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INNOVATIVE CLEAN COAL TECHNOLOGY (ICCT)

500 MW DEMONSTRATION OF ADVANCED WALL-FIRED COMBUSTION TECHNIQUES FOR THE REDUCTION OF NITROGEN OXIDE (NOx) 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.

Phase 3 LNB testing began in July 1991. Short-term tests indicated post-retrofit, full-load NO_X levels of approximately 0.65 lb/MBtu and flyash loss-on-ignition (LOI) values of 8 percent. For comparison, the baseline values were approximately 1.35 lb/MBtu at 5.2 percent LOI. 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. This represents a 47 percent NOx reduction when compared to the baseline, full-load, long-term value of 1.24 lb/MBtu. As a result of post-LNB retrofit increases in precipitator ash loading and gas flow rates, it was necessary for the unit to run at reduced loads from September 6, 1991 to December 10, 1991 to meet particulate compliance limits. Ammonia flue gas conditioning is now being utilized to improve the precipitator collection efficiency, thereby allowing full-load operation. On December 9, 1991, a damaged burner was discovered by plant personnel. In order to repair the burner, the unit went off-line on December 19, 1991.

Following repair of the burner, which should be completed in early January 1992, the LNB with AOFA test phase will begin.

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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 MWe) near Rome, Georgia.

The project is being managed by Southern Company Services, Inc. (SCS) on behalf of the project co-funders: The Southern electric system, the U. S. Department of Energy (DOE), and the Electric Power Research Institute. In addition to SCS, The Southern electric system 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 electric system.

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 Projects 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.

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 the 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.

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 is a Foster Wheeler Energy Corporation (FWEC) balanced draft, opposed wall-fired boiler rated at 500 gross MWe with design steam conditions of 2500 psig and 1000/1000 ^{O}F superheat/reheat temperatures, respectively. 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 Intervane burners. During the recent LNB outage, the existing burners were replaced with FWEC Control Flow/Split Flame burners and in addition, two of the existing mills were replaced with Babcock and Wilcox MPS 75 mills. The burners are arranged in a matrix of 12 burners (4W x 3H) on opposing walls with each mill supplying coal to 4 burners in an elevation. As part of this demonstration project, the unit was retrofitted with an Advanced Overfire Air System (AOFA), to be described later. The unit is equipped with a coldside electrostatic precipitator (ESP) and utilizes two Ljungstrom air preheaters. Plant Hammond is located near Rome, Georgia, northwest of Atlanta.

Table 1: Work Breakdown Structure

500 MW Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NOx) 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 NOx Burner Retrofit	
	1.3.1	Project Management and Reporting	3/91 - 4/92
	1.3.2	LNB Design and Retrofit	3/91 - 5/91
	1.3.3	LNB Testing with and without AOFA	5/91 - 4/92
4	1.4	Final Reporting and Disposition	
	1.4.1	Project Management and Reporting	4/92 - 12/92
	1.4.2	Disposition of Hardware	5/92

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 which lowers combustion temperatures. This staging also reduces the quantity of oxygen available to the fuel-bound nitrogen. Typical overfire air (OFA) systems accomplish this staging by diverting ten to twenty 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 in greater quantities, with more control, and at higher pressures (Figure 2). The resulting system is capable of providing deep staging of the combustion process with accurate measurement of the AOFA airflow.

2.4. Wall-Fired Low NOx Combustion System

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.

Foster Wheeler Energy Corporation (FWEC) was competitively selected to design, fabricate, and erect the opposed wall, low NO_X burner shown in Figure 3 and the AOFA system described above. In the FWEC Controlled Flow/Split Flame (CFSF) burner, 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.

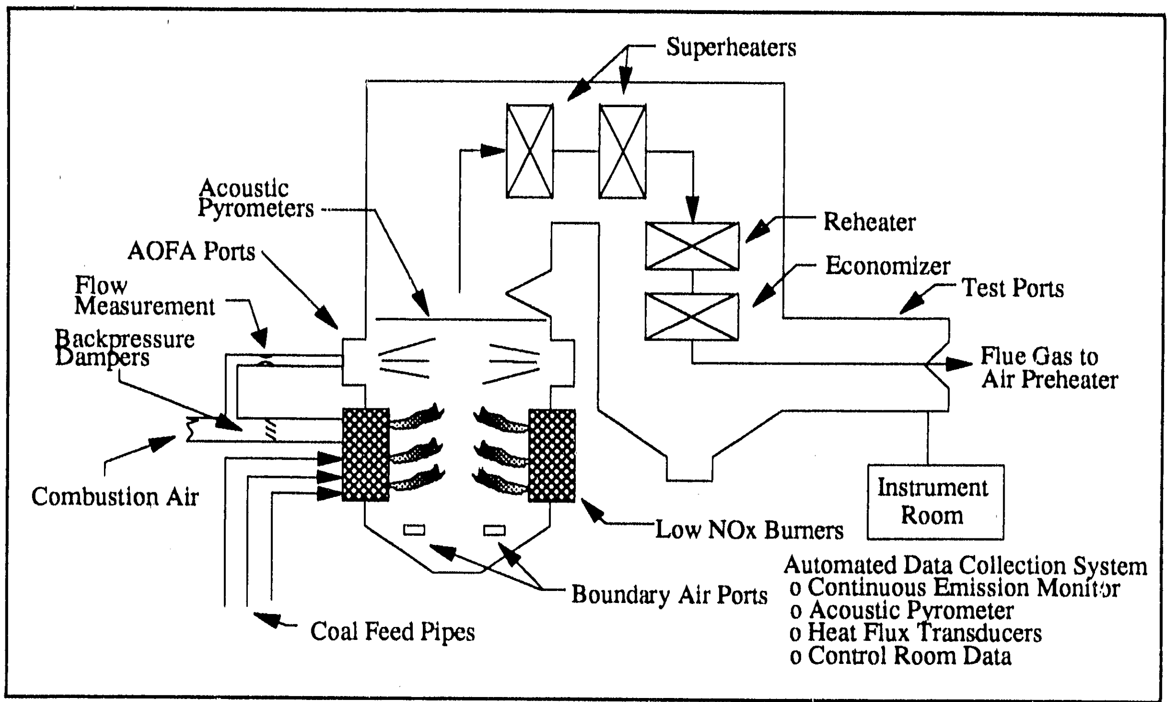

Figure 1: Plant Hammond Unit 4 Boiler

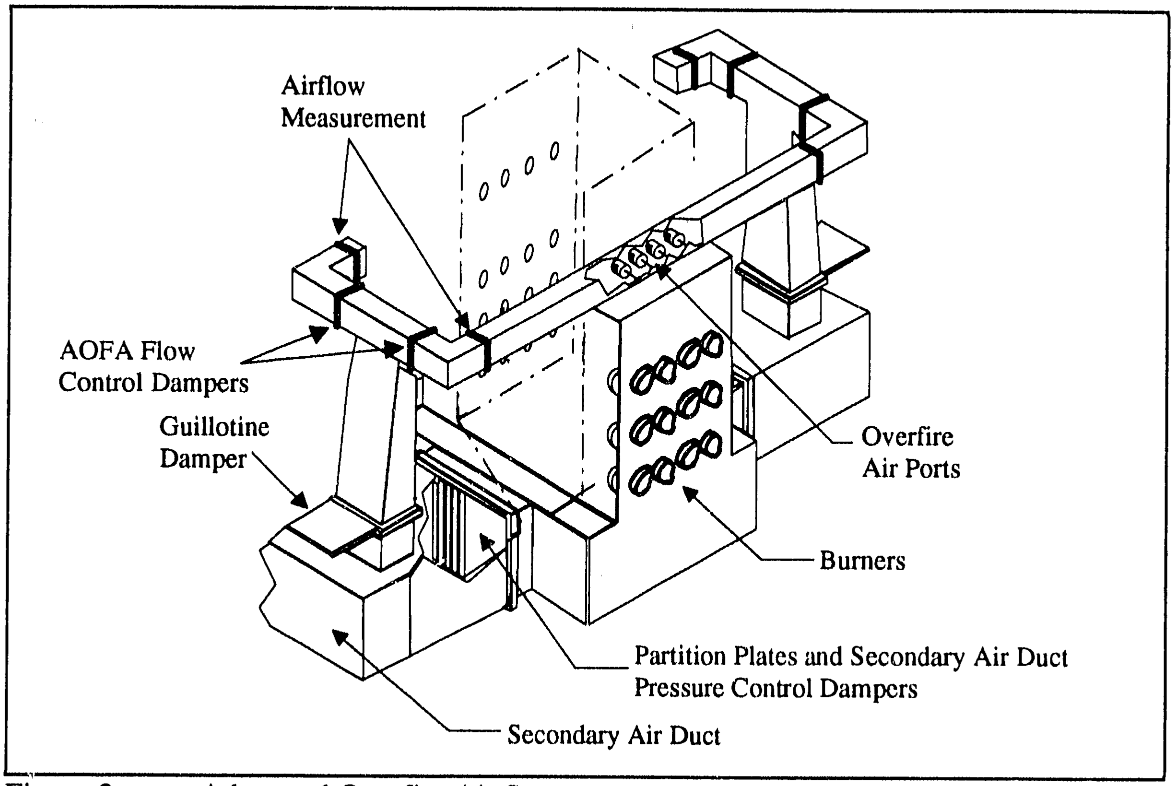

Figure 2: Advanced Overfire Air System

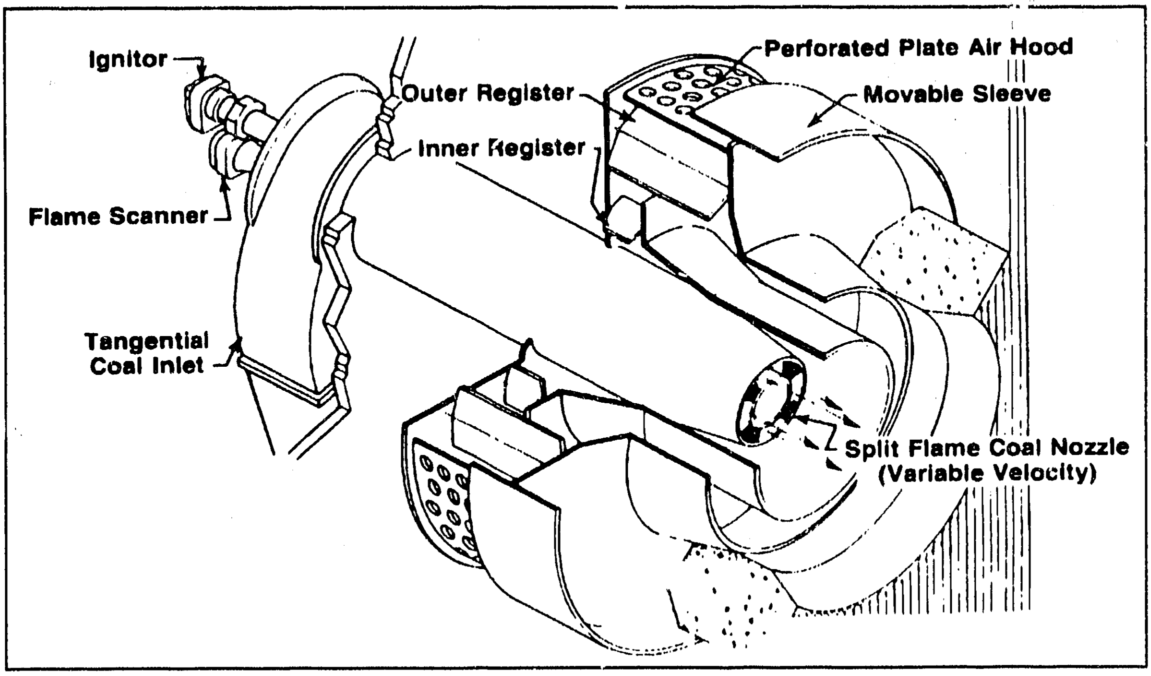

Figure 3: Low NO_X Burner Installed at Plant Hammond

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 NOx	Stack SO2
Stack O2	Stack Opacity
Generation	Overfire Air Flows

3. PROJECT STATUS

3.1. Phase 1 - Baseline Characterization

3.1.1. Task 1.5 Baseline Testing

Phase 1 baseline testing ended in April 1990. A summary of the baseline tests results is shown in Table 3 and Figures 4 and 5. During baseline testing, 52 days of long-term data were collected producing an average NOx emission level of 1.12 lb/MBtu. NOx 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 1.24 lb/MBtu at the nominal 2.7 percent excess oxygen operating condition while the short-term test results show a mean level of 1.35 lb/MBtu. The explanation for this disparity most likely is a result of such variables as coal variability, minor unit operating changes (air register settings, etc.) and possibly weather conditions affecting the coal grinding (wet coal) as well as the fact that long-term data includes transients in operating O_2 level which may be greater than the steady load excursions. The important point is that these normal excursions can influence the short-term data taken at one point in time but are essentially averaged out during normal, long-term operation.

3.2. Phase 2 - Advanced Overfire Air Retrofit

3.2.1. Task 2.3 AOFA Testing

Phase 2 AOFA testing ended in March 1991. A summary of NO_x emissions from Phase 1 long-term testing is presented in Table 3 and Figures 4 and 5. The short-term tests results from the AOFA operation show a substantial reduction (up to 40 percent at full-load reducing to 25 percent at 300 MW) in NO_x emissions. However, long-term tests indicate a maximum NO_x emissions reduction of only 25 percent. The difference between the short- and long-term test results emanate from the same operating variabilities as discussed previously and a change in operating excess air O_2 levels between the short- and long-term test segments.

3.3. Phase 3 - Low NO_X Burner Retrofit

3.3.1. Task 3.2 LNB Design and Retrofit

The new LNBs were installed during a seven week outage which began March 8, 1991, and continued to April 28, 1991. Optimization of the burners for NO_X reduction was performed by FWEC personnel during a three week period in June. The outage and optimization is described in detail in the *Second Quarter 1991 Technical Progress Report.*

3.3.2. Task 3.3 LNB Testing without AOFA

Phase 3A diagnostic testing of the low NO_X burner system began on July 9, 1991 and was completed on July 15. Performance testing began July 16. 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. Preliminary findings from these tests indicate short-term, full-load NO_X emissions of approximately .65 lb/MBtu at flyash loss-on-ignition (LOI) values of 8 percent (Figures 4 and 5). For comparison, the baseline values were approximately 1.35 lb/MBtu at 5.2 percent LOI.

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 (Table 3 and Figure 4). 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. As can be seen in Figure 6, the load-term variability in NO_X emissions was small, especially at high-loads. This variability is less than in previous tests phases and is probably due to an improvement in burner condition. Appendix A shows the NO_X emissions and unit generation trends for each week of the of the long-term test phase. This data was recorded in five minute intervals using the data acquisition system at the site. For reasons discussed below, from September 6, 1991 through December 10, 1991 the unit was limited to reduced loads.

As shown in Figure 7, baseline CO emissions were highly dependent on load, increasing from approximately 10 ppm at minimum load to 100 ppm at full load. This dependency was not evident in either the long-term AOFA testing or the short-term LNB tests, for which maximum CO values were approximately 20 ppm. This change is probably attributable to plant operating personnel beginning to monitor CO emission levels and taking action to reduce these emissions. Prior to the AOFA long-term test phase, CO emission levels were not displayed in the control room.

Full-load, long-term stack O_2 levels for the LNB test phase were approximately 30 percent higher than the corresponding baseline values (Figure 8). This change in O_2 level is mostly attributable to an increase of approximately 6 percent in combustion air for the LNB test configuration. Although an increase in the stack O_2 is indicated in this figure, the combustion air to the furnace did not change appreciably between the baseline and AOFA test phases, the change in O_2 levels primary cause being leakage in the furnace backpass.

