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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. Flyash LOI values for the LNB configuration are approximately 8 percent at full-load. Corresponding values for the AOFA configuration are 0.94 lb/MBtu and approximately 10 percent. Abbreviated diagnostic tests for the LNB+AOFA configuration indicate that at 500 MWe, NO_X emissions are approximately 0.55 lb/MBtu with corresponding flyash LOI values of approximately 11 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+AOFA configuration will be performed when the stack particulate emissions issue is resolved.

Testing of a process optimization package on Plant Hammond Unit 4 was performed during this quarter. The software was configured to minimize NO_X emissions using total combustion air flow and advanced overfire air distribution as the controlled parameters. Preliminary results from this testing indicate that this package shows promise in reducing NO_X emissions while maintaining or improving other boiler performance parameters.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

TABLE OF ABBREVIATIONS

AOFA	Advanced Overfire Air
ASME	American Society of Mechanical Engineers
C	carbon
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
ICCT	Innovative Clean Coal Technology
lb(s)	pound(s)
LNB	low NOx burner
LOI	loss on ignition
(M)Btu	(million) British thermal unit
MW	megawatt
N	nitrogen
NO_x	nitrogen oxides
O, O_2	oxygen
psig	pounds per square inch gauge
PTC	Performance Test Codes
RSD	relative standard deviation
S	sulfur
SCS	Southern Company Services
SO_2	sulfur dioxide
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 MWe) 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 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 (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.

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]	
	1.4.1	Project Management and Reporting	9/93 - 12/93
	1.4.2	Disposition of Hardware	5/93

[1]Dates of these tasks reflects change from original project schedule.

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.

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.

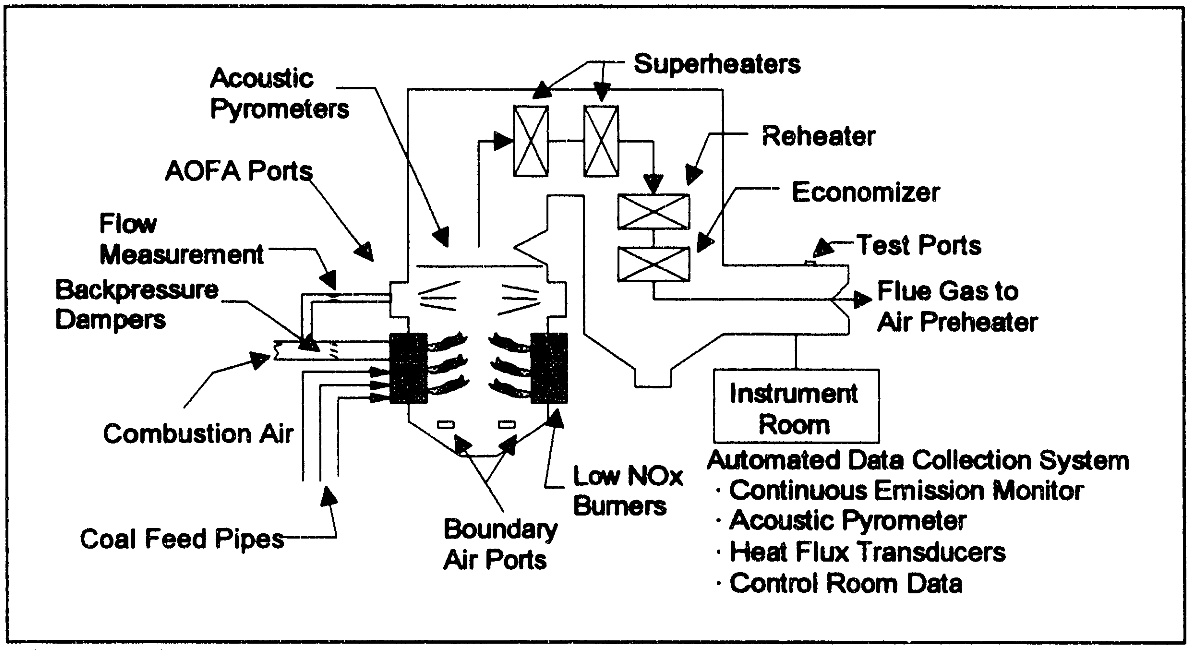


Figure 1. Plant Hammond Unit 4 Boiler

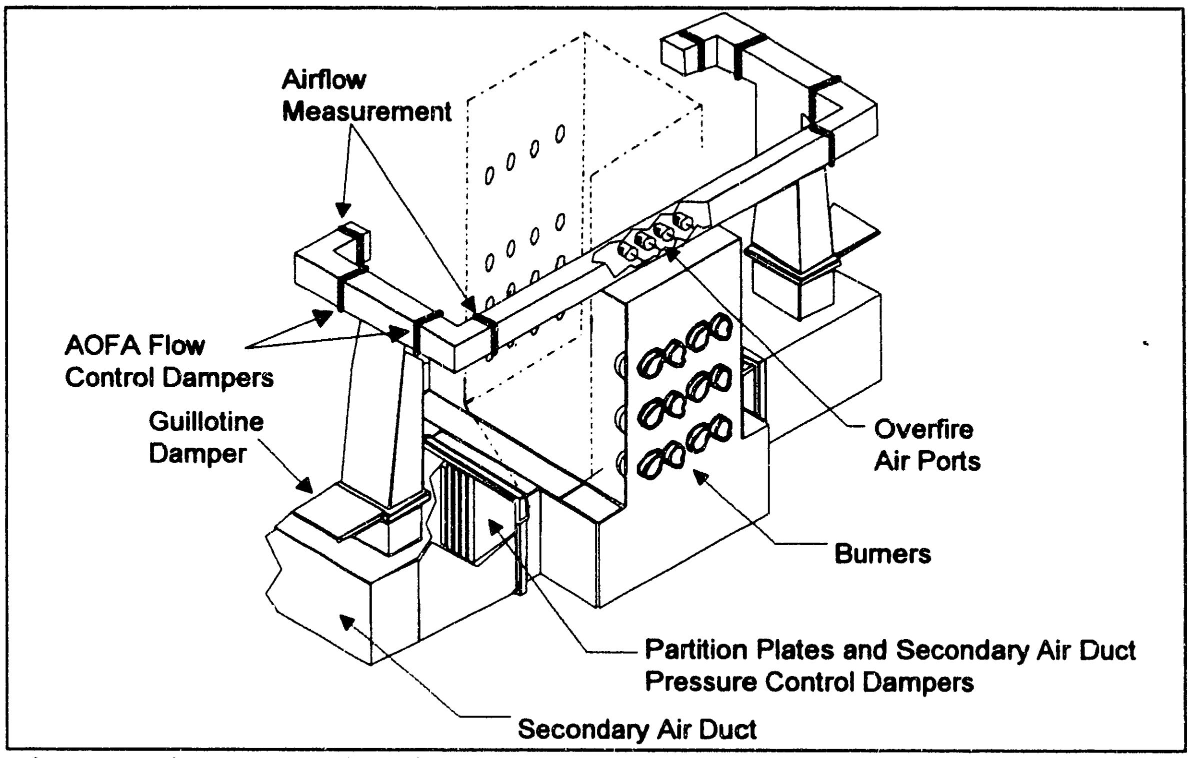


Figure 2. Advanced Overfire Air System

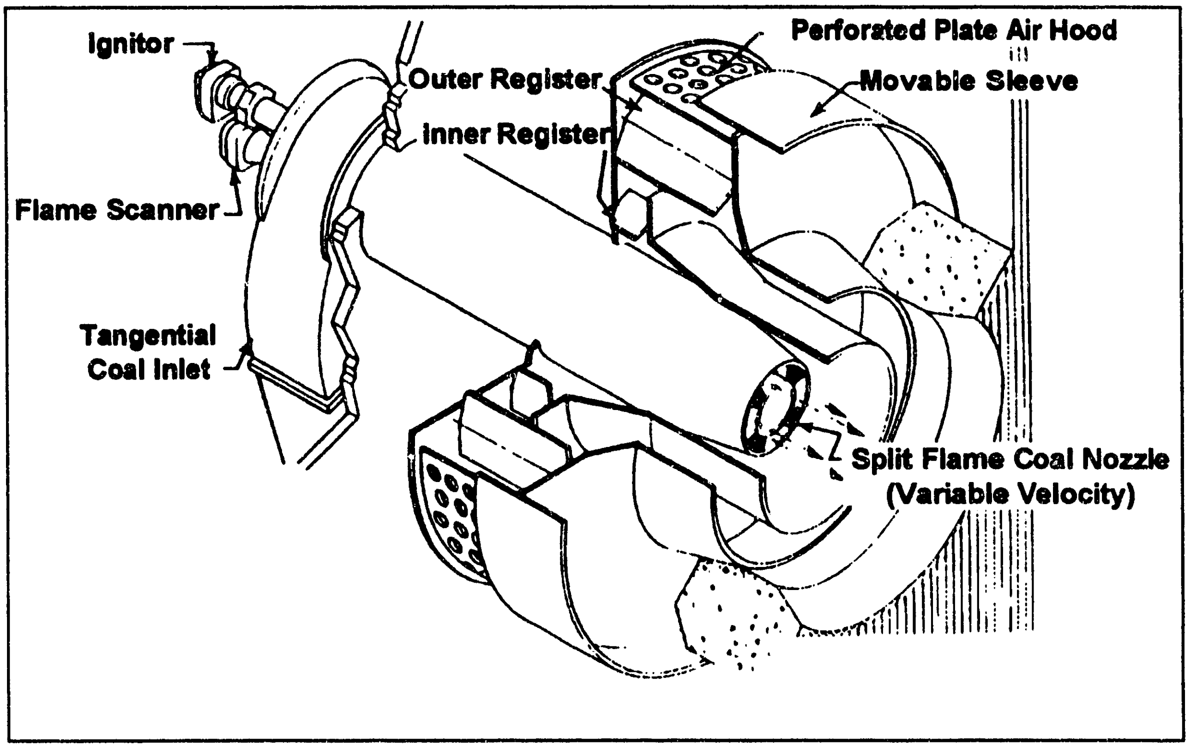


Figure 3. Low NO_X Burner Installed at Plant Hammond

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 NO_x	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 Summary

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 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 (Figure 6). The band about the mean represents the range between the 5th and 95th percentiles of the data set and show the variability of NO_x emissions during long-term operation. 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 (wet measurement, plant O_2 system) 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.

The objective of the short-term testing was to establish the NO_x trends for the major parameters that influence emissions on this unit, i.e., excess air, mill pattern, and load. At the high load condition of 480 MW, characterization of the NO_x emissions over the excess O_2 operating range was complicated by unit design constraints which limited the range to 0.75 percent about the nominal 2.7 percent O_2 operating point. The full load, design O_2 level for this boiler is approximately 3.3 percent at full load. Full load, short-term NO_x emission levels ranged from approximately 1.2 to 1.5 lb/MBtu. At the boiler design O_2 level, NO_x emissions were approximately 1.4 lb/MBtu.

As an indication of mill performance during this phase, approximately 63 percent of the coal passed 200 mesh while 2.8 percent remained in 50 mesh (Table 4). Coal fineness data is collected during the performance tests.

3.2. Phase 2 - Advanced Overfire Air Retrofit and Characterization

3.2.1. Task 2.2 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*.

3.2.2. Task 2.3 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. A summary of the long-term test results is shown, along with the baseline results, in Table 3. During AOFA testing, 86 days of long-term data were collected for which the average NO_x emission level was 0.92 lb/MBtu. As compared to the baseline characteristic, NO_x emissions were not highly dependent on load during the AOFA test phase (Figure 7). Mill performance during this phase was slightly better than during the baseline phase (Table 4).

3.3. Phase 3 - Low NO_x Burner Retrofit and Characterization

3.3.1. Task 3.2 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*.

3.3.2. Task 3.3 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 (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 8, 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.

3.3.3. Task 3.3 LNB with AOFA Test Summary

Comprehensive testing of the LNBs in conjunction with AOFA is scheduled to start the second quarter of 1993. However, to provide preliminary data, abbreviated testing (short- and long-term) of the LNB+AOFA configuration was performed at Plant Hammond from February to March 1992, during which approximately one week of long-term data was collected. The combined system was optimized by FWEC and operated per their instructions. As shown in Figure 9, long-term NO_X emissions were somewhat independent of load above 275 MW. However, below this load, NO_X emissions increased rapidly. The decrease in effectiveness of this configuration at low loads is the result of the operating procedures calling for the closure of AOFA dampers below 300 MW.

Appendix A contains a summary of the NO_X emissions and load during August and September 1992. The following observations can be made from the graphs contained in this appendix:

- In order to remain within stack particulate compliance limits, the unit ran at loads below 450 MW during this period,

- The NO_X emissions versus load characteristic was concave-upward with NO_X emissions a minimum at approximately 225 MW,

- NO_X emissions showed a much greater sensitivity to load at loads below 225 MW than above this load point.

As stated previously, comprehensive testing of the LNB+AOFA configuration is scheduled for 1993. This test schedule is dependent on the unit being able to achieve full load while remaining within stack particulate compliance limits. Until full load can be achieved, long-term data will be collected.

3.4. Data Comparison

Figure 4 compares the baseline, AOFA, LNB, and LNB+AOFA short- and long-term NO_X emissions data. The AOFA and LNBs provide a long-term, **full load**, NO_X reduction of 24 and 48 percent, respectively. Although the abbreviated long-term testing of the LNB+AOFA configuration performed to date does not provide sufficient data to fully characterize NO_X emissions at full-load, the incremental percent NO_X reduction of the combined LNB+AOFA system above LNB alone has averaged less than 10 percent over the load range. As shown, long-term emission levels can be significantly different than that indicated by short-term tests.

Flyash loss-on-ignition (LOI) values increased significantly for both the AOFA, LNB, and LNB+AOFA test phases (Figure 5). LOI measurements for the baseline, AOFA, and LNB test segments were made during each performance test using EPA's Method 17 at the secondary air heater outlet. High volume sampling was used for the abbreviated LNB+AOFA phase. Mill performance was generally better in the AOFA, LNB, and LNB+AOFA test phases than during baseline (Table 4). Although it was expected to increase following the AOFA and LNB retrofits, CO remained below 20 ppm over the load range following the retrofits.

An important segment of the test program is to determine the impact of the low NO_X combustion technologies on boiler performance. Boiler efficiency testing is performed as part of the performance tests and follows guidelines set forth in ASME PTC 4.1 [1]. Although it can be affected by a number of factors unrelated to the AOFA and LNB retrofits, boiler efficiency has decreased following installation of these technologies on Hammond Unit 4 (Table 5). The major contributors to the loss of efficiency are (1) an increase in combustion air requirements leading to increased dry flue gas losses and (2)

1 ASME Performance Test Codes, PTC 4.1, "Steam Generating Units," New York: American Society of Mechanical Engineers, latest edition.

higher carbon in ash values.

A side effect of the post-retrofit shift in ash loading has been a post-LNB retrofit rise in primary air heater plugging rates. Also, these increases, coupled with the higher post-LNB retrofit flyash LOI, adversely impacted particulate emissions such that the unit had to be run at reduced loads to meet particulate compliance limits. The impact of the LNBs on precipitator performance and stack particulate emissions is highly dependent on a number factors including the size of the precipitator (Hammond Unit 4 precipitator is sized at approximately 161 SCA) and pre-LNB retrofit slagging characteristics (Hammond Unit 4 was characterized as a heavy slagging unit prior to the LNB retrofit). Ammonia flue gas conditioning was used to improve precipitator collection efficiency, allowing full load operation and the completion of the LNB test phase.

3.5. Reliability

Three low NO_X burners have been damaged due to excessive heat since the spring 1991 low NO_X burner retrofit. In each instance, portions of the cast burner nozzle assembly melted away, especially in the vicinity of the coal nozzle. The damaged burners were supplied coal from both the new Babcock and Wilcox mills and the FWEC mills, front and rear furnace walls, and upper and lower burner elevations. Two burners were damaged since resumption of unit operation following the spring 1992 outage. The last and most severe occurred on June 16, 1992, and required a one week outage to repair. Damage in this instance was not limited to the cast burner nozzle and sliding tip assembly, but also included the inner and outer barrel, secondary air register, adjacent burners, and windbox. Following this last failure, an enhanced burner thermocouple monitoring system was installed to provide more comprehensive alarming capabilities. The root cause of these failures is at this time undetermined.

3.6. ECEM Certification

ECEM certification tests were conducted by Spectrum Systems, Inc. starting July 23, 1992 and continuing through July 30, 1992. Reference Method Tests were performed on the stack gas stream and were carried out in accordance with the emission monitoring requirements as set forth by the Environmental Protection Agency on May 25, 1991. The results of these tests (Table 6) clearly showed that the ECEM is in conformance with all requirements of EPA's "Performance Specifications and Specification Test Procedures for

Sulphur Dioxide and Nitrogen Oxides Continuous Emission Monitoring Systems in Stationary Sources". Additional information on the certification of the ECEM can be found in Appendix B.

3.7. Ultramax Exploratory Experiments

Initial investigations by the Center for Electric Power personnel into the development of digital control strategies as relates to NO_X emissions indicates that the software package Ultramax may be suitable as the optimization core of the strategy. Ultramax is an optimization package by which the improvements to the process are achieved by making adjustments to the process inputs, monitoring the output response, and using the response from prior perturbations to make performance predictions. This commercial package has been available for a number of years and is used extensively in the process industries. This package traverses the multi-dimensional process space in it's search for the optimum operating condition and in doing so develops a regression model of the process. Ultramax uses a goal-oriented, locally accurate model to make predictions and operating recommendations.

Preliminary *on-line* testing of this software package was conducted at Plant Hammond Unit 4 on July 28-29, 1992. The objective of this experiment was to determine the validity of the data used with the optimization package and the statistical process model (for NO_X, CO, opacity, etc.) created by this package. The accuracy of the model represents Ultramax's ability to predict the process outputs given the optimization objective function and constraints (both physical and those defined in the software). Since the present pneumatic combustion control system is not suitable for implementation of this package, closed-loop control of NO_X emissions was achieved by operators making changes to excess air and AOFA distribution based upon recommendations generated by the optimization package. The results of these changes on NO_X, CO, and opacity were fed back into the optimization package manually. The software was running on a personal computer. The variables considered in this first test were:

Controlled Variables

- Total Combustion Air Flow
- Overfire Air Flow - West / Front
- Overfire Air Flow - East / Front
- Overfire Air Flow - West / Rear
- Overfire Air Flow - East / Rear

Total Coal Flow

Results Variables

NO_X Emissions

CO Emissions

Opacity

The objective function (i.e. parameter to be minimized) consisted only of NO_X emissions.

The test was run at approximately 450 MW with five mills in service (mill D out of service). During the test, a "snapshot" reading of the process data was taken from the wall-fired project's data acquisition system following a change in one of the controlled variables and settling of the boiler. A total of 45 data points were collected during the two days of testing of which 42 were considered suitable for Ultramax's use. These snapshot readings were used in real time to generate the advice for the settings of the control variables. In addition to this data, five minute averages were also collected for later analysis. Results from this test indicate that when using snapshot data, the optimization package was not able to define a unique optimum due to the high process noise levels. However, a post-test analysis of the five minute average data showed that a reliable process model could be developed.

A second test of the optimization package was conducted at Plant Hammond Unit 4 from September 26-27, 1992. The objectives of this experiment were:

- To continue the sequential optimization process started in the first test series,
- To incorporate a simple boiler efficiency loss model into the optimization.

As in the first test, the unit was run near 450 MW with five mills in service (mill D out of service). The first portion of the test continued the optimization process began in the earlier test. After reaching a minimum NO_X emission level, the measure of performance was changed to minimize boiler efficiency losses with constraints on NO_X, CO, and opacity. To reduce the impact of process noise and improve the quality of the model, five minute averages were used instead of snapshot data used in the first test. By using five minute averages, the optimization package was able to develop more reliable models of the process.

During the course of the optimization sequence (Experiments 1 and 2), NO_X was reduced from approximately 260 ppm to 220 (Figure 10). As shown in Figure 11, the CO constraint of CO emission levels being less than 30 ppm was violated a number of times, especially towards the end of the optimization sequence. However, the software package was able to identify a number of operating points in which both NO_X and CO emissions were relatively low. Further analysis of these tests is required to determine the suitability of Ultramax to this application. Details of this testing can be found in Appendices C and D.

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 NO_x 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
NO_x 30 Day Achievable Emission Limit (lb/MBtu)	1.24	-	1.03	-	0.64	-
NO_x Annual Achievable Emission Limit (lb MBtu)	1.13	-	0.93	-	0.55	-

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

Table 4. 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
LNB+AOFA*	1.3	73.6

*Preliminary, data from one test only, 500 MW.

Table 5. Full Load Boiler Performance (Preliminary)									
Phase	Test	Load MW	Total Fuel lb/hr	Total Air lb/hr	Excess O2 Percent	Excess Air^ Percent	Flyash LOI Percent	Efficiency Percent	Change* Percent
Design	N/A	480	3.9E+05	4.2E+06	3.3	18%	4.5%	89.0	-
Baseline	Average	474	3.5E+05	3.7E+06	2.9	10%	5.1%	89.8	-
AOFA	43-1,3	478	3.4E+05	3.8E+06	3.9	14%	9.6%	89.1	0.7
LNB	Average	476	3.3E+05	3.9E+06	3.7	19%	8.0%	88.2	1.6

*Change relative to baseline average.
^Calculated using measured total air and fuel.

