DOE/PC/89653--T2

DOE/PC/89653--T2

DE92 010962

INNOVATIVE CLEAN COAL TECHNOLOGY (ICCT)

180 MW DEMONSTRATION OF ADVANCED TANGENTIALLY-FIRED COMBUSTION TECHNIQUES FOR THE REDUCTION OF NITROGEN OXIDE (NO_x) EMISSIONS FROM COAL-FIRED BOILERS

Technical Progress Report
Third Quarter 1991

DOE Contract Number
DE-FC22-90PC89653

SCS Contract Number
C-91-000028

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EXECUTIVE SUMMARY

This quarterly report discusses the technical progress of a U. S. Department of Energy (DOE) Innovative Clean Coal Technology (ICCT) Project demonstrating advanced tangentially-fired combustion techniques for the reduction of nitrogen oxide (NO_x) emissions from a coal-fired boiler. The project is being conducted at Gulf Power Company's Plant Lansing Smith Unit 2 located near Panama City, Florida. The primary objective of this demonstration is to determine the long-term effects of commercially available tangentially-fired low NO_x combustion technologies on NO_x emissions and boiler performance. A target of achieving fifty percent NO_x reduction using combustion modifications has been established for the project.

The stepwise approach that is being used to evaluate the NO_x control technologies requires three plant outages to successively install the test instrumentation and the different levels of the low NO_x concentric firing system (LNCFS). Following each outage, a series of four groups of tests are performed. These are (1) diagnostic, (2) performance, (3) long-term, and (4) verification. 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.

This quarterly update contains the Phase II test data. These data include the diagnostic, performance, long-term and verification results from testing LNCFS Level II. Based on the long-term test results, the average NO_x emission rate with LNCFS Level II was 0.40 lb/MBtu. However, NO_x emission at low loads were well above this value at 0.60 lb/MBtu.

Diagnostic test results from the Low NO_x Bulk Furnace Staging (LNBFS) system are presented. In general, these tests showed that offset air has little or no effect on NO_x emissions. Due to the short duration of these tests, the advantages that offset air provides, such as eliminating the reducing atmosphere along the boiler walls, were difficult to quantify.

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1. INTRODUCTION

This document discusses the technical progress of a U. S. Department of Energy (DOE) Innovative Clean Coal Technology (ICCT) Project demonstrating advanced tangentially-fired combustion techniques for the reduction of nitrogen oxide (NOx) emissions from coal-fired boilers. The project is being conducted at Gulf Power Company's Plant Lansing Smith near Panama City, Florida.

The project is being managed by Southern Company Services, Inc. (SCS) on behalf of the project co-funders: The Southern electric system, the U. S. Department of Energy (DOE), and the Electric Power Research Institute. In addition to SCS, The Southern electric system includes five electric operating companies: Alabama Power, Georgia Power, Gulf Power, Mississippi Power, and Savannah Electric and Power. SCS provides engineering and research services to the Southern electric system. Through cost sharing in the installed low NOx retrofit technology, Asea Brown Boveri Combustion Engineering Services (ABB CES) is also participating as a project co-funder.

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. The traditional projects focused on long-range, high-risk, high-payoff technologies with the DOE providing the majority of the funding. In contrast, the goal of 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.

ABB CES's Low NOx Bulk Furnace Staging (LNBFS) System and Low NOx Concentric Firing System (LNCFS) are demonstrated in stepwise fashion. These systems incorporate the concepts of advanced overfire air (AOFA), clustered coal nozzles, and offset air. A complete description of the installed technologies is provided in the following section.

The primary objective of the Plant Lansing Smith demonstration is to determine the long-term effects of commercially available tangentially-fired low NOx combustion technologies on NOx 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 NOx reduction using combustion modifications has been established for the project. Through modifications shown in Figure 1, the project seeks to address the following objectives:

1. Demonstrate in a logical stepwise fashion the short-term NOx reduction capabilities of the following advanced low NOx combustion technologies:
 - a. Low NOx Bulk Furnace Staging (LNBFS)
 - b. Low NOx Concentric Firing System (LNCFS) Levels I, II, and III
2. Determine the dynamic long-term emissions characteristics of each of these combustion NOx reduction methods using sophisticated statistical techniques.
3. Evaluate the progressive cost effectiveness (i.e., dollars per ton NO_x removed) of the low NOx combustion techniques tested.
4. Determine the effects on other combustion parameters (e.g., CO production, carbon carryover, particulate characteristics) of applying the NOx reduction methods listed above.

Figure 1. Plant Lansing Smith Unit 2 Boiler

2. DEMONSTRATED TECHNOLOGIES

As shown in the Statement of Work (SOW) revised in February 1991, four different low NO_x combustion technologies offered by ABB Combustion Engineering (ABB CES) for tangentially-fired boilers are planned for this demonstration. The demonstration of these technologies progresses in the most logical manner from an engineering and construction viewpoint. During Phase I of the project, the baseline conditions of the unit will be studied. During Phase II, the Low NO_x Bulk Furnace Staging (LNBFS) system and the Low NO_x Concentric Firing System (LNCFS) Level II will be demonstrated. Finally, LNCFS Levels I and III will be demonstrated during Phase III.