Results from this project indicate that operation with low NO_x burners has substantially reduced boiler slagging. The site has also noticed a reduction in bottom ash production. However, the particulate that had previously been deposited on the boiler waterwalls and in the bottom hoppers is now exiting the furnace with the flue gas. As shown in Table 4, the post-LNB retrofit increases in particulate mass loading and gas flow rate were approximately 25 percent and 11 percent, respectively. Another side effect of the post-LNB shift in ash loading has been a rise in primary air heater plugging rates. The post-AOFA retrofit gas flow rate was approximately 17 percent greater than baseline; however, most of this change is due to air in-leakage in the furnace backpass and is not attributable to increased combustion air requirements. For the LNB test phase, combustion air requirements did rise. These increases, coupled with the higher post-LNB retrofit flyash LOI, adversely impacted particulate emissions such that it was necessary to run the unit at reduced loads to meet particulate compliance limits. Ammonia flue gas conditioning is now being utilized to improve the precipitator collection efficiency, thereby allowing full-load operation.

NOx production and flyash LOI are highly dependent on coal properties and mill performance. As can be seen in Table 5, coal fineness was generally better in both the AOFA and LNB tests phases than during baseline. Also, Hammond Unit 4's coal supply has been consistent for the three test phases (Figures 9-12).

3.3.3. Burner Failure

On December 9, 1991, a damaged burner was discovered by plant personnel. This burner is supplied coal by mill "B" and is located on the bottom, rear row of burners (Figure 13). The burner was isolated and unit operation continued until December 19, 1991. Following notification, FWEC began fabrication of a new inner barrel and nozzle tip and the new tip arrived on site December 26, 1991. After removal of the complete burner from the furnace, the damaged burner tip was cut off from the outer barrel assembly and the new burner tip welded into place. As of December 31, 1991, the new inner barrel had not been delivered.

The damaged burner tip is shown in Figures 14 and 15. A preliminary analysis indicated that coking between the nozzle and inner barrel preceeded the failure. Further investigations are planned to determine operating parameters (primary air/fuel ratio, coal condition, etc.) which may have contributed to this failure. An inspection of the other burners during the December outage indicated that they had not been damaged and no erosion of the coal nozzles was detected.

Table 3. Baseline, AOFA, and LNB Long-Term Test Results						
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	-

* RSD = Relative Standard Deviation = 100 * Standard Deviation / Mean

Table 4. ESP Inlet Conditions				
	Mass Loading		Gas Flow	
Phase	Gr/SCF#	Change* Percent	ACFM@	Change* Percent
Baseline	1.58	-	1.99E+06	-
AOFA	1.65	5	2.29E+06	17
LNB	1.96	25	2.21E+06	11

* Change relative to baseline.
\# Grains / Standard Cubic Feet
@ Actual Cubic Feet per Minute

Table 5: Mill Performance at Full Load Mill Coal Flow Weighted Averages		
Phase	Left in 50 Mesh Percent	Passing 200 Mesh Percent
Baseline	2.8	63.0
AOFA	2.6	66.5
LNB	1.3	66.5