Table 6. ECEM Certification Tests Results - June - July 1991				
Test	SO2	NO_x	O2	EPA Specs.
Zero Drift (24 hr)	1.24%	0.00%	-	Less than or equal to 2.5% / day
	-	-	0.20%	Less than or equal to 0.5% / day
Calibration Drift (24 hr)	-1.04%	-0.36%	-	Less than or equal to 2.5% / day
	-	-	0.00	Less than or equal to 0.5% / day
Relative Accuracy	1.82%	13.19%	-	Less than or equal to 20%

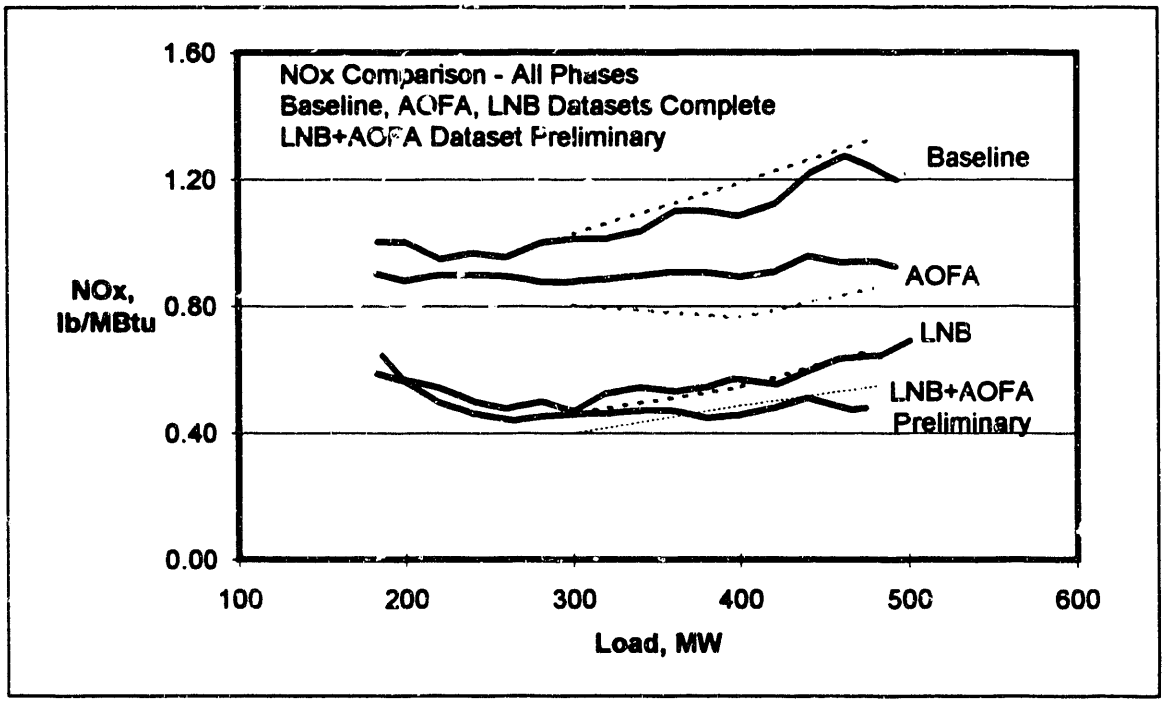


Figure 4. NO_x Emissions Comparision

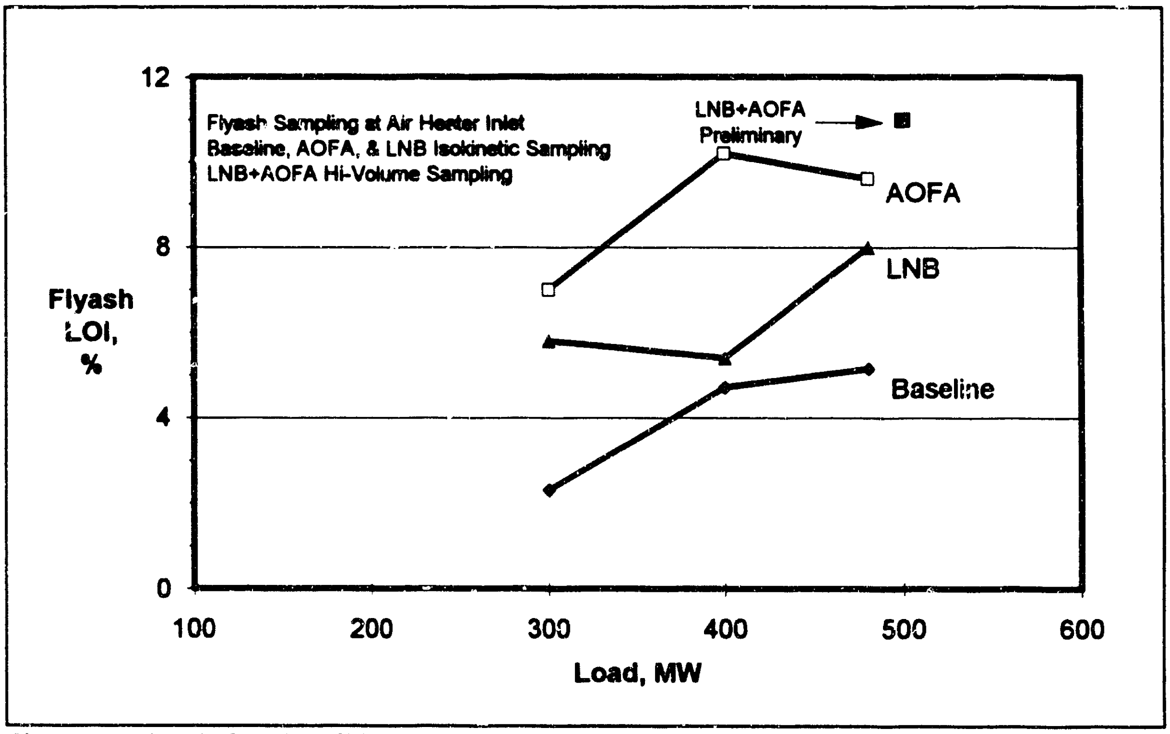


Figure 5. Flyash Combustibles Loss-on-Ignition

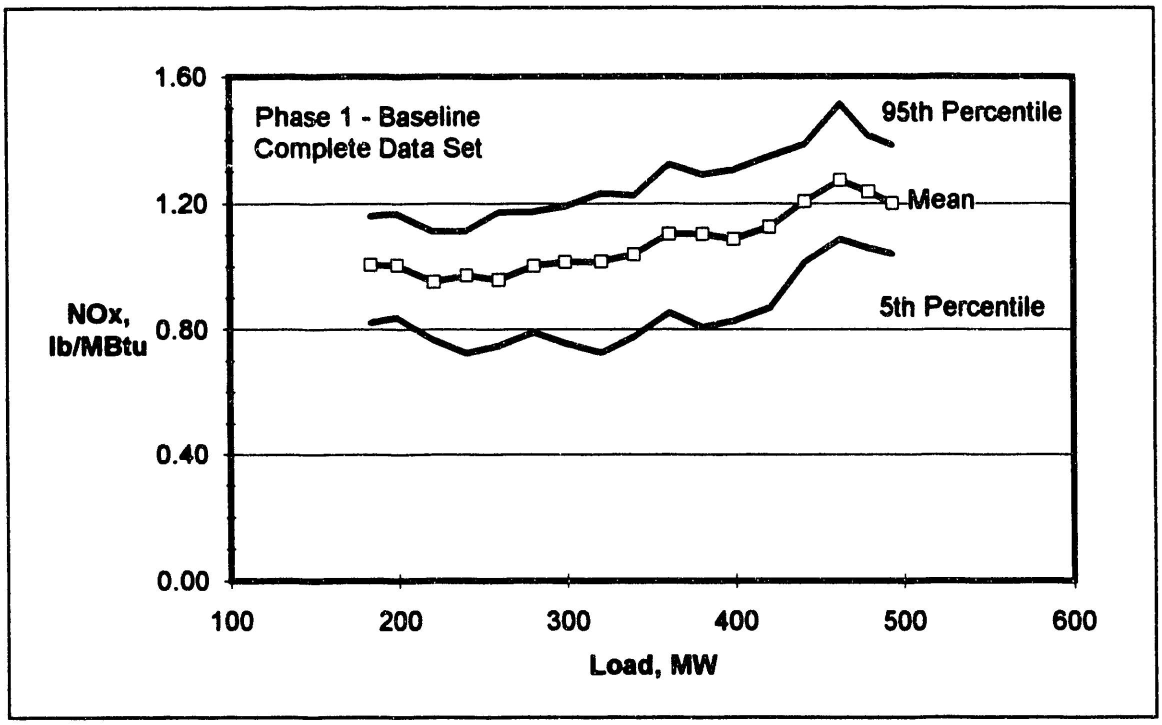


Figure 6. Baseline Long-Term NO_X Trend

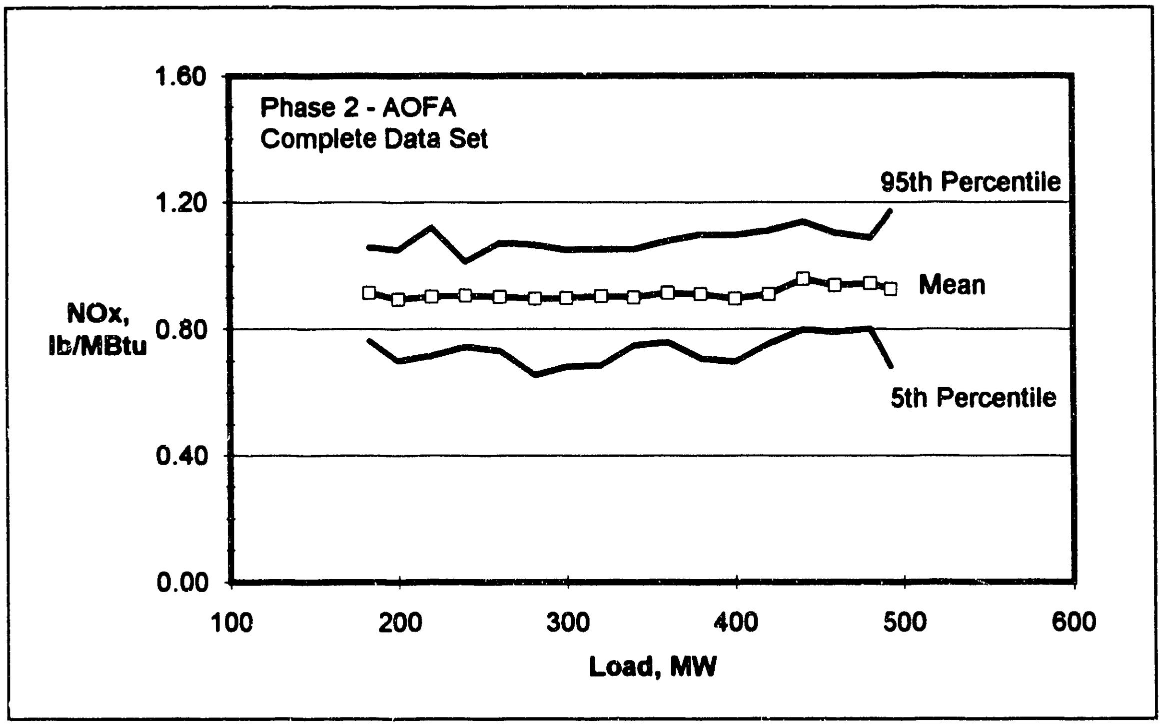


Figure 7. AOFA Long-Term NO_X Trend

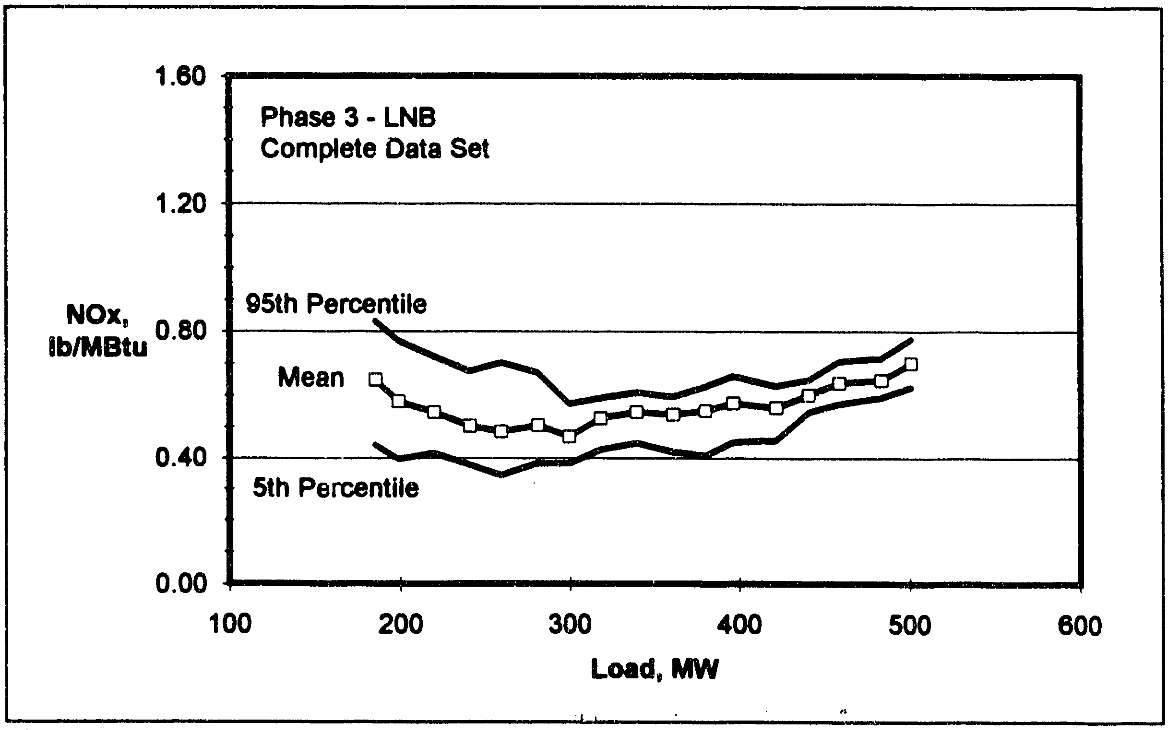


Figure 8. LNB Long-Term NO_X Trend

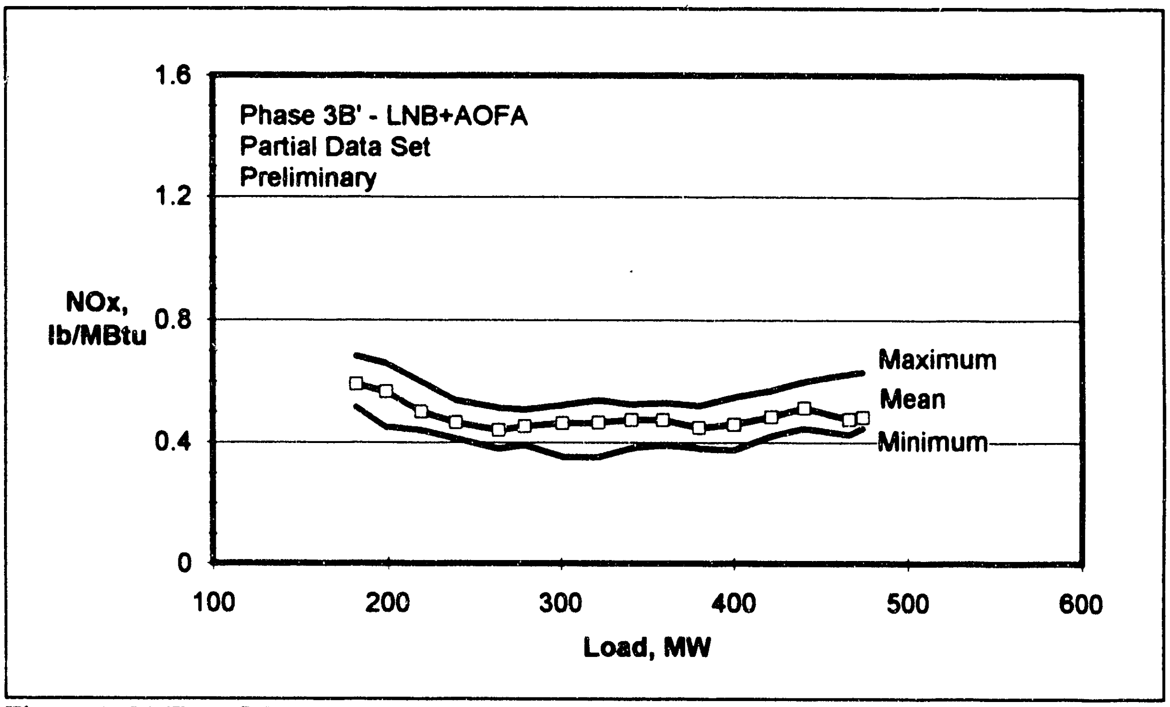


Figure 9. LNB+AOFA Long-Term NO_X Trend - Preliminary

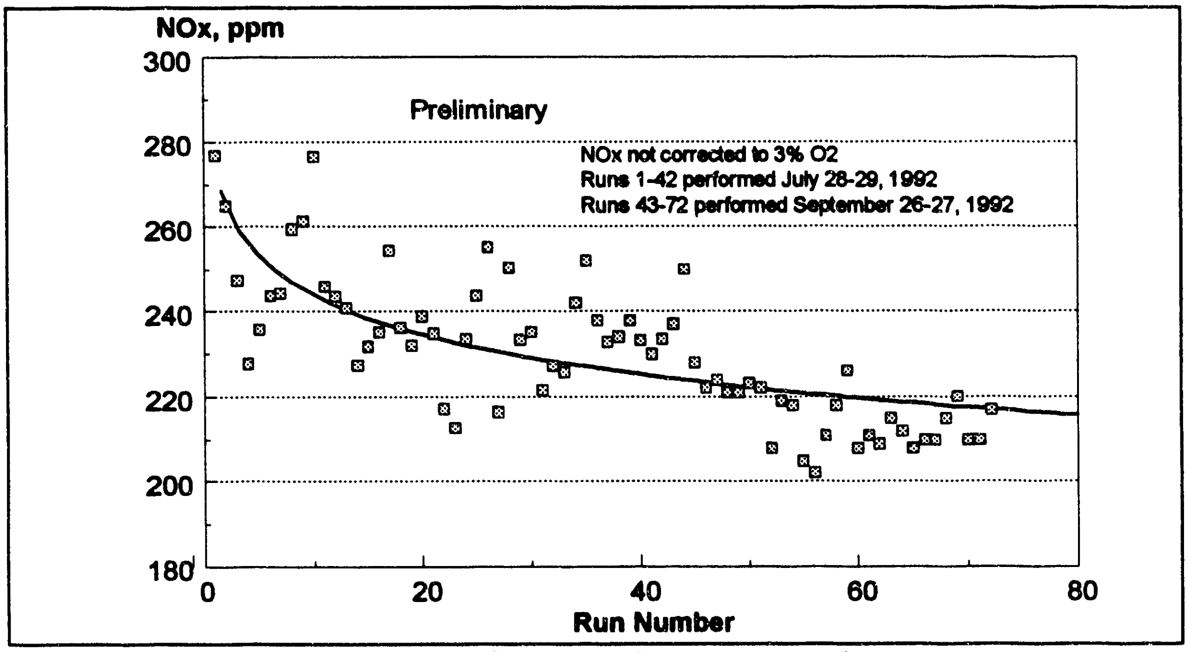


Figure 10. Optimization Experiment #1 & 2 - NO_X vs. Run Number

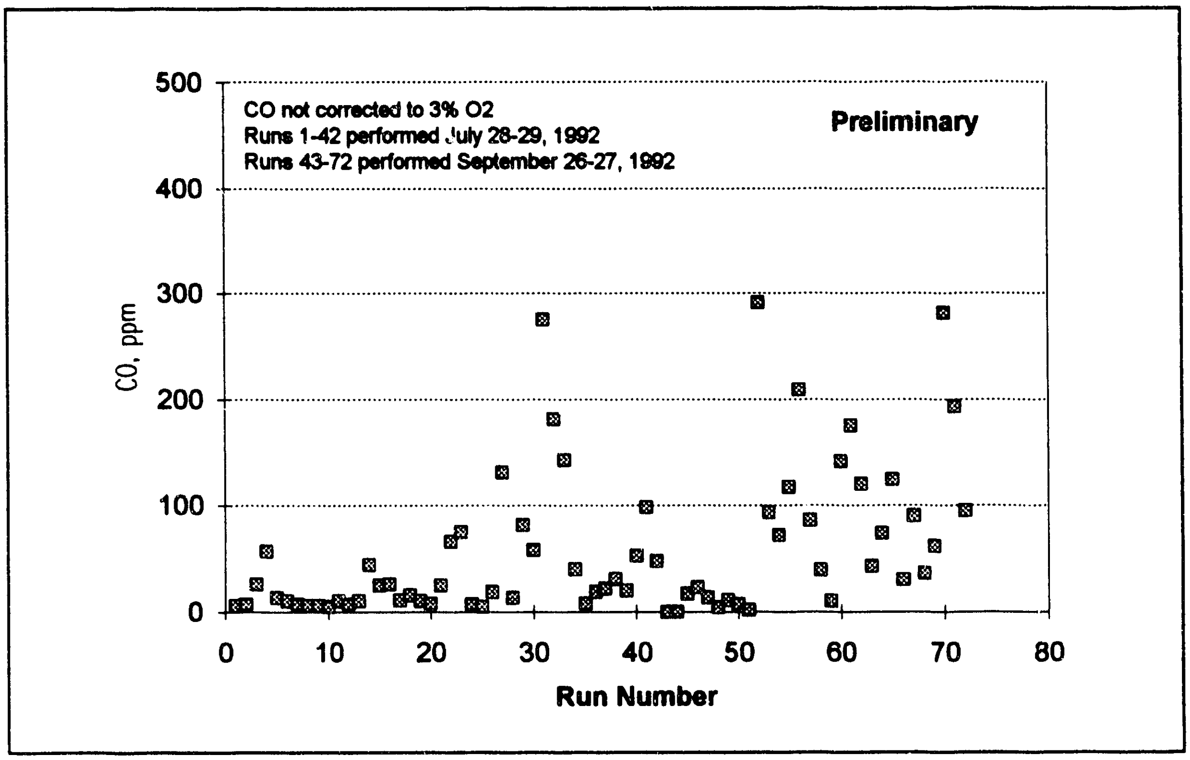


Figure 11. Optimization Experiment #1 & 2 - CO Emissions vs. Run Number

4. FUTURE PLANS

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

Table 7. Future Plans

Quarter	Activity
Forth Quarter 1992	• Continue Long-Term LNB+AOFA Test
First Quarter 1993	• Continue Long-Term LNB+AOFA Test
Second Quarter 1993	• Diagnostic Tests of the LNB+AOFA • Post Retrofit Chemical Emissions Tests • Performance Tests of the LNB+AOFA
Third Quarter 1993	• Complete Long-Term LNB+AOFA Tests • Verification Tests of the LNB+AOFA • Begin Final Reporting • Begin Disposition
Forth Quarter 1993	• Complete Final Reporting • Complete Disposition • Project Completion

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 marginal, incremental NOx reduction benefits averaging less than 10 percent over the load range. When compared to baseline, the full load long-term and short-term NOx reductions in this configuration were approximately 55 percent and 62 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 flyash.