The concept of overfire air is demonstrated in all of these systems. In LNCFS Level I, a Close-Coupled Overfire Air (CCOFA) system is integrated directly into the windbox. Compared to the baseline configuration, LNCFS Level I is arranged by exchanging the highest coal nozzle with the air nozzle immediately below it. This configuration provides the NO_x reducing advantages of an overfire air system without major pressure part modifications to the boiler.

In LNBFS and LNCFS Level II, a Separated Overfire Air (SOFA) system is used. This is an advanced overfire air system having backpressuring and flow measurement capabilities. The air supply ductwork for the SOFA is taken off from the secondary air duct and routed to the corners of the furnace above the existing windbox. The inlet pressure to the SOFA system can be increased above windbox pressure using dampers downstream of the takeoff in the secondary air duct. The intent of operating at a higher pressure is to increase the quantity and injection velocity of the overfire air into the furnace. A multicell venturi is used to measure the amount of air flow through the SOFA system. LNCFS Level III utilizes both CCOFA and SOFA.

In addition to overfire air, the LNCFS incorporates other NO_x reducing techniques into the combustion process. Using offset air, two concentric circular combustion regions are formed. The inner region contains the majority of the coal thereby being fuel rich. This region is surrounded by a fuel lean zone containing combustion air. For this demonstration, the size of this outer circle of combustion air will be varied using adjustable offset air nozzles. The separation of air and coal at the burner level further reduces the production of NO_x.

The LNBFS consists of a standard tangentially-fired windbox with a SOFA system. This technology will be demonstrated by repositioning the offset air nozzles in the main windbox to be

in line with the fuel nozzles. No other modifications to the windbox will be required. Due to the limits of the project schedule, LNBFS will be demonstrated using short-term diagnostic tests only.

When the Statement of Work (SOW) for this project was prepared in June 1990, ABB CES offered the following low NOx combustion systems:

- 1) Low NOx Concentric Firing System (LNCFS)
- 2) Concentric Clustered Tangential Firing System (CCTFS)

Since that time, the technologies which ABB CES offers to the public have evolved to reflect the results of their most recent knowledge. The equipment that is presently offered comprises a family of technologies called the Low NOx Concentric Firing System Levels I, II, and III as discussed above. These technologies provide a stepwise reduction in NOx emissions with LNCFS Level III providing the greatest reduction.

Although the names of these technologies have changed, the basic concepts for the reduction of NOx emissions have remained constant. The Low NOx Concentric Firing System (LNCFS) included the NOx reduction techniques of overfire air and adjustable offset air nozzles as part of its design. These features are now incorporated into the design of LNCFS Level II.

The Concentric Clustered Tangential Firing System (CCTFS) included two sets of overfire air and clustered coal nozzles. Both LNCFS Levels I and III utilize clustered coal nozzles and overfire air in their design. Research by ABB CES has shown that the use of clustered coal nozzles does not positively or negatively affect the production of nitrogen oxides in a coal-fired boiler. As a result, one set of coal nozzles at the top of the main windbox are clustered to facilitate the addition of the CCOFA system discussed in the section above. This modification allowed the low pressure overfire air system (now designated the CCOFA) to be integrated directly into the windbox. This design change reduced the number of pressure part modifications required to install this low NOx combustion technology. No significant design changes to the high pressure overfire air system (now designated the SOFA) were made.

Figure 2: Demonstrated Technologies

Figure 3: Concentric Firing System

3. UNIT DESCRIPTION

Plant Lansing Smith Unit 2 is a 180 MWe tangentially-fired boiler owned and operated by Gulf Power Company. The unit is located in Lynn Haven, Florida, near Panama City. The boiler is a Combustion Engineering radiant reheat, natural circulation steam generator. It is designed for continuous indoor service to deliver 1,306,000 pounds of steam per hour at normal rated load, a pressure of 1800 psig, and a temperature of 1000°F at the superheater and the reheater outlets. It is fired with pulverized coal through twenty tangential coal nozzles with five nozzles at each corner. Five Combustion Engineering Raymond Bowl mills equipped with exhausters at the outlet of each mill deliver coal to the furnace. The unit is equipped with Ljungstrom air preheaters and two forced-draft fans which deliver all the combustion air to the boiler. Although originally designed for pressurized furnace operation, the unit was converted to balanced-draft operation in 1976.

4. PROJECT DESCRIPTION

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. Although this project structure is inconsistent with the typical ICCT project phase structure of (1) permitting and design, (2) construction, and (3) operation, it prevents phases from starting and stopping several times during the project.

The stepwise approach to evaluating the NOx control technologies requires that three plant outages be used to successively install (1) the test instrumentation and new air heater baskets, (2) the LNCFS Level II, and (3) the LNCFS Levels I and III. These outages are scheduled to coincide with existing plant outages in the fall of 1990, spring of 1991, and the fall of 1991.

