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

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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.

The LNB without AOFA test segment has 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. This NO_x level represents a 48 percent reduction when compared to the baseline, full-load value of 1.24 lb/MBtu. Optimization of the LNBs with AOFA was performed by Foster Wheeler Energy Corporation personnel from January 17 to February 17, 1992. Due to the adverse impacts of the LNBs on electrostatic precipitator performance, testing can not be completed within the original schedule. Therefore, the LNB+AOFA diagnostic, performance, chemical emissions, and long-term tests have been rescheduled to follow the spring 1992 unit outage. In order to provide preliminary data for the LNB+AOFA configuration, abbreviated diagnostic tests were performed from February 17 to February 25, 1992. These test indicate that at 500 MWe, NO_x emissions are approximately 0.55 lb/MBtu with corresponding flyash LOI values of approximately 11 percent. As in previous test phases, LNB plus AOFA long-term NO_x emissions may be considerably different than the short-term results.

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1. INTRODUCTION

This document discusses the technical progress of a U. S. Department of Energy (DOE) Innovative Clean Coal Technology (ICCT) Project demonstrating advanced wall-fired combustion techniques for the reduction of nitrogen oxide (NO_x) emissions from coal-fired boilers. The project is being conducted at Georgia Power Company's Plant Hammond Unit 4 (500 MWe) near Rome, Georgia.

The project is being managed by Southern Company Services, Inc. (SCS) on behalf of the project co-funders: The Southern Company, the U. S. Department of Energy (DOE), and the Electric Power Research Institute. In addition to SCS, The Southern Company system includes five electric operating companies: Alabama Power, Georgia Power, Gulf Power, Mississippi Power, and Savannah Electric and Power. SCS provides engineering, research, and financial services to The Southern 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, 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 meet the schedule and needs of the various testing efforts throughout the demonstration program. A summary of the type of data collected is shown in Table 2.

Following each outage, a series of four groups of tests are planned. These are (1) diagnostic, (2) performance, (3) long-term, and (4) verification. The diagnostic,

performance, and verification tests consist of short-term data collection during carefully established operating conditions. The diagnostic tests are designed to map the effects of changes in boiler operation on NO_x emissions. The performance tests evaluate a more comprehensive set of boiler and combustion performance indicators. The results from these tests will include particulate characteristics, boiler efficiency, and boiler outlet emissions. Mill performance and air flow distribution are also tested. The verification tests are performed following the end of the long-term testing period and serve to identify any potential changes in plant operating conditions.

As stated previously, the primary objective of the demonstration is to collect long-term, statistically significant quantities of data under normal operating conditions with and without the various NO_x reduction technologies. Earlier demonstrations of emissions control technologies have relied solely on data from a matrix of carefully established short-term (one to four hour) tests. However, boilers are not typically operated in this manner, considering plant equipment inconsistencies and economic dispatch strategies. Therefore, statistical analysis methods for long-term data are available that can be used to determine the achievable emissions limit or projected emission tonnage of an emissions control technology. These analysis methods have been developed over the past fifteen years by the Control Technology Committee of the Utility Air Regulatory Group (UARG). Because the uncertainty in the analysis methods is reduced with increasing data set size, UARG recommends that acceptable 30 day rolling averages can be achieved with data sets of at least 51 days with each day containing at least 18 valid hourly averages.

2.2. Unit Description

Georgia Power Company's Plant Hammond Unit 4 is a Foster Wheeler Energy Corporation (FWEC) balanced draft, opposed wall-fired boiler rated at 500 gross MWe with design steam conditions of 2500 psig and 1000/1000 °F superheat/reheat temperatures, respectively. Prior to the LNB retrofit, six FWEC Planetary Roller and Table type mills provided pulverized eastern bituminous coal (12,900 Btu/lb, 33% VM, 53% FC, 1.7% S, 1.4% N) to 24 Intervane burners. During the recent LNB outage, the existing burners were replaced with FWEC Control Flow/Split Flame burners and in addition, two of the existing mills were replaced with Babcock and Wilcox MPS 75 mills. The burners are arranged in a matrix of 12 burners (4W x 3H) on opposing walls

with each mill supplying coal to 4 burners in an elevation. As part of this demonstration project, the unit was retrofitted with an Advanced Overfire Air System (AOFA), to be described later. The unit is equipped with a coldside electrostatic precipitator (ESP) and utilizes two Ljungstrom air preheaters. Plant Hammond is located near Rome, Georgia, northwest of Atlanta.

