountered (above 200 PPM) the Overfire Air (OFA) Control Dampers should be biased closed until proper CO levels are obtained.

c. The overfire air pressure control dampers and boiler excess oxygen should be set as indicated below for the following megawatt ranges:

NOTE

The OFA Control Dampers should not be adjusted to control O2 levels. If a significant discrepancy exists between left and right side O2 levels, the OFA System should be taken out of service to ascertain the cause.

(1) 475 to 500 MWG

- Maintain total OFA flow no greater than 750-800 KLBH.

CD-F1	200 KLBH	CD-R1	200 KLBH
CD-F2	185 KLBH	CD-R2	185 KLBH

- O2 level is to be maintained at no less than 3.8%.

(2) 430 - 475 MWG (6 Mill Operation)

- Maintain total OFA flow no greater than 600 KLBH.

CD-F1	155 KLBH	CD-R1	155 KLBH
CD-F2	145 KLBH	CD-R2	145 KLBH

- O2 level is to be maintained at no less than 3.8%.

(3) 390 - 430 MWG (6 Mill Operation)

- Maintain total OFA flow no greater than 400 KLBH.

CD-F1	105 KLBH	CD-R1	105 KLBH
CD-F2	95 KLBH	CD-R2	95 KLBH

- O2 level is to be maintained at no less than 3.8%.

(4) 390 - 430 MWG (5 Mill Operation)

- Maintain total OFA flow no greater than 300 KLBH.

CD-F1	80 KLBH	CD-R1	80 KLBH
CD-F2	70 KLBH	CD-R2	70 KLBH

- O2 level is to be maintained at no less than 3.8%.
- On the upper burners that are out of service, the sleeve dampers are to be set at light off. On any intermediate or lower burners that may be out of service, set the sleeve damper to closed position.

NOTE

If the Out of Service Burner Tip temperature exceed 1200F, all sleeve dampers on the associated burner deck are to be placed in the light off position.

(5) 300 - 390 MWG

- Maintain total OFA no greater than 300 KLBH

CD-F1	80 KLBH	CD-R1	80 KLBH
CD-F2	70 KLBH	CD-42	70 KLBH

- O2 level is to be maintained at levels dictated by current O2 vs. load curves.
- Out-of-service upper burner sleeve dampers should be set at light off. Out-of-service intermediate or lower burner sleeve dampers are to be set closed.

NOTE

If the out-of-service burner tip temperatures exceed 1200F, all sleeve dampers on the associated burner deck are to be placed in the light off position.

6. 200 - 300 MWG

- The OFA control dampers should be set at the closed position.
- O2 level is to be maintained at levels dictated by current O2 vs. load curves.
- Out-of-service upper burner sleeve dampers should be set at light off. Out-of-service intermediate or lower burner sleeve dampers are to be set closed.

NOTE

If the Out-of-service burner tip temperatures exceed 1200F, all burner sleeve dampers on the same burner deck are to be placed in the light-off position.

3.2 Placing OFA System in Service, Load Upramps and Load Downramps

a. Increasing the OFA damper opening will result in a slight increase in O2. The opposite will occur when decreasing damper opening. This is partially explained by system resistance pressure changes. It is therefore imperative, that changes be made in a timed/balanced manner in an effort to minimize operational upsets.

b. OFA dampers are to be opened to recommended settings following completion of an upramp.

c. OFA dampers are to be preset to projected load settings prior to a downramp.

d. These dampers are to be brought into position systematically while watching O2 and CO levels.

4 SHUTDOWN

4.1 Closing Overfire Air Pressure Control Dampers

a. Slowly close the overfire air flow control dampers CD-F1, CD-F2, CD-R1 and CD-R2 as indicated below:

(1) Close all four dampers, one at a time, down to 50% open.

(2) Wait five minutes and close all dampers, one at a time, an additional 15%.

(3) Continue to reduce damper opening as in step (2) above, until the 10% open position is reached. Then close an

additional 10% after waiting five minutes to obtain a 0% open position.

CAUTION

THE CLOSED POSITION OF THE OVERFIRE AIR (GUILLOTINE) DAMPERS IS CONSIDERED TO BE AT THE SIX INCH OPEN POSITION. THESE DAMPERS MUST NEVER BE CLOSED WITH THE UNIT RUNNING.