The Data Acquisition System (DAS) for the Lansing Smith Unit 2 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 two continuous emissions monitoring systems (NOx, SO2, O2, 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

Table 1: Work Breakdown Structure			
Phase	Task	Description	Scheduled Date
0		Pre-Award Activities	
I		Setup and Pre-Retrofit	
	1.1.1	Project Management and Reports	9/90 - 3/91
	1.1.2	Site Preparation	10/90 - 11/90
	1.1.3	Flow Modeling	9/90 - 7/91
	1.1.4	Instrumentation	8/90 - 12/90
	1.1.5	Baseline Characterization	11/90 - 3/91
II		LNCFS Level II Retrofit	
	1.2.1	Project Management and Reports	4/91 - 9/91
	1.2.2	LNCFS Level II Installation	4/91 - 5/91
	1.2.3	LNBFS and LNCFS Level II Characterization	5/91 - 9/91
	1.2.4	Chemical Emissions Testing	9/91 - 12/91
III		LNCFS Level III Retrofit	
	1.3.1	Project Management and Reports	9/91 - 1/93
	1.3.2	LNCFS Level III Installation	9/91 - 10/91
	1.3.3	LNCFS Levels I and III Characterization	10/91 - 8/92
	1.3.4	Chemical Emissions Testing	12/91 - 9/92
IV		Final Reporting and Disposition	
	1.4.1	Project Management and Reports	8/92 - 9/93
	1.4.2	Disposition	11/92

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 performed. 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 will be used to characterize any changes that might have occurred during long-term testing.

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,

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	Tempering Air Flows
Main Steam Temperatures	Cold Reheat Temperature
Hot Reheat Temperature	Feedwater Temperature
Desuperheater Outlet Temp.	Desuperheater Inlet Temp.
Economizer Outlet Temp.	Air Heater Air Inlet Temp.
Air Heater Air Outlet Temp.	Ambient Temperature
BFP Discharge Temperature	Relative Humidity
Stack NOx	Stack SO2
Stack O2	Stack Opacity

boilers are not typically operated in this manner considering plant equipment inconsistencies and economic dispatch strategies. Therefore, statistical analysis methods for long-term data have been developed that can be used to determine the achievable emissions limit or emission tonnage of a 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 results can be achieved with data sets of at least 51 days with each day containing at least 18 valid hourly averages.

5. PROJECT STATUS

5.1. Phase I Setup and Pre Retrofit

5.1.3. Task 1.1.5 Baseline Characterization

The Phase I Baseline test report was issued in draft form during this quarter. It is anticipated that the final version of this report will be issued in the first quarter 1992.

5.2. Phase II LNCFS Level II Retrofit

5.2.2. Task 1.2.3 LNBFS and LNCFS Level II Characterization

Phase II Characterization tests of the LNCFS Level II and LNBFS continued during this quarter. Through early October 1991, there have been 138 Phase II short-term tests conducted. These tests include 77 diagnostic tests of LNCFS Level II, 7 performance tests of LNCFS Level II, 29 verification tests of LNCFS Level II, and 25 diagnostic tests of LNBFS. The data from all of these tests are compiled in Table A-1 (Appendix A). Long-term testing began on June 23, 1991

and was completed on September 12, 1991. All these results will be documented in the topical report discussing the Phase II testing to be issued in 1992.

5.2.2.1. Short-Term Testing

Diagnostic and Performance Testing. The results of the LNCFS Level II diagnostic and performance tests are discussed in this project's **Technical Progress Report, Second Quarter 1991**. These test results (25-1 through 43-8) are included in Table A-1 for completeness.

Verification Testing. Twenty-nine verification tests of LNCFS Level II were conducted during this quarter. The data from these tests (44-1 through 50-2) are shown in Table A-1. Results showed that there was little change in unit conditions over the long-term test period. Figure 4 compares all the baseline and LNCFS Level II short-term test results.

Figure 4: Comparison of baseline and LNCFS Level II short-term NOx emissions

LNBFS Testing. Twenty-five tests of the LNBFS configuration were conducted during this quarter. The results of these tests (51-1 through 54-6) are shown in Table A-1. The purpose of these tests was to determine the effectiveness of the offset air nozzles on NOx production. (Offset air is the predominant difference between LNBFS and LNCFS Level II.) Preliminary results indicate that the position of these nozzles has little or no effect on NOx emissions. However, the primary purpose of the offset air nozzles is to bathe the boiler walls in an oxygen rich environment

to avoid a reducing environment. Due to the nature of these tests, this effect was not measured. Carbon loss values encountered during these tests are not yet available.