- 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. 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
Long-Term NO_X Emissions - August - September, 1992

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions

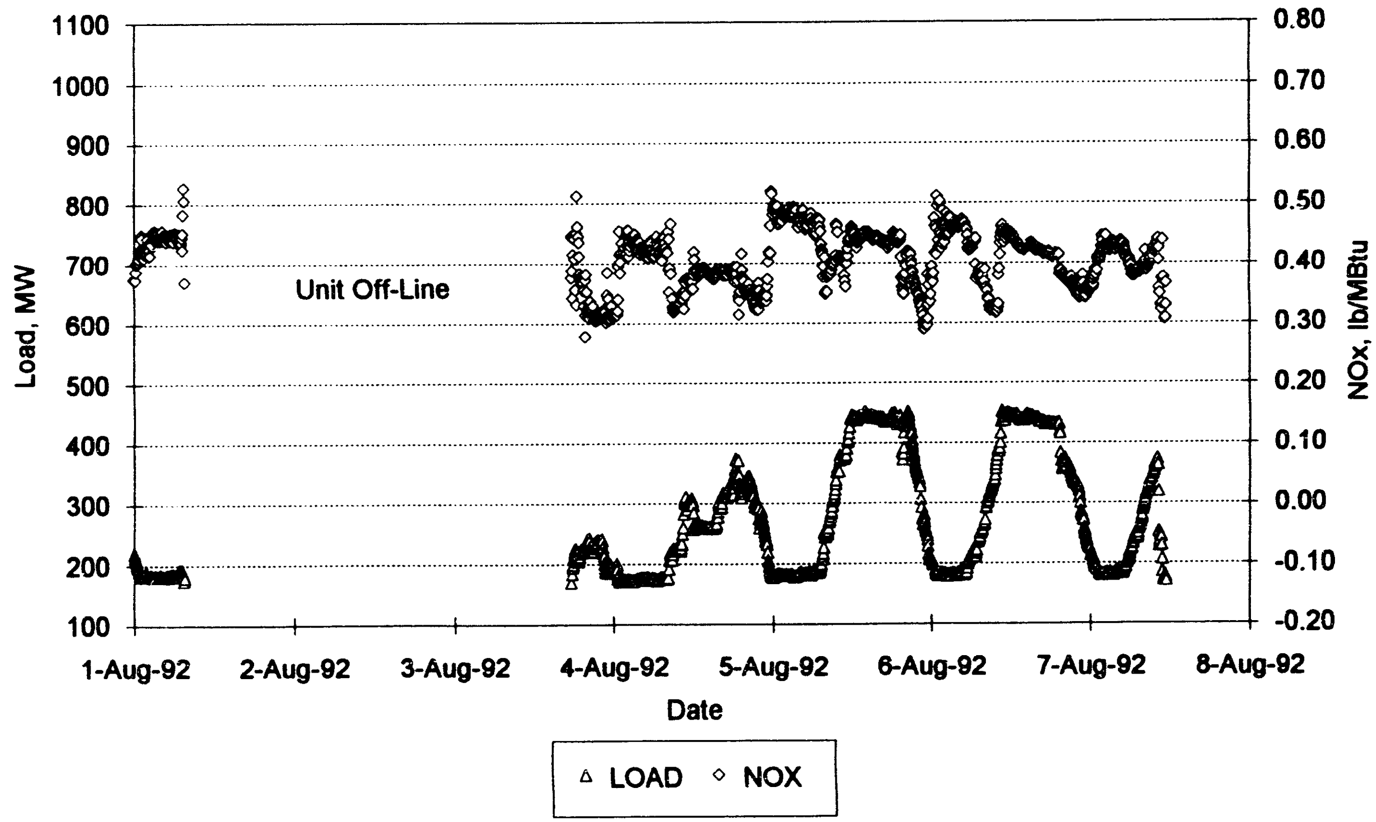


Figure A-1

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions

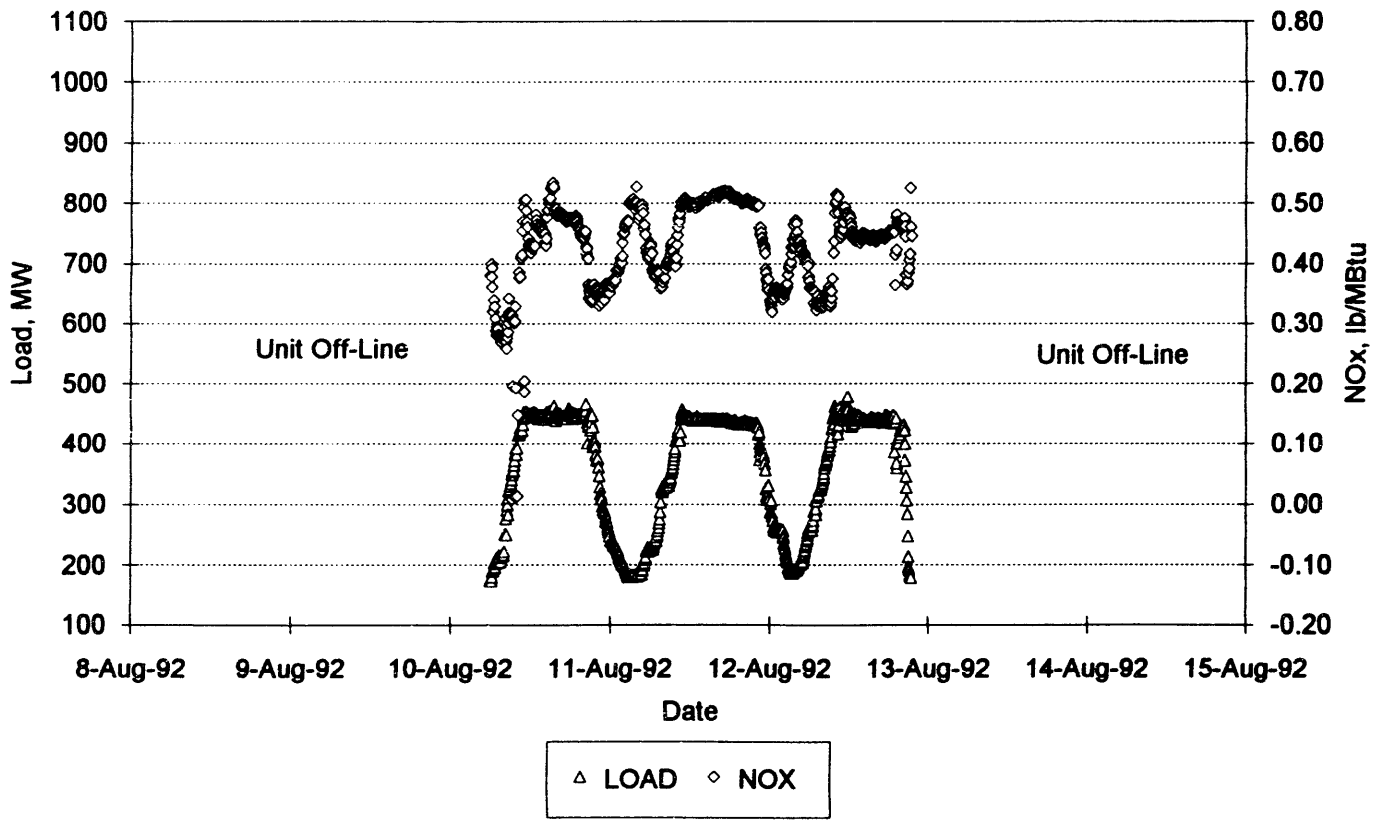


Figure A-2

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions

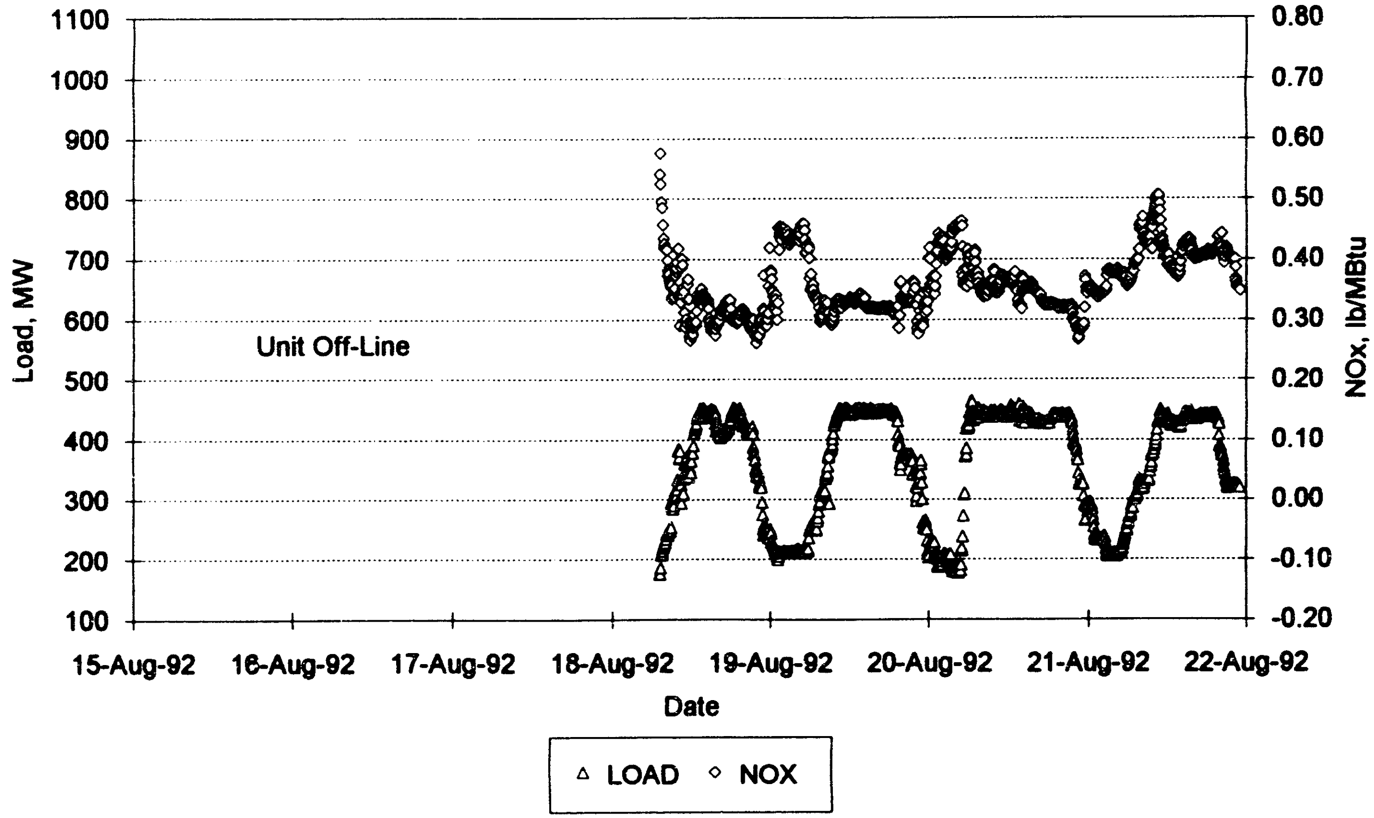


Figure A-3

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions

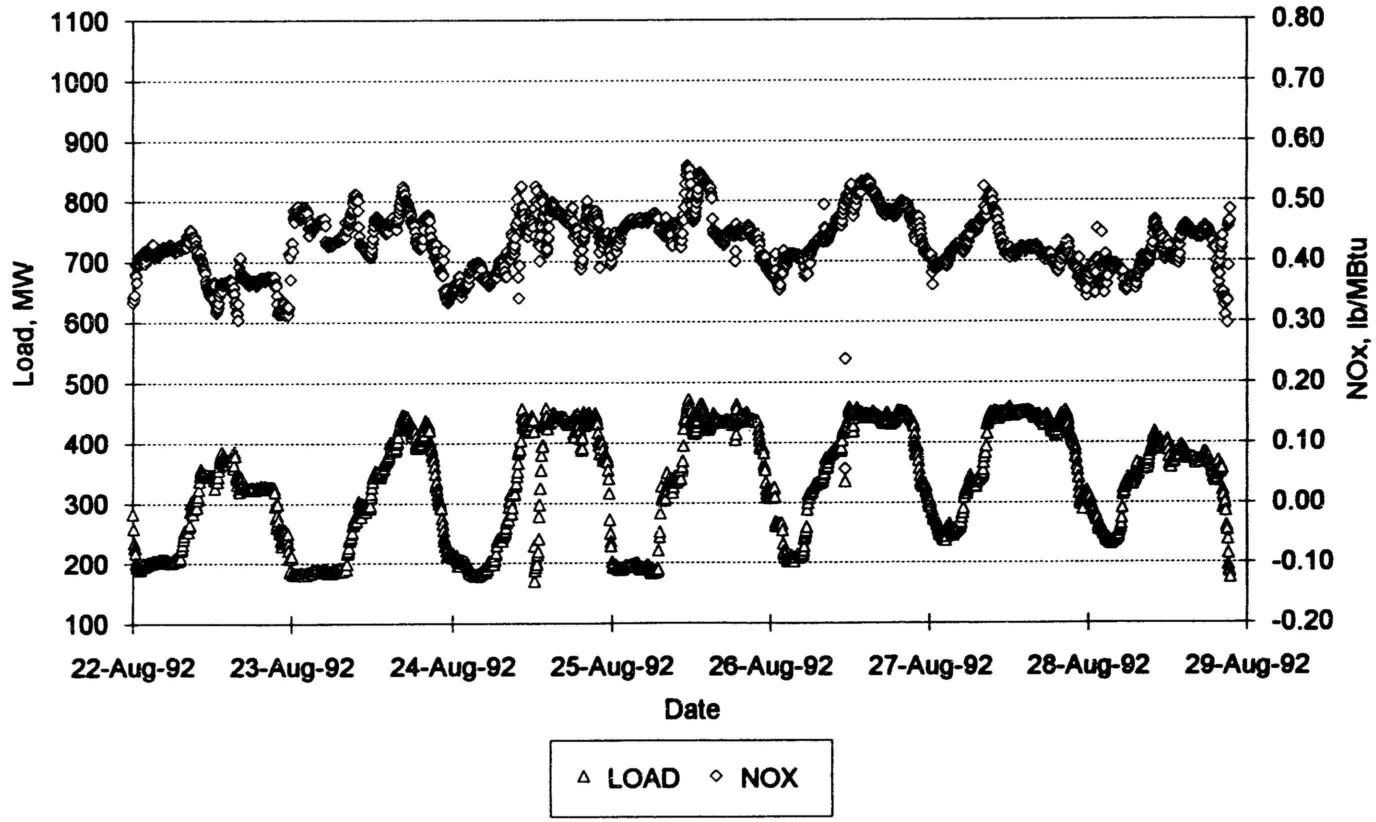


Figure A-4

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions

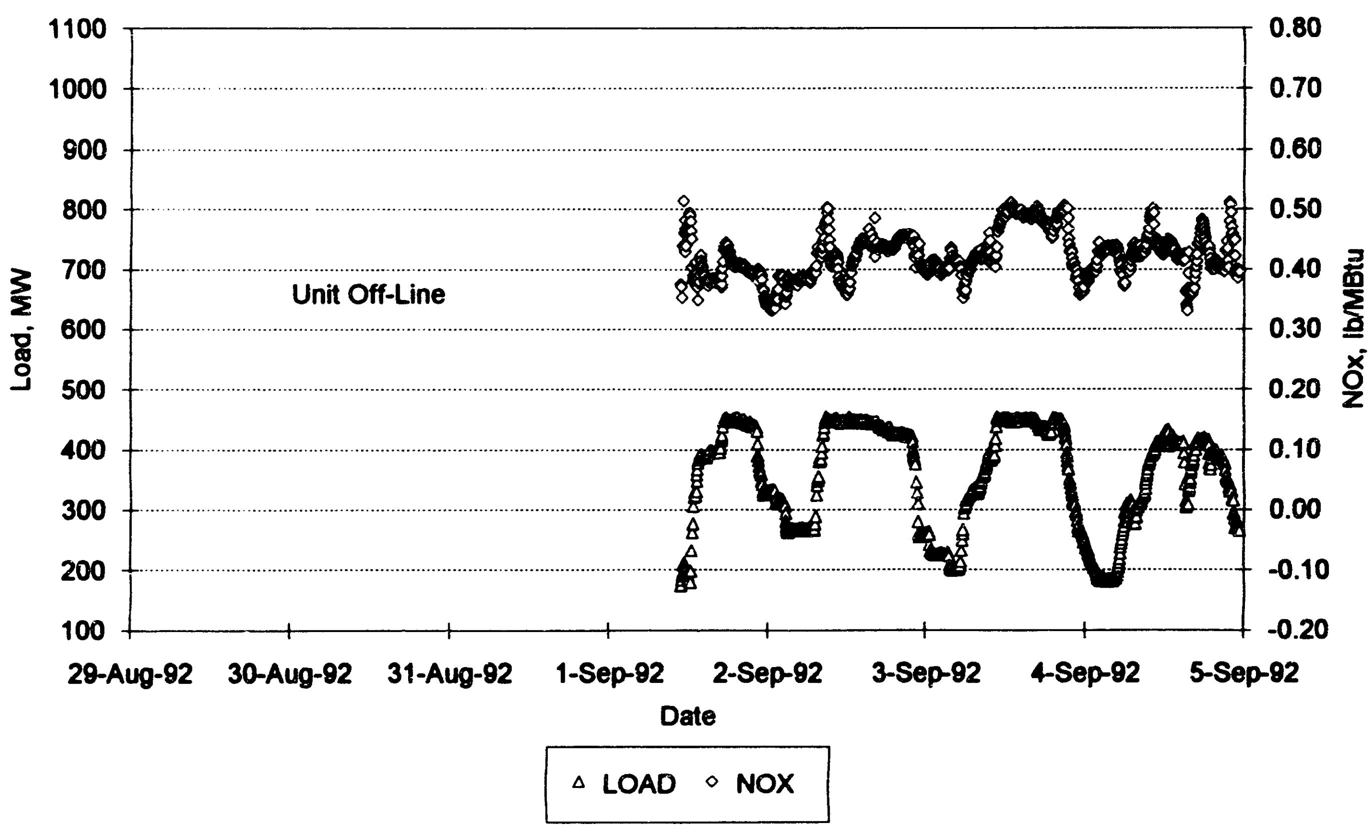


Figure A-5

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions

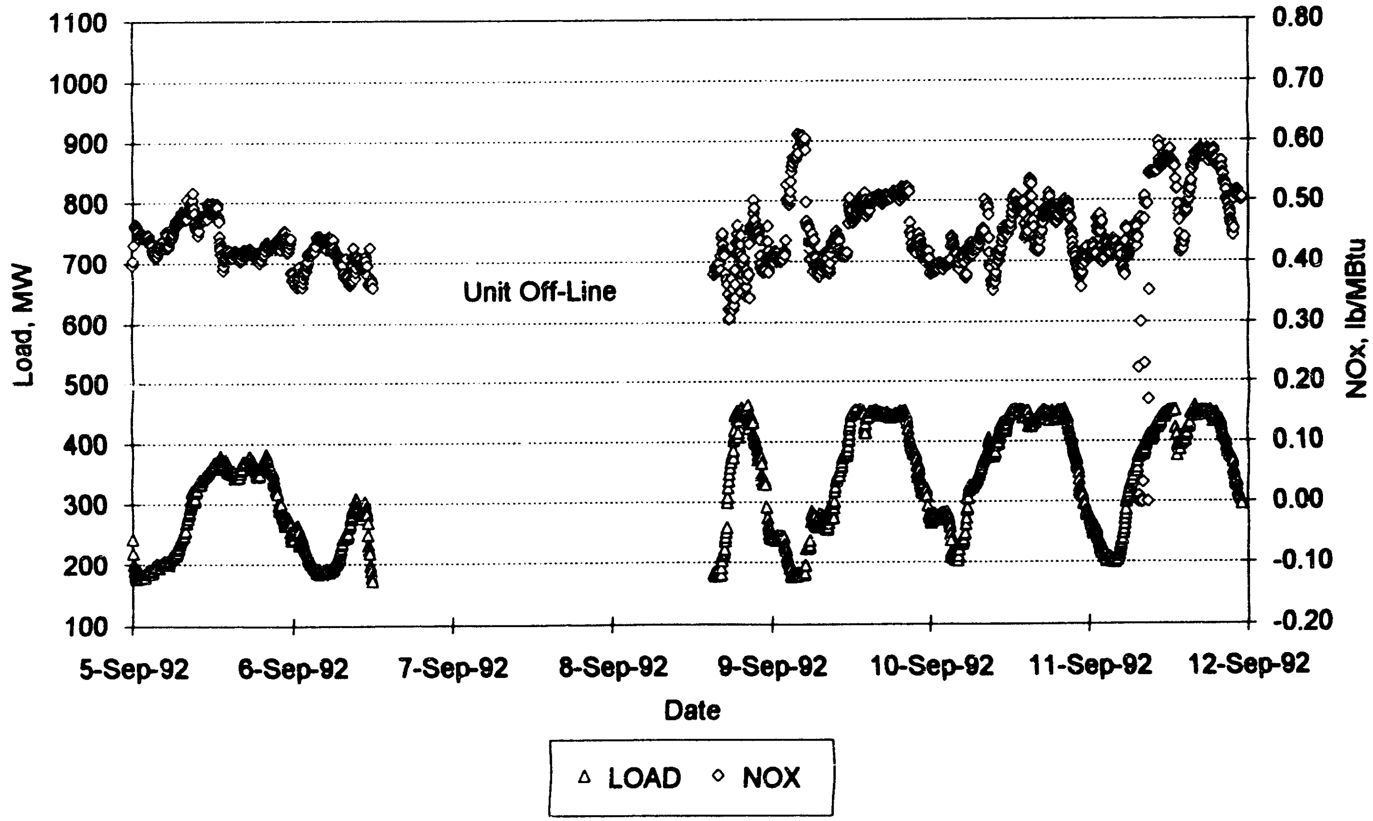


Figure A-6

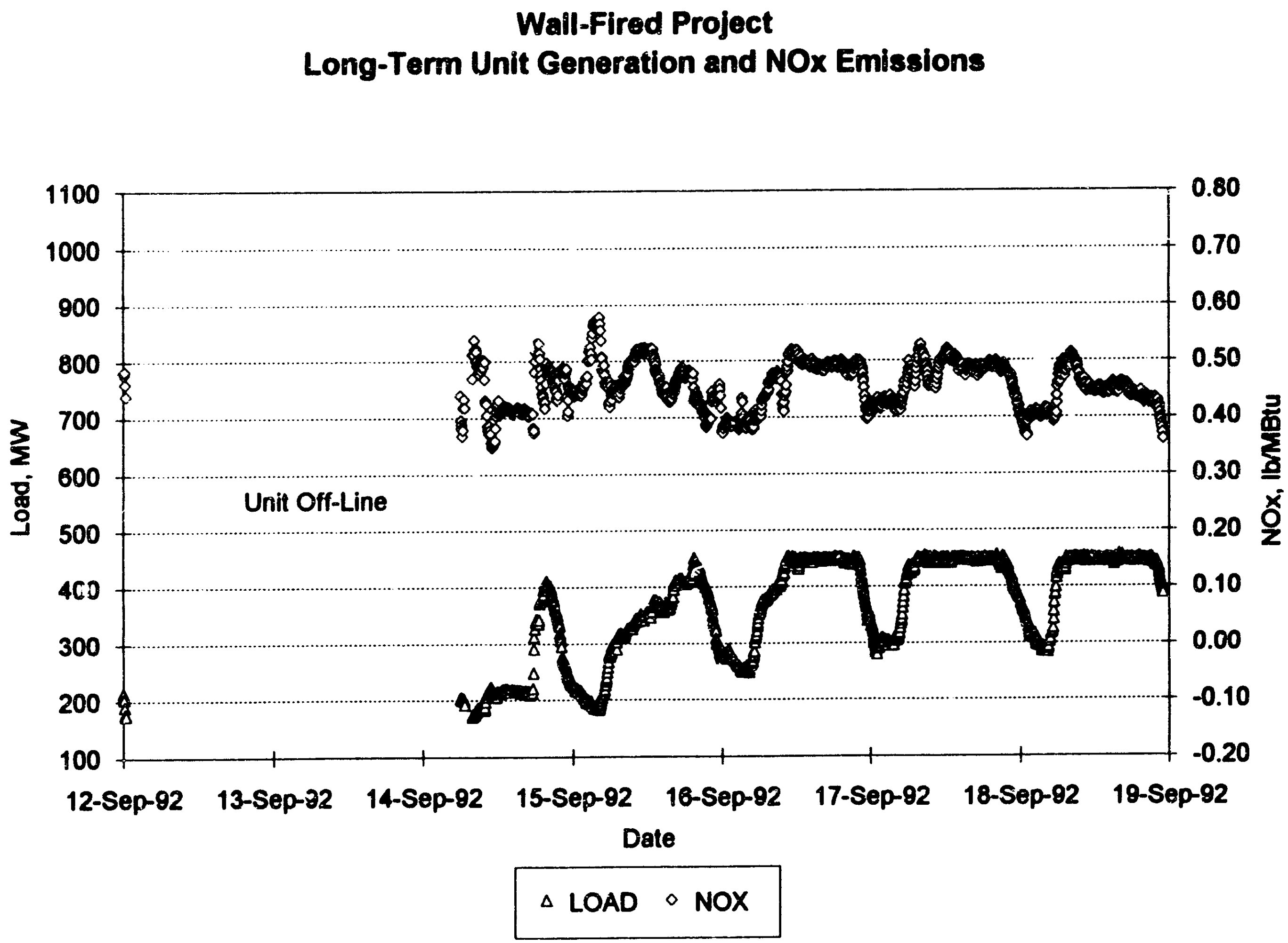

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions
1100
1000
900
800
700
600
500
400
300
200
100
Load, MW
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
NOx, lb/MBtu
Unit Off-Line
12-Sep-92
13-Sep-92
14-Sep-92
15-Sep-92
16-Sep-92
17-Sep-92
18-Sep-92
19-Sep-92
Date
LOAD
NOX