APPENDIX B
Summary of LNB+AOFA Diagnostic and Performance Tests

Summary of LNB+AOFA Diagnostic and Performance Tests

TEST NUMBER	DATE	START TIME	LOAD MWe	FEEDWTR FLOW KPPH	MOOS PATTERN	OFA FLOW KPPH	CO ppm	CONTROL ROOM O2 Percent	STACK O2 Percent	ECONO O2 Percent	NOX lbs/MBtu	TEST CONDITIONS
101-1	05/06/93	10:28	449	3155	AMIS	600	28	3.4	5.8	3.5	0.465	HIGH LOAD TEST AFTER PWEC TUNING
101-2	05/06/93	13:38	452	3252	AMIS	455	75	3.8	5.8	3.6	0.488	HI LOAD - 75% OF OFA
101-3	05/06/93	15:32	446	3132	AMIS	300	29	3.7	5.6	3.6	0.525	HI LOAD - 50% OF OFA
102-1	05/07/93	07:27	394	2735	AMIS	400	14	4.5	6.5	4.4	0.479	MID LOAD - HIGH O2
102-2	05/07/93	10:35	397	2749	AMIS	400	27	3.5	5.5	3.3	0.404	MID LOAD - NORMAL O2
102-3	05/07/93	13:25	397	2752	AMIS	400	145	2.9	5.2	2.7	0.349	MID LOAD - MINIMUM O2
102-4	05/07/93	15:45	479	3285	AMIS	763	234	3.0	5.3	3.1	0.405	HI LOAD - OPACITY TEST (FAILED)
103-1	05/08/93	07:35	407	2864	E	310	18	4.2	6.2	4.1	0.492	MID LOAD - E MOOS NORMAL O2
103-2	05/08/93	09:44	402	2846	B	320	33	4.9	6.8	4.6	0.476	MID LOAD - B MOOS HI O2
103-3	05/08/93	12:55	398	2829	B	300	27	4.3	6.1	4.0	0.440	MID LOAD - B MOOS NORMAL O2
103-4	05/08/93	14:44	399	2815	B	303	82	3.5	5.5	3.1	0.385	MID LOAD - B MOOS LOW O2
104-1	05/09/93	08:05	305	2039	D&F	305	10	5.5	7.4	5.2	0.344	LOW LOAD - HI O2 DF MOOS (Not Normal)
104-2	05/09/93	10:00	295	2080	D&F	295	11	4.1	6.1	3.9	0.288	LOW LOAD - LO O2 DF MOOS (Not Normal)
105-1	05/10/93	07:52	395	2849	F	300	68	4.0	6.0	3.9	0.362	MID LOAD - NORM O2 F MOOS (Not Norm)
105-2	05/10/93	10:53	398	2875	F	344	32	5.4	6.9	5.1	0.442	MID LOAD - HI O2 F MOOS (Not Norm)
106-1	06/08/93	09:16	450	3289	AMIS	585	234	2.7	6.4	3.6	0.367	HIGH LOAD - LOW O2 - FA OUT
106-2	06/08/93	12:27	477	3590	AMIS	794	140	3.3	6.6	3.9	0.391	HIGH LOAD - NORMAL O2
106-3	06/08/93	15:05	468	3492	AMIS	829	14	3.7	7.1	4.5	0.441	HIGH LOAD - HIGH O2
107-1	06/09/93	12:54	465	3401	AMIS	813	20	3.7	6.8	4.0	0.501	HIGH LOAD - HIGH O2
108-1	06/10/93	07:50	463	3405	AMIS	824	28	3.8	6.9	4.1	0.395	HIGH LOAD - HIGH O2
108-2	06/10/93	14:00	449	3240	AMIS	782	62	3.4	6.6	3.8	0.371	HIGH LOAD - NORMAL O2
108-3	06/10/93	16:25	472	3462	AMIS	802	239	2.9	5.9	3.1	0.351	HIGH LOAD - LOW O2
109-1	06/11/93	07:30	470	3429	AMIS	797	100	3.3	6.5	3.7	0.380	NORMAL O2 - NORMAL OFA
109-2	06/11/93	09:19	470	3433	AMIS	962	183	3.3	6.4	3.5	0.369	NORMAL O2 - HIGH OFA
109-3	06/11/93	13:58	474	3491	AMIS	611	183	3.4	6.2	3.6	0.405	NORMAL O2 - LOW OFA
110-1	06/12/93	02:55	302	2087	E	314	9	4.6	8.1	5.3	0.404	NORMAL O2 - "E" MOOS NOT NORMAL
110-2	06/12/93	05:45	305	2056	B&E	250	57	3.6	7.6	4.6	0.318	LOW O2
110-3	06/12/93	07:40	305	2014	B&E	326	12	4.8	8.3	5.5	0.369	NORMAL O2
110-4	06/12/93	10:00	302	1997	B&E	315	9	5.9	8.9	6.4	0.421	HIGH O2

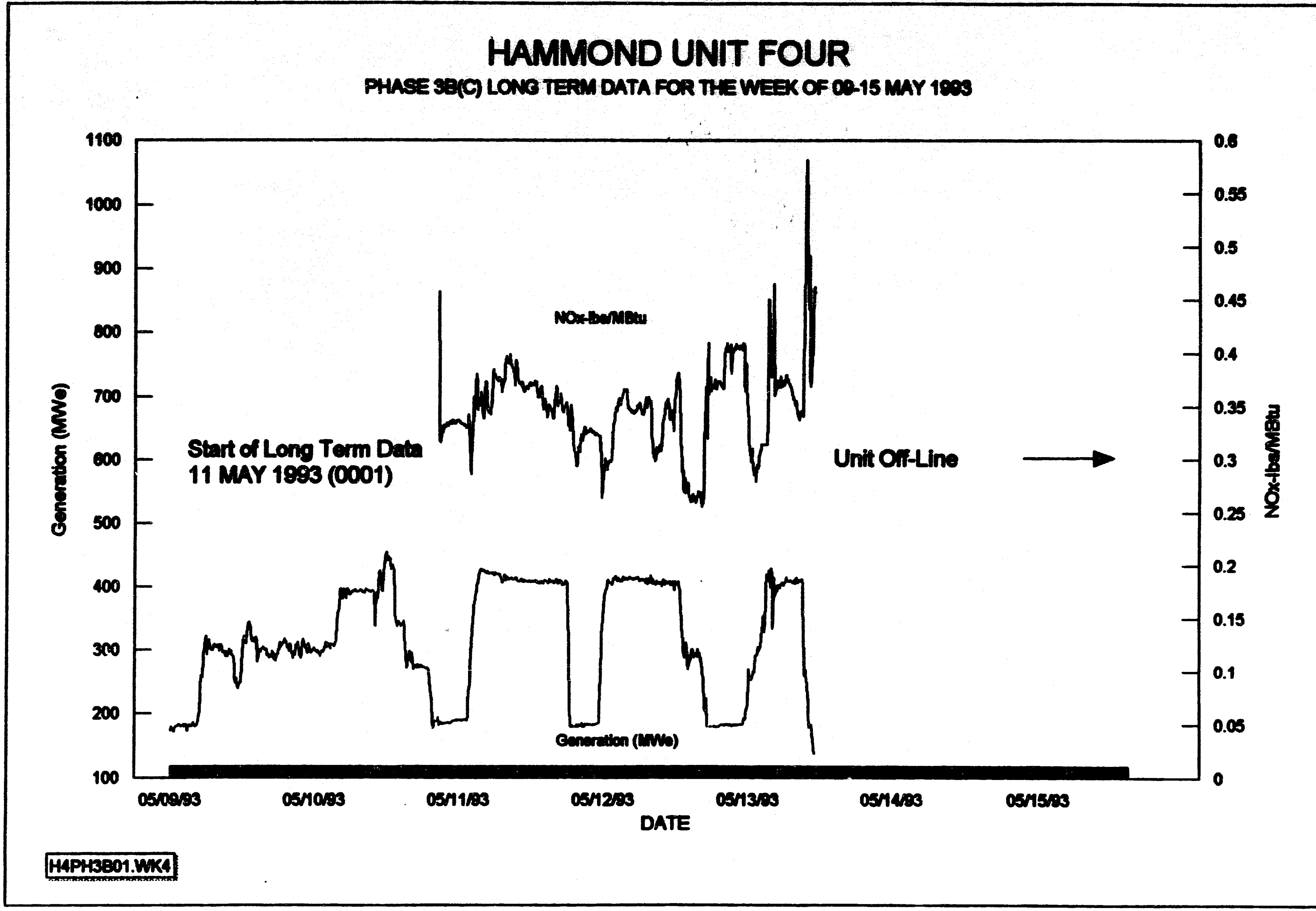
Summary of LNB+AOFA Diagnostic and Performance Tests