5.2.2.2. Long-Term Testing

Long-term testing of LNCFS Level II began on June 23, 1991, and was completed on September 12, 1991. The long-term data for each week during the test period are shown in Figures A-1 through A-12. These graphs show the NO_x emissions and unit load for each day of long-term testing. At full load, NO_x emissions range from 0.33 lb/MBtu to 0.43 lb/MBtu. Contrary to the baseline data set (**Technical Progress Report, First Quarter 1991**), LNCFS Level II data show that NO_x emissions increase when unit load decreases. The data collected on June 23 (Figure A-1) show that NO_x emissions as high as 0.65 lb/MBtu have been encountered at minimum load. During long-term data collection, test days were lost due to various situations encountered at the plant. In some cases (June 27 through July 1 or August 10), the power plant was off line for unscheduled maintenance such as a tube leak in the reheat section. Other data losses were due to maintenance of the data acquisition system (August 15). Finally, data were lost due to maintenance of the continuous emissions monitoring system (August 29 and 30).

Figure 5 shows the average of the LNCFS Level II long-term data as a function of load. The upper 95 percent and lower 5 percent confidence limits of this data are shown as the upper and lower bounds of the shaded area of the graph. The short-term test results are also shown on the chart.

As stated previously, the primary objective of this project is to determine the long-term NO_x emissions for a T-fired boiler retrofit with low NO_x combustion equipment. Long-term data collection is the definitive method to determine the actual NO_x reduction characteristics of a low NO_x combustion system. Figure 6 presents the average long-term NO_x emissions collected through the end of this quarter. These data show that at full load (200 MW), the unit is able to meet a 0.45 lb/MBtu standard for NO_x emissions with an average emission level of 0.38 lb NO_x/MBtu. Compared to the baseline full load emission of 0.64 lb NO_x/MBtu, LNCFS Level II provides a full load NO_x reduction of 40 percent. However, this is not the case for low load operation. NO_x emissions during off peak hours when the unit is at minimum load are well above the 0.45 lb/MBtu limit. At minimum load, NO_x emissions average 0.58 lb/MBtu which translates to a 5.5 percent increase in NO_x emissions over baseline levels.

Figure 5: Comparison of long-term and short-term LNCFS Level II NOx emissions

Figure 6: Comparison of baseline and LNCFS Level II long-term NOx emissions

Using the long-term data, an achievable emission limit can be calculated. This limit is derived from a statistical analysis of the test data and assumes that the operating conditions during which the data were collected are representative of future operating conditions and the statistical properties of the twenty-four hour averages are true population values. A brief summary of the statistical analysis results of the LNCFS Level II long-term data are shown in Table 3 with the baseline long-term data. The average load during the LNCFS Level II long-term testing was 174 MW with a relative standard deviation (RSD) of 6.2 percent. The average emission level was 0.40 lb NO_x/MBtu with an RSD of 5.8 percent. Using this long-term data collected, an achievable emission limit was calculated in a manner similar to the method for the baseline data. The thirty day rolling average achievable emission limit when operating with LNCFS Level II was 0.42 lb NO_x/MBtu.

Table 3. Baseline and LNCFS Level II Long-Term Test Results				
Unit Configuration	Baseline		LNCFS Level II	
	Mean	RSD, %	Mean	RSD, %
Number of Daily Averaged Values	75	-	43	-
Average Load (MW)	156	14.8	174	6.2
Average Emissions (lb NO _x /MBtu)	0.62	5.8	0.40	5.5
Average O ₂ Level (at stack)	6.56	11.2	6.25	6.4
Achievable Emission Limit (lb NO _x /MBtu)	0.68	-	0.42	-

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

There is a difference in the characteristics of the baseline and LNCFS Level II long-term data sets. The LNCFS Level II long-term data were collected during the hot summer months when system demands are the greatest. Plant Smith operates around the clock at or near full load during the summer months. As a result, the average unit load was 174 MW and the RSD was 6.2 percent. In contrast, the baseline data were collected during the winter months when system load profiles in the Southeastern United States are more variable. During this time period, the average unit load was lower at 156 MW with a higher RSD of 14.8 percent. By applying the baseline load information to the LNCFS Level II data, Figure 6 shows that a reduction in average load will increase the average NO_x emissions of the unit. As a result, unit emissions may or may not be within the proposed 0.45 NO_x standard when operating under an off-peak load scenario.

During short-term tests, baseline CO emission maintained a band in the 5 to 20 ppm range over the entire load range. Post-retrofit CO emissions were not as predictable. CO emissions with LNCFS Level II are highly dependant upon unit excess oxygen levels. As the excess oxygen level decreases, unit CO emissions increase. During some tests, reductions of only 0.50 percent in excess oxygen levels have caused CO emissions to increase over 60 ppm. CO levels as high as

148 ppm were witnessed during short-term tests of the LNCFS Level II system. Figure 7 presents the average long-term baseline and LNCFS Level II CO emissions. These data show that there has been a 5 to 15 ppm increase in CO emissions over the entire load range of the unit.