Figure A-7

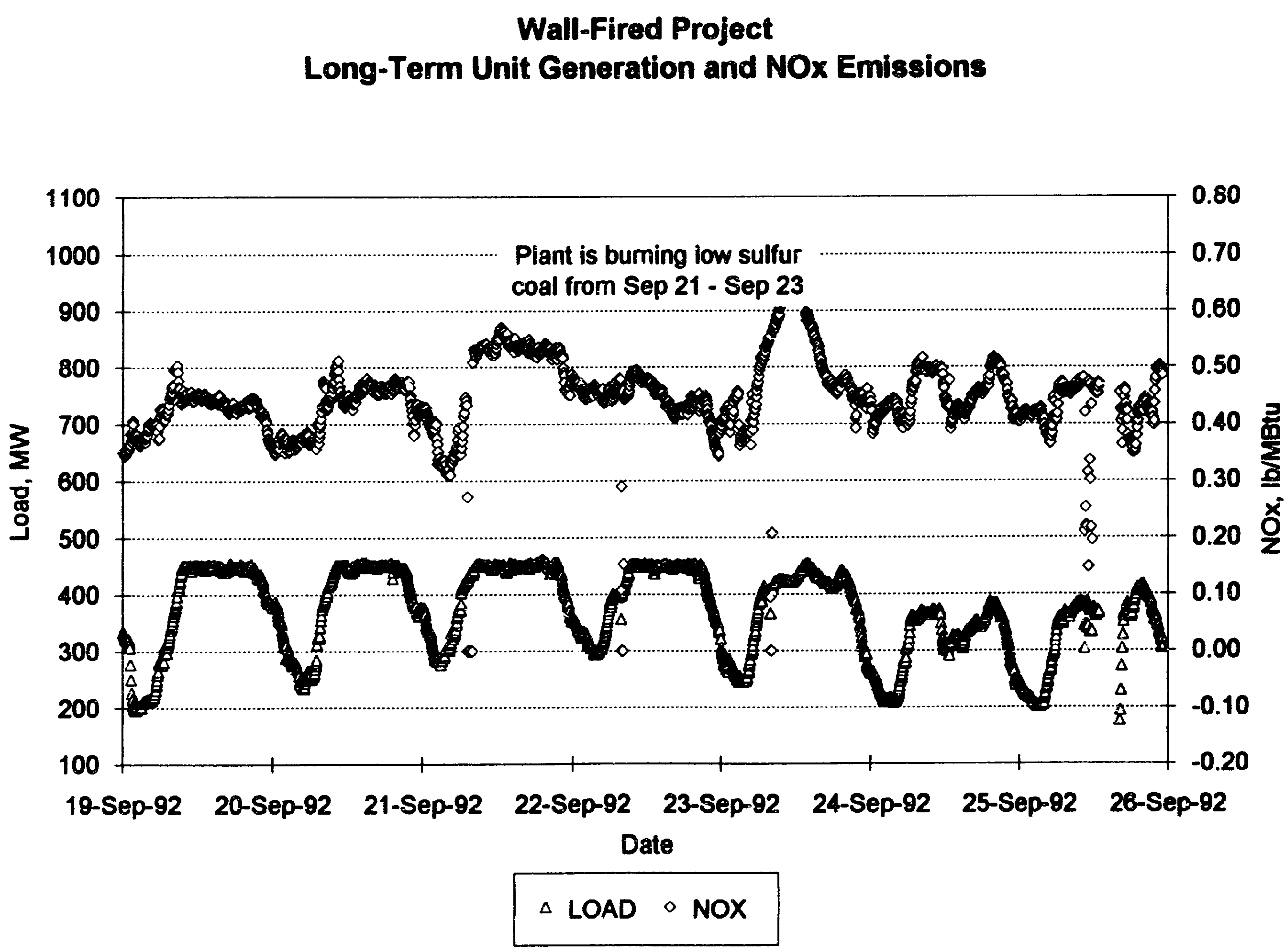

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions
Plant is burning low sulfur coal from Sep 21 - Sep 23
1100
1000
900
800
700
600
500
400
300
200
100
Load, MW
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
NOx, lb/MBtu
19-Sep-92
20-Sep-92
21-Sep-92
22-Sep-92
23-Sep-92
24-Sep-92
25-Sep-92
26-Sep-92
Date
LOAD
NOX

Figure A-8

Wall-Fired Project
Long-Term Unit Generation and NOx Emissions

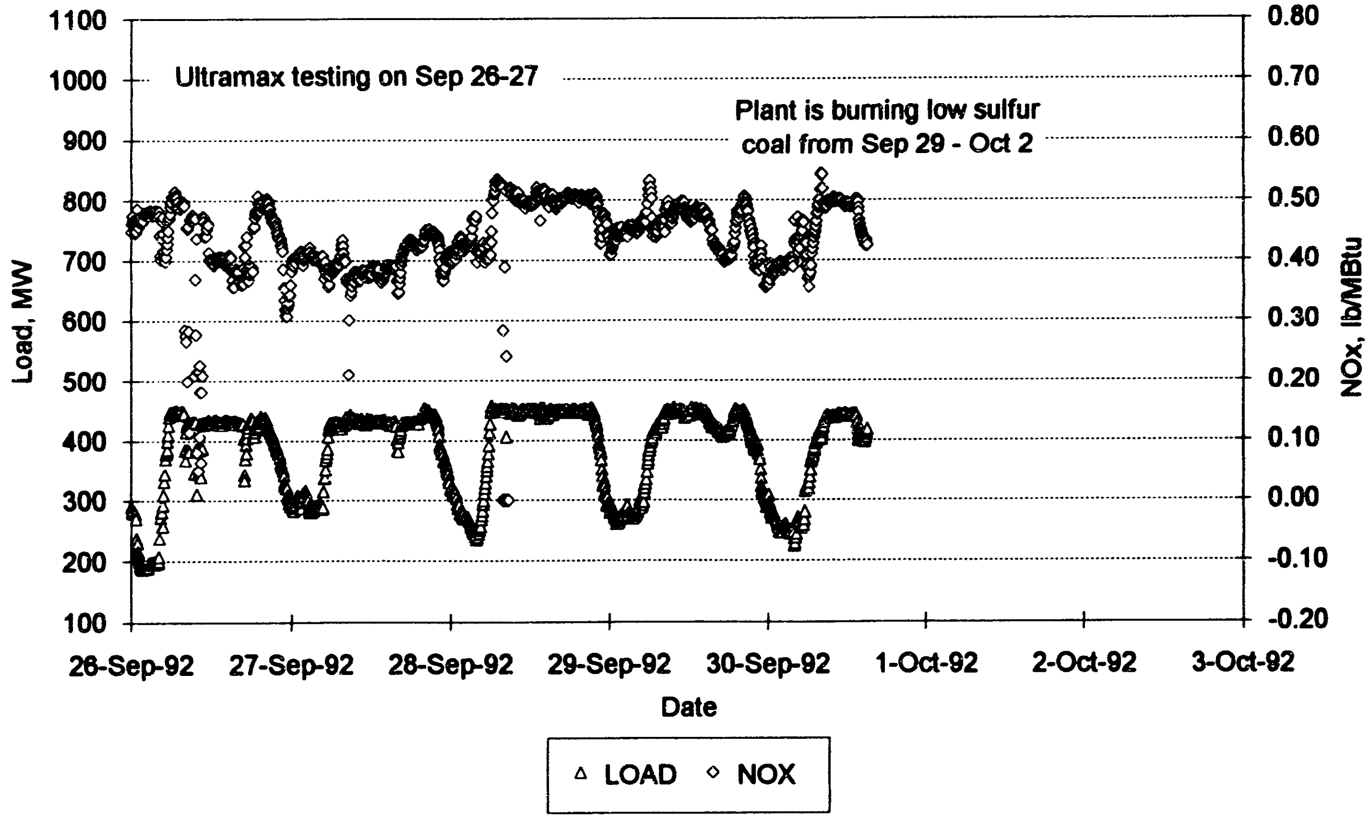


Figure A-9

APPENDIX B
CEM Certification Testing - August 1992

CERTIFICATION TESTING

UNIT #4

GEORGIA POWER COMPANY

PLANT HAMMOND

AUGUST 20, 1992

Prepared by:

Spectrum Systems, Inc.
Pensacola, Florida

KVB O_2 Analyzer S/N CO58405(B)-1
KVB SO_2 Analyzer S/N 89-721AT2-7543-3
KVB NO_x Analyzer 10 A/R-25864-222

TABLE OF CONTENTS

DOE/SOUTHERN COMPANY SERVICES, INC
INNOVATIVE CLEAN COAL TECHNOLOGY PROJECT
GEORGIA POWER - PLANT HAMMOND - UNIT FOUR

EQUIPMENT INVENTORY - CEM SYSTEM

SYSTEM	MANUFACTURER	SERIAL NUMBER	MODEL	RANGE
KVB-O2	AMETEK	CO58405(B)-1	WDGIII	0-25PCT
KVB-SO2	WESTERN RES.	89-721AT2-7543-3	721AT	0-2500PPM
KVB-NOx	TECO	10A/R-25864-222	10	0-2500PPM
KVB-THC	BECKMAN IND.	100952	400A	0-100PPM
KVB-CO	SIEMENS	7MB1122-1CA13-1BA1	21P	0-300PPM
CABINET	KVB	50525	N/A	N/A
DATA LOGGER	KAYE	907157	4M PLUS	N/A
DAS	ZENITH SYSTEM	934CC003385	386 PC	N/A

I. INTRODUCTION

Spectrum Systems, Inc. was contracted by Georgia Power Company to conduct a Performance Evaluation of the Plant Hammond Continuous Emission Monitoring Systems (CEMS), comprised of an Ametek Model WDGIII O_2 Analyzer, Serial Number CO58405(B)-1; Western Research Model 721-AT SO_2 Analyzer, Serial Number 89-721AT2-7543-3; and a Thermo Environmental Model 10 NO_x Analyzer, Serial Number 10 A/R-25864-222. The KVB extractive system monitors the exhaust gas duct as well as several intermediate ducts, on command. Reference Method Tests were performed on the stack gas stream at a point located 250' up the stack to determine instrument accuracies. The installation was made on the multi-fuel boiler located on Unit #4 at the Plant Hammond facility. This certification was performed in accordance with the emission monitoring requirements as promulgated on May 25, 1984, by the Environmental Protection Agency. Field tests were conducted from July 23, 1992, through July 30, 1992. The instrument operated continuously throughout the operational test period without maintenance or service. During the relative accuracy test period, the boiler was operated at greater than 50% of normal load. Results in this report include data from a diluent monitor since reporting is required in a mass emission output format. The diluent monitors were also certified during this test.

II. INSTALLATION DESCRIPTION

The instruments were installed on the main exhaust duct of the Unit #4 Boiler located at the Plant Hammond facility. Further installation information can be obtained from the affected facility. The initial start-up was on November 2, 1989, for the KVB system. The effluent gases are assumed to be representative in accordance with para. 3.1.1. of the referenced specification since the monitor location is more than eight diameters downstream of the nearest control device and in the centroid into the effluent stream. These monitoring systems are used to evaluate the effects of NO_x reduction procedures under test at the facility.

III. SUMMARY

Test results of the Performance Evaluation are presented in Table III-1 A. These results are based on data obtained in Rome, Georgia during normal operation at the facility. The test results clearly show that the KVB continuous emissions monitor is in conformance with all requirements of "Performance Specifications and Specification Test Procedures for Sulphur Dioxide and Nitrogen Oxides Continuous Emission Monitoring Systems in Stationary Sources".

IV. DISCUSSION OF RESULTS

Calibration Drift Test

Calibration drift was tested in accordance with paragraph 1 of Performance Specification 2. Both SO_2/NO_x monitors are designed to provide automatically timed zero and span calibration checks at 24 hour intervals throughout the required 7 consecutive days. The zero value is determined by mechanically introducing to the probe measurement cavity or sample probe a supply of zero air, thereby producing a zero condition that checks the analyzer's internal components and all electronic circuitry including the radiation source and detector assembly. The span of the system is checked with a calibration gas equivalent to between a 50 and 90 percent deflection of span concentration, utilizing the probe measurement cavity in a manner similar to that described above. Adjustments were not made on the gas monitor or the diluent monitor during the Calibration Drift Test. Twenty-four (24) hour results were calculated by taking the daily recorded monitor response and subtracting this reading from the reference value. Daily calibration drift tests are contained in the reports entitled, "Plant Hammond Unit 4 Clean Coal Project", Valve Group 199, 200 and 201, taken from the plant reporting data acquisition system and found in Appendix D of this report.

Calibration Drift Test Results

Results of the two (2) point Calibration Drift Test are as follows:

> Sulphur Dioxide and Nitrogen Oxide stack gas monitor and the oxygen diluent monitor calibration drift for the seven (7) consecutive day period did not exceed 2.5% of the zero or span value for pollutant parameters, or 0.5% oxygen by volume for the diluent monitor for any given day. Drift test results are displayed in tabular formats on the following pages.

Federal Register specifications permit calibration drift to be less than equal to 2.5% of span for sulphur dioxide and nitric oxide and 0.5 % O_2 by volume for diluent oxygen for each 24 hour period of the seven (7) day calibration drift test. The test data used in calculating these results is presented on the following pages.

Calibration Error Test

A calibration error test or cylinder gas audit was performed in accordance with the QA guideline contained in the Title 40 Part 60 Appendix F of Code of Federal Regulations. This test was used to access the accuracy of each CEMS prior to the reference method testing procedures. No adjustments were made to the CEMS as a result of the gas audits.

A secondary purpose of this procedure was to validate the calibration procedures used by contractor personnel to maintain instrument accuracy.

Relative Accuracy

Relative Accuracy is defined in the Federal Register as "the degree of correctness with which the continuous monitoring system yields the value of gas concentration of a sample relative to the value given by a defined reference method." The defined reference method , in this case, is EPA Reference Methods 3A, 6C and 7E. Nine sets of tests were performed on August 20, 1992, at a point established in accordance with Section 7.1 of the Federal Register. Additional details can be found in the appendix of this report.

The accuracy is reported as an error and is the sum of the absolute mean value of the difference between the reference test and the combined readings, plus a 95% confidence interval of the differences, expressed as a percentage of the mean combined reference value. The analyzer's average response was determined from the computer printouts corresponding to the time period the relative accuracy tests were performed. Since the Land measurement systems are insitu instruments, the outputs are expressed in ppm concentration on a wet basis. A moisture test correction factor was used in the conversion formula so instrument readings could be corrected to a dry basis prior to comparison with the reference method values and are shown in the Appendix.

When using computer printouts for comparisons to the reference methods, one minute instrument averages were used, corresponding to the time frame of stack gas samples. The method for arriving at the comparison of LBS/MBTU is obtained by using a formula that calculates the emission output based on raw PPM the percent of oxygen and moisture factor. The formulas used for conversion are explained in the Appendix, under the section entitled, "Mathematical Explanation."

The relative accuracy is displayed in tabular form on the Relative Accuracy Determination worksheet found on the following pages. Federal Register specifications limit the allowable error to 20% of the mean calculated reference method value.

LOG OF OPERATIONS

KVB SYSTEM S/N 50525

Model and Manufacturer	KVB Model 50 Extractive
Instrument Serial Number	50525 - Cabinet 89-721AT2-7543-3-SO_2 10 A/R-25864-222-NO_x
Diluent Serial Number	Ametek CO58405(B)-1
Initial Start-up	11/02/89
Start of Performance Calibration	07/23/92
Start of Calibration Drift Test	07/23/92
End of Calibration Drift Test	07/30/92
Start of Relative Accuracy Test	08/20/92
End of Relative Accuracy Test	08/20/92

TABLE III-1A

PERFORMANCE TEST RESULTS

KVB SYSTEM (S/N 50525)

	Monitor Performance	*EPA Specifications*
SO_2 Instrument Serial Number	89-721AT2-7543-3	
NO_x Instrument Serial Number	10 A/R-25864-222	
Diluent Serial Number	CO58405(B)-1	
Calibration Period	seven (7) consecutive days	seven (7) consecutive days
NO_x Analyzer Cal. Drift (Lo pt. 0-20%)	0.00% largest daily difference (NO_x)	less than or equal to 2.5% span per day
SO_2 Analyzer Cal. Drift (Lo pt. 0-20%)	1.24% largest daily difference (NO_x)	less than or equal to 2.5% span per day
Diluent Oxygen Analyzer (Downscale checkpoint)	.20% largest daily difference (O_2)	less than or equal to 0.5% O_2 by volume per dat
SO_2 Analyzer Cal. Drift (Hi pt. 50-100%)	-1.04% largest daily difference (NO_x)	less than or equal to 2.5% span per day
NO_x Analyzer Cal. Drift (Hi pt. 50-100%)	-.36% largest daily difference (NO_x)	less than or equal to 2.5% span per day
Diluent Oxygen Analyzer (Upscale checkpoint)	0.00% largest daily difference (O_2)	less than or equal to 0.5% O_2 by volume per day
System Relative Accuracy computed in lbs/Mbtu (SO_2)	1.82%	less than or equal to 20%
System Relative Accuracy computed in lbs/Mbtu (NO_x)	13.19%	less than or equal to 20%

DOE/SOUTHERN COMPANY SERVICES, INC.
INNOVATIVE CLEAN COAL TECHNOLOGY PROJECT
GEORGIA POWER COMPANY - PLANT HAMMOND UNIT FOUR

CEM CALIBRATION DRIFT DETERMINATION

SYSTEM	KVB-O2	GAS	O2
MANUFACTURER	AMETEK	SPAN RANGE	25PCT
MODEL	WDGIII	OPERATOR	JOSE PEREZ
SERIAL NUMBER	C058405(B)-1		

SPAN DRIFT

DAY	DATE	TIME	CALIBRATION VALUE PCT	MONITOR VALUE PCT	DIFFERENCE IN PCT	TOTAL ERROR
START	23-Jul-92	07:56 AM	19.90	19.90	0.00	0.00%
1	24-Jul-92	07:57 AM	19.90	19.90	0.00	0.00%
2	25-Jul-92	07:56 AM	19.90	19.90	0.00	0.00%
3	26-Jul-92	07:56 AM	19.90	19.90	0.00	0.00%
4	27-Jul-92	07:56 AM	19.90	19.90	0.00	0.00%
5	28-Jul-92	07:56 AM	19.90	19.90	0.00	0.00%
6	29-Jul-92	07:21 AM	19.90	19.90	0.00	0.00%
7	30-Jul-92	07:56 AM	19.90	19.90	0.00	0.00%

ZERO DRIFT

DAY	DATE	TIME	CALIBRATION VALUE PCT	MONITOR VALUE PCT	DIFFERENCE IN PCT	TOTAL ERROR
START	23-Jul-92	08:03 AM	0.00	0.10	0.10	0.10%
1	24-Jul-92	08:05 AM	0.00	0.20	0.20	0.20%
2	25-Jul-92	08:03 AM	0.00	0.10	0.10	0.10%
3	26-Jul-92	08:03 AM	0.00	0.10	0.10	0.10%
4	27-Jul-92	08:03 AM	0.00	0.10	0.10	0.10%
5	28-Jul-92	08:03 AM	0.00	0.20	0.20	0.20%
6	29-Jul-92	07:28 AM	0.00	0.20	0.20	0.20%
7	30-Jul-92	08:03 AM	0.00	0.20	0.20	0.20%

MAXIMUM ALLOWANCE ERROR = PLUS OR MINUS 0.5% O2 BY VOLUME

DOE/SOUTHERN COMPANY SERVICES, INC.
INNOVATIVE CLEAN COAL TECHNOLOGY PROJECT
GEORGIA POWER COMPANY - PLANT HAMMOND UNIT FOUR

CEM CALIBRATION DRIFT DETERMINATION

SYSTEM	KVB-NOx		
MANUFACTURER	THERMO ENVIRONMENTAL	GAS	NOx
MODEL	10	SPAN RANGE	2500PPM
SERIAL NUMBER	10A/R-25864-222	OPERATOR	JOSE PEREZ

SPAN DRIFT

DAY	DATE	TIME	CALIBRATION VALUE PPM	MONITOR VALUE PPM	DIFFERENCE IN PPM	PERCENT OF SPAN VALUE
START	23-Jul-92	08:03 AM	1510	1509	-1	-0.04%
1	24-Jul-92	08:05 AM	1510	1510	0	0.00%
2	25-Jul-92	08:03 AM	1510	1515	5	0.20%
3	26-Jul-92	08:03 AM	1510	1501	-9	-0.36%
4	27-Jul-92	08:03 AM	1510	1508	-2	-0.08%
5	28-Jul-92	08:03 AM	1510	1502	-8	-0.32%
6	29-Jul-92	07:28 AM	1510	1511	1	0.04%
7	30-Jul-92	08:03 AM	1510	1517	7	0.28%

ZERO DRIFT

DAY	DATE	TIME	CALIBRATION VALUE PPM	MONITOR VALUE PPM	DIFFERENCE IN PPM	PERCENT OF SPAN VALUE
START	23-Jul-92	07:56 AM	0	0	0	0.00%
1	24-Jul-92	07:57 AM	0	0	0	0.00%
2	25-Jul-92	07:56 AM	0	0	0	0.00%
3	26-Jul-92	07:56 AM	0	0	0	0.00%
4	27-Jul-92	07:56 AM	0	0	0	0.00%
5	28-Jul-92	07:56 AM	0	0	0	0.00%
6	29-Jul-92	07:21 AM	0	0	0	0.00%
7	30-Jul-92	07:56 AM	0	0	0	0.00%

%SPAN = ((INSTRUMENT RESPONSE-EXPECTED CONCENTRATION)/SPAN VALUE)*100

DOE/SOUTHERN COMPANY SERVICES, INC.
INNOVATIVE CLEAN COAL TECHNOLOGY PROJECT
GEORGIA POWER COMPANY - PLANT HAMMOND UNIT FOUR

CEM CALIBRATION DRIFT DETERMINATION

SYSTEM	KVB-SO2		
MANUFACTURER	WESTERN RESEARCH	GAS	SO2
MODEL	721-AT	SPAN RANGE	2500PPM
SERIAL NUMBER	89-721AT2-7543-3	OPERATOR	JOSE PEREZ

SPAN DRIFT

DAY	DATE	TIME	CALIBRATION VALUE PPM	MONITOR VALUE PPM	DIFFERENCE IN PPM	PERCENT OF SPAN VALUE
START	23-Jul-92	08:03 AM	1500	1488	-12	-0.48%
1	24-Jul-92	08:05 AM	1500	1489	-11	-0.44%
2	25-Jul-92	08:03 AM	1500	1497	-3	-0.12%
3	26-Jul-92	08:03 AM	1500	1481	-19	-0.76%
4	27-Jul-92	08:03 AM	1500	1474	-26	-1.04%
5	28-Jul-92	08:03 AM	1500	1494	-6	-0.24%
6	29-Jul-92	07:28 AM	1500	1501	1	0.04%
7	30-Jul-92	08:03 AM	1500	1504	4	0.16%

ZERO DRIFT

DAY	DATE	TIME	CALIBRATION VALUE PPM	MONITOR VALUE PPM	DIFFERENCE IN PPM	PERCENT OF SPAN VALUE
START	23-Jul-92	07:56 AM	0	29	29	1.16%
1	24-Jul-92	07:57 AM	0	18	18	0.72%
2	25-Jul-92	07:56 AM	0	16	16	0.64%
3	26-Jul-92	07:56 AM	0	11	11	0.44%
4	27-Jul-92	07:56 AM	0	15	15	0.60%
5	28-Jul-92	07:56 AM	0	26	26	1.04%
6	29-Jul-92	07:21 AM	0	31	31	1.24%
7	30-Jul-92	07:56 AM	0	29	29	1.16%

%SPAN = ((INSTRUMENT RESPONSE - EXPECTED CONCENTRATION)/SPAN VALUE)*100

RELATIVE ACCURACY DETERMINATION

SPECTRUM SYSTEMS INC.
PENSACOLA, FLORIDA 32526-7808

DATE - AUGUST 20 1992
SOURCE - HAMMOND UNIT 4

CEM SERIAL NUMBERS	
SO2	89-721AT2-7543-3
NOX	10AR-25464-222
O2	CO58405(B)-1
CO2	
CO	

CEM	DRY
RM	DRY

Run Number	Run Start Time	SO2 PPM			NOX PPM			O2 %			CO2 %			CO PPM		
		RM-6C	CEM	DIFF	RM-7E	CEM	DIFF	RM-3A	CEM	DIFF	RM-3A	CEM	DIFF	RM-10	CEM	DIFF
1	10:11	954.8	1016.00	61.18	218.9	207.50	-11.40	7.57	6.70	-0.87						
2	10:48	933.9	983.40	49.52	227.0	213.80	-13.17	7.87	6.90	-0.97						
3	11:21	937.1	998.50	61.37	223.7	211.60	-12.12	7.77	6.80	-0.97						
4	11:53	947.5	999.90	52.43	225.0	210.80	-14.25	7.67	6.70	-0.97						
5	12:26	943.8	991.80	48.05	228.9	212.30	-16.56	7.72	6.80	-0.92						
6	13:00	954.4	1007.00	52.60	207.5	193.90	-13.59	7.47	6.60	-0.87						
7	13:33	969.7	1029.90	60.17	215.2	202.30	-12.90	7.26	6.40	-0.86						
8	14:05	943.5	990.05	46.52	221.3	206.30	-14.97	7.67	6.70	-0.97						
9	14:37	944.7	999.70	55.01	221.1	206.50	-14.60	7.67	6.70	-0.97						
10																
11																
12																
AVERAGE		947.71	1001.81	54.09	220.95	207.22	-13.73	7.63	6.70	-0.93						
CONFIDENCE COEFFICIENT				4.39			1.20			0.04						
RELATIVE ACCURACY				6.17			6.76			12.68						

Run Number	Run Start Time	SO2 #/MMBTU			NOX #/MMBTU			CO* PPM		
		RM-6C	CEM	DIFF	RM-7E	CEM	DIFF	RM-10	CEM	DIFF
1	10:11	2.43	2.43	-0.00	0.4007	0.3566	-0.0441			
2	10:48	2.43	2.38	-0.05	0.4251	0.3727	-0.0524			
3	11:21	2.42	2.40	-0.02	0.4158	0.3663	-0.0496			
4	11:53	2.43	2.39	-0.04	0.4151	0.3623	-0.0528			
5	12:26	2.43	2.39	-0.04	0.4238	0.3675	-0.0563			
6	13:00	2.41	2.39	-0.02	0.3770	0.3309	-0.0460			
7	13:33	2.41	2.41	-0.00	0.3852	0.3405	-0.0447			
8	14:05	2.42	2.37	-0.05	0.4081	0.3546	-0.0536			
9	14:37	2.42	2.39	-0.03	0.4078	0.3549	-0.0529			
10										
11										
12										
AVERAGE		2.423	2.394	-0.029	0.4065	0.3563	-0.0503			
CONFIDENCE COEFFICIENT				0.015			0.0034			
RELATIVE ACCURACY				1.82			13.19			

V. APPENDIX

NOTICE OF FIELD CERTIFICATION - KVB CEMS

Certification is hereby given that the KVB stack gas monitoring system (S/N 50525) described below has been installed, tested, and satisfactorily evaluated in accordance with EPA requirements, CFR, Title 40, Part 60, Appendix B, Specification 2 as promulgated in the May 25, 1983 Federal Register, Vol. 48, No. 102, Part IV. Relative accuracy and calibration drift have been demonstrated over the required seven (7) day period in accordance with Paragraph 6 and have been shown to meet specification. Copies of the attached certified test data can be submitted to the appropriate regulator agency in compliance with source performance monitoring requirements. Additional copies are available by request from Spectrum Systems, Inc.