TEST NUMBER	DATE	START TIME	LOAD MWe	FEEDWTR FLOW KPPH	MOOS PATTERN	OFA FLOW KPPH	CO ppm	CONTROL ROOM O2 Percent	STACK O2 Percent	ECONO O2 Percent	NOX lbs/MBtu	TEST CONDITIONS
110-5	08/12/93	12:19	394	2711	B	327	19	5.2	6.1	5.6	0.489	HIGH O2
110-6	08/12/93	14:15	391	2686	B	313	59	4.1	7.1	4.3	0.492	NORMAL O2 - LOW OFA
110-7	08/12/93	15:59	391	2721	B	403	50	4.1	7.0	4.3	0.377	NORMAL O2 - NORMAL OFA
111-1	08/13/93	02:55	283	1958	B&D	310	8		8.8	6.3	0.410	HIGH O2
111-2	08/13/93	04:25	285	2007	B&D	317	11		7.9	5.0	0.345	NORMAL O2
111-3	08/13/93	05:40	282	1942	B&D	308	30		7.3	4.3	0.309	LOW O2
112-1	08/14/93	07:20	400	2734	AMIS	398	98	4.1	7.0	4.3	0.423	NORMAL O2
112-2	08/14/93	10:55	400	TEST ABORTED DUE TO MILL FEEDER PROBLEM								
112-3	08/14/93	15:10	404	2785	AMIS	416	50	4.3	7.3	4.7	0.447	NORMAL O2
113-1	08/15/93	12:00	476	3422	AMIS	789	128	3.8	6.5	3.8	0.395	HIGH OFA
113-2	08/15/93	13:10	474	3354	AMIS	585	217	3.5	6.2	3.6	0.422	MEDIUM [illegible]
113-3	08/15/93	14:15	474	3336	AMIS	276	315	3.2	6.2	3.4	0.451	LOW OFA
114-1	08/16/93	01:25	179	1376	B,D,E	94	7	6.3	9.5	6.8	0.412	HIGH O2
114-2	08/16/93	03:05	186	1384	B,D,E	93	10	5.3	8.5	5.4	0.377	MEDIUM O2
114-3	08/16/93	04:10	183	1381	B,D,E	90	14	4.7	7.8	4.5	0.346	LOW O2
115-1A	08/17/93	07:15	480	3535	AMIS	780	31	3.7	6.6	3.8	0.433	PERFORMANCE TEST 480 MWe
115-1B	08/17/93	08:40	467	3447	AMIS	784	29	3.7	6.7	4.0	0.441	PERFORMANCE TEST 480 MWe
115-1C	08/17/93	13:25	462	3373	AMIS	774	38	3.7	6.6	3.9	0.427	PERFORMANCE TEST 480 MWe
116-1A	08/18/93	08:00	476	3461	AMIS	787	54	3.6	6.5	3.9	0.421	PERFORMANCE TEST 480 MWe
116-1B	08/18/93	12:30	472	3437	AMIS	805	300	3.7	6.4	3.8	0.412	PERFORMANCE TEST 480 MWe
117-1A	08/19/93	09:00	303	2038	B	311	62	4.0	6.9	4.0	0.320	PERFORMANCE TEST 300 MWe
117-1B	08/19/93	13:00	299	1990	B	297	40	4.2	7.1	4.1	0.320	PERFORMANCE TEST 300 MWe
118-1A	08/20/93	09:00	302	2035	B	321	37	4.3	7.1	4.3	0.317	PERFORMANCE TEST 300 MWe
118-1B	08/20/93	12:30	298	1981	B	308	41	4.3	7.2	4.3	0.315	PERFORMANCE TEST 300 MWe
119-1A	08/21/93	23:00	400	2879	B	427	105	4.2	7.2	4.5	0.413	PERFORMANCE TEST 400 MWe
119-1B	08/22/93	03:00	400	2725	B	409	123	4.2	7.2	4.5	0.424	PERFORMANCE TEST 400 MWe
120-1A	08/22/93	20:45	401	2705	B	421	87	4.2	7.2	4.5	0.415	PERFORMANCE TEST 400 MWe
120-1B	08/23/93	00:30	401	2798	B	424	91	4.3	7.5	4.6	0.419	PERFORMANCE TEST 400 MWe
121-1	08/24/93	07:30	483	3543	NONE	954	43	3.6	6.3	3.7	0.411	MAX OFA FLOW

Summary of LNB+AOFA Diagnostic and Performance Tests

TEST NUMBER	DATE	START TIME	LOAD MWe	FEEDWTR FLOW KPPH	MOOS PATTERN	OFA FLOW KPPH	CO ppm	CONTROL ROOM O2 Percent	STACK O2 Percent	ECONO O2 Percent	NOX lb/MBtu	TEST CONDITIONS
121-2	08/24/93	09:10	482	3465	NONE	791	58	3.6	6.4	3.9	0.413	NOMINAL OFA FLOW
121-3	08/24/93	10:45	481	3814	NONE	603	191	3.5	6.2	3.8	0.414	LOW OFA FLOW
121-4	08/24/93	15:45	495	3658	NONE	777	43	3.6	6.3	3.8	0.421	500 MWe, NOMINAL OFA FLOW
122-1	08/25/93	07:20	401	2765	NONE	409	55	3.7	6.6	4.0	0.365	NOM OFA - NOM O2
122-2	08/25/93	08:30	402	2713	NONE	275	44	3.6	6.7	4.1	0.389	LOW OFA - NOM O2
122-3	08/25/93	09:50	397	2707	NONE	516	34	3.4	6.7	4.2	0.348	HIGH OFA - NOM O2
122-4	08/25/93	10:50	396	2701	NONE	510	15	4.1	7.1	4.7	0.365	HIGH OFA - HIGH O2
122-5	08/25/93	12:55	395	2697	NONE	401	14	4.2	7.1	4.7	0.404	NOM OFA - HIGH O2
122-6	08/25/93	14:20	392	2667	NONE	395	82	2.9	5.9	3.3	0.321	NOM OFA - LOW O2