Figure 7: Comparison of baseline and LNCFS Level II long-term CO emissions

6. FUTURE PLANS

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

QUARTER	ACTIVITY
Fourth Quarter 1991	Complete Long-Term LNCFS Level II Tests Complete LNCFS Level I and III Retrofit Diagnostic Tests of LNCFS Level I and III Performance Tests of LNCFS Level I and III Begin Long-Term LNCFS Level I and III Tests
First Quarter 1992	Continue Long-Term LNCFS Level I and III Tests
Second Quarter 1992	Complete Long-Term LNCFS Level I and III Tests Verification Tests of LNCFS Level I and III Configuration
Third and Fourth Quarters 1992 1993	Complete Final Reporting Disposition Project Completion

7. ACKNOWLEDGEMENTS

The management of this project wish to gratefully acknowledge the support and dedication of the following personnel for their work at the tangentially-fired test site: Mr. J. D. McDonald, Gulf Power Company, and Mr. Lamar Sumerlin, Southern Company Services, for their coordination of the design and retrofit efforts and Mr. James Gibson, full-time Instrumentation Specialist from Spectrum Systems, Inc. We also thank Messrs Jim Witt, John Sorge, and Jimmy Horton of Southern Company Services for their work coordinating the procurement and installation of the instrumentation at this site. We would also like to recognize the following companies for their outstanding testing and data analysis efforts: Energy Technology Consultants, Inc., Flame Refractories, Inc., Southern Research Institute, W. S. Pitts Consulting, and Radian Corporation.

APPENDIX A
LNCFS Level II
Long- and Short-Term Data

TABLE A-1: Summary of Phase II Short-Term Operating Conditions and Test Results

TEST	DATE	LOAD MW	MOOS	UPPER SOFA %	MIDDLE SOFA %	LOWER SOFA %	CR O2 %	DAS O2 %	NOx ppm	NOx lb/MBtu	CO	COMMENTS
25-1	05-07-91	181	none	101	100	100	5.4	3.9	296	0.40	8	LOI AT NOMINAL O2
25-2	05-07-91	180	none	101	100	100	4.7	3.6	246	0.34	70	LOI AT LOWER O2
25-3	05-07-91	181	none	101	100	100	5.6	4.3	288	0.39	16	LOI AT HIGHER O2
26-1	05-08-91	180	none	101	100	100	6.2	5.2	288	0.39	9	DAMPER TILTS AT ZERO, NOMINAL O2
26-2	05-08-91	180	none	101	100	100	5.0	4.3	274	0.37	17	DAMPER TILTS AT ZERO, LOWER O2
27-1	05-09-91	180	none	100	100	100	4.6	3.8	264	0.36	6	EFFECT OF DAMPER TILT POSITION
27-2	05-09-91	180	none	100	100	100	4.7	3.8	262	0.36	4	
27-3	05-09-91	180	none	-	-	-	-	-	-	-	-	LOST TEST 27-3 DUE TO LOAD DEMAND
27-4	05-09-91	200	none	60	100	100	3.9	3.2	260	0.35	80	
28-1	05-14-91	201	A	0	0	0	4.5	3.4	399	0.54	8	MAX LOAD WITH A-MOOS, NO OPA