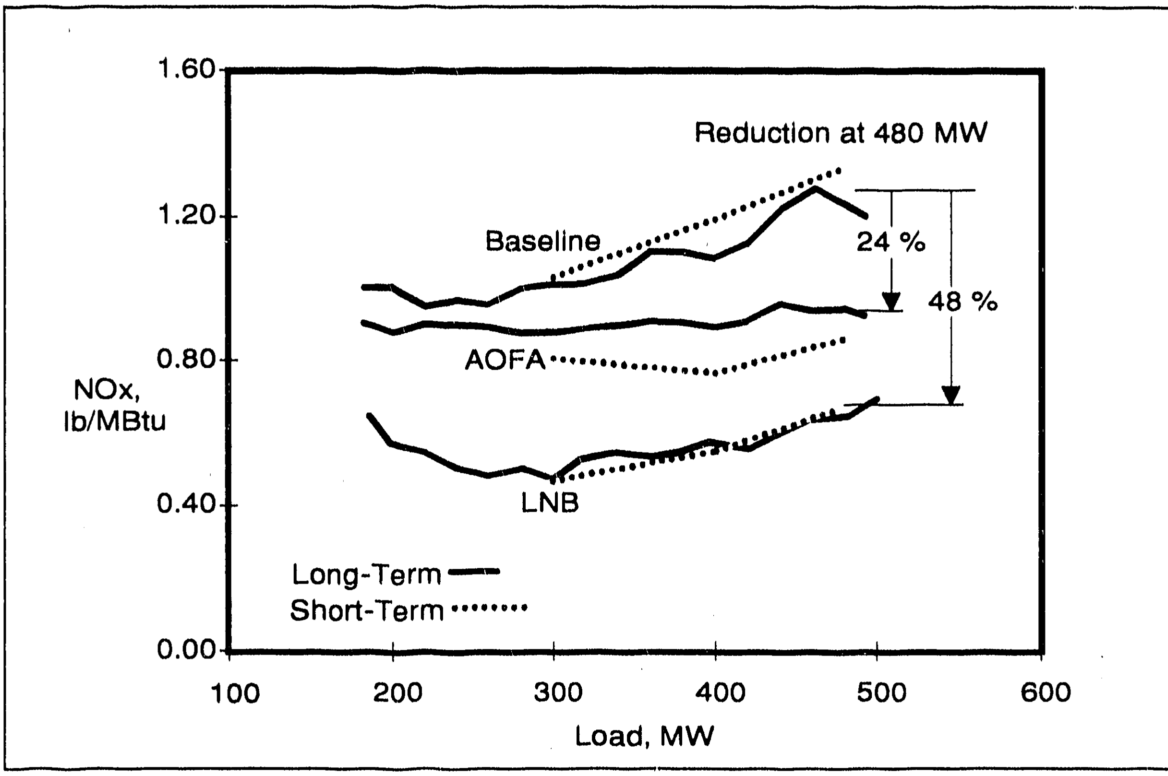

Figure 4: NOx Emission Comparision

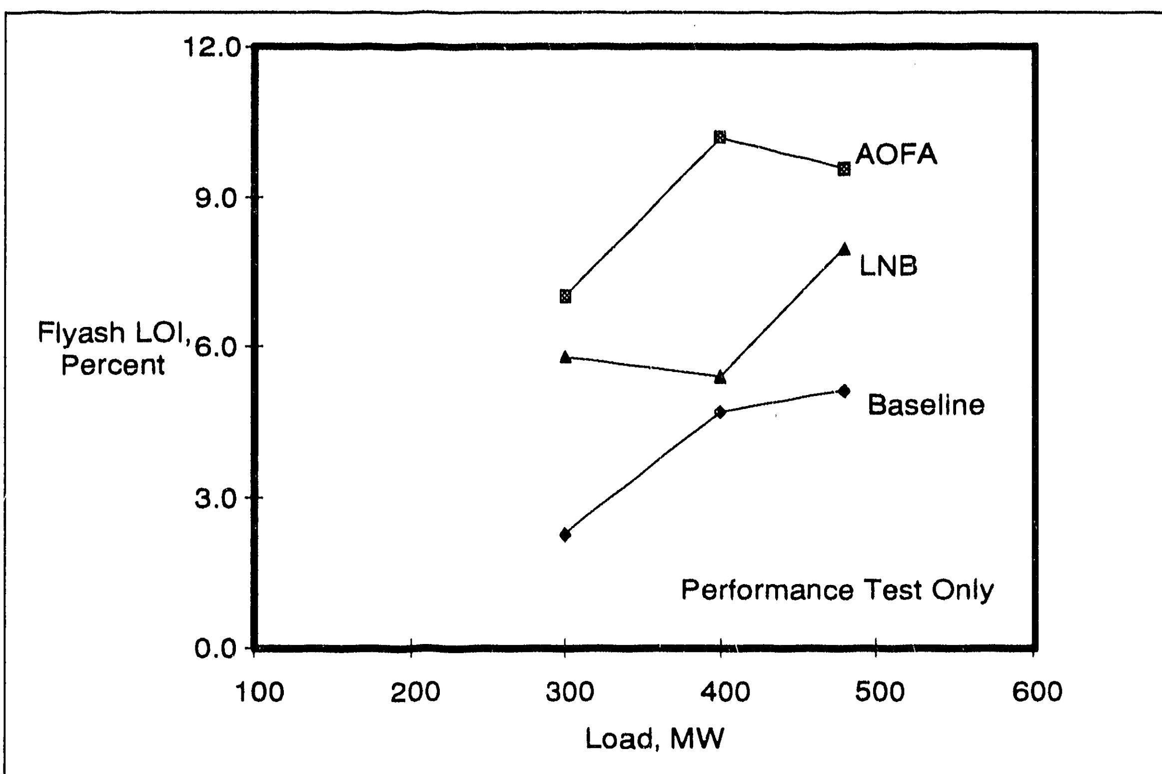

Figure 5: Flyash Combustibles Loss-on-Ignition

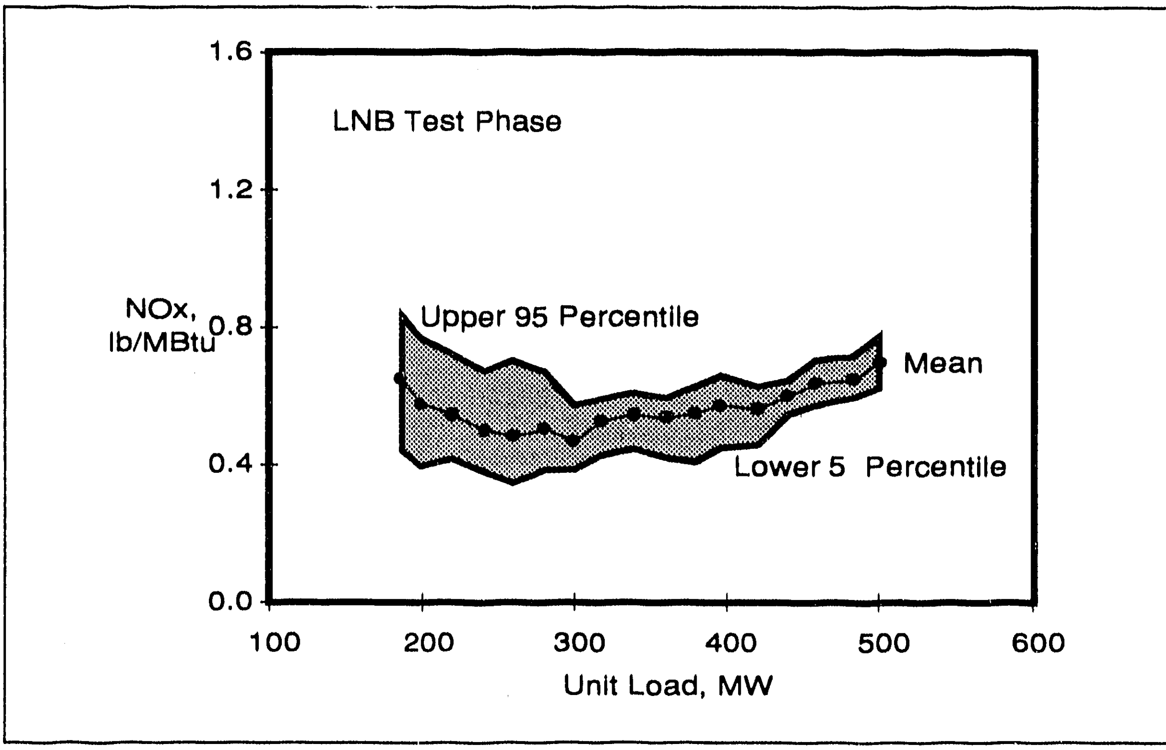

Figure 6: LNB Long-Term NO_X Trend

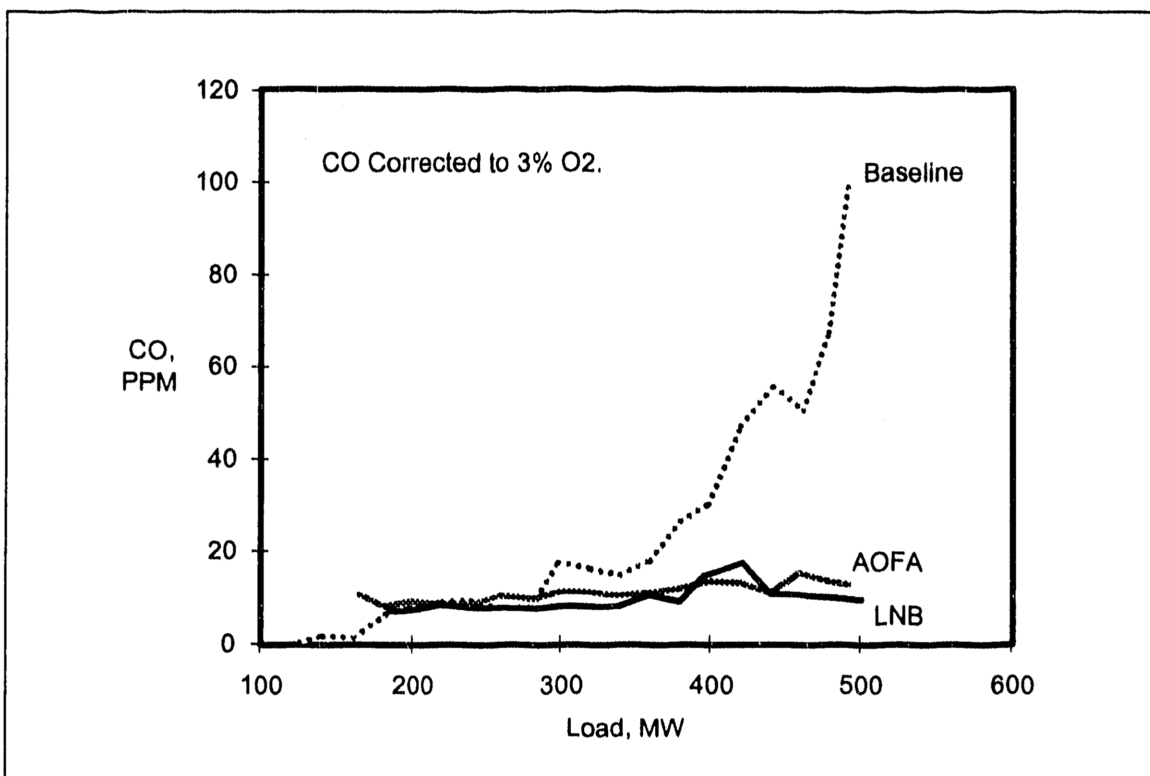

Figure 7: Long-Term CO Emissions

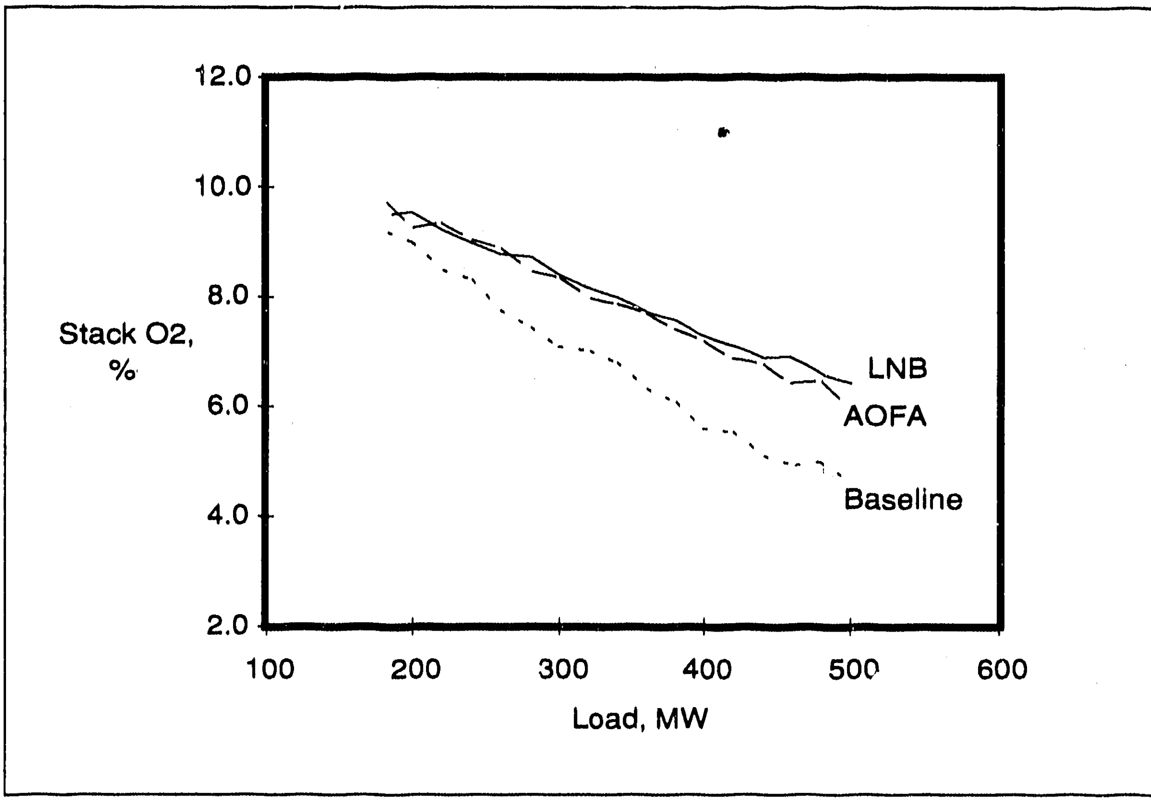

Figure 8: Stack O_2 Levels

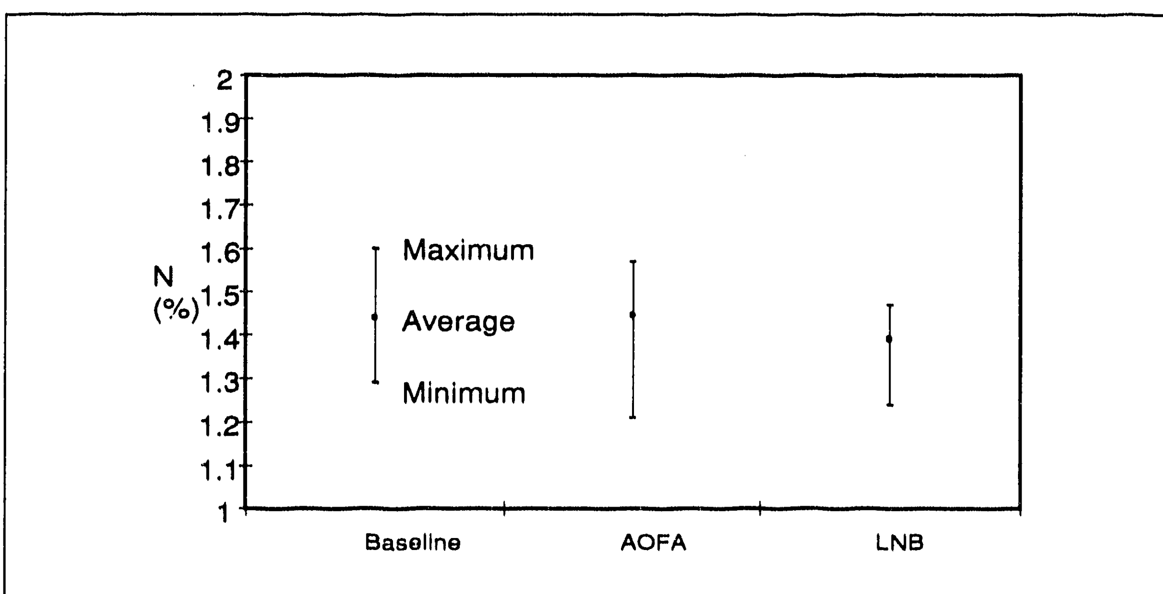

Figure 9: Coal Comparision - Nitrogen (N) Content

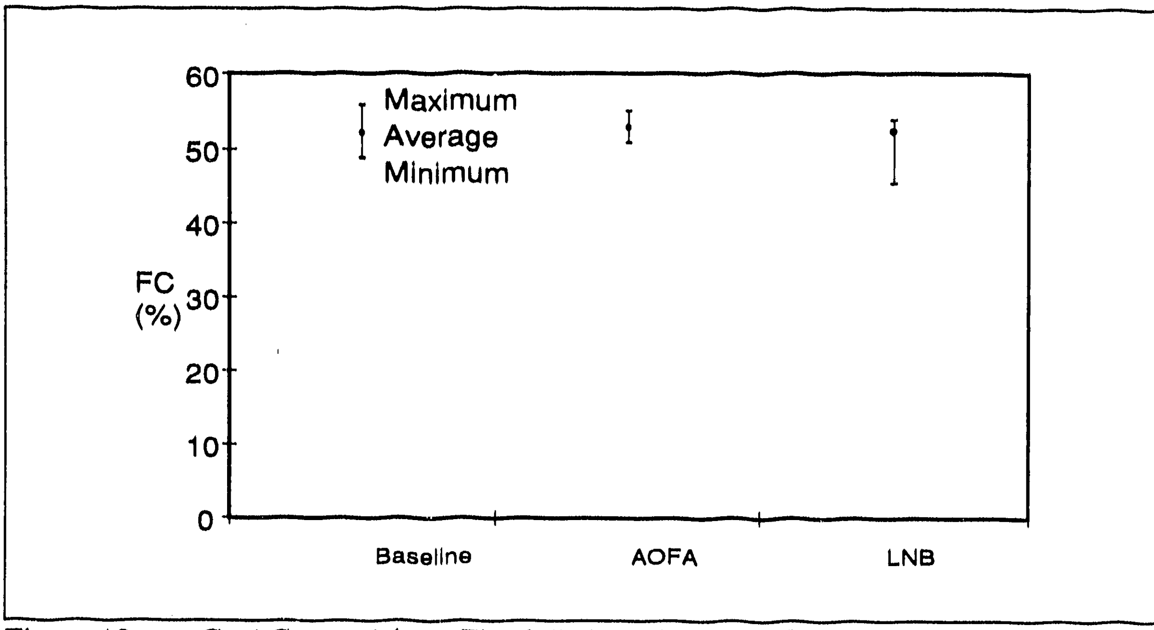

Figure 10: Coal Comparision - Fixed Carbon Content (FC)