APPENDIX C
Long-Term NO_X Emissions and Load - May - June, 1993


HAMMOND UNIT FOUR
PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 09-15 MAY 1993
1100
1000
900
800
700
600
500
400
300
200
100
Generation (MWe)
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
NOx-lbs/MBtu
NOx-lbs/MBtu
Start of Long Term Data
11 MAY 1993 (0001)
Unit Off-Line
Generation (MWe)
05/09/93
05/10/93
05/11/93
05/12/93
05/13/93
05/14/93
05/15/93
DATE
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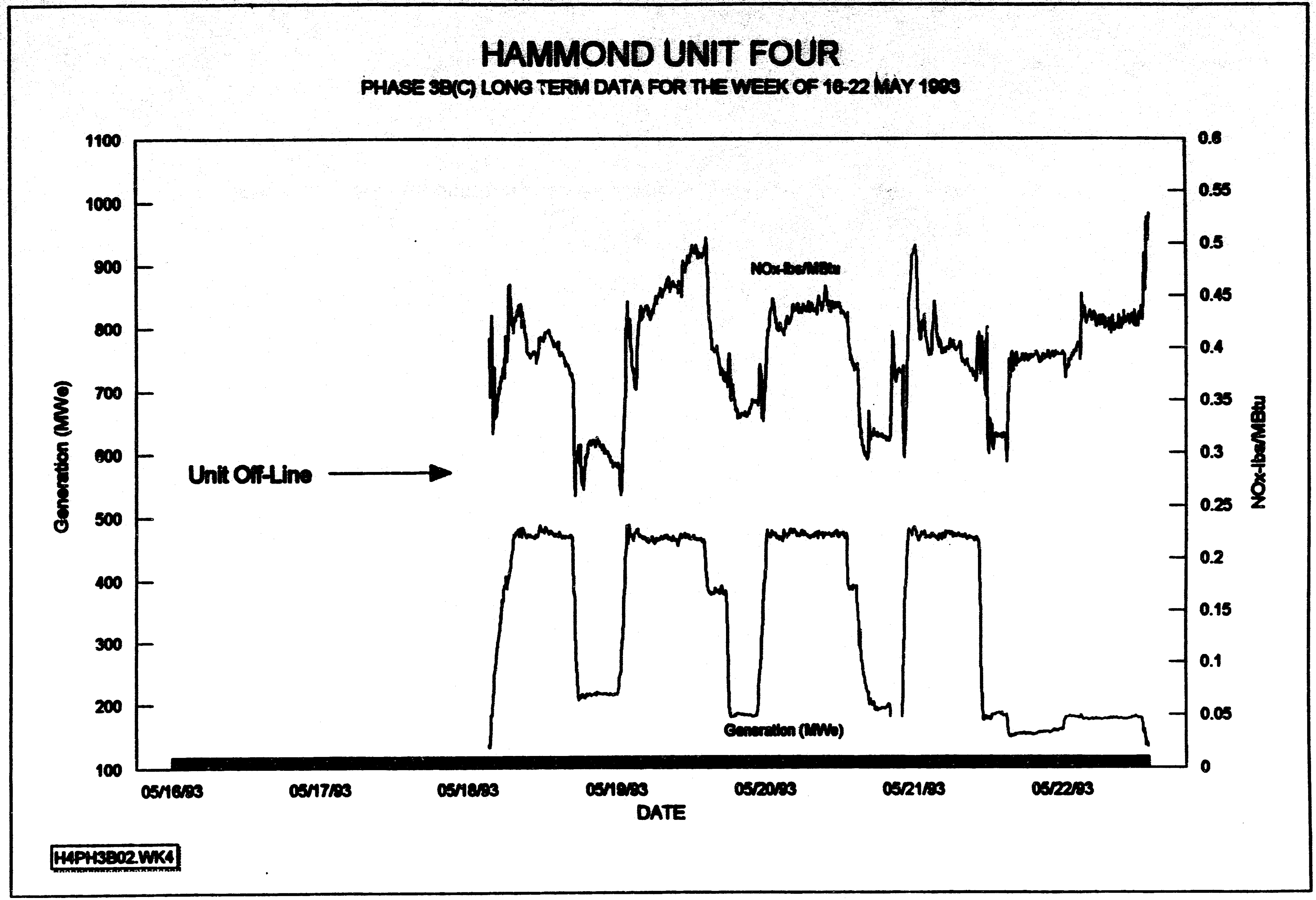
HAMMOND UNIT FOUR
PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 16-22 MAY 1993
Generation (MWe)
NOx-lbs/MBtu
Unit Off-Line
1100
1000