28-2	05-14-91	200	A	60	100	100	5.0	3.3	282	0.38	94	OPA OPERATION
29-1	05-14-91	140	A	20	101	100	3.4	2.4	245	0.33	22	NORMAL MILL PATTERN
29-2	05-15-91	140	A	20	101	100	4.6	3.7	278	0.38	7	
29-3	05-15-91	140	A	20	101	100	6.0	5.3	318	0.43	5	
29-4	05-15-91	140	A	0	0	100	4.5	3.9	298	0.41	3	
29-5	05-15-91	140	A	0	0	0	4.6	4.1	379	0.52	4	
30-1	05-16-91	141	AB	20	100	100	3.3	2.4	251	0.34	18	
30-2	05-16-91	142	AB	20	100	100	3.8	3.0	230	0.31	16	
30-3	05-16-91	143	AB	20	100	100	4.8	4.2	265	0.36	4	
30-4	05-16-91	142	AB	20	100	100	6.1	5.4	292	0.40	6	
30-5	05-16-91	142	A	20	100	100	5.5	4.7	293	0.40	4	
30-6	05-16-91	142	A	20	100	100	4.0	3.2	248	0.34	3	
31-1	05-16-91	115	AB	0	0	0	3.6	2.4	282	0.38	15	
31-2	05-17-91	117	AB	0	60	100	3.5	2.4	250	0.34	148	
31-3	05-17-91	117	AB	0	60	100	4.8	3.9	266	0.36	6	
31-4	05-17-91	114	AB	0	60	100	5.8	4.7	286	0.39	7	
31-5	05-17-91	181	A	100	100	100	4.9	3.2	257	0.35	8	
32-1	05-17-91	115	AB	0	60	100	3.7	2.4	250	0.34	118	REPEAT OF TEST 31-2
32-2	05-18-91	116	AB	0	60	100	4.9	3.7	283	0.39	25	REPEAT OF TEST 31-3
32-3	05-18-91	116	AB	0	60	100	5.6	4.8	288	0.39	10	
33-1	05-18-91	75	ABC	0	0	0	5.7	5.4	330	0.45	9	OPA CLOSED; LOW O2
33-2	05-19-91	76	ABC	0	0	50	5.0	4.8	269	0.37	10	NOMINAL OPA; LOW O2
33-3	05-19-91	76	ABC	0	0	50	6.7	6.5	311	0.42	10	NOMINAL OPA; MID O2
33-4	05-19-91	76	ABC	0	0	50	7.3	7.7	338	0.46	13	NOMINAL OPA; HIGH O2
33-5	05-19-91	76	ABC	0	0	0	7.5	7.8	398	0.54	12	OPA CLOSED; HIGH O2
34-1	05-28-91	181	none	100	100	100	4.8	3.7	252	0.34	74	FUEL AIR DAMPERS ALL AT 32% OPEN
34-2	05-28-91	181	none	100	100	100	3.5	2.7	204	0.28	74	BEHIND AIR @ 15%, ALL OTHERS @ 22%
34-3	05-28-91	181	none	100	100	100	4.0	3.0	221	0.30	12	
34-4	05-28-91	181	none	100	100	100	4.4	3.5	249	0.34	7	
34-5	05-28-91	181	none	100	100	100	5.1	4.1	276	0.38	9	
34-6	05-28-91	181	none	100	100	100	4.8	3.7	252	0.34	9	BEHIND AIR @ 15%, ALL OTHERS @ 32%
35-1	05-29-91	181	none	100	114	114	5.1	3.9	245	0.33	24	PERFORMANCE
35-2	05-29-91	181	none	100	114	114	4.9	3.7	255	0.35	5	PERFORMANCE, MULTIPOINT
35-3	05-29-91	181	none	100	114	114	4.9	3.7	255	0.35	5	PERFORMANCE, CONT'D
36-1	05-30-91	181	none	100	114	114	4.5	3.4	229	0.31	75	LOW O2
36-2	05-30-91	181	none	100	114	114	5.3	3.9	243	0.33	15	PERFORMANCE
36-3	05-30-91	180	none	100	114	114	5.3	3.9	243	0.33	15	
37-1	5-31-91	201	none	114	114	114	5.8	3.8	272	0.37	21	PERFORMANCE
37-2	5-31-91	201	none	114	114	114	4.5	3.9	309	0.42	8	PERFORMANCE, MULTIPOINT
37-3	5-31-91	200	none	114	114	114	5.7	4.7	351	0.48	8	HIGH O2