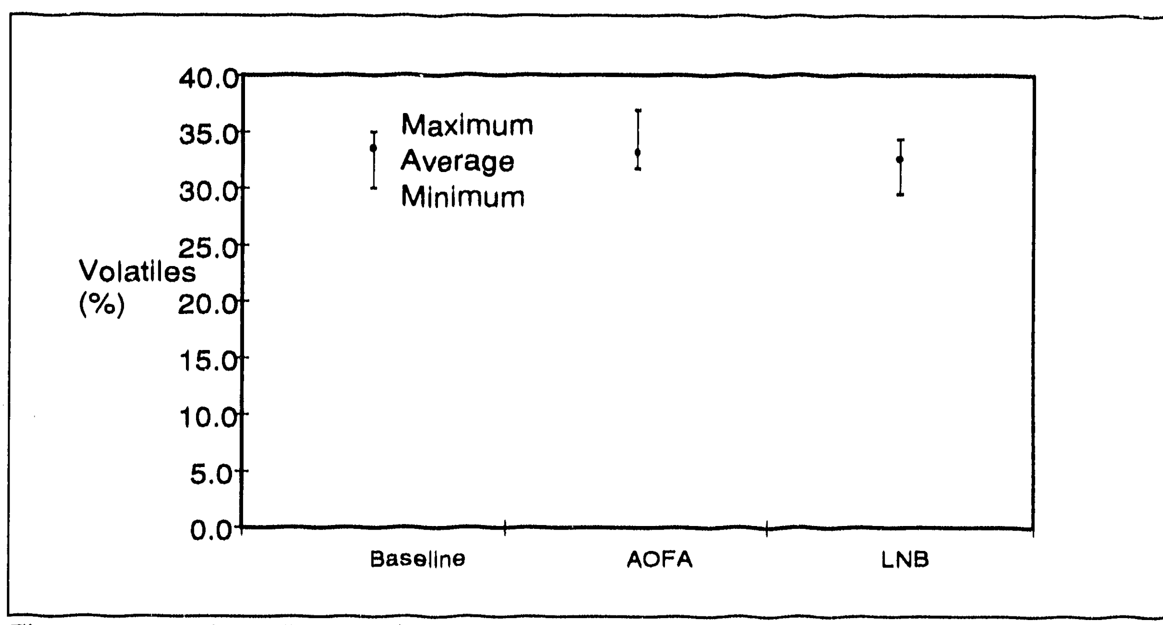

Figure 11: Coal Comparision - Volatiles

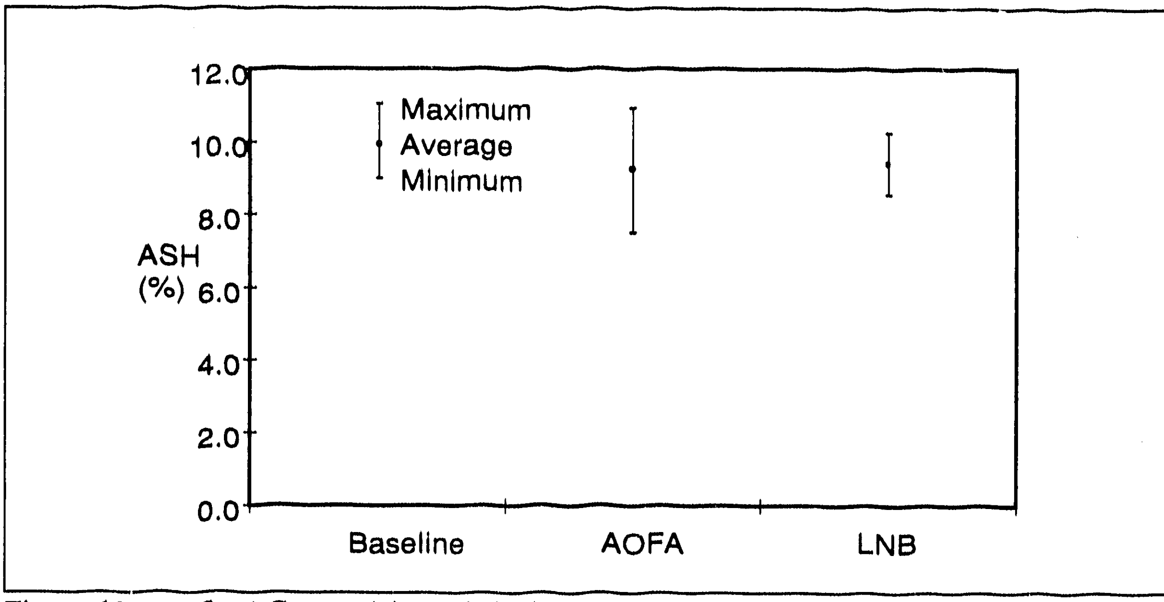

Figure 12: Coal Comparision - Ash Content

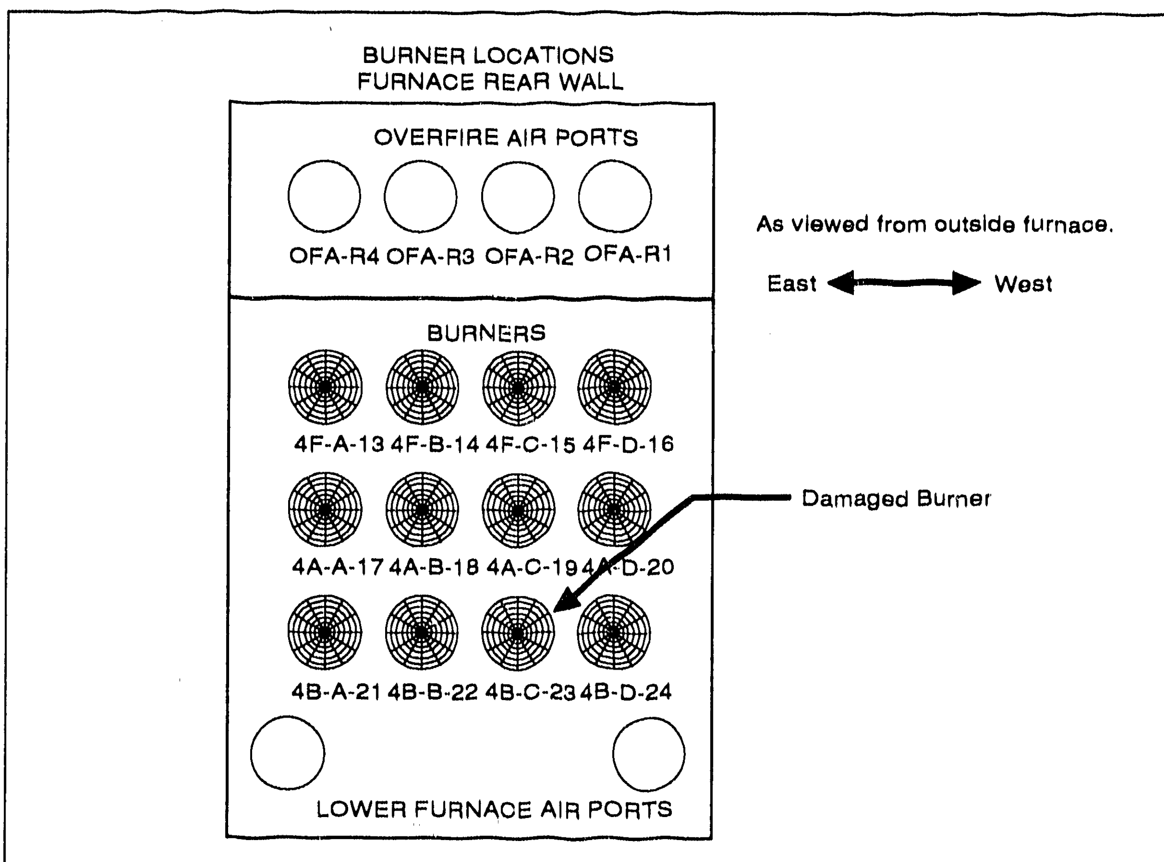

Figure 13: Damaged Burner Location

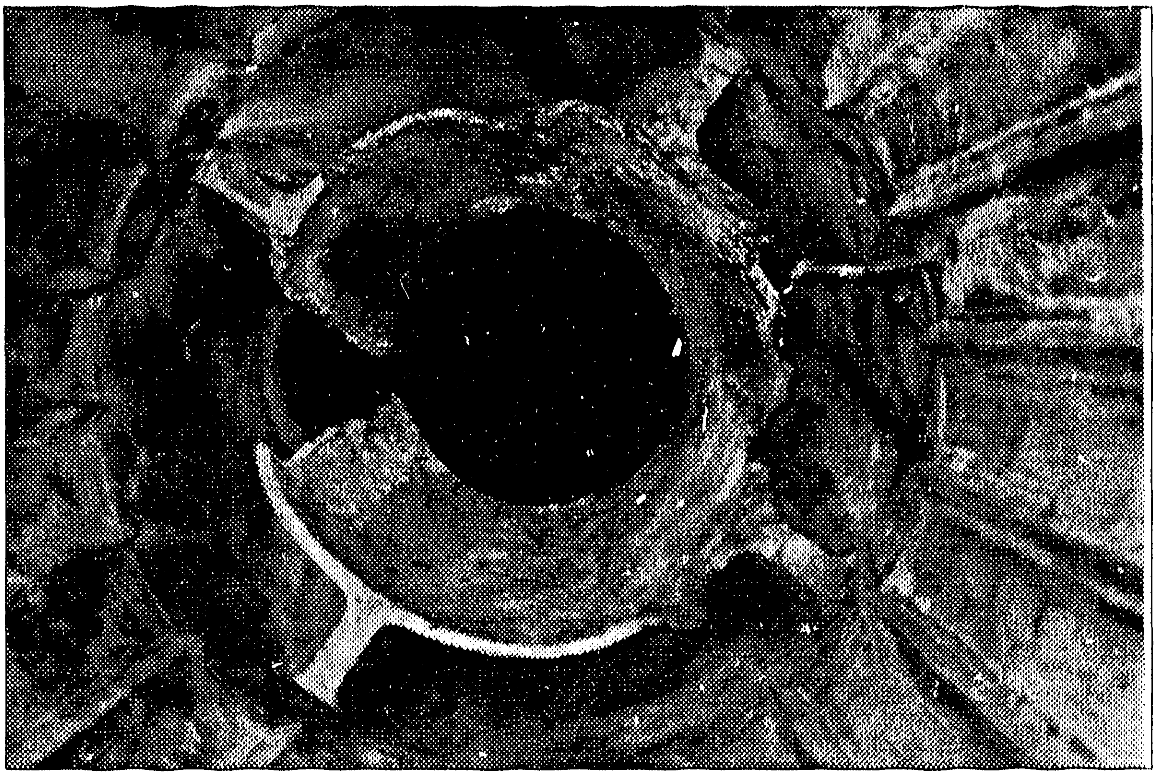

Figure 14: Damaged Burner Viewed From Inside Burner Barrel

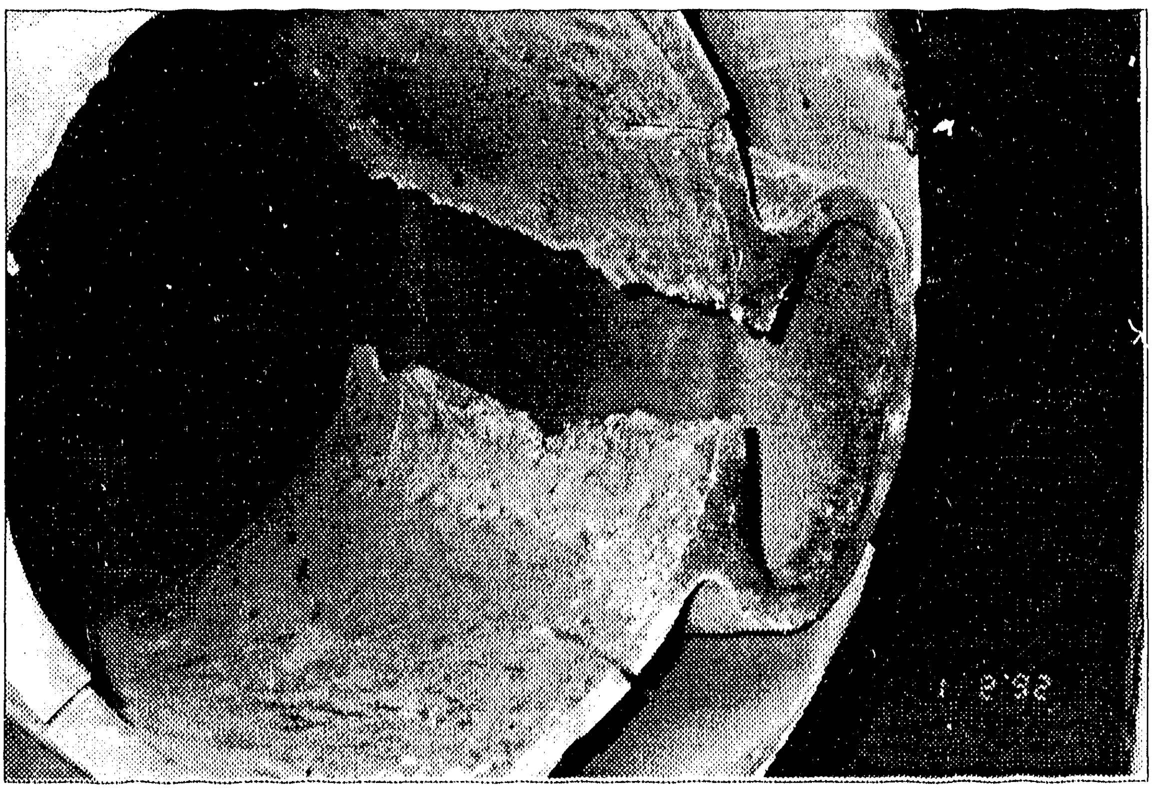

Figure 15: Damaged Burner Viewed From Burner Tip End

4. FUTURE PLANS

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

Future Plans	
Quarter	Activity
First Quarter 1992	• Diagnostic Tests of the LNB's+AOFA • Begin Long-Term LNB+AOFA Tests • Performance Tests of the LNB's+AOFA • Complete Long-Term LNB+AOFA Tests • Verification Tests of the LNB's+AOFA • Begin Final Reporting
Second Quarter 1992	• Complete Final Reporting • Disposition • Project Completion

5. ACKNOWLEDGEMENTS

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.

APPENDIX A
Phase 3 Long-Term NO_X Emissions and Generation

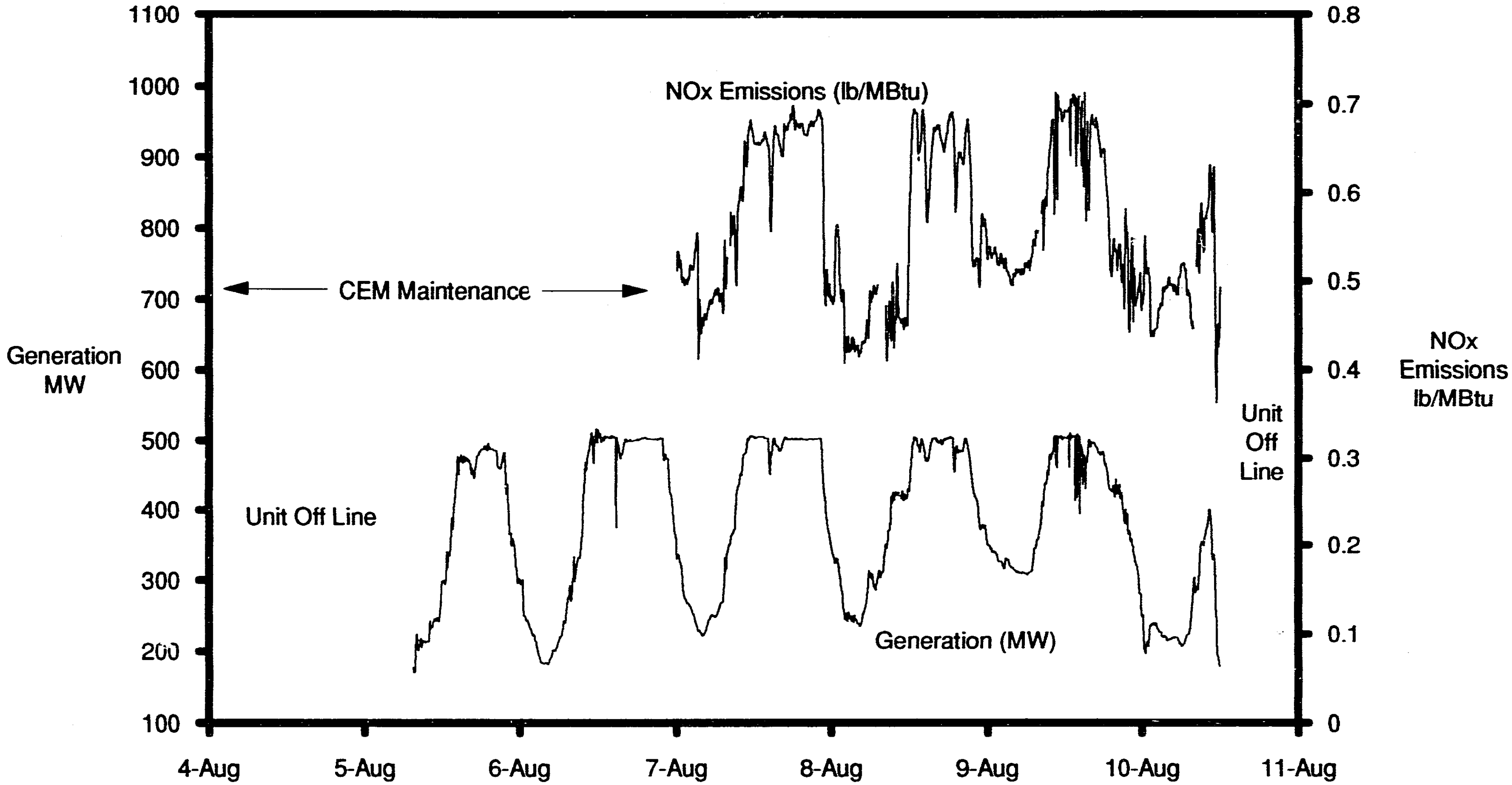

Figure A-1: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of August 4, 1991

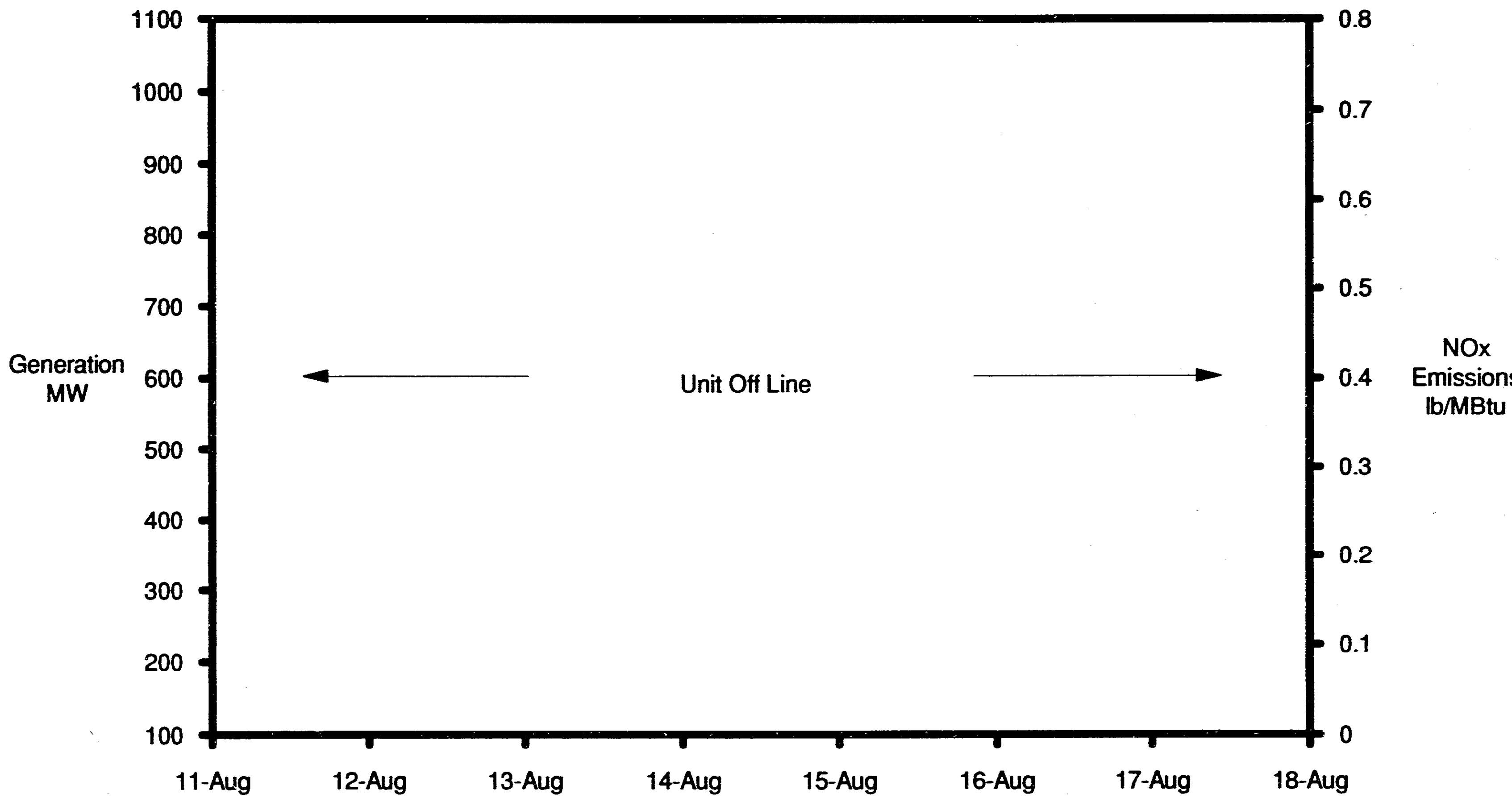

Figure A-2: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of August 11, 1991

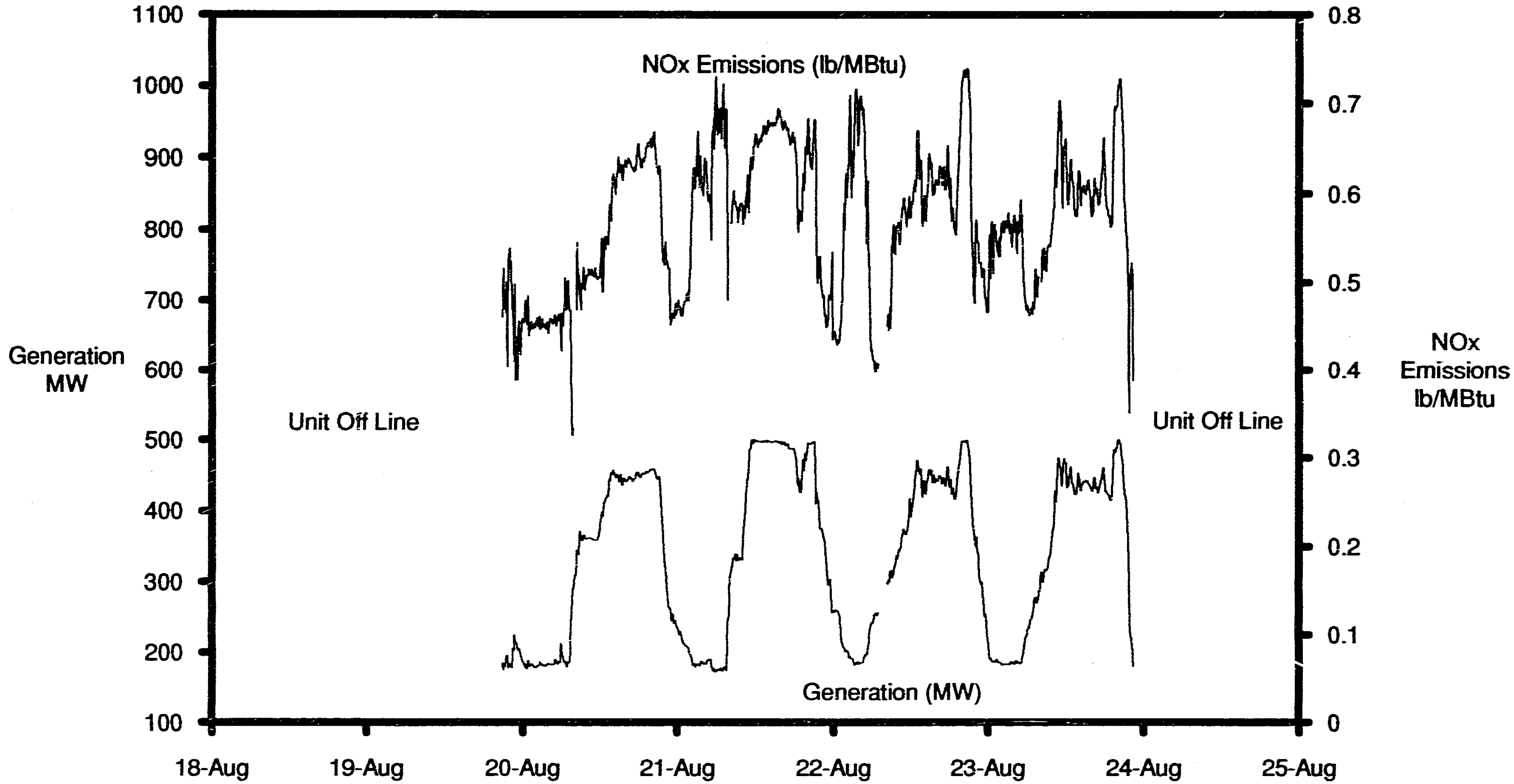

Figure A-3: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of August 18, 1991