900
800
700
600
500
400
300
200
100
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
05/16/93
05/17/93
05/18/93
05/19/93
05/20/93
05/21/93
05/22/93
DATE
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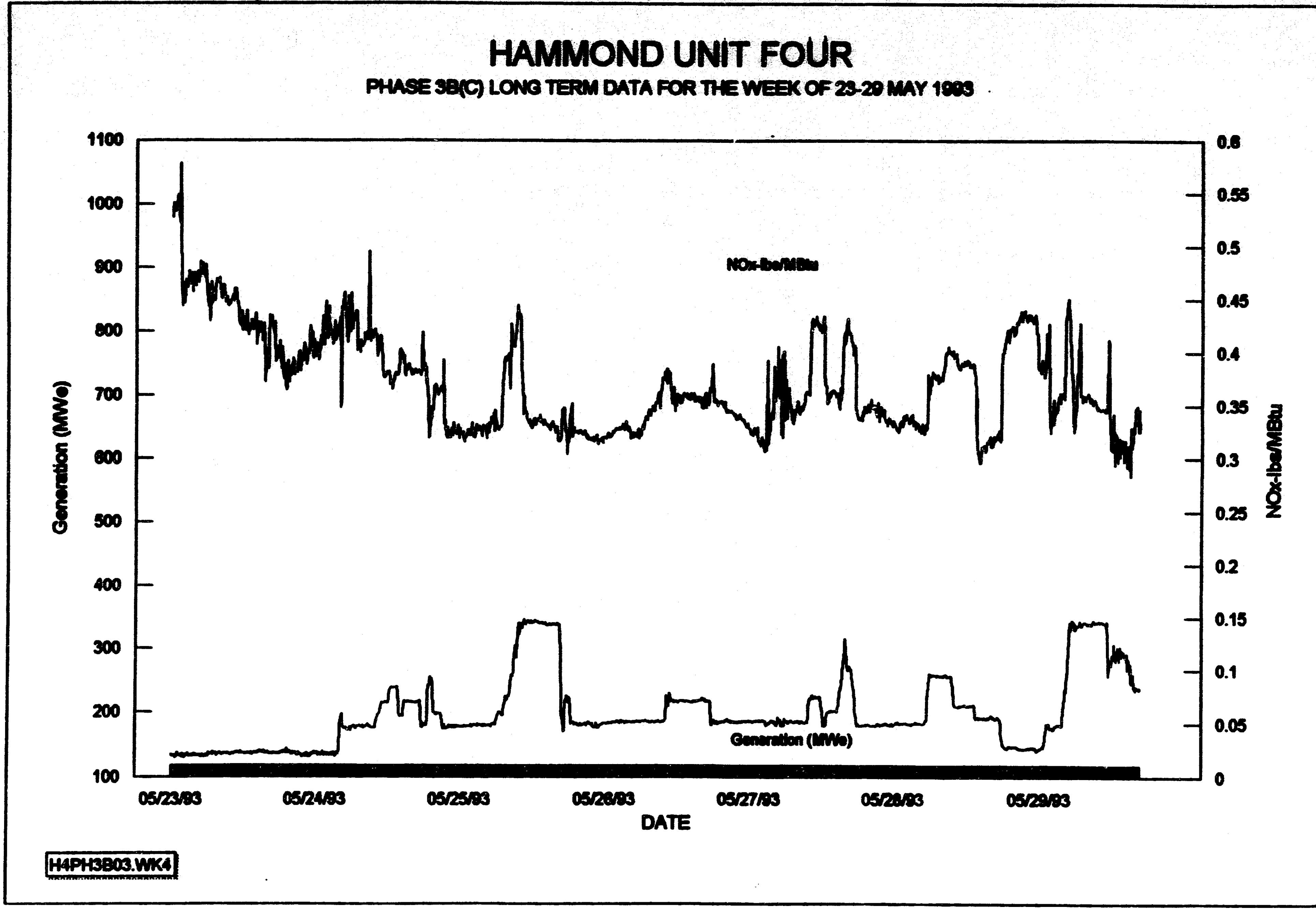
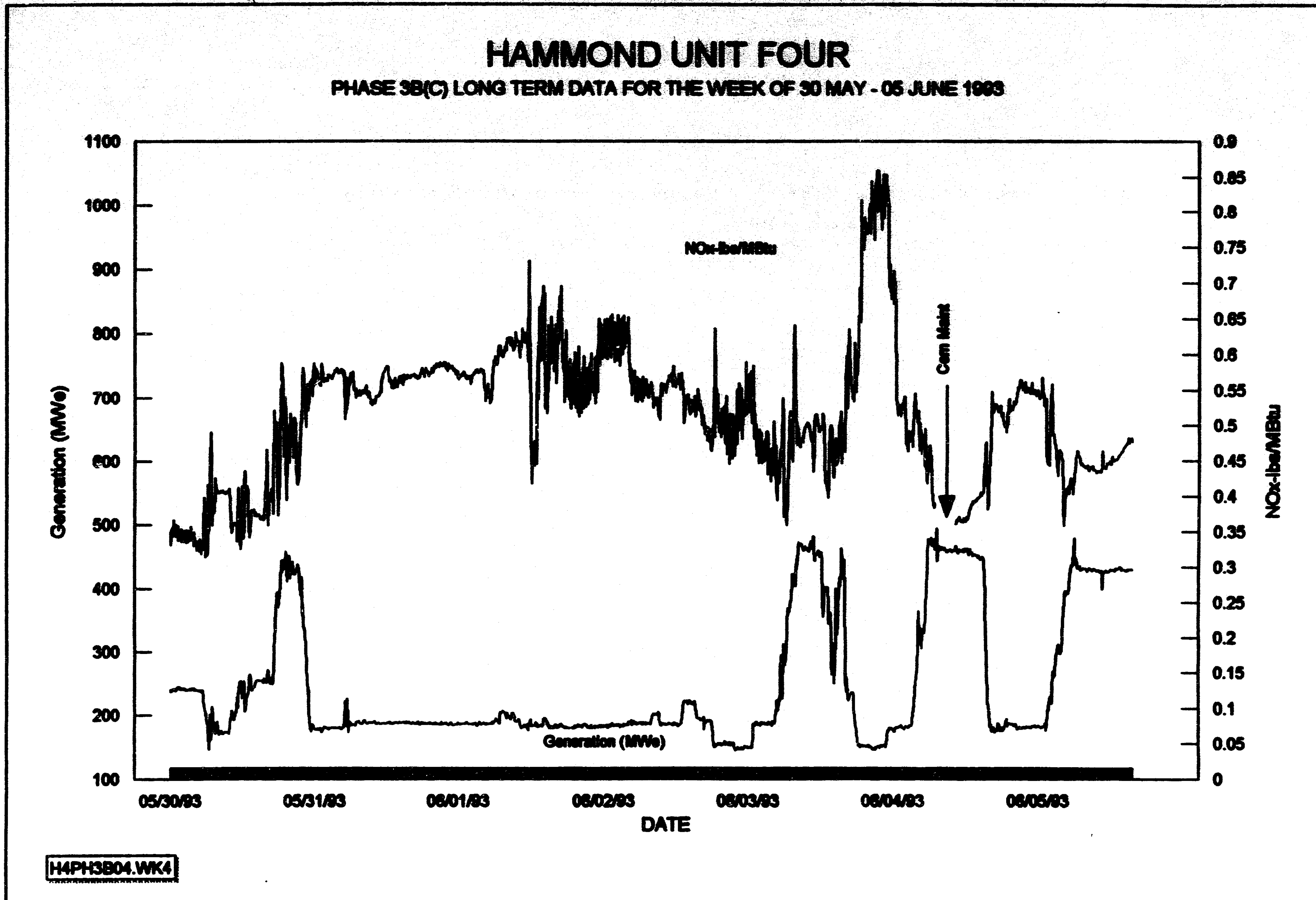
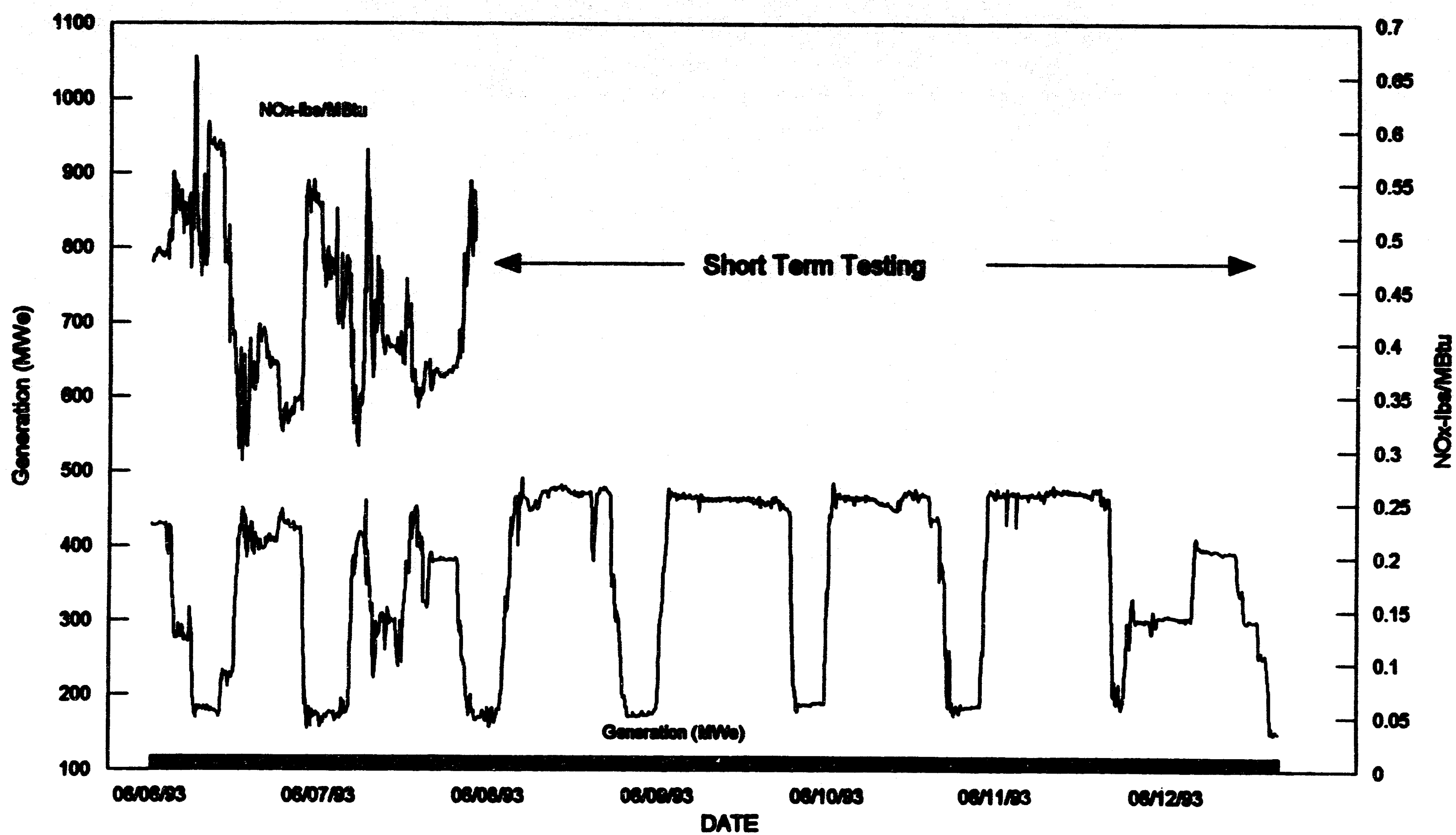