TABLE A-1: Summary of Phase II Short-Term Operating Conditions and Test Results (Continued)

TEST	DATE	LOAD MW	MOOS	UPPER SOFA %	MIDDLE SOFA %	LOWER SOFA %	CR O2 %	DAS O2 %	NOx ppm	NOx lb/MBtu	CO	COMMENTS
38-1	6-01-91	115	A,B	0	53	114	4.4	3.7	251	0.34	6	LOW O2
38-2	6-01-91	115	A,B	0	54	114	5.0	4.3	261	0.36	5	PERFORMANCE
38-3	6-01-91	115	A,B	0	54	114	4.9	4.6	256	0.35	5	PERFORMANCE, MULTIPOINT
38-4	6-01-91	115	A,B	0	57	114	5.5	5.3	265	0.36	6	HIGH O2
39-1	6-02-91	115	A,B	0	54	114	4.8	4.5	255	0.35	4	PERFORMANCE
39-2	6-02-91	115	A,B	0	55	114	5.0	4.4	257	0.35	4	PERFORMANCE
39-3	6-02-91	115	A,B	0	56	114	4.3	3.7	239	0.33	6	LOW O2
39-4	6-02-91	115	A,B	0	56	114	5.8	5.4	279	0.38	6	HIGH O2
40-1	6-03-91	137	A	15	104	114	4.5	3.9	248	0.34	10	PERFORMANCE
40-2	6-03-91	137	A	15	105	114	4.2	3.8	255	0.35	7	PERFORMANCE, MULTIPOINT
40-3	6-03-91	137	A	15	105	114	3.7	3.0	242	0.33	11	LOW O2
40-4	6-03-91	137	A	15	105	114	5.5	5.0	272	0.37	11	HIGH O2
41-1	6-04-91	135	A	11	97	114	5.5	4.9	284	0.39	9	HIGH O2
41-2	6-04-91	136	A	11	100	114	4.8	4.1	266	0.36	9	PERFORMANCE
41-3	6-04-91	136	A	12	100	114	4.7	3.9	266	0.36	8	PERFORMANCE, CONT'D
41-4	6-04-91	136	A	100	100	114	4.8	3.8	245	0.33	8	HIGH OFA
41-5	6-04-91	136	A	100	100	114	4.8	3.9	259	0.35	8	HIGH OFA + BURNER DAMPERS OPEN
41-6	6-04-91	136	A	13	100	114	4.8	4.2	274	0.37	7	NORMAL OFA + BURNER DAMPERS OPEN
42-1	6-05-91	182	none	101	114	114	5.6	3.9	253	0.34	46	DIAGNOSTIC,
42-2	6-05-91	182	none	75	75	75	5.5	3.9	258	0.35	46	75% OFA
42-3	6-05-91	181	none	50	50	50	5.5	4.0	275	0.37	22	50% OFA
42-4	6-05-91	182	none	25	25	25	5.8	4.0	321	0.44	22	25% OFA
42-5	6-05-91	182	none	0	0	0	5.0	4.0	412	0.56	12	0% OFA
42-6	6-05-91	181	none	100	0	0	5.0	4.2	384	0.52	8	33% OFA (UPPER)
42-7	6-05-91	181	none	100	100	0	5.3	4.0	305	0.42	11	66% OFA, (UPPER + MIDDLE)
42-8	6-05-91	182	none	100	100	100	5.6	4.0	256	0.35	16	100% OFA
43-1	6-06-91	182	none	100	114	114	5.3	4.0	247	0.34	49	DIAGNOSTIC,
43-2	6-06-91	181	none	100	114	114	5.4	3.8	245	0.33	42	CHANGE FUEL/AIR DAMPER SETTINGS
43-3	6-06-91	182	none	100	114	114	5.3	4.0	252	0.34	6	CHANGE FUEL/AIR DAMPER SETTINGS
43-4	6-06-91	182	none	100	114	114	5.2	4.0	275	0.37	5	CHANGE FUEL/AIR DAMPER SETTINGS
43-5	6-06-91	181	none	100	114	114	5.4	4.0	287	0.39	6	A MOOS,
43-6	6-06-91	182	A	100	114	114	4.0	2.9	243	0.33	10	A MOOS, LOW O2
43-7	6-06-91	182	A	100	114	114	6.1	5.2	323	0.44	7	A MOOS, HIGH O2
43-8	6-06-91	181	A	100	114	114	5.2	4.0	285	0.39	5	A MOOS, A MILL & BOTTOM DAMPERS OPEN
44-1	09-12-91	182	none	103	108	108	3.4	2.2	191	0.26	90	LOW O2
44-2	09-12-91	182	none	104	108	108	4.5	3.4	231	0.32	201	MID O2
44-3	09-13-91	181	none	105	108	108	5.3	4.3	274	0.37	12	HIGH O2
44-4	09-13-91	180	none	104	108	108	6.2	5.3	323	0.44	11	HIGH O2
45-1	09-13-91	180	none	103	108	108	4.1	3.2	201	0.27	21	MAX TILT
45-2	09-13-91	180	none	106	108	108	4.5	3.4	224	0.31	169	INTERMED TILT
46-1	09-13-91	142	A	24	108	108	3.8	3.2	244	0.33	11	LOW O2
46-2	09-13-91	140	A	21	108	108	4.8	4.4	277	0.38	8	MID O2
46-3	09-14-91	139	A	23	108	108	5.7	5.3	303	0.41	9	HIGH O2
46-4	09-14-91	139	A,B	18	106	108	5.6	5.1	314	0.43	8	HIGH O2, AB MOOS
46-5	09-14-91	138	A,B	15	105	108	4.9	4.4	289	0.39	7	MID O2, AB MOOS
46-6	09-14-91	138	A,B	18	107	108	3.9	3.2	256	0.35	13	LOW O2, AB MOOS
46-7	09-14-91	140	A,B	16	104	108	3.9	3.3	260	0.35	10	LOW O2, AB MOOS, HI DELT P

TABLE A-1: Summary of Phase II Short-Term Operating Conditions and Test Results (Continued)