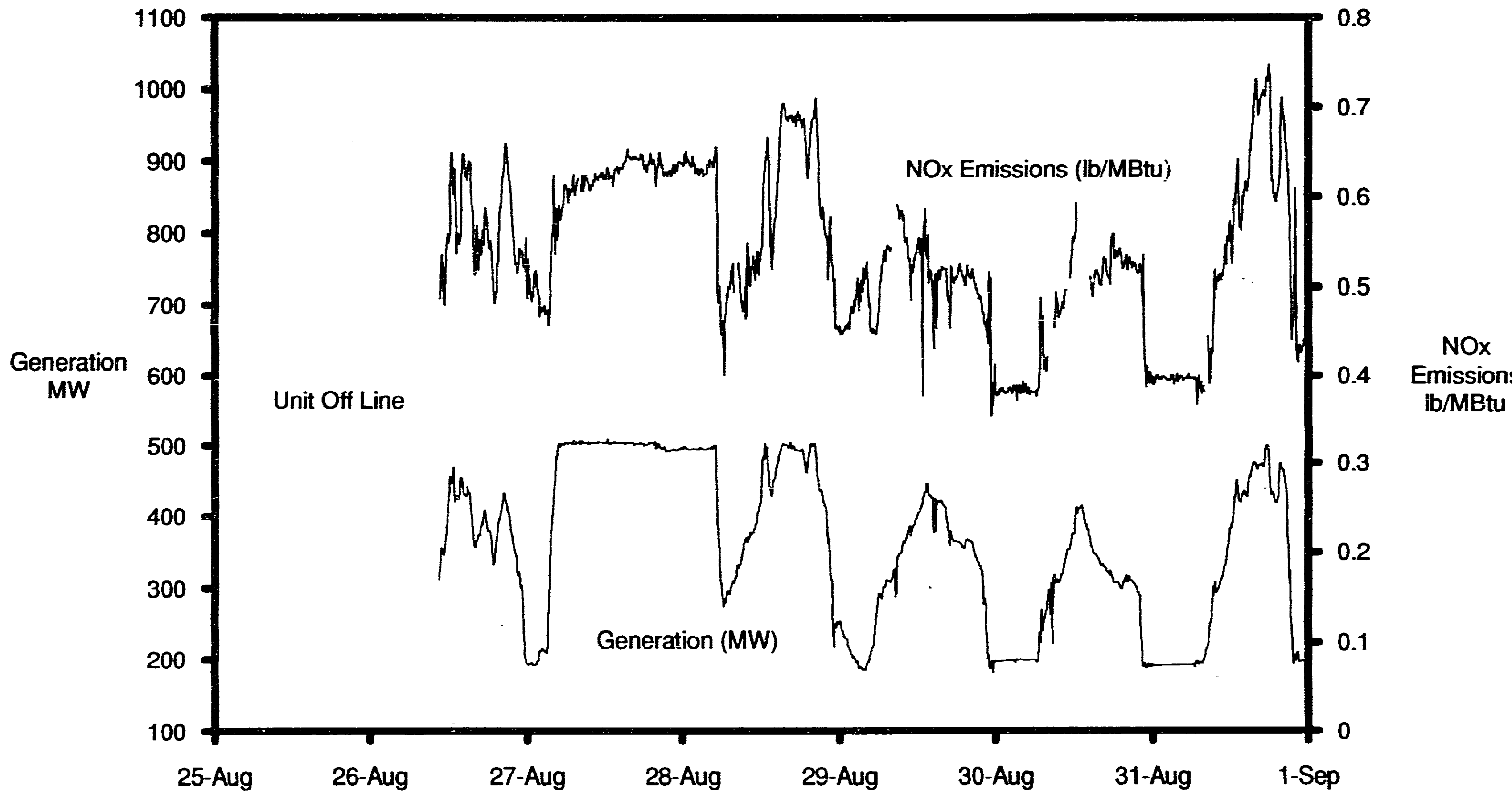

Figure A-4: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of August 25, 1991

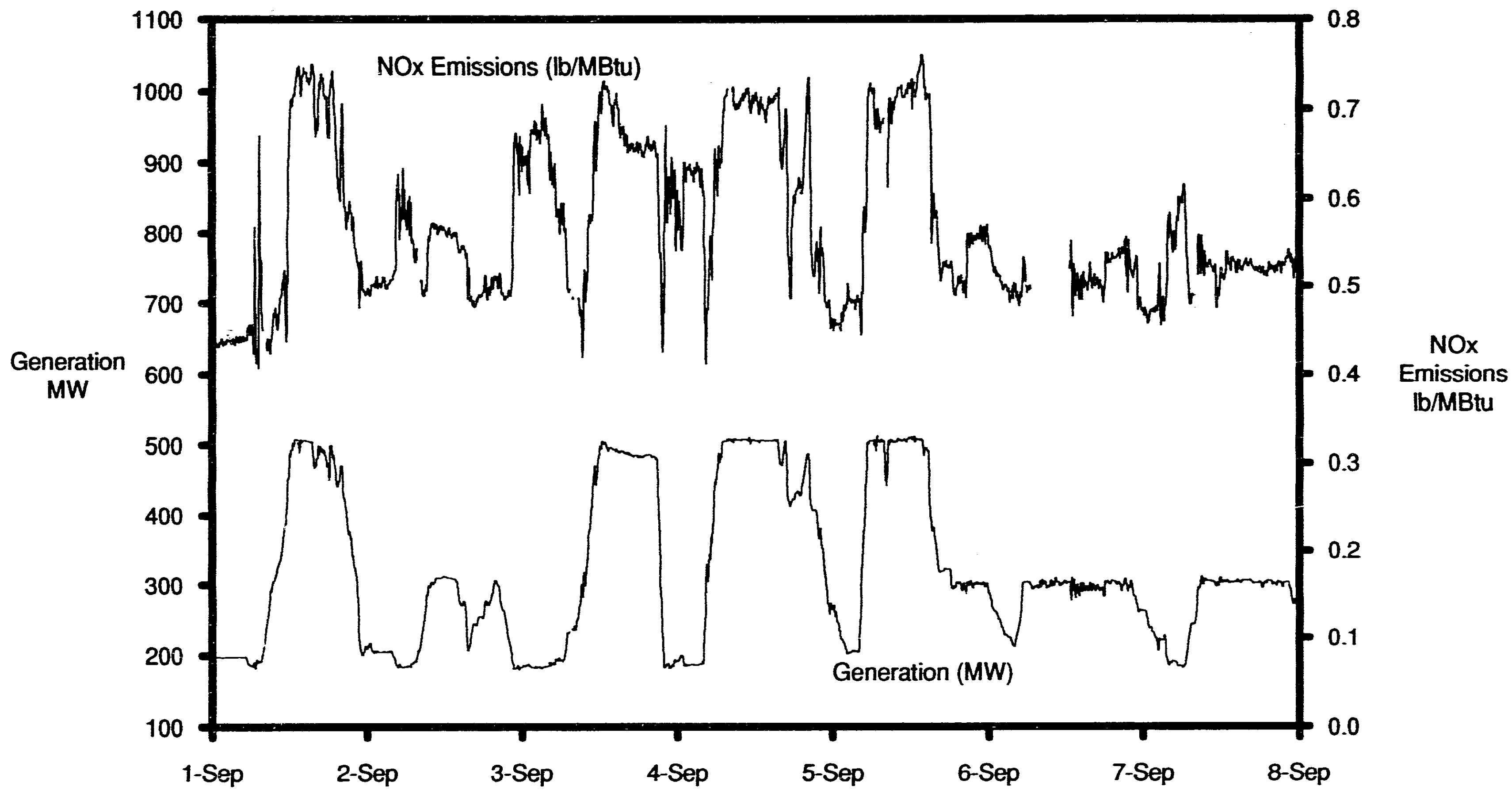

Figure A-5: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of September 1, 1991

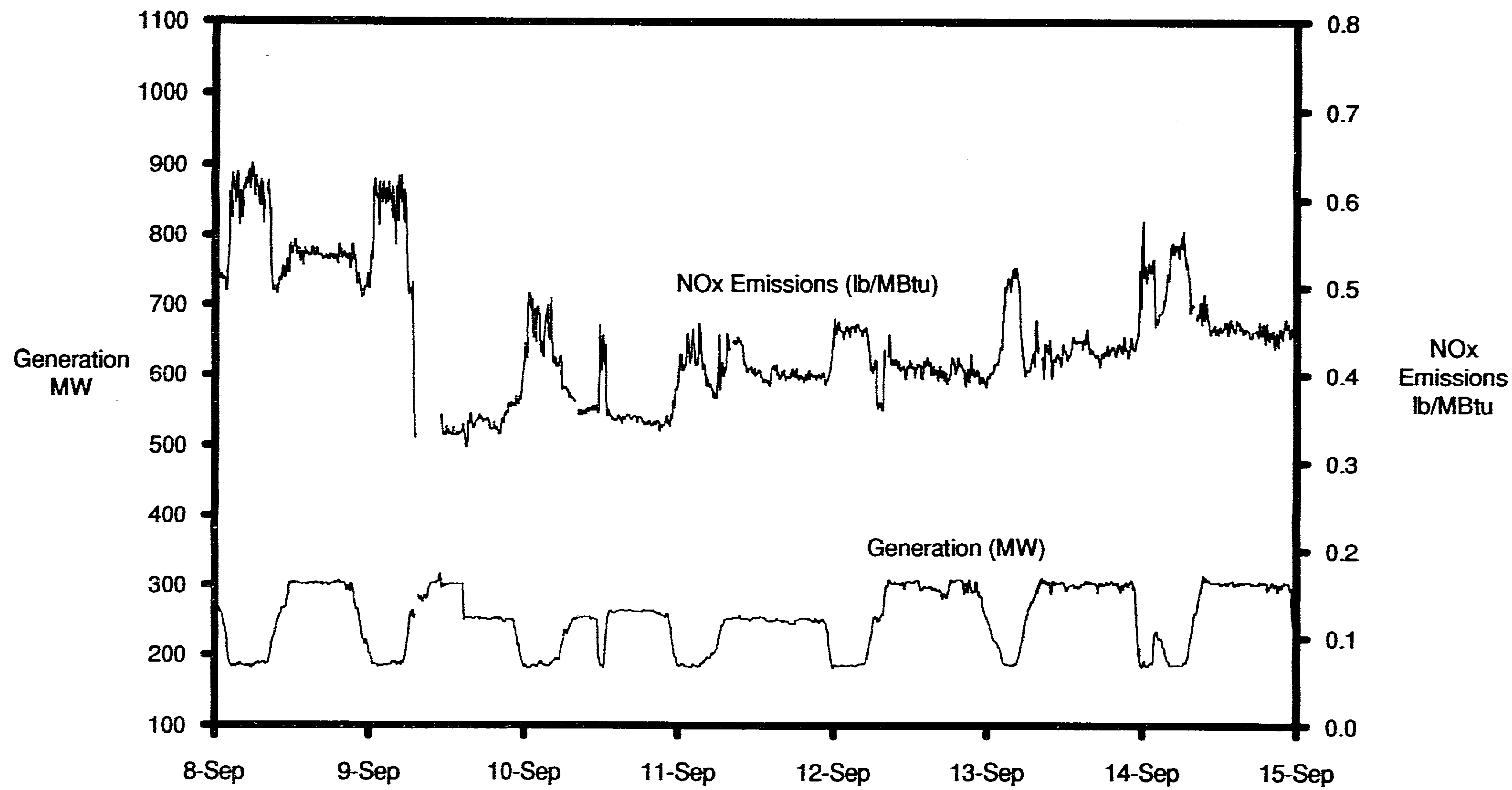

Figure A-6: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of September 8, 1991

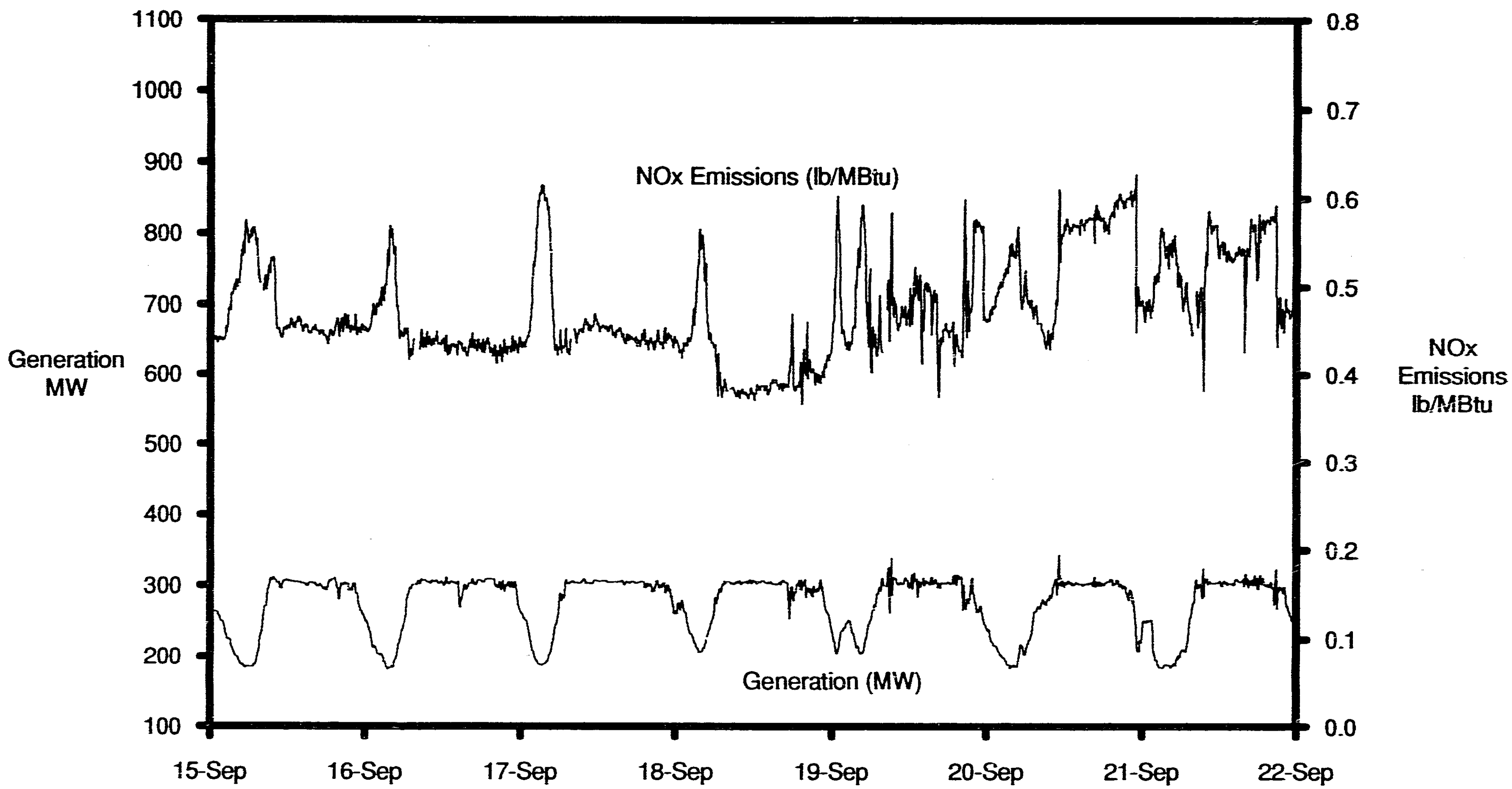

Figure A-7: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of September 15, 1991