HAMMOND UNIT FOUR
PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 23-29 MAY 1993
NOx-lbs/MBtu
Generation (MWe)
1100
1000
900
800
700
600
500
400
300
200
100
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
05/23/93
05/24/93
05/25/93
05/26/93
05/27/93
05/28/93
05/29/93
DATE
H4PH3B03.WK4


HAMMOND UNIT FOUR
PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 30 MAY - 05 JUNE 1993
NOx-lbs/MBtu
Cam Maint
Generation (MWe)
Generation (MWe)
NOx-lbs/MBtu
DATE
05/30/93
05/31/93
06/01/93
06/02/93
06/03/93
06/04/93
06/05/93
1100
1000
900
800
700
600
500
400
300
200
100
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
H4PH3B04.WK4

HAMMOND UNIT FOUR

PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 06-12 JUNE 1993



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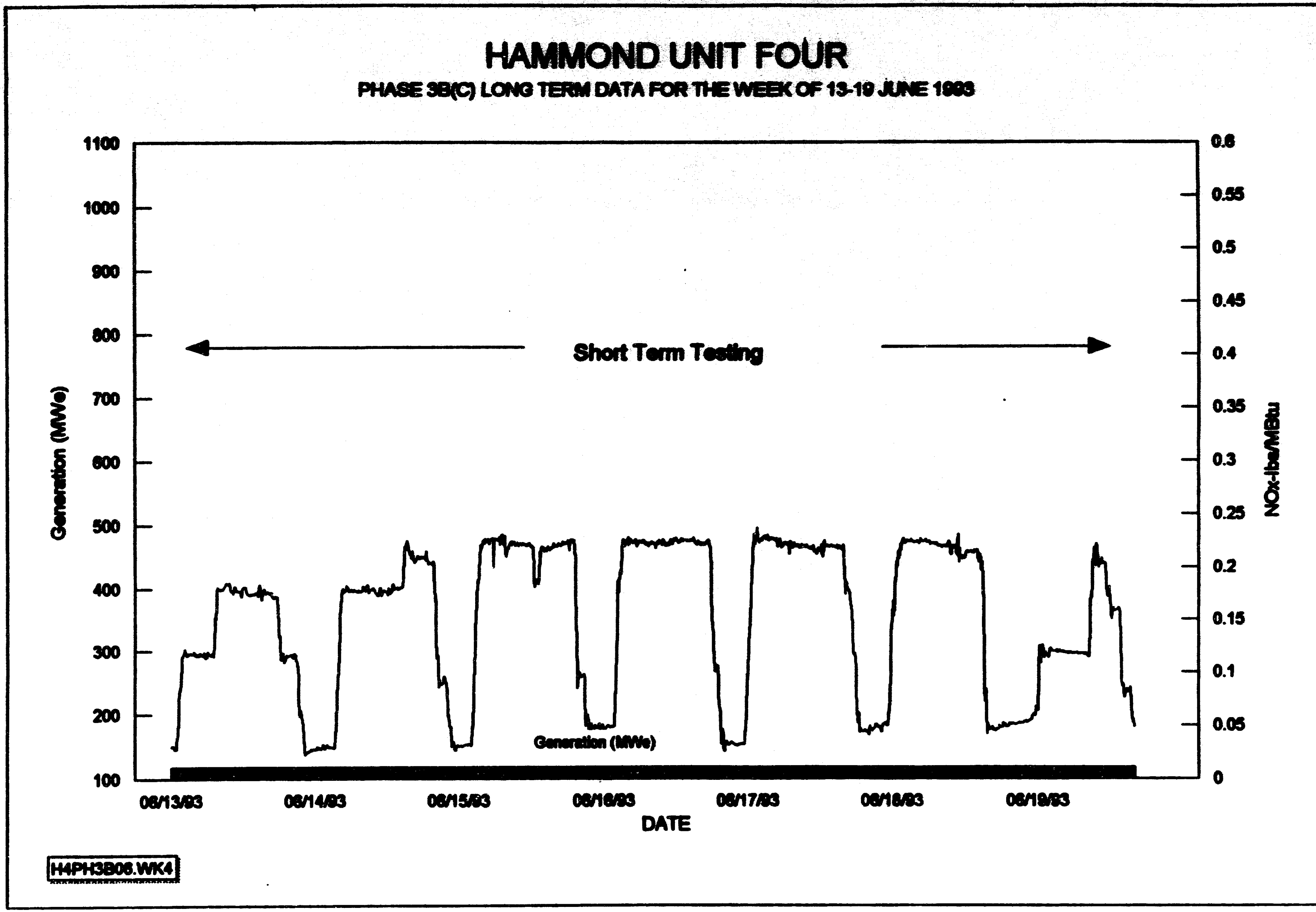