Table 1: Work Breakdown Structure			
500 MW Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (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 - 4/93
4	1.4	Final Reporting and Disposition ¹	
	1.4.1	Project Management and Reporting	4/93 - 12/93
	1.4.2	Disposition of Hardware	5/93

¹Dates 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 which lowers combustion temperatures. This staging also reduces the quantity of oxygen available to the fuel-bound nitrogen. Typical overfire air (OFA) systems accomplish this staging by diverting ten to twenty percent of the total combustion air to ports located above the primary combustion zone. AOFA improves this concept by introducing the OFA through separate ductwork with more control and accurate measurement of the AOFA airflow, thereby providing the capability of improved mixing (Figure 2).

2.4. Wall-Fired Low NO_x Combustion System

Low NO_x burner systems attempt to stage the combustion without the need for the additional ductwork and furnace ports required by OFA and AOFA systems. These commercially-available burner systems introduce the air and coal into the furnace in a well controlled, reduced turbulence manner. To achieve this, the burner must regulate the initial fuel/air mixture, velocities and turbulence to create a fuel-rich core, with sufficient air to sustain combustion at a severely sub-stoichiometric air/fuel ratio. The burner must then control the rate at which additional air, necessary to complete combustion, is mixed with the flame solids and gases to maintain a deficiency of oxygen until the remaining combustibles fall below the peak NO_x producing temperature (around 2800°F). The final excess air can then be allowed to mix with the unburned products so that the combustion is completed at lower temperatures. Burners have been developed for single wall and opposed wall boilers.

Foster Wheeler Energy Corporation (FWEC) was competitively selected to design, fabricate, and erect the opposed wall, low NO_x burner shown in Figure 3 and the AOFA system described above. In the FWEC Controlled Flow/Split Flame (CFSF) burner, secondary combustion air is divided between inner and outer flow cylinders. A sliding sleeve damper regulates the total secondary air flow entering the burner and is used to balance the burner air flow distribution. An adjustable outer register assembly divides the burners secondary air into two concentric paths and also imparts some swirl to the air streams. The secondary air which traverses the inner path, flows across an adjustable inner register assembly that, by providing a variable pressure drop, apportions the flow between the inner and outer flow paths. The inner register also controls the degree of additional swirl imparted to the coal/air mixture in the near throat region. The outer air flow enters the furnace axially, providing the remaining air necessary to complete

combustion. An axially movable inner sleeve tip provides a means for varying the primary air velocity while maintaining a constant primary flow. The split flame nozzle segregates the coal/air mixture into four concentrated streams, each of which forms an individual flame when entering the furnace. This segregation minimizes mixing between the coal and the primary air, assisting in the staged combustion process. The adjustments to the sleeve dampers, inner registers, outer registers, and tip position are made during the burner optimization process and thereafter remain fixed unless changes in plant operation or equipment condition dictate further adjustments.

Figure 1: Plant Hammond Unit 4 Boiler

Figure 2: Advanced Overfire Air System

Figure 3: Low NO_x Burner Installed at Plant Hammond

Table 2: Plant Data Points	
Boiler Drum Pressure	Superheat Outlet Pressure
Cold Reheat Pressure	Hot Reheat Pressure
Barometric Pressure	Superheat Spray Flow
Reheat Spray Flow	Main Steam Flow
Feedwater Flow	Coal Flows
Secondary Air Flows	Primary Air Flows
Main Steam Temperature	Cold Reheat Temperature
Hot Reheat Temperature	Feedwater Temperature
Desuperheater Outlet Temp.	Desuperheater Inlet Temp.
Economizer Outlet Temp.	Air Heater Air Inlet Temp.
Air Heater Air Outlet Temp.	Ambient Temperature
BFP Discharge Temperature	Relative Humidity
Stack NO _x	Stack SO ₂
Stack O ₂	Stack Opacity
Generation	Overfire Air Flows

3. PROJECT STATUS

3.1. Phase 1 - Baseline Characterization

3.1.1. Task 1.5 Baseline Characterization

Phase 1 baseline testing ended in April 1990. A summary of the baseline tests results is shown in Table 3 and Figures 4, 5, and 6. During baseline testing, 52 days of long-term data were collected producing an average NO_x emission level of 1.12 lb/MBtu. NO_x emissions generally increased with load and ranged from 0.9 to 1.3 lb/MBtu. The long-term data demonstrates a full-load, mean NO_x level of 1.24 lb/MBtu at the nominal 2.7 percent excess oxygen (wet measurement, plant O₂ 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 O₂ 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.