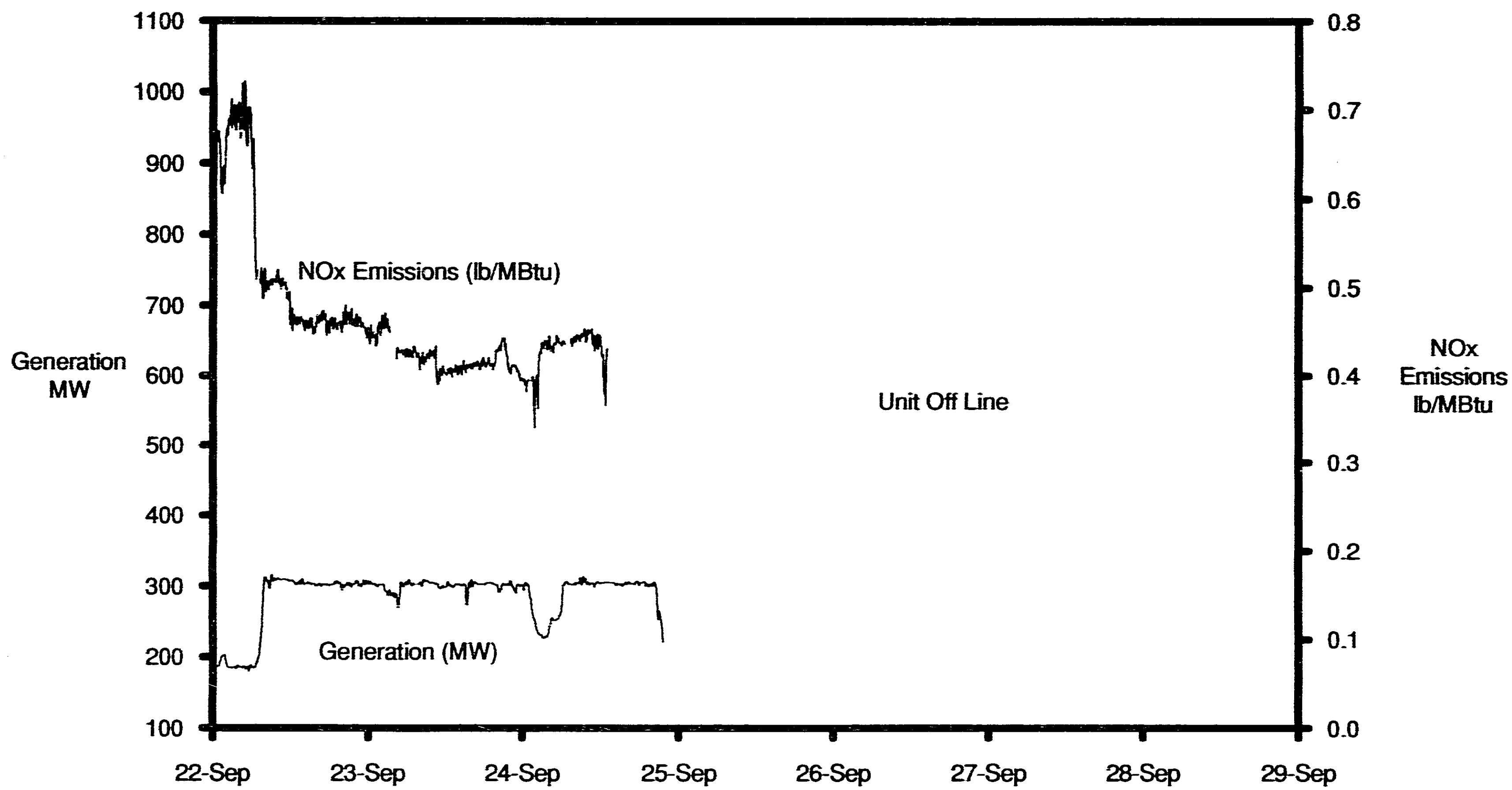

Figure A-8: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of September 22, 1991

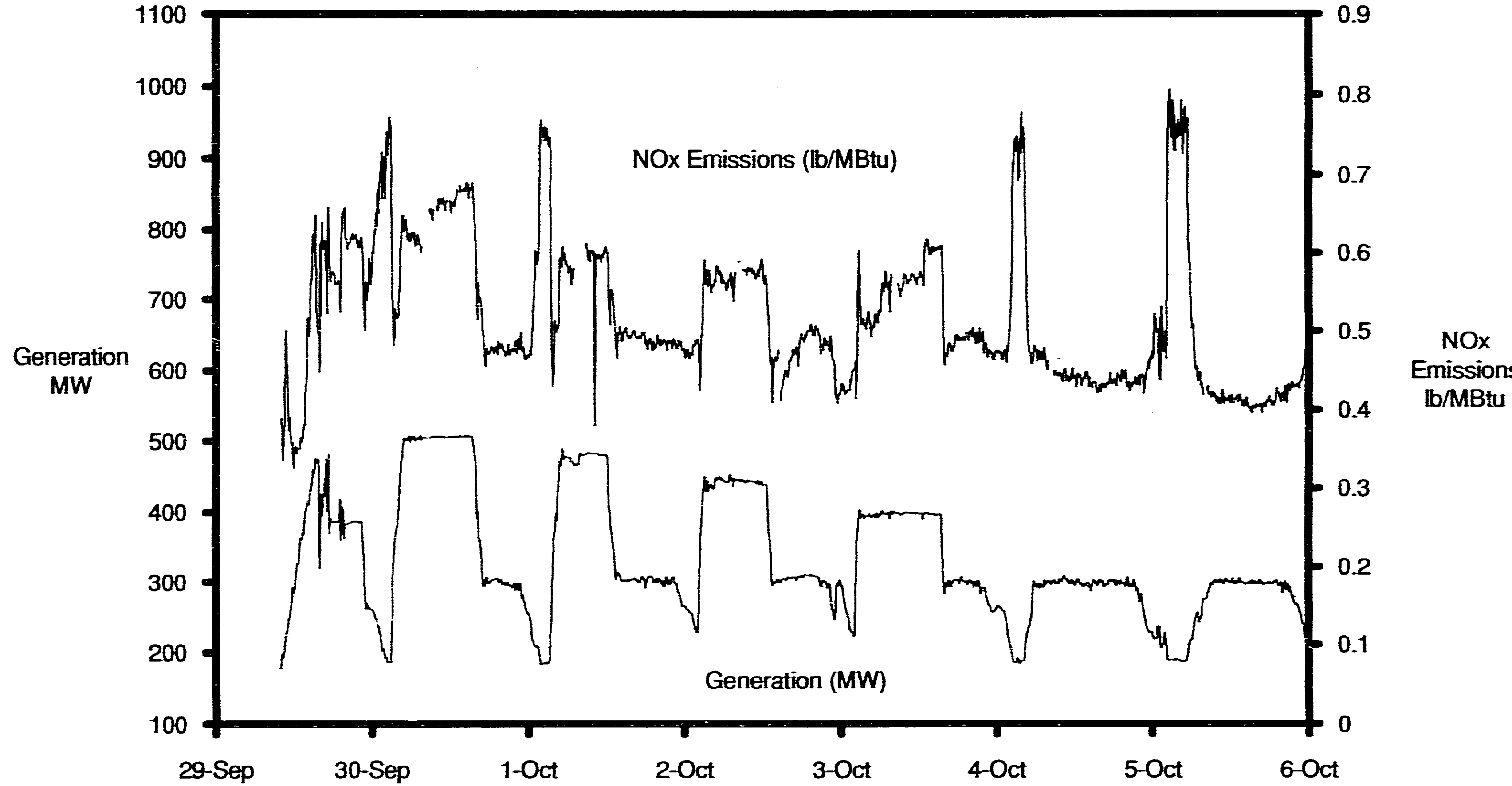

Figure A-9: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of September 29, 1991

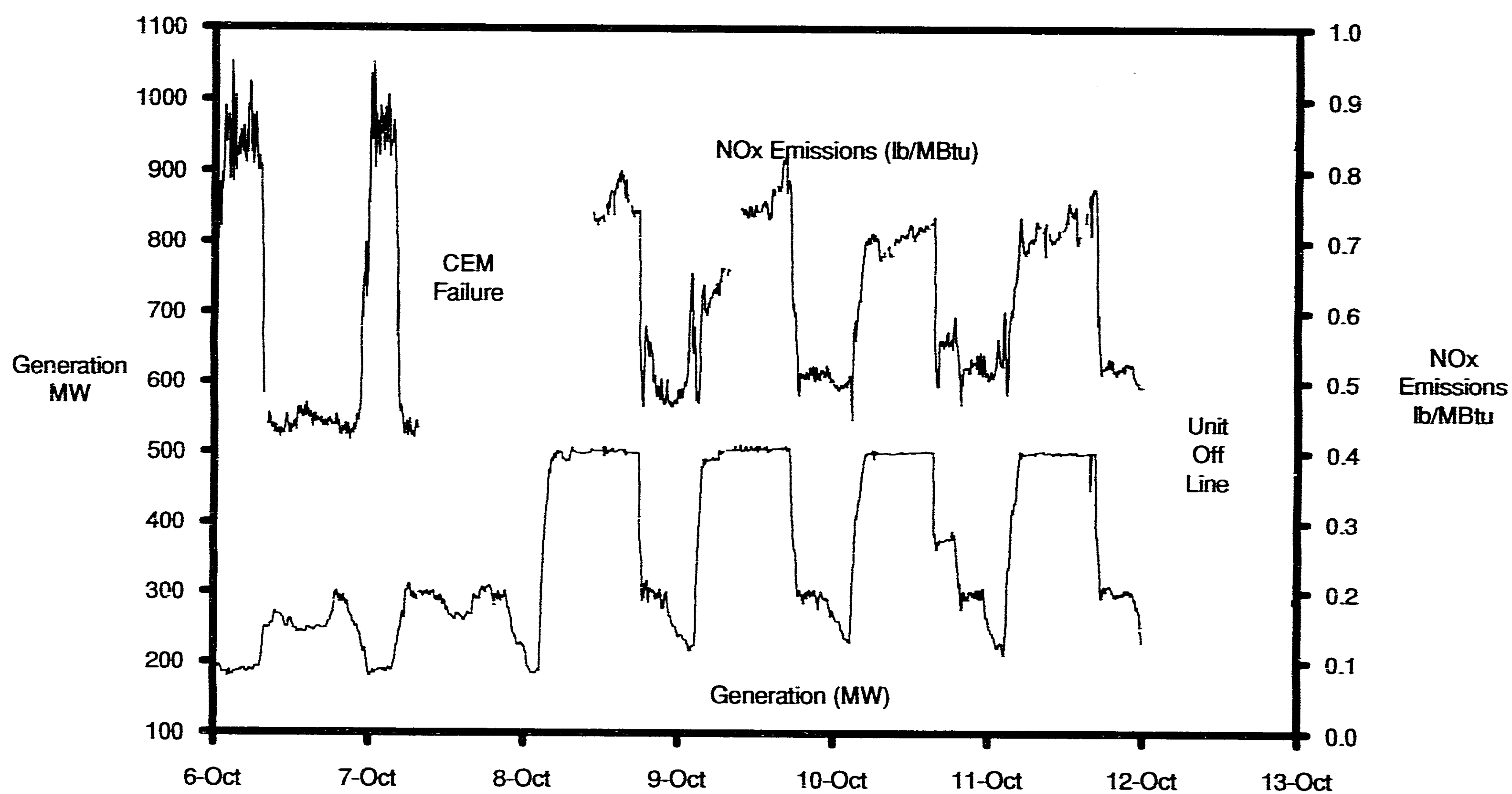

Figure A-10: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of October 6, 1991

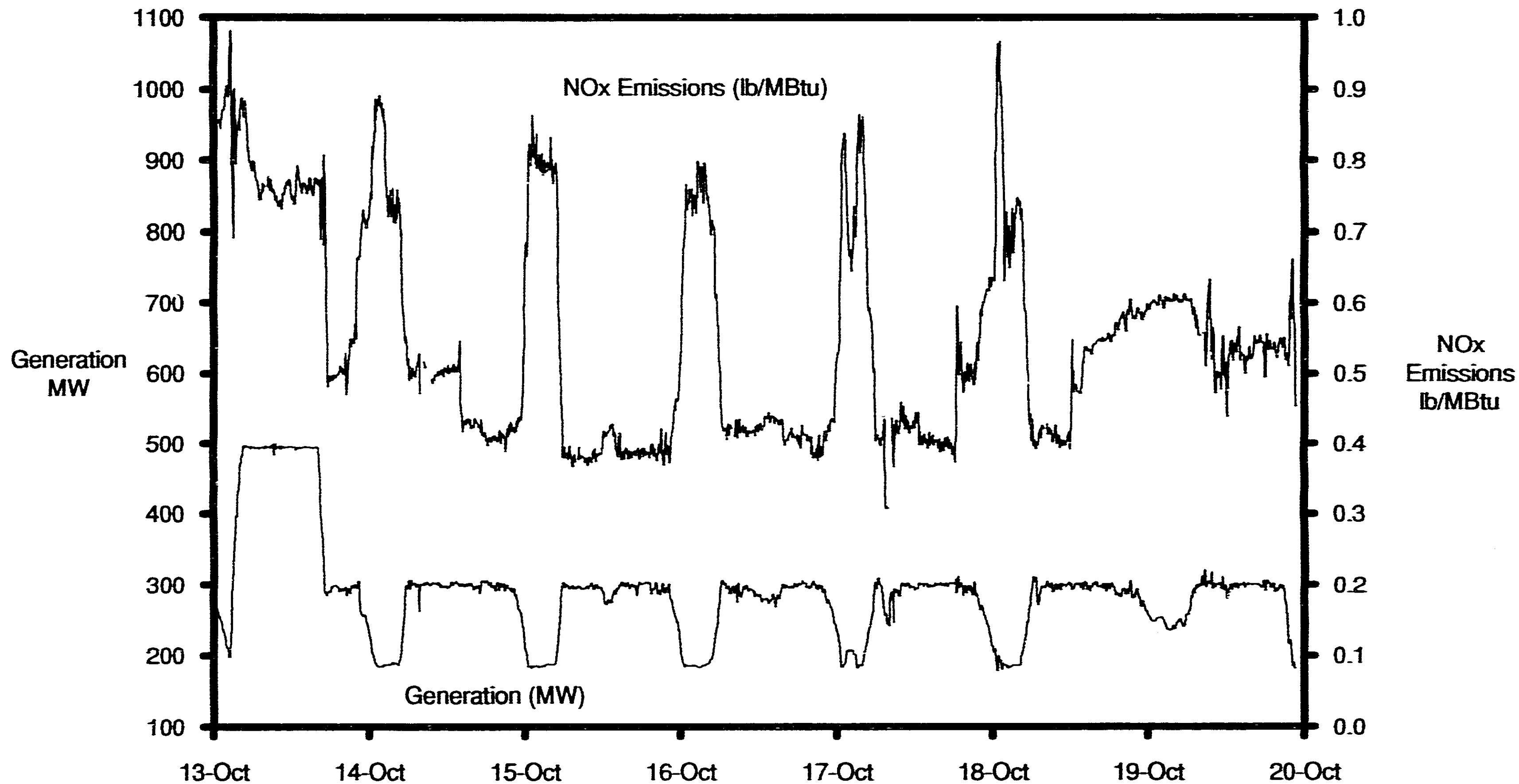

Figure A-11: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of October 13, 1991

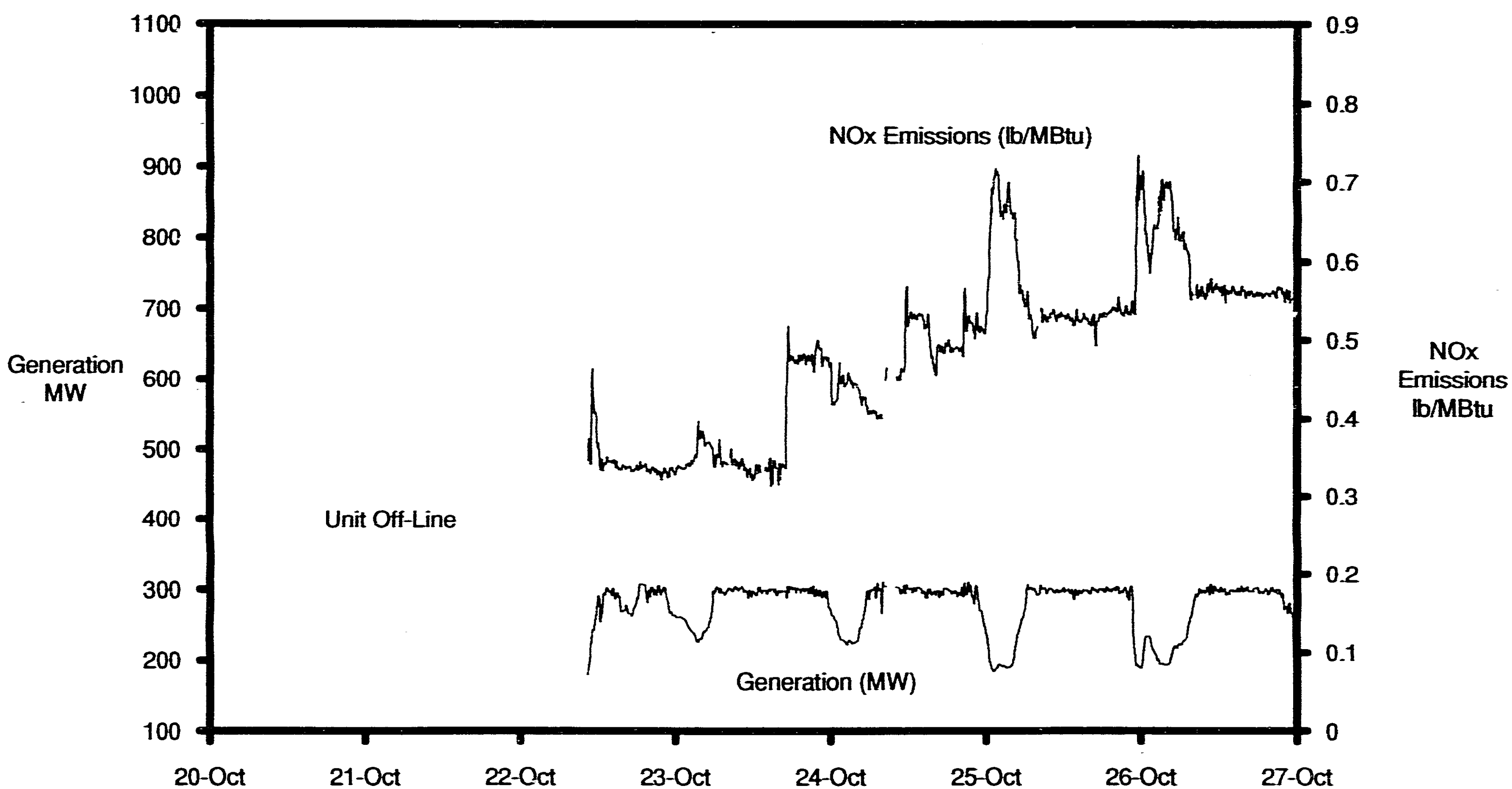

Figure A-12: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of October 20, 1991