Customer: Georgia Power Company, Plant Hammond, Unit #4

Diluent O_2 Serial Number: CO58405(B)-1

721-AT SO_2 Stack Gas Monitor s/n: 89-721AT2-7543-3

10 A/R NO_x Stack Gas Monitor s/n: 10 A/R-25864-222

Gas: SO_2	**Gas: NO_x**
Measurement Range ppm: 0-2500	Measurement Range ppm: 0-2500
Data Logger - Model: Kaye 4M Plus	Data Logger - Model: Kaye 4M Plus
Instrument Output (MA/DC): 4-20	Instrument Output (MA/DC): 4-20

Certification Test Results:	***SO_2***	***NO_x***	***O_2***	***EPA Specs.***
Zero Drift (24 hr.):	1.24%	0.00%	-----	less than or equal to 2.5% per day
	----	----	0.20%	less than or equal to 0.5% O_2 per day
Calibration Drift (24 hr.)	-1.04%	-.36%	----	less than or equal to 2.5% per day
	----	----	0.00%	less than or equal to 0.5% O_2 per day
Relative Accuracy	1.82%	13.19%	----	less than or equal to 20%

Test Performed by: R. Davis Date: August 20, 1992

Test Reviewed by: Nick Dixon Date: August 26, 1992

REPORT CERTIFICATION

The sampling and analysis for this report was carried out under my direction and supervision.

Date: August 26, 1992 Signature: ________________

Reginald Davis
Field Engineer

I have reviewed the testing details and results in this report and hereby certify that the test report is authentic and accurate to the best of my knowledge.

Date: August 26, 1992 Signature: ________________

Nick Dixon
Service Manager

APPENDIX C
Ultramax Exploratory Experiment - July 1992

ULTRAMAX PROBLEM FORMULATION

PLANT HAMMOND EXPLORATORY EXPERIMENT 07:12 MON, 03 AUG 1992

VAR #	NAME	UNITS	TY PE	MO DE	TR SF	PRIOR REGION LO	PRIOR REGION HI	CONSTRAINTS LO	CONSTRAINTS HI
1	TOTAL AIR	MPPH	1	H	0	3.4	4.	3.35	5.
2	OFA W FRONT	KPPH	1	H	0	120.	160.	50.	250.
3	OFA E FRONT	KPPH	1	H	0	120.	160.	50.	250.
4	OFA W REAR	KPPH	1	H	0	120.	160.	50.	250.
5	OFA E REAR	KPPH	1	H	0	120.	160.	50.	250.
6	TOTAL COAL	KPPH	2	H	0	100.	370.17	0.	500.
7	LOAD	MW	0	H	0	100.	460.	0.	0.
8	FLUEGAS TEMP	F	0	H	0	200.	800.	0.	0.
9	KVB SO2	PPM	0	H	0	500.	900.	0.	0.
10	KVB THC	PPM	0	H	0	0.	5.	0.	0.
11	KVB O2	PCT	4	H	0	5.	15.	0.	0.
12	KVB CO	PPM	5	H	0	25.	60.	0.	40.
13	ECON O2	PCT	5	H	0	3.	19.	2.5	25.
14	OPACITY	PCT	5	H	0	10.	15.	0.	30.
15	LOI	PCT	0	C	0	1.	4.	0.	0.
16	LOSSES	PCT	0	C	0	4.	8.	0.	0.
17	KVB NOX	LBS/MBTU	6	H	0	0.2	0.4	0.	0.5

MINIMIZING variable # 17 KVB NOX (Type 6)

LIST of NON-DEFAULT PARAMETERS (if any). Parameters control Operations, Data entry, or Reports. See Users Guide Ch.9, "Problem Formulation". Parameters with no description should be reset to default.

```
PAR(10) =   1.8   Size of AREA OF CONFIDENCE
PAR(11) =   1.5   Factor of PAR(10) to limit TRAVEL
PAR(40) =    0.   Do not limit ADVICE to AREA OF CONFIDENCE
PAR(45) =    1.   Local models with fixed selection rule
PAR(55) =    2.   Terminal: NORMAL MODE (Needs ANSI.SYS Driver)
PAR(56) =    0.   Line printer: LPT1
PAR(57) =    1.   Reports saved automatically
```

LIST of GLOBAL FACTORS (if any)

```
GLOBAL( 1) =      2.83   LOI CALC. COEF.
GLOBAL( 2) =    -1.866   LOI CALC. COEF.
GLOBAL( 3) =   0.00652   LOI CALC. COEF.
GLOBAL( 4) =   0.01026   LOI CALC. COEF.
GLOBAL( 5) =  -0.01164   LOI CALC. COEF.
GLOBAL( 6) =-0.009486   LOI CALC. COEF.
GLOBAL( 7) =   0.02711   LOI CALC. COEF.
GLOBAL(16) =    14093.   HEAT OF COMBUSTION FOR C
GLOBAL(17) =   -24.952   H CALC. COEF.
GLOBAL(18) =   0.25976   H CALC. COEF.
GLOBAL(19) =   0.48571   H CALC. COEF.
GLOBAL(20) =    0.0974   ASH IN COAL (9.74%)
GLOBAL(21) =    0.7276   C IN COAL
GLOBAL(22) =    12862.   HEAT OF COMBUSTION FOR COAL
GLOBAL(23) =     4347.   HEAT OF COMBUSTION FOR CO
GLOBAL(24) =     0.005   MULTIPLICATIVE RADIATION LOSSES FACTOR
GLOBAL(25) =      0.02   MULTIPLICATIVE "UNCOUNTED FOR" LOSSES FA
GLOBAL(26) =     970.3   LATENT HEAT (BTU/lb)
GLOBAL(27) =       5.6   % PERCENT MOISTURE BY WEIGHT
```

Contd. ...

```
GLOBAL(28) =    0.505   WATER IN COAL
```

M O D E L   S H A P E   R E P O R T S

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT
ULTRAMAX 4.1 (R): Copyright 1982-90,Ultramax Corp.
07:15 MON, 03 AUG 1992

17 KVB NOX   MIN. PREDICTION ERROR =   0.020
% VAR. EXPL. (R2, Adj.R2, Signal): 86.3 59.8 84.8
MODEL TYPE : LOCAL FIXED-POINT-CENTERED QUADRATIC
Count, Latest, Active : 42 42 41.93
COEF.FIT, # DEG.FREED, # PRIOR : 28 13.90 0.00
DISCRIMINATION PARAMETERS : 0. 0.001 34.00 34.00

#	VARIABLE	UNITS	T	E	REF.	2S-SPREAD	EFFECTS IN 2S-SPREAD Linear	Curvatures		
DEGREE:							1	2.	2.	2.
17	KVB NOX	LBS/MBTU	6	H	0.391	0.062	1.13	1.02	-0.42	0.37
1	TOTAL AIR	MPPH	1	H	3.54	0.28	0.96	0.04	0.11	0.01
2	OFA W FRONT	KPPH	1	H	122.	154.	-0.06	-0.03	0.04	0.11
3	OFA E FRONT	KPPH	1	H	121.	109.	-0.41	-0.17	-0.02	0.00
4	OFA W REAR	KPPH	1	H	119.	144.	-0.10	-0.02	0.00	0.20
5	OFA E REAR	KPPH	1	H	142.	140.	-0.15	-0.09	-0.18	0.02
6	TOTAL COAL	KPPH	2	H	320.8	8.7	0.39	0.68	-0.07	0.03

Standard Distance of REFERENCE 1.4   Set at Default: LOCAL CENTER

#	VARIABLE	REFERENCE	2S-SPREAD	CURVATURES	
DEGREE:				2.	2.
17	KVB NOX	0.391	0.062	0.27	-0.20
1	TOTAL AIR	3.54	0.28	-0.02	0.03
2	OFA W FRONT	122.	154.	0.15	0.00
3	OFA E FRONT	121.	109.	0.01	0.15
4	OFA W REAR	119.	144.	-0.08	0.00
5	OFA E REAR	142.	140.	0.00	-0.01
6	TOTAL COAL	320.8	8.7	0.01	0.01

RUN #	ACTUAL KVB NOX	MODEL KVB NOX	ERROR
43.00	0.385	0.388	-0.003
42.00	0.391	0.379	0.012
41.00	0.411	0.401	0.010
40.00	0.401	0.400	0.001
39.00	0.399	0.414	-0.015
38.00	0.410	0.414	-0.004
37.00	0.406	0.392	0.014
36.00	0.444	0.431	0.013
35.00	0.443	0.440	0.003
34.00	0.402	0.391	0.011
33.00	0.377	0.366	0.011
32.00	0.375	0.374	0.001
31.00	0.361	0.367	-0.006
30.00	0.391	0.393	-0.002
29.00	0.388	0.390	-0.002

Contd. ...

28.00	0.427	0.430	-0.003
27.00	0.363	0.378	-0.015
26.00	0.425	0.412	0.013
25.00	0.425	0.430	-0.005
24.00	0.401	0.395	0.006
23.00	0.355	0.352	0.003
22.00	0.360	0.374	-0.014
21.00	0.390	0.400	-0.010
20.00	0.421	0.429	-0.008
19.00	0.388	0.389	-0.001
18.00	0.383	0.385	-0.002
17.00	0.410	0.412	-0.002
16.00	0.376	0.379	-0.003
15.00	0.373	0.386	-0.013
14.00	0.363	0.364	-0.001
13.00	0.396	0.380	0.016
12.00	0.410	0.389	0.021
11.00	0.414	0.419	-0.005
10.00	0.495	0.501	-0.006
9.00	0.465	0.451	0.014
7.00	0.415	0.435	-0.020
6.00	0.419	0.435	-0.016
5.00	0.385	0.408	-0.023
4.00	0.372	0.390	-0.018
3.00	0.413	0.408	0.005
2.00	0.436	0.416	0.020
1.00	0.483	0.461	0.022

M O D E L   S H A P E   R E P O R T S

PROBLEM: PLANT.HAMMOND EXPLORATORY EXPERIMENT

07:16 MON, 03 AUG 1992

14 OPACITY MIN. PREDICTION ERROR = 4.2
% VAR. EXPL. (R2, Adj.R2, Signal): 85.5 57.3 84.1
MODEL TYPE : LOCAL FIXED-POINT-CENTERED QUADRATIC
Count, Latest, Active : 42 42 41.93
COEF.FIT, # DEG.FREED, # PRIOR : 28 13.90 0.00
DISCRIMINATION PARAMETERS : 0. 0.001 34.00 34.00

#	VARIABLE	UNITS	T	E	REF.	2S-SPREAD	EFFECTS IN 2S-SPREAD Linear	Curvatures		
DEGREE:							1	2.	2.	2.
14	OPACITY	PCT	5	H	15.	13.	0.53	1.93	-0.84	0.44
1	TOTAL AIR	MPPH	1	H	3.54	0.28	0.17	0.10	-0.01	0.02
2	OFA W FRONT	KPPH	1	H	122.	154.	0.11	0.00	0.23	-0.10
3	OFA E FRONT	KPPH	1	H	121.	109.	-0.34	0.00	0.10	0.27
4	OFA W REAR	KPPH	1	H	119.	144.	-0.02	-0.75	-0.10	-0.01
5	OFA E REAR	KPPH	1	H	142.	140.	0.05	-0.01	-0.32	0.02
6	TOTAL COAL	KPPH	2	H	320.8	8.7	-0.35	1.07	-0.08	-0.02

Standard Distance of REFERENCE 1.4 Set at Default: LOCAL CENTER

#	VARIABLE	REFERENCE	2S-SPREAD	CURVATURES	
DEGREE:				2.	2.
14	OPACITY	15.	13.	-0.23	0.12
1	TOTAL AIR	3.54	0.28	-0.08	0.04
2	OFA W FRONT	122.	154.	0.01	0.00
3	OFA E FRONT	121.	109.	0.05	0.00
4	OFA W REAR	119.	144.	0.03	0.04
5	OFA E REAR	142.	140.	0.00	-0.02
6	TOTAL COAL	320.8	8.7	0.05	0.01

RUN #	ACTUAL OPACITY	MODEL OPACITY	ERROR
43.00	21.7	17.9	3.8
42.00	19.2	20.7	-1.5
41.00	18.4	17.0	1.4
40.00	19.9	24.2	-4.3
39.00	20.5	20.6	-0.1
38.00	18.6	21.3	-2.7
37.00	20.4	15.4	5.0
36.00	19.3	19.6	-0.3
35.00	24.6	26.0	-1.4
34.00	21.6	17.7	3.9
33.00	19.2	19.1	0.1
32.00	18.2	20.8	-2.6
31.00	21.2	16.8	4.4
30.00	15.6	17.9	-2.3
29.00	54.4	50.3	4.1

Contd. ...

28.00	19.9	20.2	-0.3
27.00	16.3	17.6	-1.3
26.00	17.1	17.0	0.1
25.00	25.1	24.6	0.5
24.00	22.1	24.6	-2.5
23.00	27.6	28.1	-0.5
22.00	16.9	17.2	-0.3
21.00	16.4	20.7	-4.3
20.00	24.4	23.5	0.9
19.00	19.9	20.5	-0.6
18.00	17.9	17.9	0.0
17.00	18.3	15.5	2.8
16.00	16.7	17.8	-1.1
15.00	14.2	15.6	-1.4
14.00	15.5	19.2	-3.7
13.00	13.0	11.2	1.8
12.00	19.2	16.5	2.7
11.00	15.8	18.6	-2.8
10.00	16.0	16.4	-0.4
9.00	22.2	21.1	1.1
7.00	20.5	17.0	3.5
6.00	15.3	18.6	-3.3
5.00	13.0	15.1	-2.1
4.00	15.1	13.3	1.8
3.00	13.1	14.6	-1.5
2.00	17.5	15.5	2.0
1.00	21.7	20.4	1.3

M O D E L   S H A P E   R E P O R T S

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT
ULTRAMAX 4.1 (R):
07:16 MON, 03 AUG 1992

12 KVB CO   MIN. PREDICTION ERROR =   38.
% VAR. EXPL. (R2, Adj.R2, Signal): 79.3 39.0 78.6
MODEL TYPE : LOCAL FIXED-POINT-CENTERED QUADRATIC
Count, Latest, Active : 42 42 41.93
COEF.FIT, # DEG.FREED, # PRIOR : 28 13.90 0.00
DISCRIMINATION PARAMETERS : 0. 0.001 34.00 34.00

#	VARIABLE	UNITS	T	E	REF.	2S-SPREAD	EFFECTS IN 2S-SPREAD Linear	Curvatures		
DEGREE:							1	2.	2.	2.
12	KVB CO	PPM	5	H	61.	97.	1.32	-1.85	-1.30	0.73
1	TOTAL AIR	MPPH	1	H	3.54	0.28	-1.05	-0.04	0.00	0.54
2	OFA W FRONT	KPPH	1	H	122.	154.	0.17	-0.14	0.02	0.01
3	OFA E FRONT	KPPH	1	H	121.	109.	0.28	-0.50	0.00	-0.02
4	OFA W REAR	KPPH	1	H	119.	144.	0.42	-0.08	0.08	-0.14
5	OFA E REAR	KPPH	1	H	142.	140.	0.47	0.27	1.03	0.00
6	TOTAL COAL	KPPH	2	H	320.8	8.7	-0.39	0.82	-0.16	0.00

Standard Distance of REFERENCE 1.4   Set at Default: LOCAL CENTER

#	VARIABLE	REFERENCE	2S-SPREAD	CURVATURES	
DEGREE:				2.	2.
12	KVB CO	61.	97.	0.58	-0.37
1	TOTAL AIR	3.54	0.28	0.00	-0.02
2	OFA W FRONT	122.	154.	-0.06	0.29
3	OFA E FRONT	121.	109.	0.37	0.00
4	OFA W REAR	119.	144.	0.09	-0.03
5	OFA E REAR	142.	140.	0.03	0.00
6	TOTAL COAL	320.8	8.7	0.03	0.03

RUN #	ACTUAL KVB CO	MODEL KVB CO	ERROR
43.00	96.	44.	52.
42.00	37.	19.	18.
41.00	14.	39.	-25.
40.00	28.	46.	-18.
39.00	40.	24.	16.
38.00	12.	11.	1.
37.00	39.	39.	0.
36.00	7.	19.	-12.
35.00	9.	15.	-6.
34.00	60.	46.	14.
33.00	175.	190.	-15.
32.00	181.	147.	34.
31.00	198.	145.	53.
30.00	6.	50.	-44.
29.00	60.	60.	0.

Contd. ...

28.00	16.	11.	5.
27.00	13.	41.	-28.
26.00	11.	1.	10.
25.00	6.	-3.	9.
24.00	9.	23.	-14.
23.00	74.	80.	-6.
22.00	71.	78.	-7.
21.00	17.	10.	7.
20.00	6.	-32.	38.
19.00	11.	61.	-50.
18.00	8.	13.	-5.
17.00	8.	-13.	21.
16.00	25.	43.	-18.
15.00	22.	23.	-1.
14.00	92.	91.	1.
13.00	11.	26.	-15.
12.00	7.	-4.	11.
11.00	7.	28.	-21.
10.00	6.	9.	-3.
9.00	4.	11.	-7.
7.00	10.	12.	-2.
6.00	7.	-8.	15.
5.00	17.	32.	-15.
4.00	90.	56.	34.
3.00	19.	49.	-30.
2.00	10.	14.	-4.
1.00	6.	-3.	9.

HISTORICAL DATA REPORT (w/RE-CALCULATIONS)

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

07:27 MON, 03 AUG 1992

			RUN #	43	42	41	40	39
1	TOTAL AIR	MPPH	1 H	3.5530	3.4830	3.5330	3.5960	3.7620
2	OFA W FRONT	KPPH	1 H	149.00	176.00	249.00	206.00	106.00
3	OFA E FRONT	KPPH	1 H	135.00	55.000	122.00	106.00	208.00
4	OFA W REAR	KPPH	1 H	45.000	59.000	45.000	206.00	102.00
5	OFA E REAR	KPPH	1 H	241.00	234.00	208.00	106.00	211.00
6	TOTAL COAL	KPPH	2 H	320.00	319.00	320.00	319.00	319.00
7	LOAD	MW	0 H	432.00	430.00	431.00	431.00	432.00
8	FLUEGAS TEMP	F	0 H	322.00	322.00	322.00	321.00	321.00
9	KVB SO2	PPM	0 H	964.00	976.00	947.00	948.00	954.00
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.3000	6.3000	6.7000	6.6000	6.6000
12	KVB CO	PPM	5 H	96.000	37.000	14.000	28.000	40.000
13	ECON O2	PCT	5 H	2.9000	3.1000	3.5000	3.5000	3.5000
14	OPACITY	PCT	5 H	21.700	19.200	18.400	19.900	20.500
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.38500	0.39100	0.41100	0.40100	0.39900

			RUN #	38	37	36	35	34
1	TOTAL AIR	MPPH	1 H	3.5780	3.5860	3.8140	3.8250	3.4760
2	OFA W FRONT	KPPH	1 H	208.00	158.00	57.000	59.000	51.000
3	OFA E FRONT	KPPH	1 H	215.00	162.00	173.00	171.00	57.000
4	OFA W REAR	KPPH	1 H	106.00	151.00	72.000	71.000	239.00
5	OFA E REAR	KPPH	1 H	110.00	141.00	278.00	266.00	225.00
6	TOTAL COAL	KPPH	2 H	329.00	320.00	320.00	325.00	320.00
7	LOAD	MW	0 H	428.00	432.00	432.00	436.00	435.00
8	FLUEGAS TEMP	F	0 H	321.00	322.00	321.00	320.00	319.00
9	KVB SO2	PPM	0 H	953.00	960.00	918.00	923.00	983.00
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.6000	6.6000	7.1000	7.0000	6.4000
12	KVB CO	PPM	5 H	12.000	39.000	7.0000	9.0000	60.000
13	ECON O2	PCT	5 H	3.6000	3.6000	4.0000	3.9000	3.3000
14	OPACITY	PCT	5 H	18.600	20.400	19.300	24.600	21.600
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.41000	0.40600	0.44400	0.44300	0.40200

			RUN #	33	32	31	30	29
1	TOTAL AIR	MPPH	1 H	3.3830	3.4260	3.3680	3.5060	3.3670
2	OFA W FRONT	KPPH	1 H	93.000	109.00	217.00	54.000	98.000
3	OFA E FRONT	KPPH	1 H	124.00	95.000	112.00	89.000	78.000
4	OFA W REAR	KPPH	1 H	244.00	235.00	195.00	46.000	108.00
5	OFA E REAR	KPPH	1 H	97.000	188.00	71.000	197.00	72.000
6	TOTAL COAL	KPPH	2 H	322.00	321.00	322.00	317.00	308.00
7	LOAD	MW	0 H	433.00	436.00	435.00	429.00	417.00
8	FLUEGAS TEMP	F	0 H	320.00	319.00	317.00	316.00	313.00
9	KVB SO2	PPM	0 H	1007.0	1017.0	1029.0	1025.0	1024.0
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.1000	6.2000	6.0000	5.9000	6.1000
12	KVB CO	PPM	5 H	175.00	181.00	198.00	6.0000	60.000
13	ECON O2	PCT	5 H	2.8000	2.9000	2.7000	2.9000	2.8000
14	OPACITY	PCT	5 H	19.200	18.200	21.200	15.600	54.400
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.37700	0.37500	0.36100	0.39100	0.38800