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 Characterization

Phase 2 AOFA testing ended in March 1991. A summary of NO_x emissions from

Phase 2 long-term testing is presented in Table 3 and Figures 4, 5, and 7. The short-term tests results from the AOFA operation show a substantial reduction (up to 40 percent at full-load reducing to 25 percent at 300 MW) in NO_x emissions. However, long-term tests indicate a maximum NO_x emissions reduction of only 25 percent. The difference between the short- and long-term test results emanate from the same operating variabilities as discussed previously and a change in operating excess air O₂ levels between the short- and long-term test segments. 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 Characterization

Phase 3A characterization of the low NO_x burner system began in June 1991 and ended in January 1992. A summary of these tests is shown in Table 3 and Figures 4, 5, and 8. Diagnostic testing began on July 9, 1991 and was completed on July 20. Performance testing began July 16, 1991. This testing indicated that the low NO_x burners were not optimally configured and therefore testing was postponed for four days to allow FWEC personnel to make additional adjustments to the new burners and ancillary systems. Testing continued on July 22 and was completed July 28. Preliminary findings from these tests indicate short-term, full-load NO_x emissions of approximately 0.65 lb/MBtu at flyash loss-on-ignition (LOI) values of 8 percent. For comparison, the baseline values were approximately 1.35 lb/MBtu at 5.2 percent LOI. NO_x production and flyash LOI are highly dependent on coal properties and mill performance. As can be seen in Table 4, mill performance during this phase was slightly better than that measured during the baseline phase. Tables 5 and 6 summarize the results for the 33 diagnostic and 14 performance tests performed during this test phase. Verification tests were also performed but have not yet been tabulated.

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.

Results from this project indicate that operation with low NO_x burners has substantially reduced boiler slagging. The site has also noticed a reduction in bottom ash production. However, the particulate that had previously been deposited on the boiler waterwalls and in the bottom hoppers is now exiting the furnace with the flue gas. The post-LNB retrofit increases in particulate mass loading and gas flow rate were approximately 25 percent and 11 percent, respectively. Another side effect of the post-LNB shift in ash loading has been a rise in primary air heater plugging rates. These increases, coupled with the higher post-LNB retrofit flyash LOI, adversely impacted particulate emissions such that it was necessary to run the unit at reduced loads to meet particulate compliance limits. Ammonia flue gas conditioning is now being utilized to improve the precipitator collection efficiency, thereby allowing full-load operation.

3.3.3. Task 3.3 LNB with AOFA Optimization

Optimization of the unit by FWEC personnel for operation with LNB with AOFA began on January 17, 1992 and was completed on February 17, 1992. FWEC's initial estimate for the time required for tuning in this configuration was two weeks. The optimization schedule was adversely impacted by (1) unavailability of the unit because of problems unrelated to the LNB retrofit and (2) often, for the same burner tuning, results were not repeatable.

Using the data collected during optimization, FWEC developed operating instructions for this mode of operation (Appendix A). These operating instructions require that the AOFA flow be indexed to load (Figure 9). Since the AOFA flow is manually controlled, this manner of operation may adversely impact the rate at which the unit can be automatically dispatched. As can be seen from this figure, overfire air is not utilized below 300 MW.

The installation of the overfire air flow measurement system purge panels was completed on March 20, 1992. FWEC operating instructions for the LNB+AOFA configuration require that the AOFA flow measurement system be operational. During LNB+AOFA short-term testing, the flow measurement system was manually purged. Since manual purging is not feasible on an extended basis, long-term testing was delayed until the automatic purge system was operational. The operability of the AOFA flow measurement system was not a critical issue during the AOFA test phase because the operating instructions specified AOFA control damper positions as a function of load instead of AOFA flows (*Third Quarter 1990 Technical Progress Report*). Alternative AOFA operating procedures are being investigated for the upcoming test phase.