TEST	DATE	LOAD MW	MOOS	UPPER SOFA %	MIDDLE SOFA %	LOWER SOFA %	CR O2 %	DAS O2 %	NOx ppm	NOx lb/MBtu	CO	COMMENTS
47-1	09-14-91	142	A,B	22	108	108	3.7	3.3	243	0.73	8	LOW O2, 80% OFA
47-2	09-14-91	140	A,B	24	108	108	4.6	4.5	264	0.36	9	MID O2, 80%
47-3	09-15-91	140	A,B	24	108	108	5.5	5.4	305	0.42	8	HIGH O2, 80%
47-4	09-15-91	141	A	22	108	108	4.6	4.4	266	0.36	6	MID O2, 80%
47-5	09-15-91	141	A	0	0	108	4.6	4.4	308	0.42	7	REDUCED OFA, 33%
47-6	09-15-91	141	A	0	0	0	4.7	4.5	356	0.49	7	NO OFA
48-1	09-15-91	116	A,B	0	61	108	3.6	3.8	242	0.33	158	LOW O2, 56% OFA
48-2	09-15-91	116	A,B	0	62	108	4.3	4.4	258	0.35	47	MID O2, 56% OFA
48-3	09-16-91	116	A,B	0	61	108	5.1	5.5	273	0.37	7	HIGH O2, 56% OFA
48-4	09-16-91	117	A,B	0	0	108	4.0	4.4	267	0.36	7	MID O2, 33% OFA
48-5	09-16-91	117	A,B	0	0	50	4.0	4.2	273	0.37	9	MID O2, 17% OFA
48-6	09-16-91	117	A,B	0	0	1	4.2	4.2	288	0.39	18	MID O2, NO OFA
49-1	09-16-91	182	none	106	108	108	3.8	3.5	227	0.31	172	MAX TILT
49-2	09-17-91	183	none	106	108	108	3.7	3.7	215	0.29	266	NORMAL TILT
50-1	10-01-91	182	none	101	108	108	3.9	3.5	235	0.32	40	NORMAL TILT
50-2	10-01-91	182	none	100	108	108	4.2	3.4	224	0.31	132	MAX TILT
51-1	10-02-91	182	none	103	108	108	4.2	3.5	230	0.31	128	
51-2	10-02-91	183	none	0	0	0	4.3	3.4	326	0.44	44	NO OFA, NORMAL YAW
51-3	10-02-91	182	none	0	0	0	4.2	3.4	326	0.44	16	NO OFA, REDUCE YAW ONE NOTCH
51-4	10-02-91	183	none	0	0	0	4.1	3.4	358	0.49	7	NO OFA, REDUCE YAW MORE
51-5	10-02-91	182	none	0	0	0	4.1	3.4	356	0.49	8	NO OFA, YAWS AT ZERO
52-1	10-03-91	182	none	100	108	108	4.3	3.5	221	0.30	204	OFA 100%
52-2	10-03-91	181	none	101	108	108	4.4	3.6	226	0.31	177	, RAISED DELTA P
52-3	10-03-91	181	none	101	108	108	4.1	3.5	230	0.31	217	OFA 100 %, AUX YAW ZERO
52-4	10-03-91	179	none	101	108	108	4.4	3.6	245	0.33	49	OFA 100 %, AUX AND OFA YAWS ZERO
52-5	10-03-91	180	none	0	108	108	4.1	3.6	267	0.36	18	OFA 67 %, AUX AND OFA YAWS ZERO
52-6	10-03-91	180	none	0	0	108	4.1	3.6	314	0.43	10	OFA 33 %, AUX AND OFA YAWS ZERO
52-7	10-03-91	180	none	0	0	0	3.9	3.6	373	0.51	10	OFA 0 %, AUX AND OFA YAWS ZERO
52-8	10-03-91	179	none	0	0	0	4.1	3.6	391	0.53	10	SAME AS 52-7, CHANGED AUX/FUEL AIR
53-1	10-04-91	140	A	17	107	108	4.5	4.4	272	0.37	11	OFA 76%
53-2	10-04-91	139	A	50	105	108	4.2	4.2	247	0.34	13	OFA 88%
53-3	10-05-91	139	A	17	105	108	4.3	4.2	261	0.36	13	OFA 76%, AUX YAW ZERO
53-4	10-05-91	138	A	16	107	108	4.3	4.4	265	0.36	13	OFA 76%, AUX AND OFA YAW ZERO
53-5	10-05-91	139	A	0	0	108	4.1	4.4	332	0.45	13	OFA 33%, AUX AND OFA YAW ZERO
53-6	10-05-91	140	A	0	0	0	3.6	4.4	384	0.52	14	OFA 0%, AUX AND OFA YAW ZERO
54-1	10-05-91	114	A,B	0	56	108	4.4	4.3	246	0.34	68	OFA 35%
54-2	10-06-91	115	A,B	0	55	108	5.3	5.3	274	0.37	9	OPEN AUX AIR DAMPERS, OFA 55%
54-3	10-06-91	114	A,B	0	54	108	5.3	5.4	284	0.39	9	OFA 55%, AUX YAW ZERO
54-4	10-06-91	114	A,B	0	55	108	5.3	5.4	296	0.40	9	OFA 55%, AUX AND OFA YAW ZERO
54-5	10-06-91	113	A,B	0	0	50	5.5	5.4	345	0.47	9	OFA 17%, AUX AND OFA YAW ZERO
54-6	10-06-91	114	A,B	0	0	0	5.2	5.3	383	0.52	10	OFA 0%, AUX AND OFA YAW ZERO

Legend: MW = megawatts
MOOS = mills out of service
SOFA = separated overfire air
CR = control room
O2 = oxygen
DAS = data acquisition system
CO = carbon monoxide
LOI = loss on ignition

Figure A-1: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of June 23, 1991

Figure A-2: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of July 1, 1991

Figure A-3: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of July 8, 1991

Figure A-4: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of July 15, 1991

Figure A-5: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of July 22, 1991

Figure A-6: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of July 29, 1991

Figure A-7: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of August 5, 1991

Figure A-8: LNCFS Level II Long-Term NOx Emissions (lb/Mbtu) and Unit Generation (MW) for the Week of August 12, 1991

Figure A-9: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of August 19, 1991

Figure A-10: LNCFS Level II Long-Term NOx Emissions (lb/Mbtu) and Unit Generation (MW) for the Week of August 26, 1991

Figure A-11: LNCFS Level II Long-Term NOx Emissions (lb/MBtu) and Unit Generation (MW) for the Week of September 2, 1991

Figure A-12: LNCFS Level II Long-Term NOx Emissions (lb/Mbtu) and Unit Generation (MW) for the Week of September 9, 1991

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