			RUN #	28	27	26	25	24
1	TOTAL AIR	MPPH	1 H	3.6960	3.4140	3.5270	3.7030	3.5470
2	OFA W FRONT	KPPH	1 H	282.00	181.00	55.000	256.00	152.00
3	OFA E FRONT	KPPH	1 H	56.000	48.000	60.000	0.	150.00
4	OFA W REAR	KPPH	1 H	50.000	220.00	67.000	49.000	156.00
5	OFA E REAR	KPPH	1 H	77.000	250.00	84.000	265.00	153.00
6	TOTAL COAL	KPPH	2 H	320.00	323.00	318.00	318.00	316.00
7	LOAD	MW	0 H	433.00	429.00	433.00	428.00	427.00
8	FLUEGAS TEMP	F	0 H	310.00	310.00	312.00	300.00	299.00
9	KVB SO2	PPM	0 H	971.00	977.00	978.00	895.00	917.00
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.7000	6.3000	6.3000	7.1000	6.9000
12	KVB CO	PPM	5 H	16.000	13.200	11.000	6.0000	9.0000
13	ECON O2	PCT	5 H	3.4000	3.0000	3.2000	4.1000	3.8000
14	OPACITY	PCT	5 H	19.900	16.300	17.100	25.100	22.100
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.42700	0.36300	0.42500	0.42500	0.40100

			RUN #	23	22	21	20	19
1	TOTAL AIR	MPPH	1 H	3.3170	3.5290	3.4210	3.6430	3.5140
2	OFA W FRONT	KPPH	1 H	254.00	68.000	105.00	0.	41.000
3	OFA E FRONT	KPPH	1 H	56.000	172.00	127.00	136.00	159.00
4	OFA W REAR	KPPH	1 H	79.000	67.000	46.000	273.00	259.00
5	OFA E REAR	KPPH	1 H	245.00	253.00	79.000	72.000	71.000
6	TOTAL COAL	KPPH	2 H	317.00	319.00	311.00	320.00	321.00
7	LOAD	MW	0 H	427.00	427.00	430.00	431.00	434.00
8	FLUEGAS TEMP	F	0 H	300.00	301.00	302.00	301.00	299.00
9	KVB SO2	PPM	0 H	976.00	991.00	980.00	840.00	963.00
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.2000	6.1000	6.2000	6.8000	6.3000
12	KVB CO	PPM	5 H	74.000	71.000	17.000	6.0000	11.000
13	ECON O2	PCT	5 H	2.9000	2.9000	3.0000	3.6000	3.2000
14	OPACITY	PCT	5 H	27.600	16.900	16.400	24.400	19.900
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.35500	0.36000	0.39000	0.42100	0.38800

			RUN #	18	17	16	15	14
1	TOTAL AIR	MPPH	1 H	3.4810	3.4410	3.3450	3.4860	3.3850
2	OFA W FRONT	KPPH	1 H	94.000	0.	207.00	0.	45.000
3	OFA E FRONT	KPPH	1 H	219.00	68.000	60.000	203.00	137.00
4	OFA W REAR	KPPH	1 H	0.	42.000	41.000	45.000	135.00
5	OFA E REAR	KPPH	1 H	70.000	102.00	72.000	71.000	70.000
6	TOTAL COAL	KPPH	2 H	323.00	319.00	321.00	321.00	317.00
7	LOAD	MW	0 H	433.00	437.00	432.00	434.00	430.00
8	FLUEGAS TEMP	F	0 H	299.00	300.00	299.00	299.00	299.00
9	KVB SO2	PPM	0 H	992.00	1002.0	1020.0	1019.0	1032.0
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.0000	5.9000	5.7000	5.7000	5.7000
12	KVB CO	PPM	5 H	8.0000	8.0000	25.000	22.000	92.000
13	ECON O2	PCT	5 H	3.1000	3.0000	2.8000	2.8000	2.7000
14	OPACITY	PCT	5 H	17.900	18.300	16.700	14.200	15.500
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.38300	0.41000	0.37600	0.37300	0.36300

			RUN #	13	12	11	10	9
1	TOTAL AIR	MPPH	1 H	3.4460	3.5420	3.4910	3.9220	3.7050
2	OFA W FRONT	KPPH	1 H	100.00	0.	0.	43.000	164.00
3	OFA E FRONT	KPPH	1 H	158.00	221.00	49.000	58.000	56.000
4	OFA W REAR	KPPH	1 H	56.000	60.000	200.00	47.000	165.00
5	OFA E REAR	KPPH	1 H	73.000	76.000	76.000	204.00	79.000
6	TOTAL COAL	KPPH	2 H	321.00	318.00	320.00	319.00	322.00
7	LOAD	MW	0 H	434.00	435.00	435.00	438.00	442.00
8	FLUEGAS TEMP	F	0 H	298.00	298.00	298.00	298.00	295.00
9	KVB SO2	PPM	0 H	979.00	967.00	954.00	881.00	883.00
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.1000	6.3000	6.4000	7.2000	7.2000
12	KVB CO	PPM	5 H	11.000	7.0000	7.0000	6.0000	4.0000
13	ECON O2	PCT	5 H	3.3000	3.5000	3.3000	7.5000	4.4000
14	OPACITY	PCT	5 H	13.000	19.200	15.800	16.000	22.200
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.39600	0.41000	0.41400	0.49500	0.46500

			RUN #	7	6	5	4	3
1	TOTAL AIR	MPPH	1 H	3.6670	3.5190	3.5670	3.4320	3.4480
2	OFA W FRONT	KPPH	1 H	149.00	146.00	143.00	134.00	195.00
3	OFA E FRONT	KPPH	1 H	140.00	140.00	136.00	131.00	137.00
4	OFA W REAR	KPPH	1 H	148.00	140.00	131.00	130.00	146.00
5	OFA E REAR	KPPH	1 H	130.00	121.00	119.00	116.00	129.00
6	TOTAL COAL	KPPH	2 H	325.00	329.00	324.00	326.00	328.00
7	LOAD	MW	0 H	443.00	443.00	443.00	442.00	444.00
8	FLUEGAS TEMP	F	0 H	294.00	293.00	292.00	293.00	300.00
9	KVB SO2	PPM	0 H	945.00	938.00	982.00	989.00	971.00
10	KVB THC	PPM	0 H	0.	0.	0.	0.	0.
11	KVB O2	PCT	4 H	6.7000	6.7000	6.3000	6.0000	6.4000
12	KVB CO	PPM	5 H	10.000	7.0000	17.000	90.000	19.000
13	ECON O2	PCT	5 H	3.8000	3.8000	3.3000	2.9000	3.3000
14	OPACITY	PCT	5 H	20.500	15.300	13.000	15.100	13.100
15	LOI	PCT	0 C	2.5000	2.5000	2.5000	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000	6.0000	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.41500	0.41900	0.38500	0.37200	0.41300

			RUN #	2	1
1	TOTAL AIR	MPPH	1 H	3.4030	3.6940
2	OFA W FRONT	KPPH	1 H	148.00	156.00
3	OFA E FRONT	KPPH	1 H	144.00	151.00
4	OFA W REAR	KPPH	1 H	151.00	157.00
5	OFA E REAR	KPPH	1 H	124.00	142.00
6	TOTAL COAL	KPPH	2 H	331.00	328.00
7	LOAD	MW	0 H	445.00	446.00
8	FLUEGAS TEMP	F	0 H	300.00	300.00
9	KVB SO2	PPM	0 H	949.00	907.00
10	KVB THC	PPM	0 H	0.	0.
11	KVB O2	PCT	4 H	6.6000	7.0000
12	KVB CO	PPM	5 H	10.000	6.0000
13	ECON O2	PCT	5 H	3.5000	4.1000
14	OPACITY	PCT	5 H	17.500	21.700
15	LOI	PCT	0 C	2.5000	2.5000
16	LOSSES	PCT	0 C	6.0000	6.0000
17	KVB NOX	LBS/MBTU	6 H	0.43600	0.48300

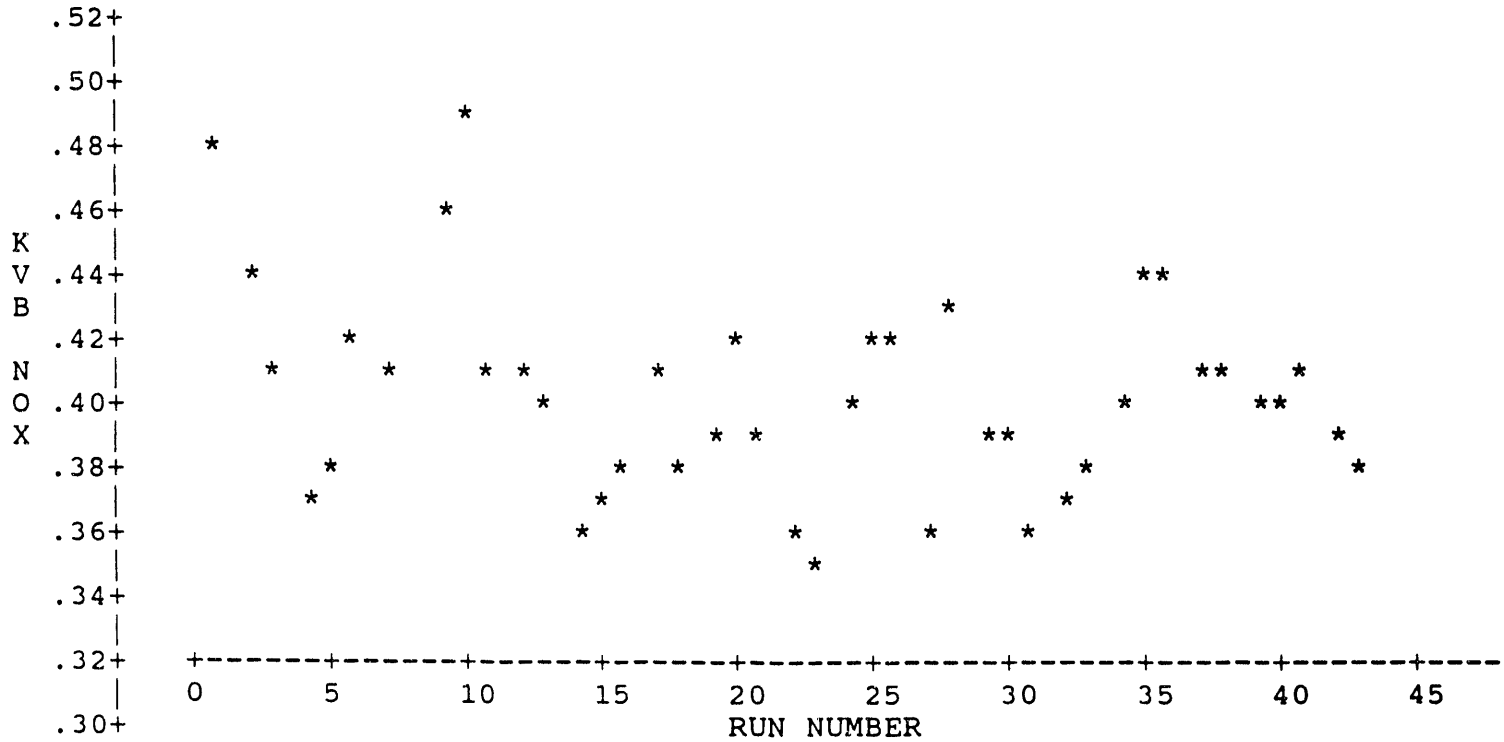
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

07:20 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 17 KVB NOX

HORIZONTAL VARIABLE: 0 RUN NUMBER



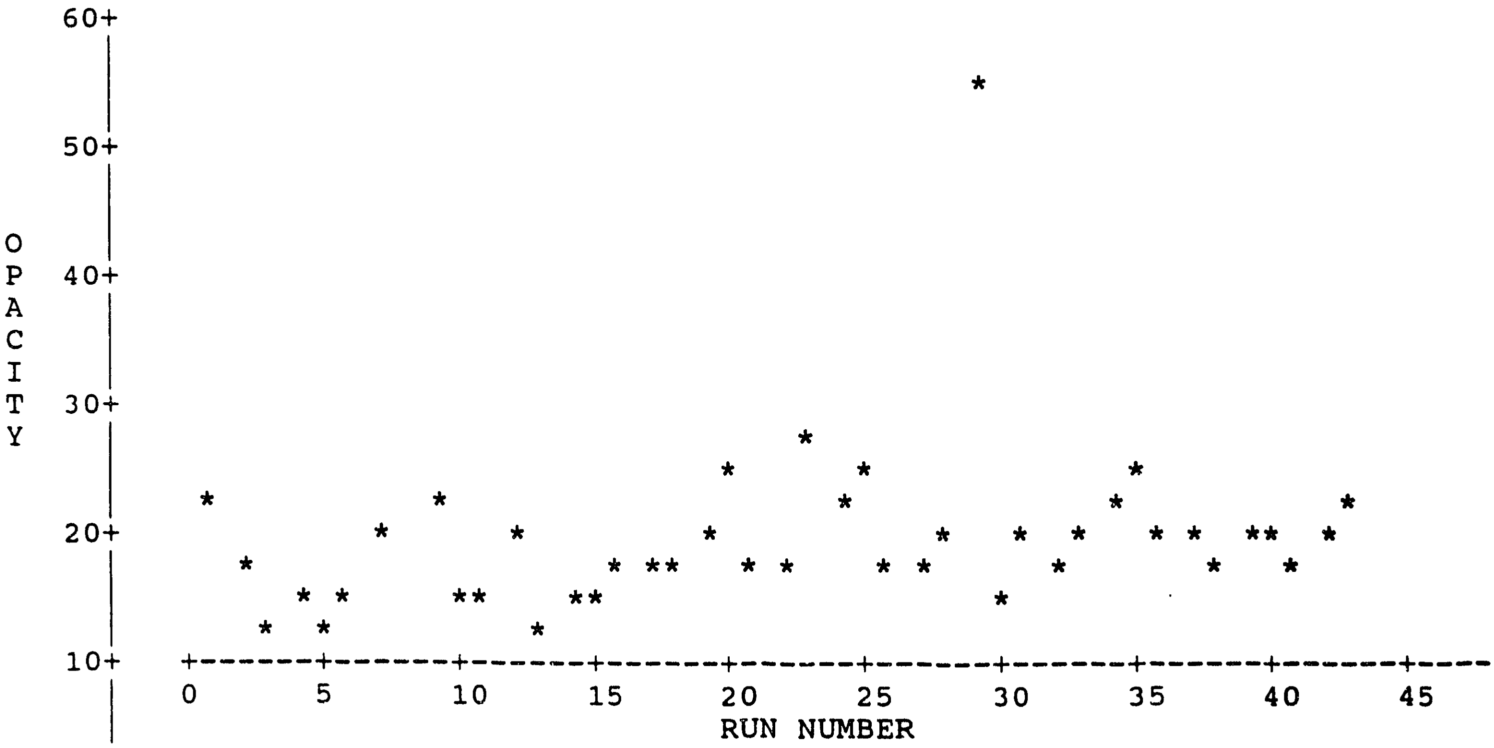
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

07:21 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 14 OPACITY

HORIZONTAL VARIABLE: 0 RUN NUMBER



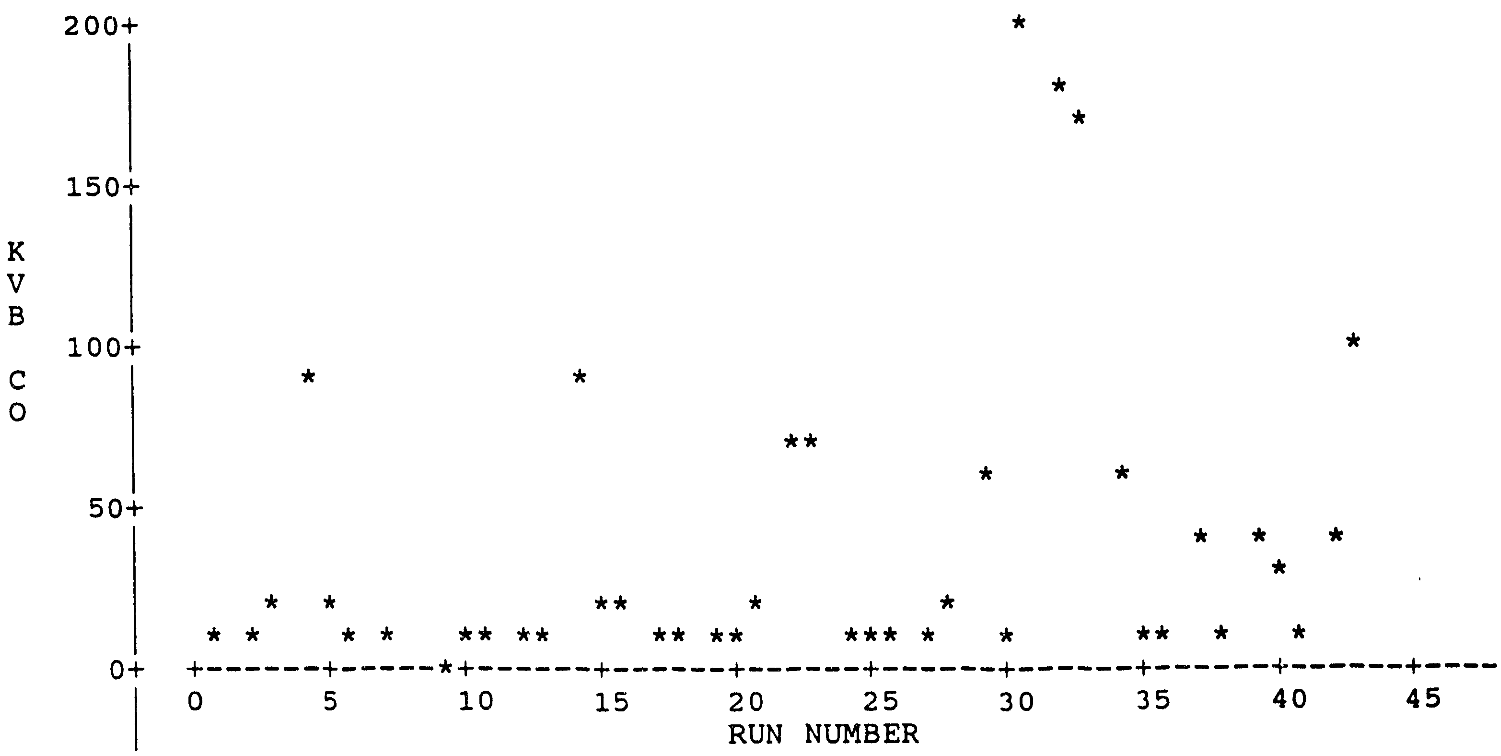
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

09:17 TUE, 04 AUG 1992

VERTICAL VARIABLE(S): 12 KVB CO

HORIZONTAL VARIABLE: 0 RUN NUMBER



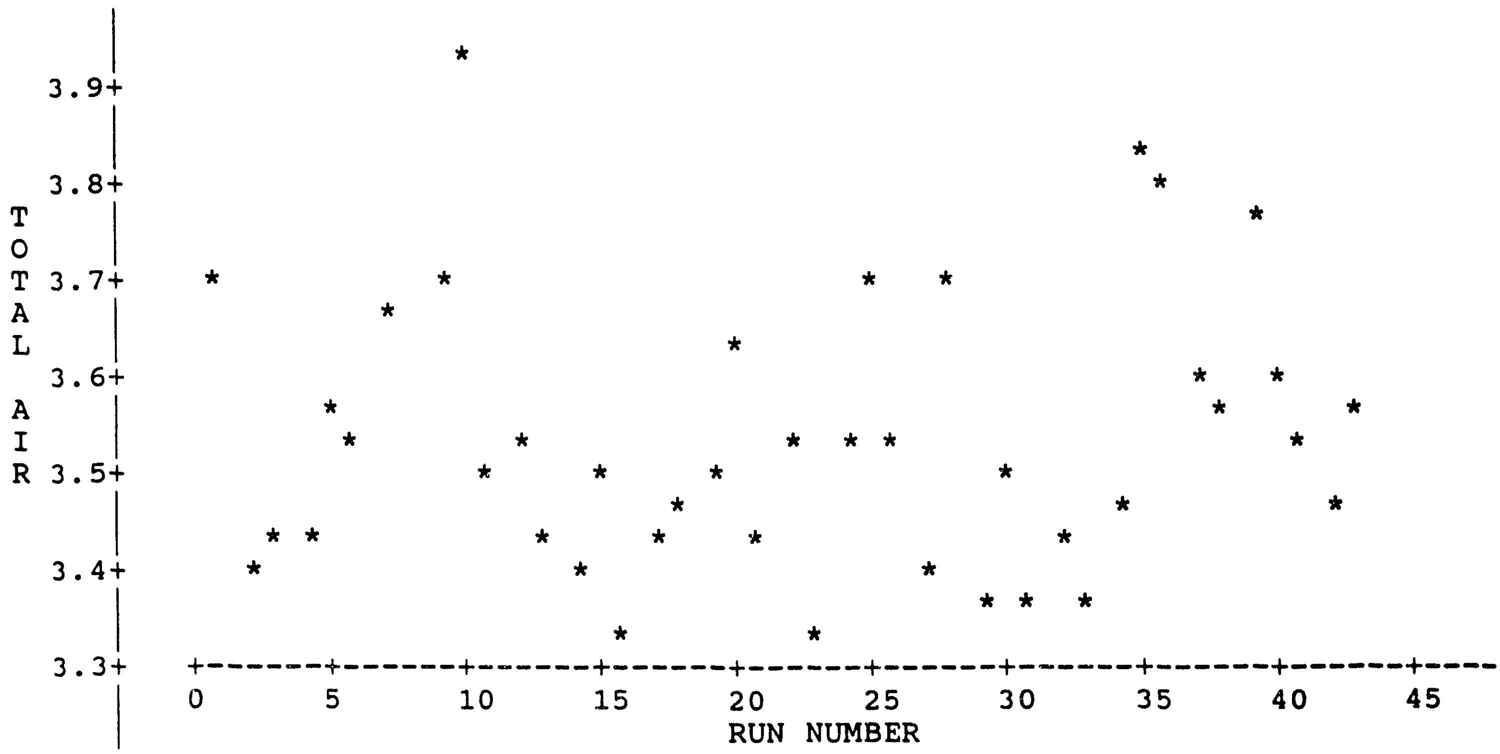
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