3.3.4. Task 3.3 LNB with AOFA Characterization

Due to the extended amount of time required by FWEC to optimize the LNB and LNB+AOFA configurations and the need to further evaluate the adverse impacts of the LNBs on electrostatic precipitator performance, testing can not be completed within the original schedule. Therefore, the LNB+AOFA diagnostic, performance, chemical emissions, long-term, and verification tests have been rescheduled to follow the spring 1992 outage. In order to provide preliminary data from this configuration and to identify changes in unit operation which may occur as a result of modifications to the unit being made during the spring 1992 outage, abbreviated diagnostic tests for the LNB+AOFA configuration were undertaken.

The abbreviated diagnostic testing for the LNB combined with AOFA began February 18, 1992 and continued to February 25, 1992. Preliminary results from these tests indicate full-load NO_x emissions are approximately 0.55 lb/MBtu with corresponding flyash loss-on-ignition values of approximately 11 percent (Figures 4 and 5). For comparison, full-load, long-term NO_x emissions for the baseline, AOFA, and LNB test phases were approximately 1.24, 0.94, and 0.65 lb/MBtu, respectively. As in previous test phases, LNB plus AOFA long-term NO_x emissions may be considerably different than the short-term results. A summary of the NO_x emissions and LOI values for the thirty-two short-term tests performed in this configuration are shown in Tables 7 and 8, respectively.

In addition to the standard regimen of diagnostic tests performed in previous phases of the project, mill performance and combustion air flow distribution were performed for one

full-load condition. These tests, normally performed during the performance tests, were added to the diagnostic test matrix in order better characterize operating parameters which have a significant impact on combustion performance. As seen in Tables 4 and 9, mill performance was improved over that seen in previous test phases. The performance was especially good on the B&W mills installed during the spring 1991 outage ("C" and "F" mills). Secondary air, overfire air, and primary air accounted for 66, 17, and 16 percent, respectively, of total combustion air at full-load (Table 10). For comparison, Phase 2 AOFA performance tests indicated that of the total combustion air flow, 50 percent was secondary air, 20-25 percent was overfire air, and 25 percent was primary air.

Approximately one week of long-term data was collected during March 1992. As shown in Figure 10, NO_x emissions were not highly dependent on load although exhibiting a slight "U" shaped NO_x vs. load characteristic. In general, LNB+AOFA NO_x emissions were less than the corresponding emission rates for LNBs alone; however at low loads the converse was true and LNB+AOFA NO_x emissions exceeded the LNB levels. Unfortunately, no data was collected near full-load since the unit was limited to lower loads as the result of ash plugging of the primary air heaters. More complete testing of this configuration is planned for summer and fall 1992.

3.3.5. Damaged Burner

On December 9, 1991, a damaged burner was discovered by plant personnel. This burner is supplied coal by mill "B" and is located on the bottom, rear row of burners (Figure 13). The burner was isolated and unit operation continued until December 19, 1991. Following notification, FWEC began fabrication of a new inner barrel and nozzle tip and the new tip arrived on site December 26, 1991. After removal of the complete burner from the furnace, the damaged burner tip was cut off from the outer barrel assembly and the new burner tip welded into place. The inner barrel was received and replaced on January 9, 1992 and the unit came back on-line January 13, 1992.

Table 3: Baseline, AOFA, and LNB Long-Term Test Results						
Unit Configuration	Baseline		AOFA		LNB	
	Mean	RSD,%	Mean	RSD,%	Mean	RSD,%
Number of Daily Averaged Values	52	-	86	-	94	-
Average Load (MW)	407	9.4	386	17.9	305	17.7
Average NOx Emissions (lb/MBtu)	1.12	9.5	0.92	8.6	0.53	13.7
Average O2 Level (percent at stack)	5.8	11.7	7.3	12.6	8.4	7.7
NOx 30 Day Achievable Emission Limit (lb/MBtu)	1.24	-	1.03	-	0.64	-
NOx Annual Achievable Emission Limit (lb MBtu)	1.13	-	0.93	-	0.55	-