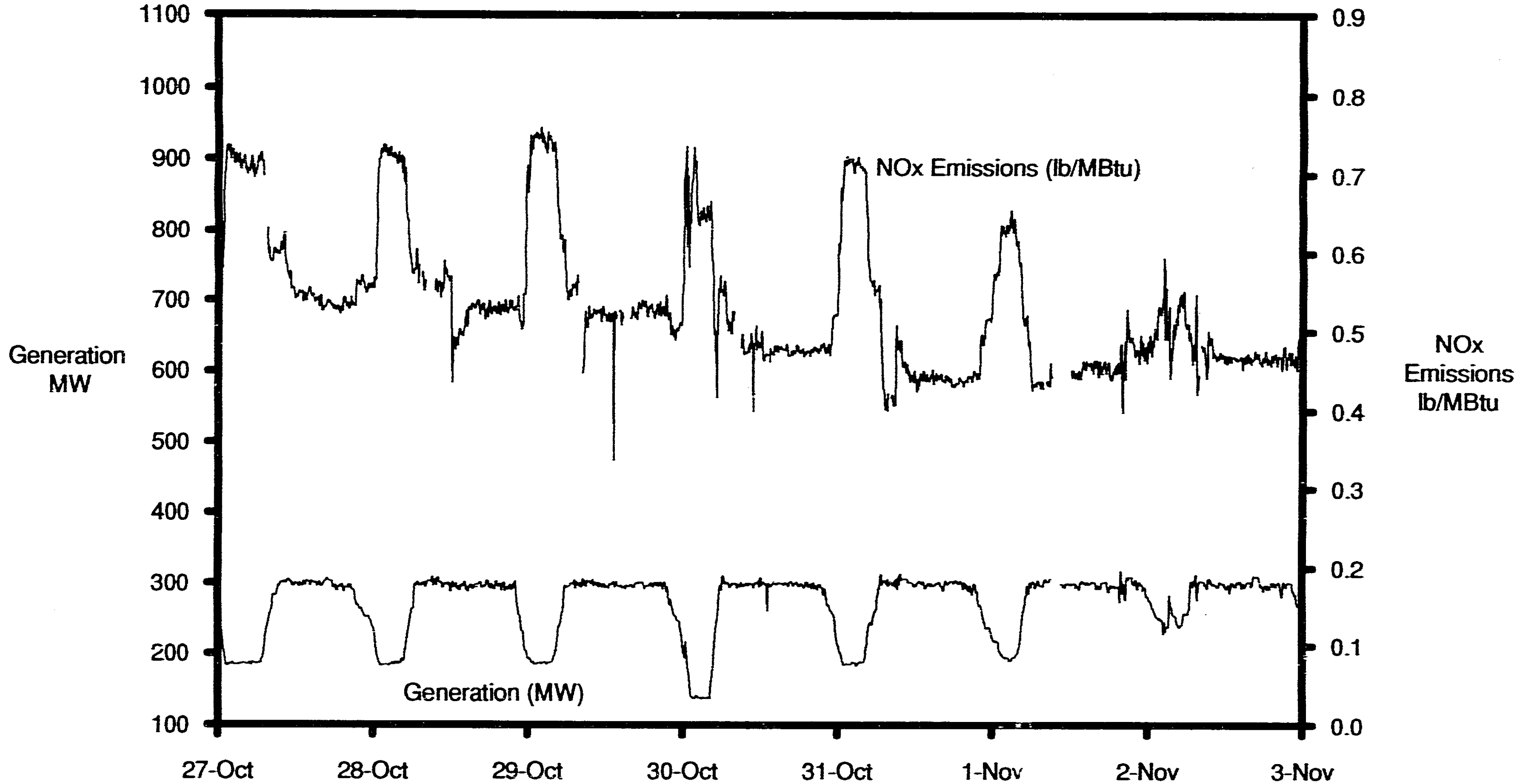

Figure A-13: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of October 27, 1991

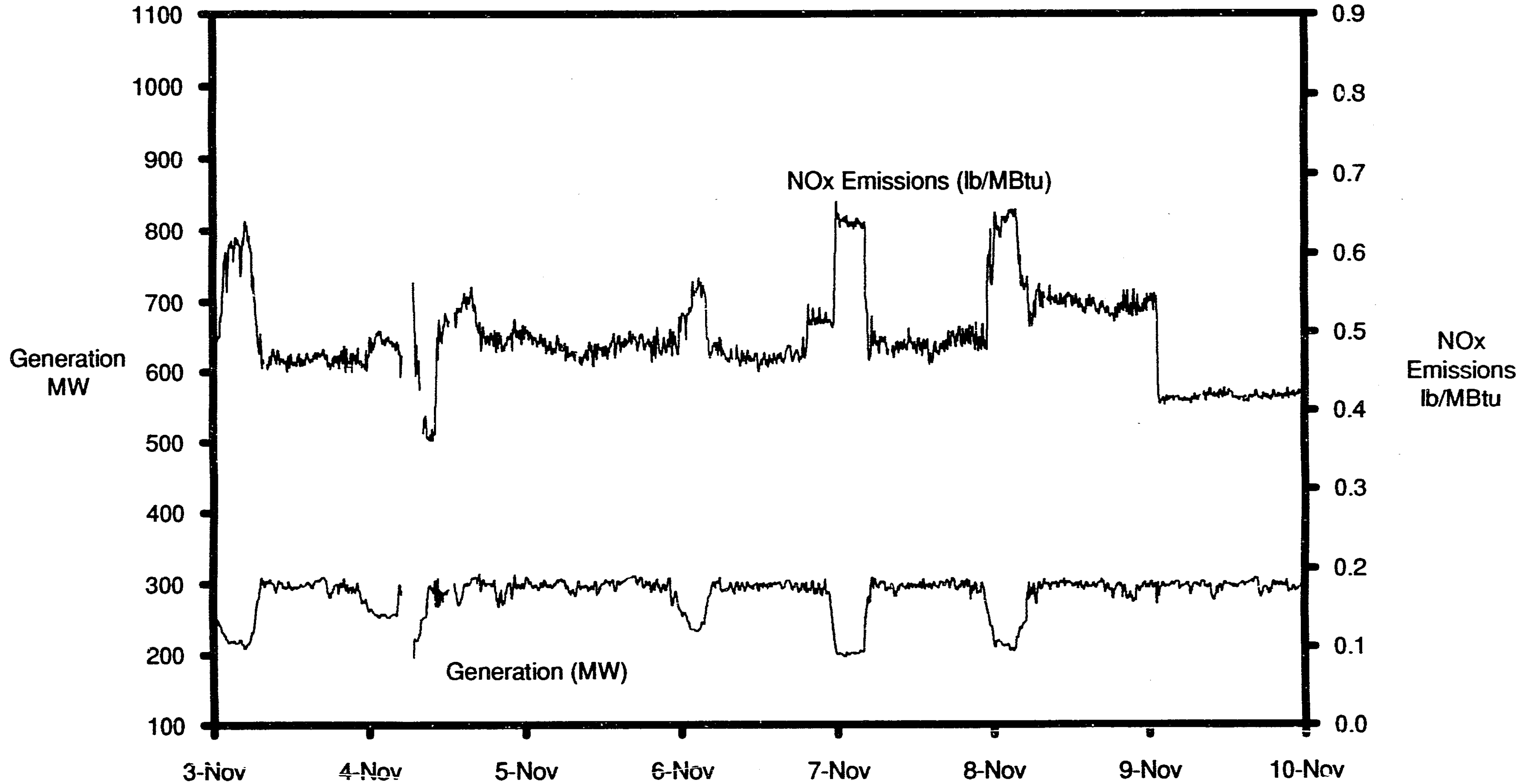

Figure A-14: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of November 3, 1991

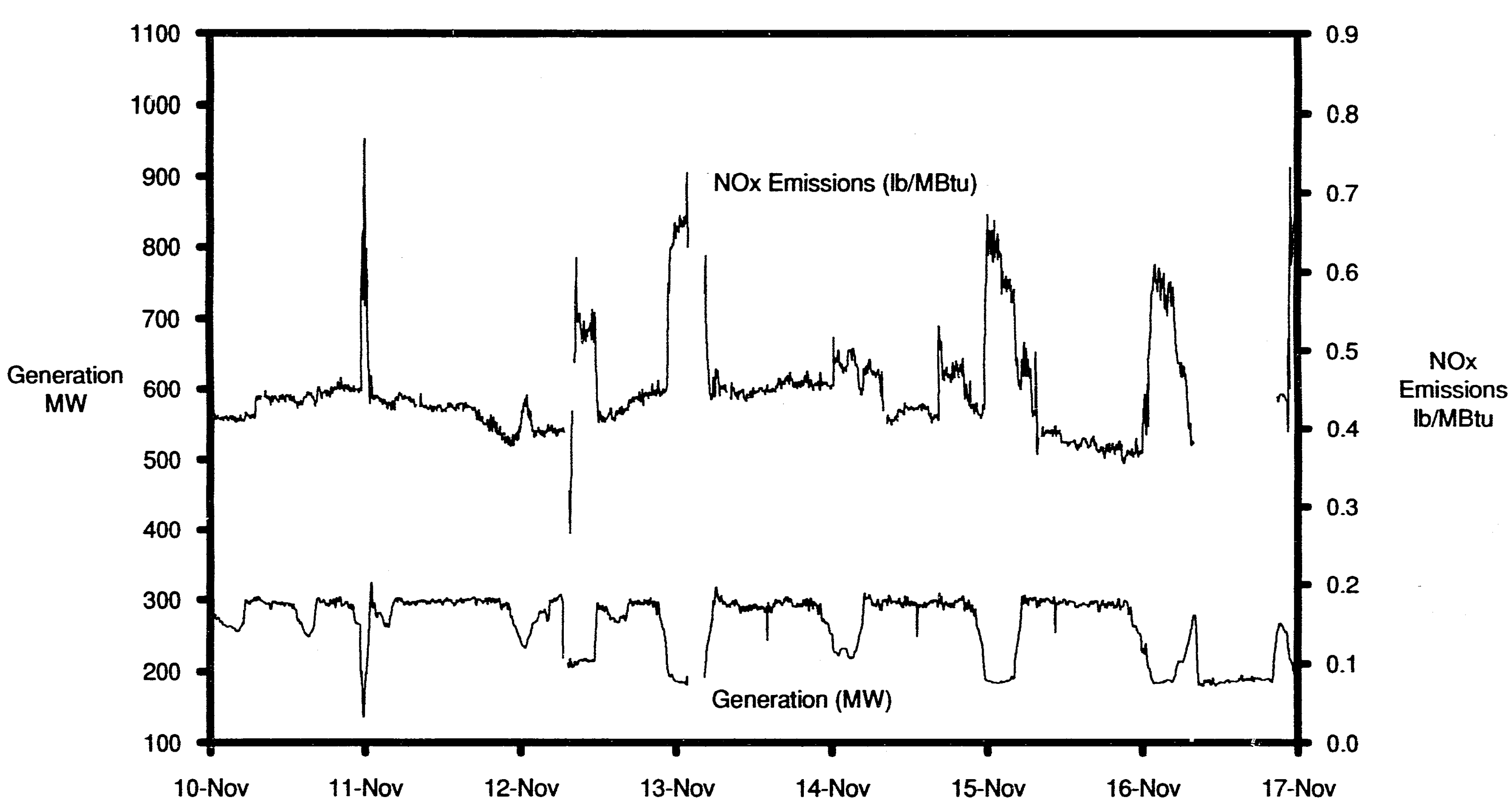

Figure A-15: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of November 10, 1991

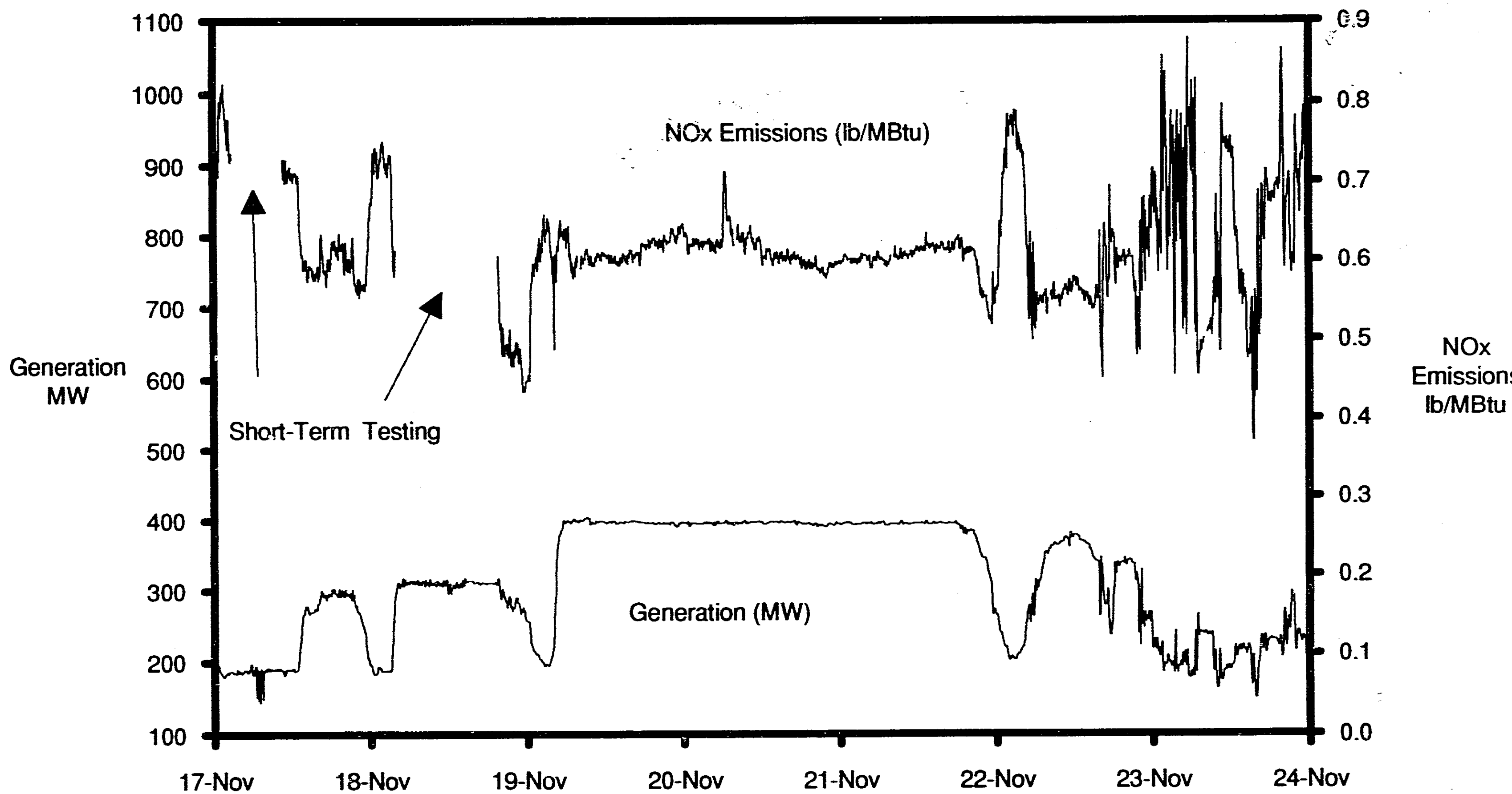

Figure A-16: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of November 17, 1991