07:22 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 1 TOTAL AIR

HORIZONTAL VARIABLE: 0 RUN NUMBER



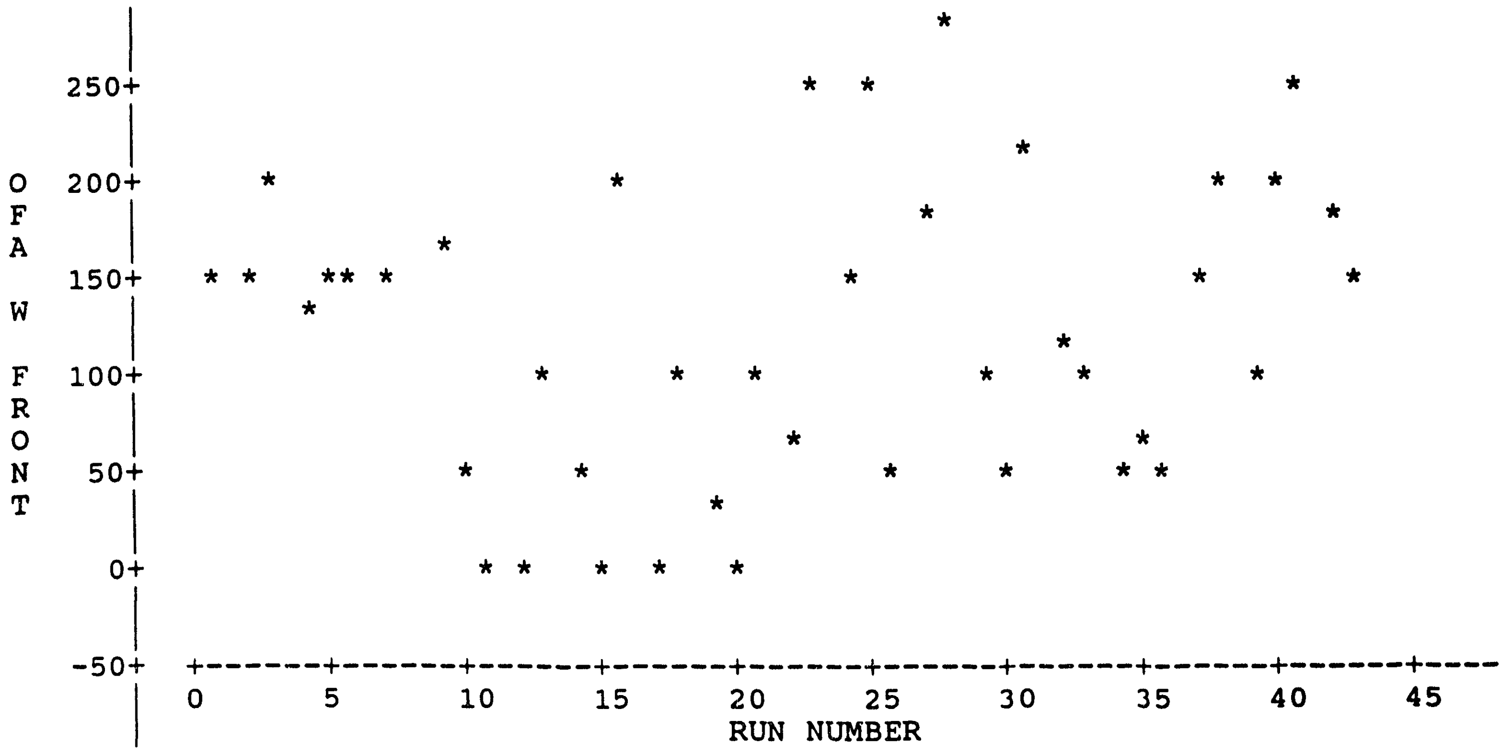
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

14:54 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 2 OFA W FRONT

HORIZONTAL VARIABLE: 0 RUN NUMBER



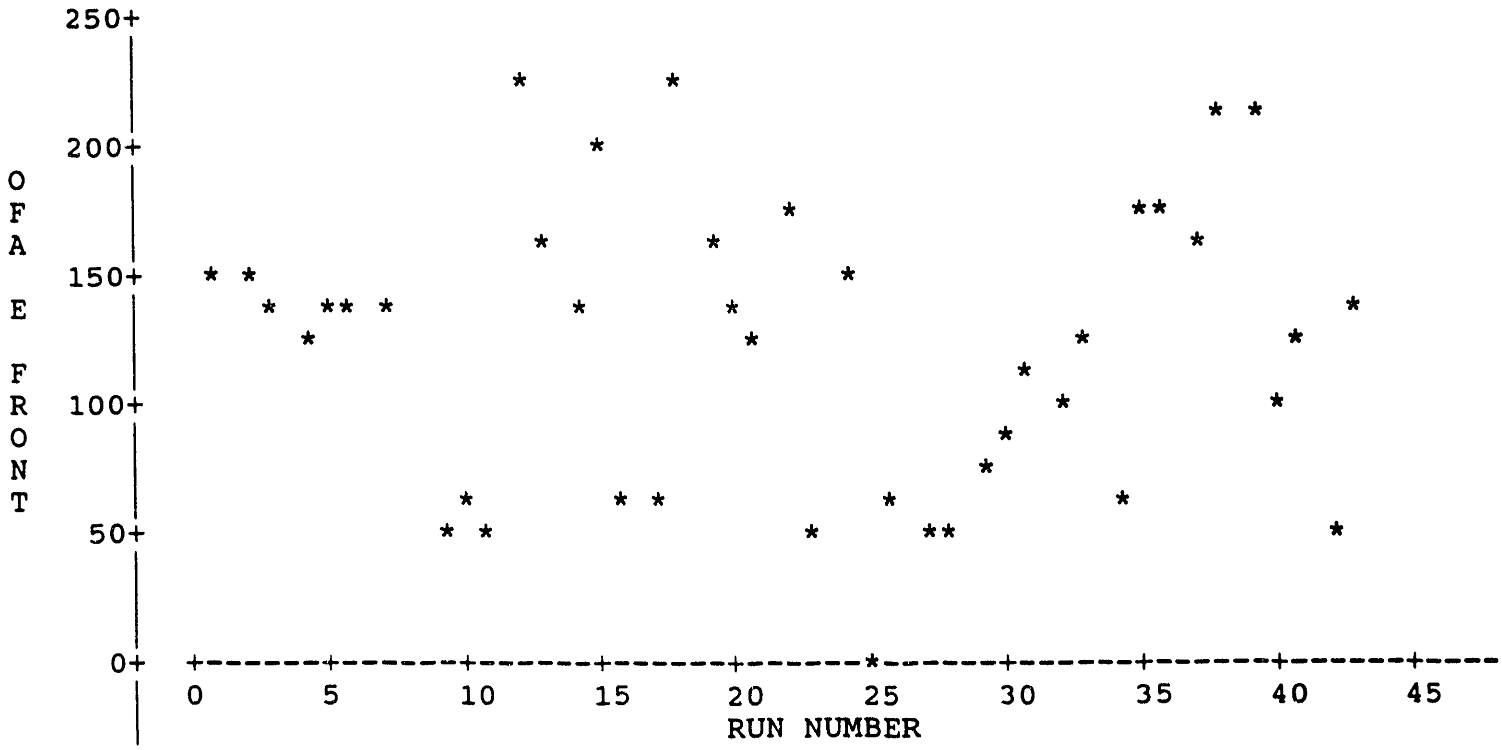
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

14:54 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 3 OFA E FRONT

HORIZONTAL VARIABLE: 0 RUN NUMBER



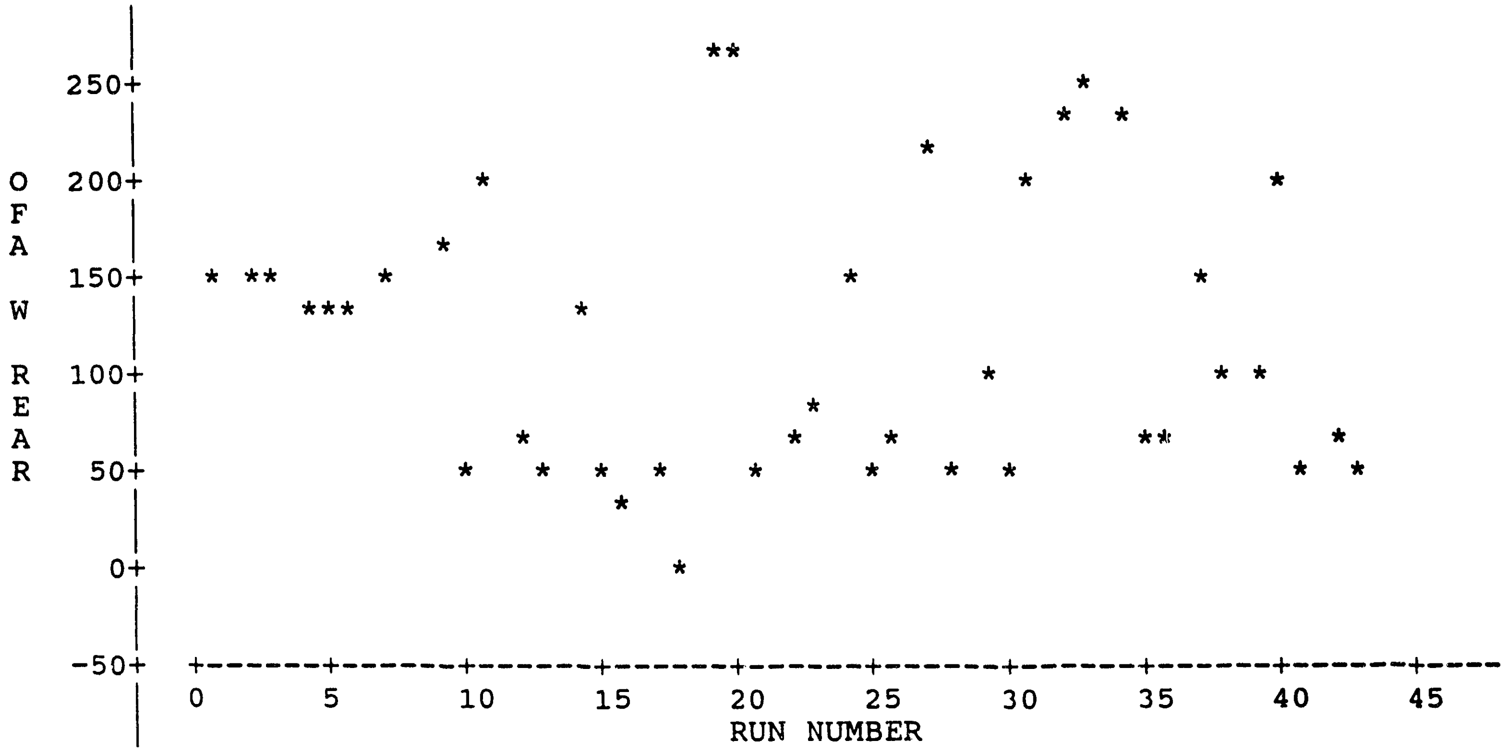
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

14:54 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 4 OFA W REAR

HORIZONTAL VARIABLE: 0 RUN NUMBER



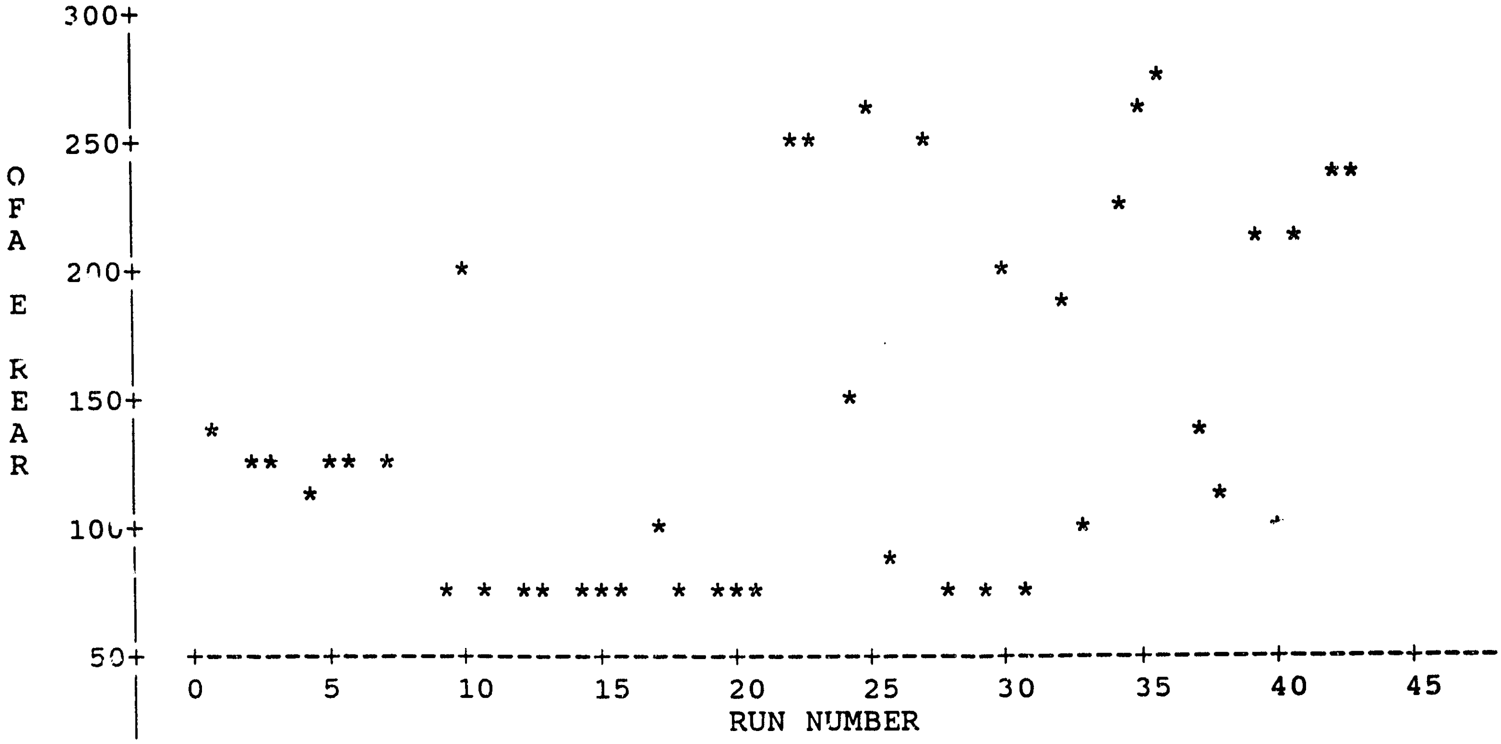
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

14:54 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 5 OFA E REAR

HORIZONTAL VARIABLE: 0 RUN NUMBER



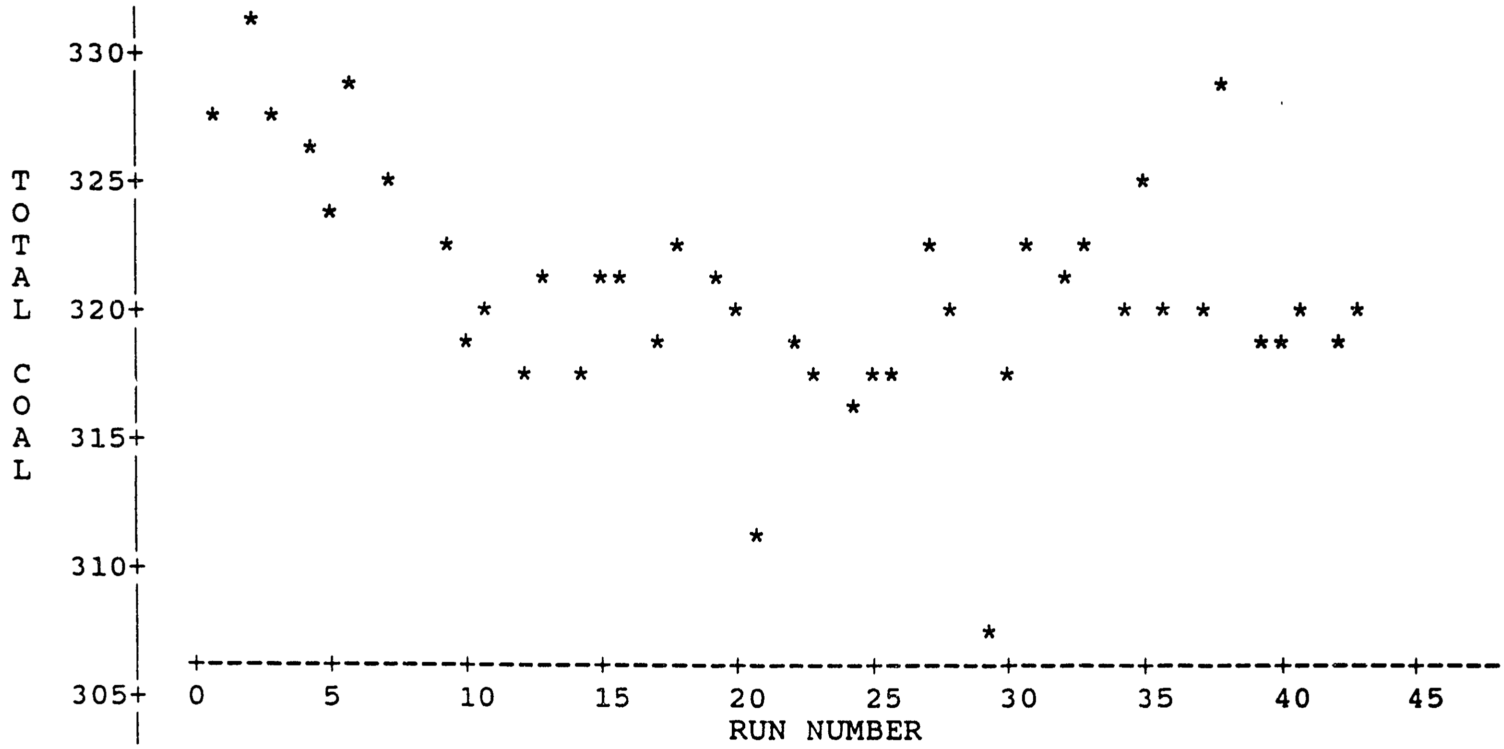
PLOT REPORT

PROBLEM: PLANT HAMMOND EXPLORATORY EXPERIMENT

14:55 MON, 03 AUG 1992

VERTICAL VARIABLE(S): 6 TOTAL COAL

HORIZONTAL VARIABLE: 0 RUN NUMBER



APPENDIX D
Ultramax Exploratory Experiment - September 1992

ULTRAMAX PROBLEM FORMULATION

PLANT HAMMOND - EXPERIMENT #2. 16:38 THU, 01 OCT 1992

VAR #	NAME	UNITS	TYPE	MODE	TRSF	PRIOR REGION LO	PRIOR REGION HI	CONSTRAINTS LO	CONSTRAINTS HI
1	TOTAL AIR	MPPH	0	H	0	3.4	3.6	2.4	5.
2	AIR EAST	MPPH	1	H	0	1.8	2.	1.8	2.3
3	AIR WEST	MPPH	1	H	0	1.3	1.6	1.3	1.6
4	OFA W FRONT	KPPH	1	H	0	50.	250.	25.	260.
5	OFA E FRONT	KPPH	1	H	0	50.	250.	25.	260.
6	OFA W REAR	KPPH	1	H	0	50.	250.	25.	260.
7	OFA E REAR	KPPH	1	H	0	50.	250.	25.	260.
8	COAL FLOW	KPPH	5	H	0	120.	370.	0.	0.
9	FLUEGAS TEMP	F	5	H	0	200.	800.	0.	0.
10	KVB NOX	PPM	5	H	0	200.	250.	0.	220.
11	KVB CO	PPM	5	H	0	5.	20.	0.	30.
12	OPACITY	PCT	5	H	0	5.	20.	0.	30.
13	HTR O2	PCT	5	H	0	3.	10.	3.	10.
14	LOI EAST	PCT	5	C	0	0.	10.	0.	0.
15	LOI WEST	PCT	5	C	0	0.	10.	0.	0.
16	LOSSES	PCT	6	H	0	0.	10.	0.	15.

MINIMIZING variable # 16 LOSSES (Type 6)

LIST of NON-DEFAULT PARAMETERS (if any). Parameters control Operations, Data entry, or Reports. See Users Guide Ch.9, "Problem Formulation". Parameters with no description should be reset to default.

PAR(10) =	3.	Size of AREA OF CONFIDENCE
PAR(20) =	4.	Fixed # of columns in Results and Advice Report
PAR(30) =	1.	What-if, Synthesis w/LEARN models, ignore CALC models
PAR(40) =	0.	Do not limit ADVICE to AREA OF CONFIDENCE
PAR(45) =	2.	Descriptive models, rather than local
PAR(48) =	3.	Display all Curvatures
PAR(49) =	0.	Static System, old data counts just as much
PAR(55) =	2.	Terminal: NORMAL MODE (Needs ANSI.SYS Driver)
PAR(56) =	0.	Line printer: LPT1
PAR(57) =	0.	Reports not saved automatically
PAR(58) =	1.	Record ALL session on file USESSION.WRK

LIST of GLOBAL FACTORS (if any)

GLOBAL(1) =	5.6	PERCENT MOISTURE IN COAL BY WEIGHT
GLOBAL(2) =	14093.	HEAT OF COMBUSTION OF CARBON (BTU/lb)
GLOBAL(3) =	0.0974	PERCENT ASH IN COAL (9.74%)
GLOBAL(4) =	970.3	LATENT HEAT OF FLUEGAS (BTU/lb)
GLOBAL(5) =	0.085	WATER IN COAL (8.5%)
GLOBAL(6) =	12862.	HEAT OF COMBUSTION OF COAL (BTU/lb)
GLOBAL(7) =	0.005	RADIATION LOSSES (0.5%)
GLOBAL(8) =	0.02	"UNCOUNTED FOR" LOSSES (2%)

*   S I G N A L S   *

Count, Latest, Active :   72   72   72.00

16	LOSSES	71. %
8	COAL FLOW	72. %
9	FLUEGAS TEMP	70. %
10	KVB NOX	94. %
11	KVB CO	88. %
12	OPACITY	71. %
13	HTR O2	90. %
14	LOI EAST	93. %
15	LOI WEST	93. %

M O D E L   S H A P E   R E P O R T S

PROBLEM: PLANT HAMMOND - EXPERIMENT #2.

16:39 THU, 01 OCT 1992

10 KVB NOX MIN. PREDICTION ERROR = 5.9
% VAR. EXPL. (R2, Adj.R2, Signal): 92.5 87.8 94.2
MODEL TYPE : LOCAL FIXED-POINT-CENTERED QUADRATIC
Count, Latest, Active : 72 72 72.00
COEF.FIT, # DEG.FREED, # PRIOR : 28 44.00 0.00
DISCRIMINATION PARAMETERS : 0. 0.000 0.00 0.00

#	VARIABLE	UNITS	T	E	REF.	2S-SPREAD	EFFECTS IN 2S-SPREAD Linear	Curvatures		
DEGREE:							1	2.	2.	2.
10	KVB NOX	PPM	5	H	231.	33.	1.58	5.38	0.38	-0.33
2	AIR EAST	MPPH	1	H	2.11	0.18	0.97	1.77	0.00	0.00
3	AIR WEST	MPPH	1	H	1.48	0.11	-0.16	-1.46	0.00	0.00
4	OFA W FRONT	KPPH	1	H	108.	136.	-0.21	-0.31	0.21	0.03
5	OFA E FRONT	KPPH	1	H	162.	160.	-0.84	-0.38	0.08	-0.07
6	OFA W REAR	KPPH	1	H	142.	177.	-0.55	-0.58	-0.01	0.19
7	OFA E REAR	KPPH	1	H	156.	144.	-0.68	-0.89	-0.07	-0.03

Standard Distance of REFERENCE 1.6 Set at Default: LOCAL CENTER

#	VARIABLE	REFERENCE	2S-SPREAD	CURVATURES		
DEGREE:				2.	2.	2.
10	KVB NOX	231.	33.	-0.18	-0.07	0.02
2	AIR EAST	2.11	0.18	0.01	0.00	0.01
3	AIR WEST	1.48	0.11	-0.02	0.03	0.00
4	OFA W FRONT	108.	136.	-0.01	-0.01	0.00
5	OFA E FRONT	162.	160.	0.09	0.00	0.00
6	OFA W REAR	142.	177.	0.05	0.00	0.00
7	OFA E REAR	156.	144.	0.00	-0.03	0.00

RUN #	ACTUAL KVB NOX	MODEL KVB NOX	ERROR
72.00	217.0	221.9	-4.9
71.00	210.0	207.8	2.2
70.00	210.0	208.9	1.1
69.00	220.0	217.3	2.7
68.00	215.0	216.8	-1.8
67.00	210.0	205.0	5.0
66.00	210.0	212.4	-2.4
65.00	208.0	205.8	2.2
64.00	212.0	214.3	-2.3
63.00	215.0	218.4	-3.4
62.00	209.0	208.4	0.6
61.00	211.0	222.5	-11.5
60.00	208.0	211.2	-3.2
59.00	226.0	241.3	-15.3
58.00	218.0	229.0	-11.0

Contd. ...