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

Table 4: Mill Performance at Full Load Mill Coal Flow Weighted Averages		
Phase	Left in 50 Mesh	Passing 200 Mesh
	Percent	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: Phase 3A LNB Diagnostic Tests							
TEST NO.	DATE	LOAD MW	MOOS	DAS O2 DRY %	NOx LB/MBtu	CO DRY PPM	COMMENTS
58-1	7/9/91	477	NONE	4.6	0.69	11	HIGH O2 - LOI TEST
58-2	7/9/91	475	NONE	4.1	0.65	11	NORMAL O2 - LOI TEST
58-3	7/9/91	473	NONE	2.9	0.58	67	LOW O2 - LOI TEST
59-1	7/10/91	471	NONE	5.0	0.66	12	HIGH O2 - LOI TEST
59-2	7/10/91	473	NONE	4.0	0.60	13	NORMAL O2 - LOI TEST
59-3	7/10/91	475	NONE	3.1	0.57	26	LOW O2 - LOI TEST
59-4	7/10/91	474	NONE	2.6	0.55	127	MINIMUM O2 - LOI TEST
59-5	7/10/91	474	NONE	3.7	0.61	31	LOWER THAN NORMAL - HVT TEST
60-1	7/11/91	393	NONE	4.6	0.56	11	HI O2
60-2	7/11/91	398	NONE	3.9	0.51	13	NORMAL O2
60-3	7/11/91	397	NONE	3.5	0.49	119	LOW O2
60-4	7/11/91	502	NONE	4.0	0.69	4	HIGH LOAD HEAT RATE TEST BY GPC
61-1	7/12/91	392	NONE	4.7	0.55	6	REPEAT HI O2
61-2	7/12/91	392	NONE	4.1	0.51	6	REPEAT NORMAL O2
61-3	7/12/91	390	NONE	3.2	0.46	81	REPEAT LOW O2
61-4	7/12/91	498	NONE	3.9	0.65	15	HIGH LOAD HEAT RATE TEST BY GPC
62-1	7/13/91	289	E	7.1	0.62	7	HIGH O2
62-2	7/13/91	291	E	5.9	0.58	7	MEDIUM O2
62-3	7/13/91	290	E	4.8	0.54	9	NORMAL O2
62-4	7/13/91	289	E	4.0	0.51	14	LOW O2 ABBREV. TEST
62-5	7/13/91	474	NONE	4.3	0.64	18	
63-1	7/14/91	302	B&E	5.8	0.50	13	
63-2	7/14/91	305	E	5.7	0.58	10	
63-3	7/14/91	303	E	4.8	0.55	26	
64-1	7/15/91	467	NONE	4.6	0.66	13	HIGH/MID O2, BALANCED MILLS
64-2	7/15/91	470	NONE	3.3	0.58	56	LOW O2, BALANCED MILLS
67-1'	7/18/91	472	NONE	4.3	0.60	16	LOI TEST, HIGH O2, OPEN INNER REG
67-2'	7/18/91	471	NONE	3.6	0.57	171	LOI TEST, MID O2, SAME INNER REG
67-3'	7/18/91	470	NONE	3.5	0.58	22	LOI TEST, LOW O2, AND OPEN OUTER REG
67-4'	7/18/91	465	NONE	3.5	0.59	16	LOI TEST, LOW O2, AND CLOSE UNDERFIRE AIR TO 25 %
68-1'	7/19/91	460	NONE	3.5	0.60	37	LOI TEST, LOWER PRIM AIR FLOW
69-1'	7/20/91	473	NONE	3.2	0.56	19	LOI TEST, MILL FINENESS MEASUREMENTS A-MILL
69-2'	7/20/91	469	NONE	3.3	0.61	15	LOI TEST, MILL FINENESS MEASUREMENTS F-MILL