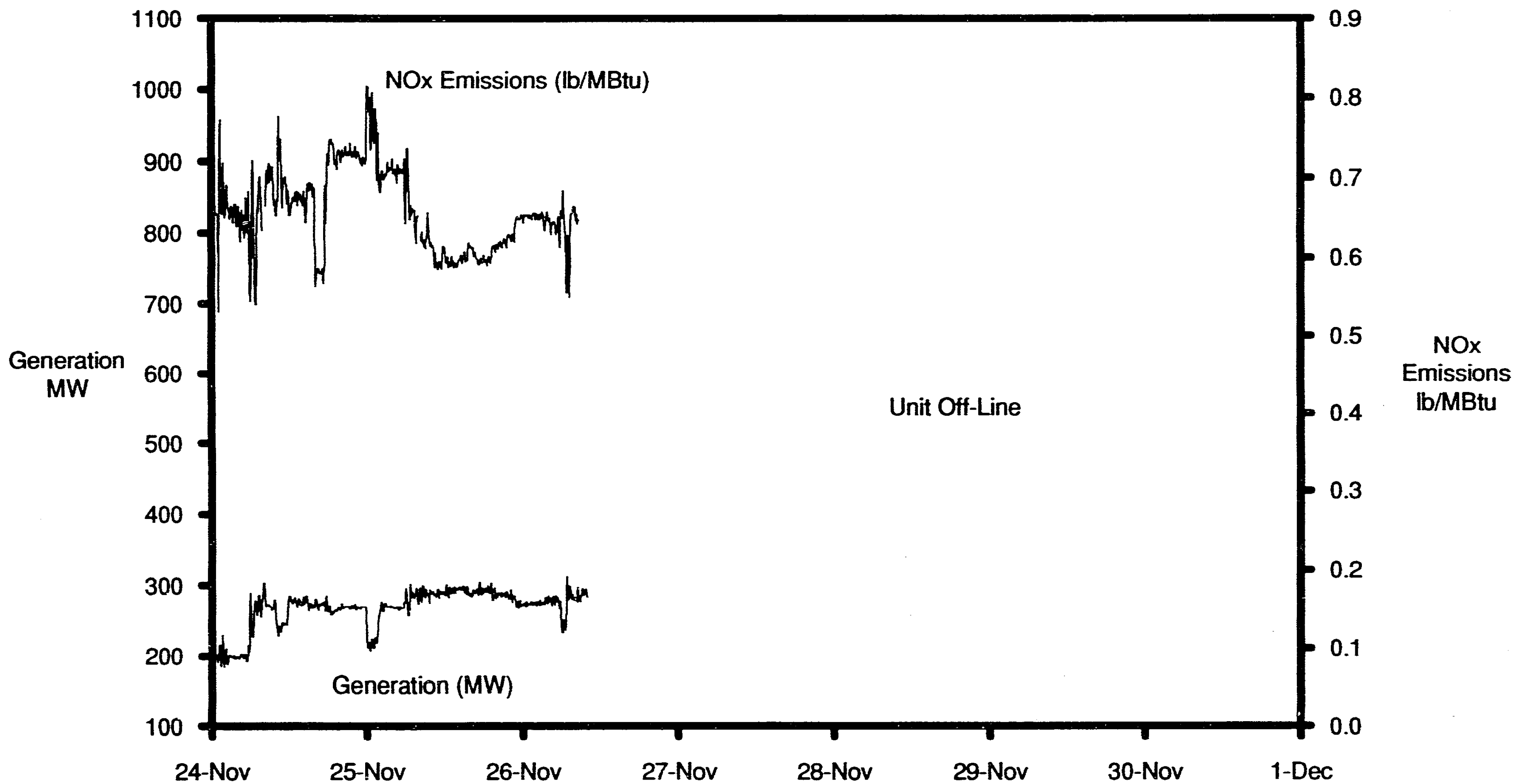

Figure A-17: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of November 24, 1991

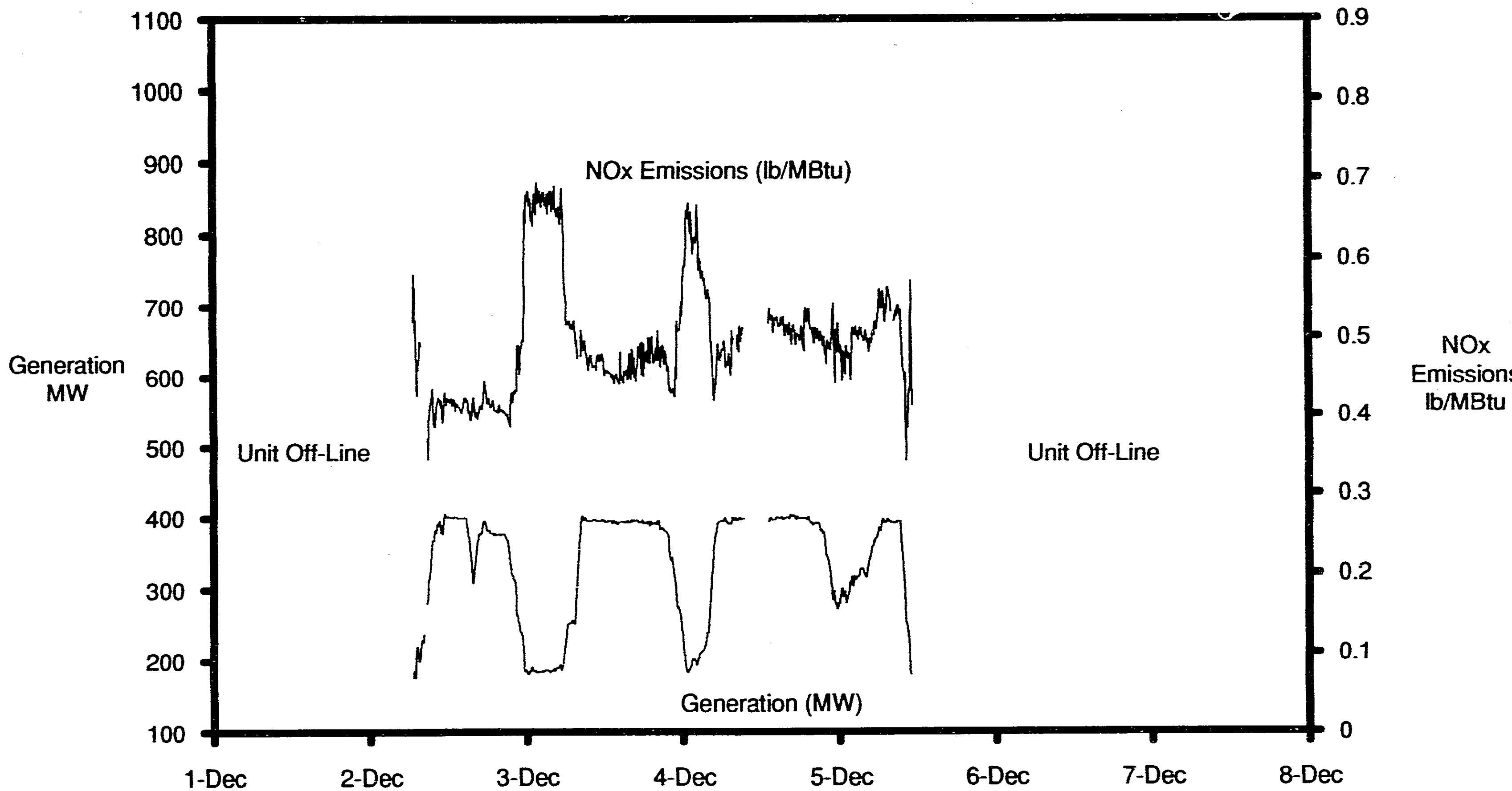

Figure A-18: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of December 1, 1991

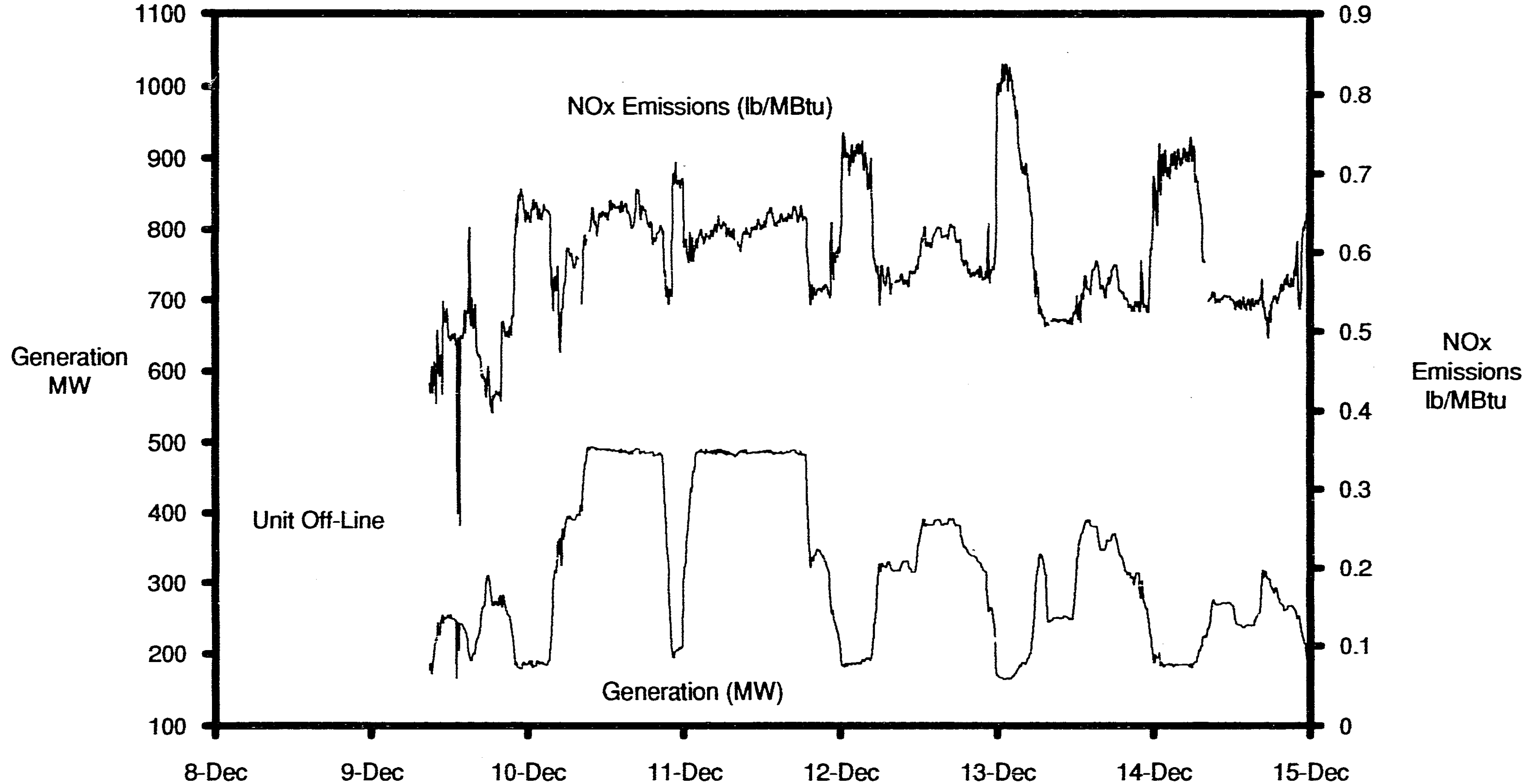

Figure A-19: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of December 8, 1991

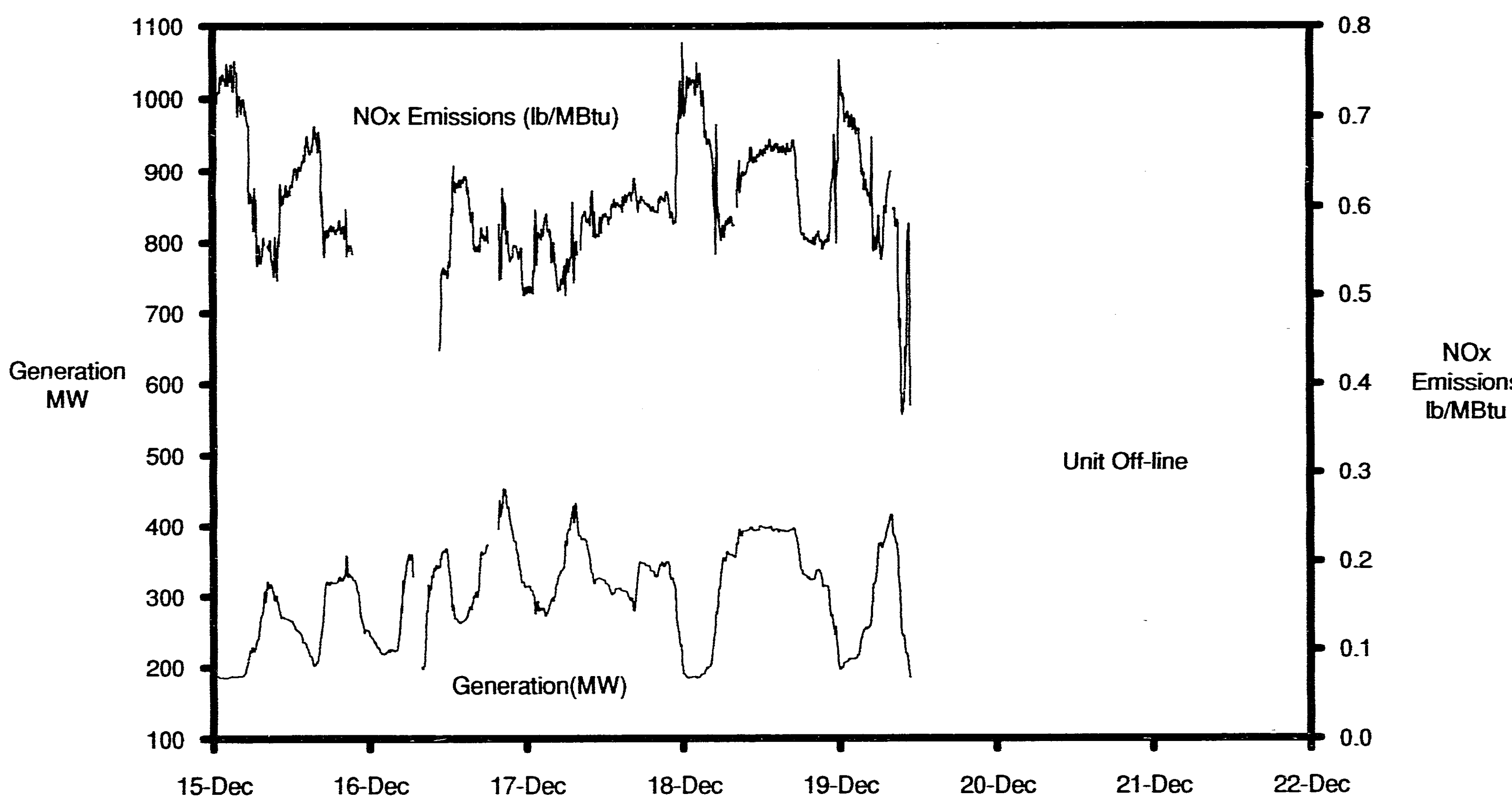

Figure A-20: Post LNB Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of December 15, 1991

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