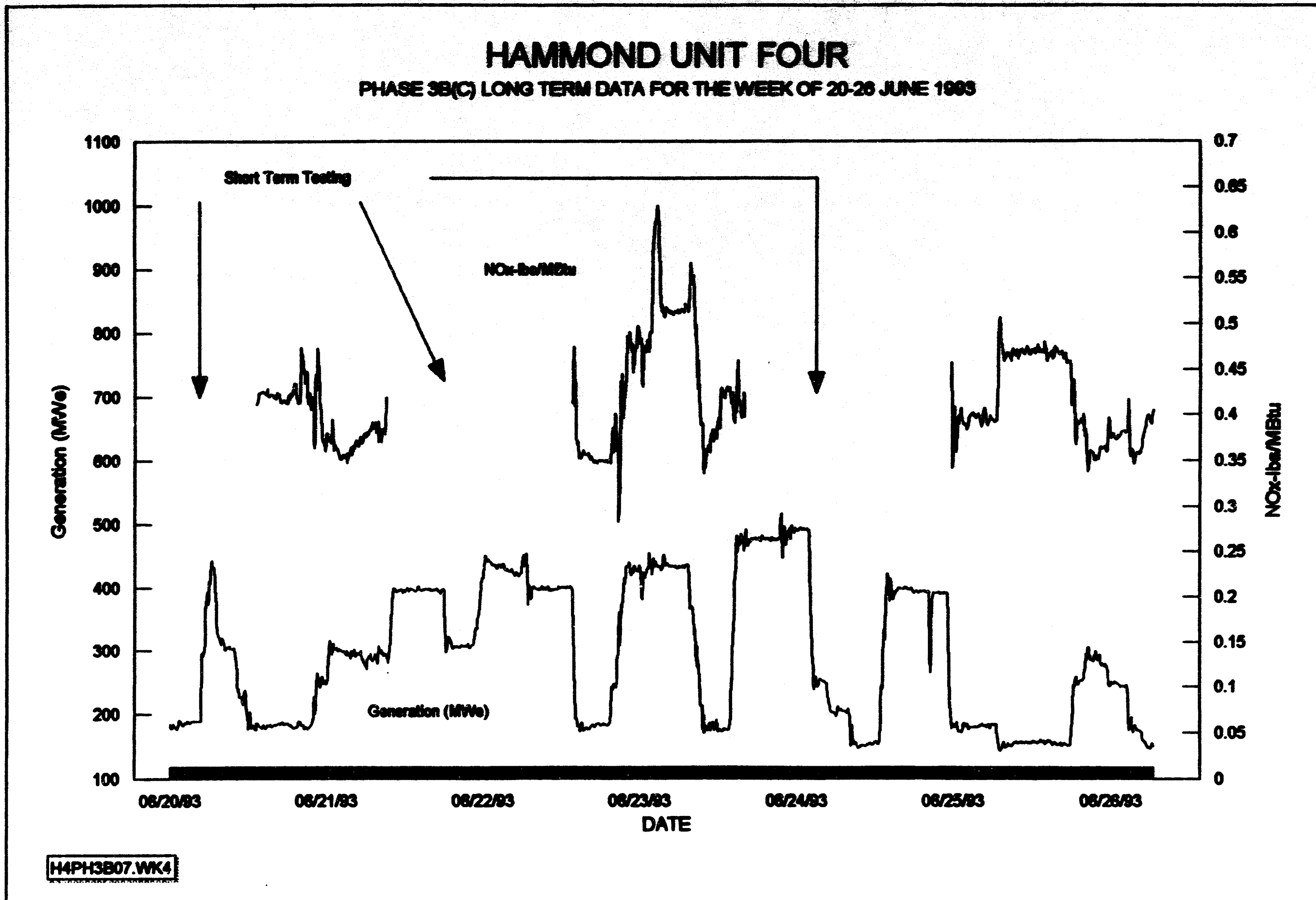
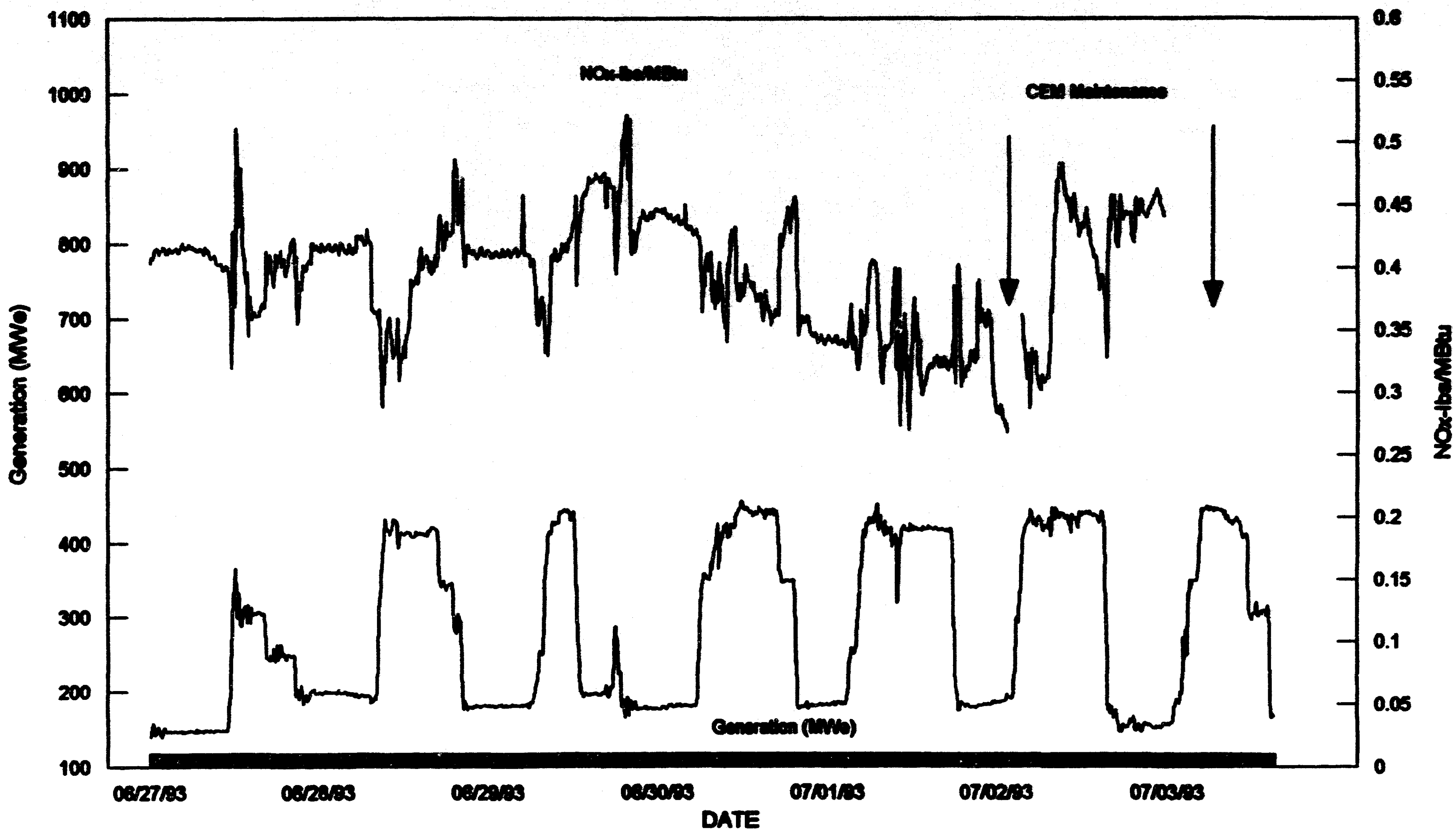


HAMMOND UNIT FOUR
PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 13-19 JUNE 1993
Short Term Testing
Generation (MWe)
1100
1000
900
800
700
600
500
400
300
200
100
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
NOx-lbs/MBtu
06/13/93
06/14/93
06/15/93
06/16/93
06/17/93
06/18/93
06/19/93
DATE
H4PH3B06.WK4


HAMMOND UNIT FOUR
PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 20-26 JUNE 1993
Short Term Testing
NOx-lbs/MBtu
Generation (MWe)
1100
1000
900
800
700
600
500
400
300
200
100
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
06/20/93
06/21/93
06/22/93
06/23/93
06/24/93
06/25/93
06/26/93
DATE
H4PH3B07.WK4

HAMMOND UNIT FOUR

PHASE 3B(C) LONG TERM DATA FOR THE WEEK OF 27 JUNE - 03 JULY 1993



H4PH3B08.WK4

DATE FILMED

8/4/94

END