1. MOOS - Mill out of service.
2. O2 as measured at economizer outlet.
3. NOx as measured at economizer outlet.

Table 6: Phase 3A LNB Performance Tests							
TEST NO.	DATE	LOAD	MOOS	DAS O2 DRY %	NOx LB/MBtu	CO DRY PPM	COMMENTS
		MW					
65-1	7/16/91	470	NONE	4	0.62	13	PERFORMANCE TEST
66-1	7/17/91	475	NONE	3.8	0.62	13	PERFORMANCE TEST
66-2	7/17/91	474	NONE	3.8	0.63	15	PERFORMANCE TEST
70-1	7/22/91	479	NONE	3.3	0.68	19	HIGH LOAD PERFORMANCE TEST, REDUCED PRIM AIR
70-2	7/22/91	470	NONE	3.6	0.66	32	HIGH LOAD PERFORMANCE TEST, REDUCED PRIM AIR
71-1	7/23/91	473	NONE	3.5	0.66	15	HIGH LOAD PERFORMANCE TEST, OPENED OUTER REG TO 50 %
71-2	7/23/91	465	NONE	3.5	0.68	15	HIGH LOAD PERFORMANCE TEST, AND REDUCED PRIM AIR
72-1	7/24/91	477	NONE	3.4	0.65	17	HIGH LOAD PERFORMANCE TEST, REDUCED PRIM AIR
73-1	7/26/91	388	NONE	4.1	0.55	11	MID LOAD PERFORMANCE TEST, HIGH O2
73-2	7/26/91	389	NONE	4.1	0.55	7	MID LOAD PERFORMANCE TEST, HIGH O2
74-1	7/27/91	403	NONE	3.8	0.55	8	MID LOAD PERFORMANCE TEST, HIGH O2
74-2	7/27/91	405	NONE	3.6	0.57	9	MID LOAD PERFORMANCE TEST, HIGH O2
75-1	7/28/91	299	E	4.3	0.47	8	LOW/MID LOAD PERFORMANCE TEST
76-1	7/28/91	298	E	4.5	0.48	8	LOW/MID LOAD PERFORMANCE TEST

1. MOOS - Mill out of service.
2. O2 as measured at economizer outlet.
3. NOx as measured at economizer outlet.

Table 7: Phase 3B' LNB+AOFA Short-Term Tests								
TEST NO.	DATE	LOAD MWe	MOOS	OFA DAMPER POSITION Percent	DASO2 Dry (54+60) Percent	NOx LB/MBTU	CO Dry (54+60) PPM	COMMENTS
83-1	02/17/92	470	None	52	4.1	0.50	18	FWEC Setup -- Bottom coal tips 2", others 3"
83-2	02/17/92	470	None	52	3.9	0.49	25	FWEC Setup -- Top coal tips 3", others 2"
83-3	02/17/92	470	None	52	4.3	0.51	27	FWEC Setup -- Top coal tips 2", others 3"
84-1	02/18/92	495	None	49	4.1	0.54	14	Full-Load -- All tips 3", I/O hoods 40/70%
84-2	02/18/92	495	None	49	4.0	0.52	47	Full-Load -- Continuation of 84-1
85-1	02/19/92	495	None	49	3.3	0.45	123	Full-Load- Low O2
85-2	02/19/92	495	None	49	4.1	0.53	16	Full-Load- Normal O2, LOI + Flow measurements
85-3	02/19/92	492	None	49	4.9	0.59	10	Full-Load -- High O2
86-1	02/20/92	400	None	27	2.9	0.37	36	Mid-Load -- Low O2
86-2	02/20/92	400	None	27	3.8	0.45	2	Mid-Load -- Normal O2
86-3	02/20/92	400	None	27	5.1	0.53	1	Mid-Load -- High O2
86-4	02/20/92	405	None	0	3.9	0.55	2	Mid-Load -- Normal O2, OFA closed
87-1	02/21/92	300	BE	28	5.5	0.42	9	Low-Load -- High O2
87-2	02/21/92	300	BE	28	4.4	0.37	31	Low-Load -- Normal O2
87-3	02/21/92	300	BE	10	4.0	0.37	31	Low-Load -- Low O2
88-1	02/22/92	290	EF	14	4.5	0.33	102	Low-Load Alt. Mill Patt. -- Low O2
88-2	02/22/92	300	EF	14	5.0	0.33	25	Low-Load Alt. Mill Patt. -- Mid O2
88-3	02/22/92	295	EF	14	5.9	0.37	15	Low-Load Alt. Mill Patt. -- High O2
88-4	02/22/92	295	EF	0	5.9	0.40	17	Low-Load Alt. Mill Patt. -- High O2, OFA closed
88-5	02/22/92	300	EF	0	5.1	0.36	41	Low-Load Alt. Mill Patt. -- Mid O2, OFA closed
89-1	02/23/92	190	BE	0	5.9	0.38	6	Minimum AGC Load -- Low O2, OFA closed
89-2	02/23/92	195	BE	0	6.6	0.40	5	Minimum AGC Load -- Mid O2, OFA closed
89-3	02/23/92	190	BE	0	8.1	0.50	4	Minimum AGC Load -- High O2, OFA closed
90-1	02/24/92	400	E	28	4.3	0.43	70	Low-Load Alt. Mill Patt. -- Low O2
90-2	02/24/92	405	E	28	4.4	0.44	70	Low-Load Alt. Mill Patt. -- Repeat of 90-1
90-3	02/24/92	405	E	25	4.8	0.48	35	Low-Load Alt. Mill Patt. -- Normal O2
90-4	02/24/92	405	E	25	6.1	0.55	13	Low-Load Alt. Mill Patt. -- High O2
90-5	02/24/92	405	E	0	5.0	0.55	11	Low-Load Alt. Mill Patt. -- Normal O2, OFA closed
91-1	02/25/92	480	None	53	4.1	0.50	12	High Load -- Normal O2
91-2	02/25/92	480	None	30	4.0	0.55	11	High Load -- Normal O2, decreased OFA
91-3	02/25/92	485	None	10	4.0	0.61	11	High Load -- Normal O2, decreased OFA
91-4	02/25/92	490	None	0	4.1	0.66	10	High Load -- Normal O2, OFA closed