57.00	211.0	208.4	2.6
56.00	202.0	203.5	-1.5
55.00	205.0	207.1	-2.1
54.00	218.0	222.0	-4.0
53.00	219.0	222.8	-3.8
52.00	208.0	211.7	-3.7
51.00	222.0	215.1	6.9
50.00	223.0	215.9	7.1
49.00	221.0	218.9	2.1
48.00	221.0	225.9	-4.9
47.00	224.0	226.1	-2.1
46.00	222.0	222.1	-0.1
45.00	228.0	227.8	0.2
44.00	250.0	253.2	-3.2
43.00	237.0	246.0	-9.0
42.00	233.6	237.8	-4.2
41.00	230.0	224.9	5.1
40.00	233.2	231.4	1.8
39.00	237.8	239.1	-1.3
38.00	234.1	227.7	6.5
37.00	232.7	230.6	2.1
36.00	237.8	232.8	5.0
35.00	251.9	244.6	7.3
34.00	242.1	240.6	1.5
33.00	225.7	224.1	1.6
32.00	227.2	219.8	7.4
31.00	221.5	226.4	-5.0
30.00	235.2	241.4	-6.2
29.00	233.3	233.3	0.0
28.00	250.4	249.8	0.5
27.00	216.5	218.4	-1.9
26.00	255.2	250.3	4.8
25.00	243.7	246.0	-2.3
24.00	233.6	231.4	2.1
23.00	212.7	211.6	1.1
22.00	217.3	218.9	-1.5
21.00	234.7	242.3	-7.6
20.00	238.9	237.7	1.2
19.00	232.0	226.8	5.2
18.00	236.2	232.1	4.2
17.00	254.3	252.7	1.6
16.00	235.2	235.3	-0.1
15.00	231.7	231.6	0.1
14.00	227.3	225.7	1.6
13.00	240.8	237.4	3.4
12.00	243.5	239.0	4.6
11.00	245.9	247.9	-2.0
10.00	276.4	272.3	4.1
9.00	261.2	262.0	-0.8
8.00	259.4	258.2	1.2
7.00	244.4	242.7	1.7
6.00	243.6	239.0	4.7
5.00	235.9	233.0	2.9
4.00	227.7	228.0	-0.3
3.00	247.4	248.5	-1.1
2.00	264.9	254.0	10.8
1.00	276.8	278.5	-1.8

M O D E L   S H A P E   R E P O R T S

PROBLEM: PLANT HAMMOND - EXPERIMENT #2.

16:39 THU, 01 OCT 1992

11 KVB CO   MIN. PREDICTION ERROR = 44.
% VAR. EXPL. (R2, Adj.R2, Signal): 75.5 60.4 88.1
MODEL TYPE : LOCAL FIXED-POINT-CENTERED QUADRATIC
Count, Latest, Active : 72 72 72.00
COEF.FIT, # DEG.FREED, # PRIOR : 28 44.00 0.00
DISCRIMINATION PARAMETERS : 0. 0.000 0.00 0.00

#	VARIABLE	UNITS	T	E	REF.	2S-SPREAD	EFFECTS IN 2S-SPREAD Linear	Curvatures		
DEGREE:							1	2.	2.	2.
11	KVB CO	PPM	5	H	65.	138.	0.94	-6.25	1.04	-0.66
2	AIR EAST	MPPH	1	H	2.11	0.18	-0.55	2.14	-0.10	0.11
3	AIR WEST	MPPH	1	H	1.48	0.11	-0.53	-2.20	-0.12	0.00
4	OFA W FRONT	KPPH	1	H	108.	136.	-0.12	-1.23	-0.17	0.00
5	OFA E FRONT	KPPH	1	H	162.	160.	0.40	-0.16	0.36	-0.02
6	OFA W REAR	KPPH	1	H	142.	177.	0.20	-0.12	0.26	0.03
7	OFA E REAR	KPPH	1	H	156.	144.	0.29	-0.40	0.03	0.51

Standard Distance of REFERENCE 1.6   Set at Default: LOCAL CENTER

#	VARIABLE	REFERENCE	2S-SPREAD	CURVATURES		
DEGREE:				2.	2.	2.
11	KVB CO	65.	138.	0.32	-0.26	-0.06
2	AIR EAST	2.11	0.18	0.04	0.01	0.01
3	AIR WEST	1.48	0.11	0.09	0.06	0.00
4	OFA W FRONT	108.	136.	-0.04	-0.03	0.02
5	OFA E FRONT	162.	160.	0.10	-0.03	0.01
6	OFA W REAR	142.	177.	-0.05	0.10	0.01
7	OFA E REAR	156.	144.	0.00	-0.02	0.00

RUN #	ACTUAL KVB CO	MODEL KVB CO	ERROR
72.00	95.	63.	32.
71.00	193.	182.	11.
70.00	281.	203.	78.
69.00	62.	48.	14.
68.00	36.	17.	19.
67.00	90.	117.	-27.
66.00	30.	23.	7.
65.00	124.	109.	15.
64.00	74.	54.	20.
63.00	43.	21.	22.
62.00	120.	93.	27.
61.00	175.	84.	91.
60.00	141.	138.	3.
59.00	10.	14.	-4.
58.00	39.	49.	-10.

Contd. ...

57.00	86.	128.	-42.
56.00	209.	215.	-6.
55.00	117.	143.	-26.
54.00	72.	80.	-8.
53.00	93.	84.	9.
52.00	291.	235.	56.
51.00	2.	65.	-63.
50.00	7.	54.	-47.
49.00	11.	26.	-15.
48.00	4.	23.	-19.
47.00	13.	65.	-52.
46.00	23.	80.	-57.
45.00	17.	40.	-23.
44.00	0.	-29.	29.
43.00	0.	-28.	28.
42.00	48.	12.	36.
41.00	98.	24.	74.
40.00	53.	35.	18.
39.00	20.	12.	7.
38.00	31.	77.	-46.
37.00	22.	51.	-29.
36.00	19.	37.	-18.
35.00	8.	-37.	45.
34.00	40.	53.	-12.
33.00	142.	141.	1.
32.00	181.	162.	20.
31.00	275.	178.	97.
30.00	58.	60.	-2.
29.00	82.	78.	3.
28.00	13.	20.	-7.
27.00	131.	153.	-22.
26.00	19.	9.	10.
25.00	5.	13.	-8.
24.00	7.	27.	-20.
23.00	75.	82.	-7.
22.00	66.	91.	-24.
21.00	25.	15.	10.
20.00	8.	-23.	31.
19.00	10.	87.	-77.
18.00	16.	12.	5.
17.00	11.	12.	-1.
16.00	26.	52.	-27.
15.00	25.	21.	3.
14.00	44.	95.	-52.
13.00	10.	16.	-5.
12.00	7.	3.	4.
11.00	10.	0.	10.
10.00	5.	53.	-48.
9.00	6.	-12.	18.
8.00	6.	9.	-3.
7.00	7.	4.	3.
6.00	10.	23.	-13.
5.00	13.	18.	-5.
4.00	57.	41.	15.
3.00	26.	92.	-66.
2.00	7.	36.	-29.
1.00	6.	-40.	45.

M O D E L   S H A P E   R E P O R T S

PROBLEM: PLANT HAMMOND - EXPERIMENT #2.
ULTRAMAX 4.1 (R):
16:40 THU, 01 OCT 1992

12 OPACITY MIN. PREDICTION ERROR = 3.8
% VAR. EXPL. (R2, Adj.R2, Signal): 47.0 14.4 71.1
MODEL TYPE : LOCAL FIXED-POINT-CENTERED QUADRATIC
Count, Latest, Active : 72 72 72.00
COEF.FIT, # DEG.FREED, # PRIOR : 28 44.00 0.00
DISCRIMINATION PARAMETERS : 0. 0.000 0.00 0.00

#	VARIABLE	UNITS	T	E	REF.	2S-SPREAD	EFFECTS IN 2S-SPREAD Linear	Curvatures		
DEGREE:							1	2.	2.	2.
12	OPACITY	PCT	5	H	21.1	8.1	1.11	-7.15	2.05	-0.56
2	AIR EAST	MPPH	1	H	2.11	0.18	0.71	-1.34	-0.66	0.01
3	AIR WEST	MPPH	1	H	1.48	0.11	-0.57	3.41	-0.04	0.09
4	OFA W FRONT	KPPH	1	H	108.	136.	-0.19	0.27	0.00	-0.01
5	OFA E FRONT	KPPH	1	H	162.	160.	-0.59	0.18	0.14	0.22
6	OFA W REAR	KPPH	1	H	142.	177.	-0.09	1.91	-0.12	-0.19
7	OFA E REAR	KPPH	1	H	156.	144.	-0.13	-0.05	1.08	-0.03

Standard Distance of REFERENCE 1.6 Set at Default: LOCAL CENTER

#	VARIABLE	REFERENCE	2S-SPREAD	CURVATURES		
DEGREE:				2.	2.	2.
12	OPACITY	21.1	8.1	0.41	-0.28	0.06
2	AIR EAST	2.11	0.18	-0.02	0.02	0.02
3	AIR WEST	1.48	0.11	-0.04	-0.04	0.01
4	OFA W FRONT	108.	136.	0.29	0.00	0.01
5	OFA E FRONT	162.	160.	0.01	0.13	0.00
6	OFA W REAR	142.	177.	-0.01	0.09	0.00
7	OFA E REAR	156.	144.	-0.03	0.00	0.02

RUN #	ACTUAL OPACITY	MODEL OPACITY	ERROR
72.00	14.0	13.5	0.5
71.00	16.0	14.7	1.3
70.00	20.0	18.6	1.4
69.00	13.0	12.4	0.6
68.00	18.0	15.7	2.3
67.00	16.0	19.0	-3.0
66.00	22.0	20.1	1.9
65.00	15.0	17.1	-2.1
64.00	15.0	18.5	-3.5
63.00	17.0	20.8	-3.8
62.00	22.0	17.5	4.5
61.00	14.0	16.5	-2.5
60.00	21.0	19.9	1.1
59.00	13.0	19.8	-6.8
58.00	32.0	22.3	9.7

Contd. ...

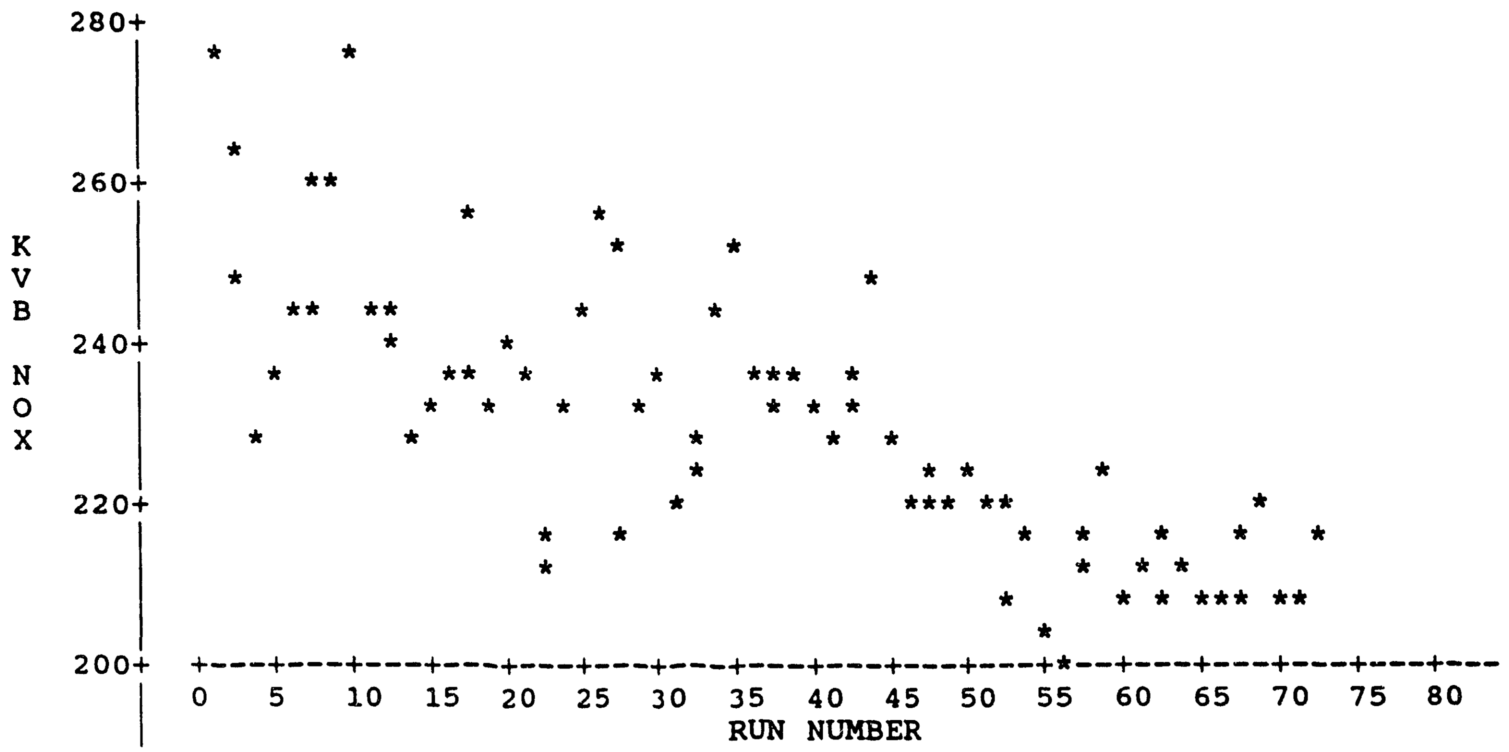
57.00	19.0	17.6	1.4
56.00	20.0	18.8	1.2
55.00	21.0	19.6	1.4
54.00	15.0	19.2	-4.2
53.00	15.0	19.4	-4.4
52.00	17.0	17.5	-0.5
51.00	14.0	16.8	-2.8
50.00	16.0	16.0	0.0
49.00	17.0	16.4	0.6
48.00	18.0	18.5	-0.5
47.00	16.0	15.6	0.4
46.00	19.0	20.0	-1.0
45.00	16.0	18.8	-2.8
44.00	15.0	10.9	4.1
43.00	21.0	22.3	-1.3
42.00	21.3	21.9	-0.6
41.00	21.9	21.6	0.2
40.00	19.2	20.5	-1.4
39.00	19.2	20.6	-1.4
38.00	26.4	22.6	3.8
37.00	20.3	21.9	-1.7
36.00	27.2	20.9	6.3
35.00	25.8	21.9	3.9
34.00	22.8	21.4	1.4
33.00	22.6	20.9	1.7
32.00	17.3	20.0	-2.7
31.00	28.2	24.1	4.2
30.00	22.5	18.8	3.6
29.00	24.7	20.5	4.2
28.00	23.6	25.6	-2.0
27.00	22.1	21.3	0.9
26.00	24.0	19.5	4.5
25.00	21.5	19.7	1.8
24.00	23.2	19.7	3.4
23.00	18.2	19.3	-1.1
22.00	22.6	24.2	-1.7
21.00	18.0	19.4	-1.5
20.00	20.8	19.9	0.9
19.00	20.3	19.5	0.8
18.00	21.3	17.2	4.1
17.00	18.1	20.3	-2.2
16.00	21.0	20.3	0.7
15.00	16.7	17.6	-0.8
14.00	15.8	19.9	-4.1
13.00	14.7	19.1	-4.4
12.00	17.3	16.4	0.8
11.00	18.2	19.0	-0.8
10.00	21.6	25.2	-3.6
9.00	25.9	24.3	1.7
8.00	22.8	23.5	-0.7
7.00	20.7	20.4	0.3
6.00	17.9	20.8	-3.0
5.00	14.5	18.5	-4.0
4.00	18.4	19.2	-0.7
3.00	14.1	17.8	-3.7
2.00	16.2	20.0	-3.8
1.00	28.7	25.6	3.1

PLOT REPORT

PROBLEM: PLANT HAMMOND - EXPERIMENT #2.
ULTRAMAX 4.1 (R):
19:06 DEC, 04 OCT 1992

VERTICAL VARIABLE(S): 10 KVB NOX

HORIZONTAL VARIABLE: 0 RUN NUMBER



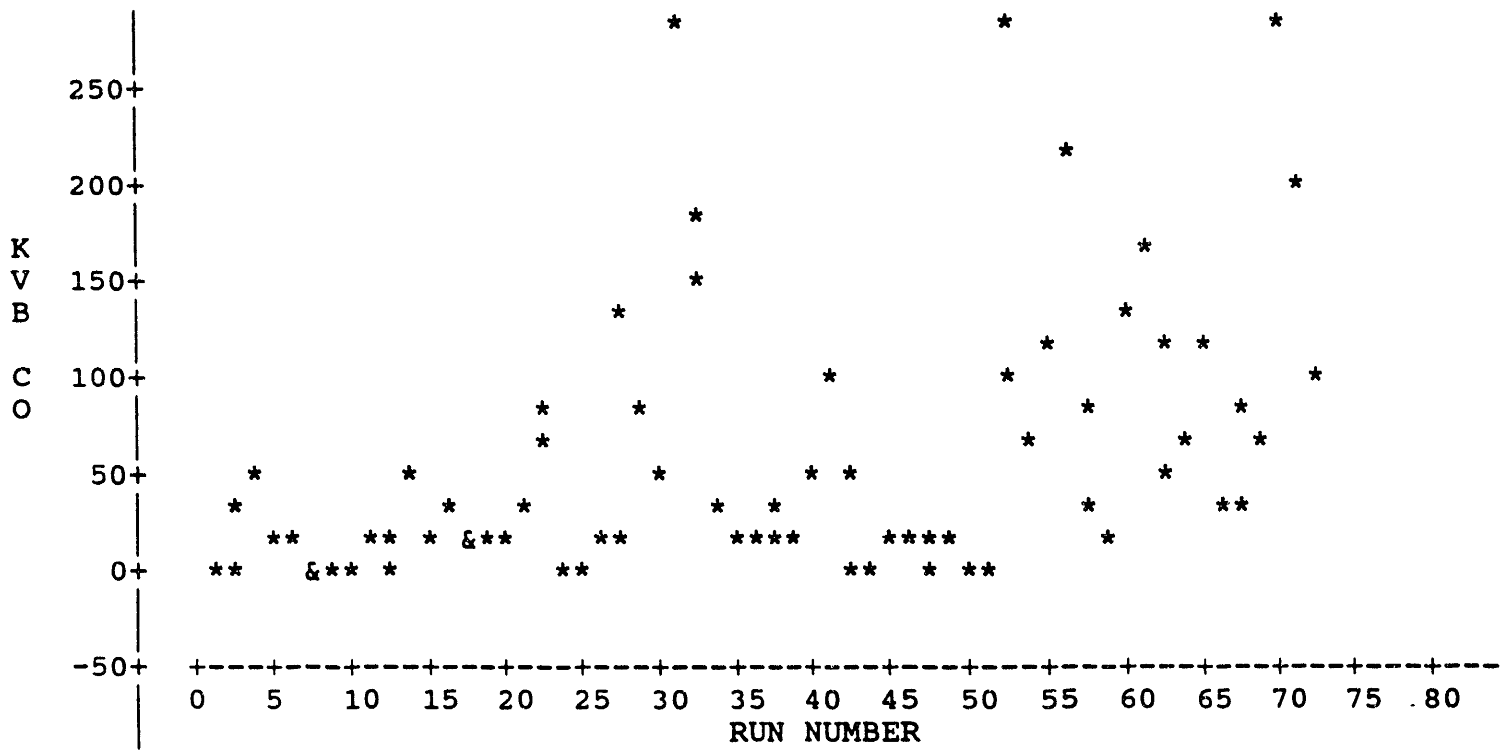
PLOT REPORT

PROBLEM: PLANT HAMMOND - EXPERIMENT #2.

19:07 DEC, 04 OCT 1992

VERTICAL VARIABLE(S): 11 KVB CO

HORIZONTAL VARIABLE: 0 RUN NUMBER



PLOT REPORT

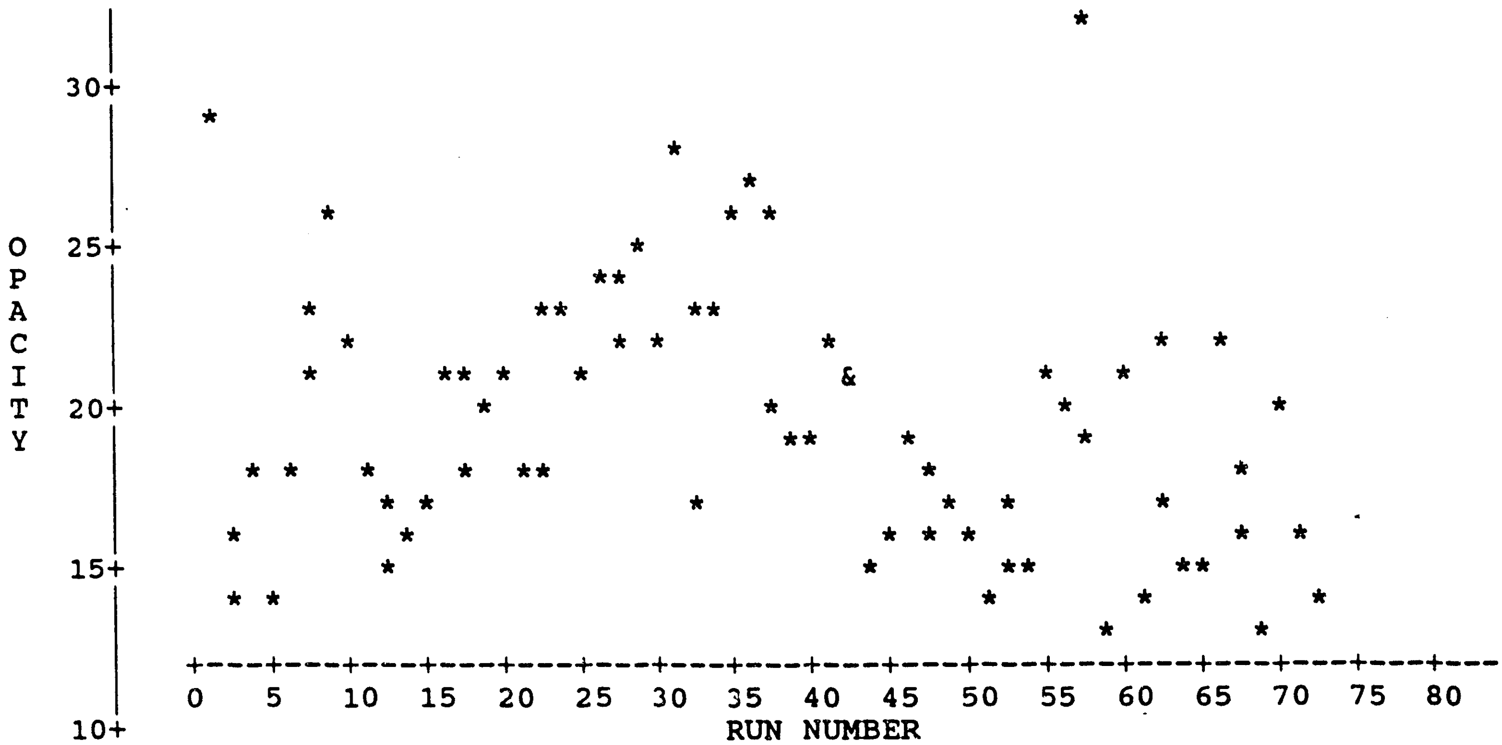
PROBLEM: PLANT HAMMOND - EXPERIMENT #2.

ULTRAMAX 4.1 (R):

19:09 DEC, 04 OCT 1992

VERTICAL VARIABLE(S): 12 OPACITY

HORIZONTAL VARIABLE: 0 RUN NUMBER



END DATE

5-11-93