1. MOOS - Mill out of service.
2. O2 as measured at economizer outlet.
3. NOx as measured at economizer outlet.

Table 8: Phase 3B' LNB+AOFA LOI Test Results				
Test No. ¹	Test Date	East LOI ² Percent	West LOI ² Percent	Average LOI Percent
FWT-157	2/12/92	7.7	8.3	8.0
FWT-158	2/12/92	10.0	9.4	9.7
FWT-159	2/12/92	7.3	5.8	6.5
FWT-160	2/13/92	3.6	5.9	4.7
FWT-161	2/13/92	7.4	8.0	7.7
FWT-162	2/13/92	7.9	7.9	7.9
FWT-164	2/14/92	5.3	8.0	5.6
FWT-165	2/14/92	8.7	8.6	8.6
FWT-166	2/15/92	12.6	9.3	10.9
FWT-167	2/15/92	10.8	9.6	10.2
FWT-168	2/15/92	12.7	9.4	11.0
FWT-169	2/17/92	7.7	12.7	10.2
83-1	2/17/92	7.5	13.6	10.6
83-2	2/17/92	7.7	11.7	9.7
83-3	2/17/92	6.9	12.4	9.6
84-1	2/18/92	9.3	14.3	11.8
84-2	2/18/92	7.7	11.5	9.6

¹FWT prefix indicates Foster Wheeler optimization tests.

²LOI samples collected at air heater outlet using hi-volume sampling.

Table 9: Phase 3B' LNB+AOFA Mill Performance ¹		
Pulverizer	Passing 200 Mesh	Remaining In 50 Mesh
A	71.49	1.50
B	66.76	1.89
C	81.57	0.02
D	72.64	2.35
E	67.67	2.46
F	77.23	0.04

¹Results from test 84.

Table 10: Phase 3B' LNB+AOFA Combustion Air Distribution ¹				
Location		Flow		
		LB/HR	LB/HR	Percent of Total
Secondary Air Flow			3273451	66%
	Boiler Left Side	1635753		
	Boiler Right Side	1637698		
Overfire Air Flow			845807	17%
	Left Rear Wall	222374		
	Left Front Wall	195894		
	Right Rear Wall	199840		
	Right Front Wall	227699		
Primary Air Flow			807240	16%
	Mill A	131046		
	Mill B	131038		
	Mill C	128618		
	Mill D	142967		
	Mill E	129992		
	Mill F	143579		

¹ Results from test 84 and 85.

Figure 4: NOx Emissions Comparison

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: Recommended AOFA Flow

Figure 10: LNB+AOFA Long-Term NO_x Trend - Preliminary

4. FUTURE PLANS

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

Future Plans (Proposed)	
Quarter	Activity
Second Quarter 1992	<ul style="list-style-type: none">• Completion of Outage
Third Quarter 1992	<ul style="list-style-type: none">• LNB+AOFA Optimization• Advanced Controls Testing• Long-Term LNB+AOFA Test
Forth Quarter 1992	<ul style="list-style-type: none">• LNB / LNB+AOFA Optimization• Diagnostic Tests of the LNB+AOFA• Post Retrofit Chemical Emissions Tests• Long-Term LNB+AOFA Test
First Quarter 1993	<ul style="list-style-type: none">• Performance Tests of the LNB+AOFA• Complete Long-Term LNB+AOFA Tests• Verification Tests of the LNB+AOFA
Second Quarter 1993	<ul style="list-style-type: none">• Begin Final Reporting• Begin Disposition
Third Quarter 1993	<ul style="list-style-type: none">• Continue Final Reporting• Continue Disposition
Forth Quarter 1993	<ul style="list-style-type: none">• Complete Final Reporting• Complete Disposition• Project Completion

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Appendix A

**Advanced Overfire Air System
Operating Instructions**

Advanced Overfire Air System Operating Instructions¹

These precautions are conservative in the fact that NO_x emission levels will be reduced with relatively little or no CO levels being experienced.

If high CO levels are encountered (above 200 PPM) the OFA control dampers should be biased until proper CO levels are obtained.

Note: The OFA control dampers should not be adjusted to control O₂ levels. If a significant discrepancy exist between left and right side O₂ levels, the OFA system should be taken out of service to ascertain cause.

1. 475 - 500 MW
 - a. Maintain total OFA flow no greater than 750 - 800 KLBH

F1 200 KLBH	R1 200 KLBH
F2 185 KLBH	R2 185 KLBH
 - b. O₂ level is to be maintained at no less than 3.8%.
2. 430 - 475 MW (6 Mill Operation)
 - a. Maintain total OFA flow no greater than 600 KLBH

F1 155 KLBH	R1 155 KLBH
F2 145 KLBH	R2 145 KLBH
 - b. O₂ level is to be maintained at no less than 3.8%.
3. 390 - 430 MW (6 Mill Operation)
 - a. Maintain total OFA flow no greater than 400 KLBH

F1 105 KLBH	R1 105 KLBH
F2 95 KLBH	R2 95 KLBH
 - b. O₂ level is to be maintained at no less than 3.8%.
4. 390 - 430 MW (5 Mill Operation)
 - a. Maintain total OFA flow no greater than 300 KLBH

F1 80 KLBH	R1 80 KLBH
F2 70 KLBH	R2 70 KLBH
 - b. O₂ level is to be maintained at no less than 3.8%.
 - c. Out of service top pulverizer burner registers are to be set at light off. Out of service intermediate or lower pulverizer burner registers are to be set closed.

¹As submitted by FWEC.

Note: If the out of service burner tip temperature exceed 1200°F, all registers on the associated burner deck are to be placed to light off position.

5. 300 - 390 MW

- a. Maintain total OFA flow no greater than 300 KLBH

F1 80 KLBH

R1 80 KLBH

F2 70 KLBH

R2 70 KLBH

- b. O₂ level is to be maintained at levels dictated by current O₂ vs. load curves.
- c. Out of service top pulverizer burner registers are to be set at light off. Out of service intermediate or lower pulverizer burner registers are to be set closed.

Note: If the out of service burner tip temperature exceed 1200°F, all registers on the associated burner deck are to be placed to light off position.

6. 200 - 300 MW

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

Note: If the out of service burner tip temperature exceed 1200°F, all registers on the associated burner deck are to be placed to light off position.

Placing The OFA System In Service, Load Up ramps, Load Down ramps

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

Load Up ramps

OFA dampers are to be opened to recommended settings following completion of the up ramp.

Load Down ramps

OFA dampers are to be preset to projected load settings prior to down ramp.

Again, dampers are to be brought to position systematically while watching O₂ and CO levels.

END

**DATE
FILMED**

3 / 16 / 93