INNOVATIVE CLEAN COAL TECHNOLOGY (ICCT)

500 MW DEMONSTRATION OF ADVANCED WALL-FIRED COMBUSTION TECHNIQUES FOR THE REDUCTION OF NITROGEN OXIDE (NOx) EMISSIONS FROM COAL-FIRED BOILERS

Technical Progress Report
Second Quarter 1992

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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 (NOₓ) 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 NOₓ combustion equipment through the collection and analysis of long-term emissions data. A target of achieving fifty percent NOₓ 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 NOₓ 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 NOₓ 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 NOx 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, NOx emissions are approximately 0.55 lb/MBtu with corresponding flyash LOI values of approximately 11 percent. For comparison, the long-term, full-load, baseline NOx emission level was approximately 1.24 lb/MBtu at 5.2 percent LOI.

Inspection of the burners during the spring 1992 maintenance outage revealed cracks in 17 of the 24 cast burner tips after less than one year operation. Also, two low NOx burners have been damaged due to excessive heat since resumption of unit operation on May 30, 1992.
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 (NOx) 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 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. 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\textsubscript{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\textsubscript{x}, SO\textsubscript{2}, O\textsubscript{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 NOX 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 NOX 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. Plant Hammond is located near Rome, Georgia, northwest of Atlanta.

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<sup>1</sup>Dates of these tasks reflects change from original project schedule.
2.3. Advanced Overfire Air (AOFA) System

Generally, combustion NOx reduction techniques attempt to stage the introduction of oxygen into the furnace. This staging reduces NOx 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 NOx 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. Wall-Fired Low NOx Combustion System

Low NOx 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 NOx 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\textsubscript{x} Burner Installed at Plant Hammond

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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 and 5. During baseline testing, 52 days of long-term data were collected producing an average NOx emission level of 1.12 lb/MBtu. NOx emissions generally increased with load and ranged from 0.9 to 1.3 lb/MBtu (Figure 6). The bands about the mean represent the 95 percentiles of the data set and show the variability of NOx emissions during long-term operation. The long-term data demonstrates a full-load, mean NOx 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. The full load, design O2 level for this boiler is approximately 3.3 percent at full load at which NOx 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 Characterization

Phase 2 AOFA testing ended in March 1991. A summary of NOX emissions from Phase 2 long-term testing is presented in Table 3 and Figures 4 and 5. The short-term tests results from the AOFA operation show a substantial reduction (up to 40 percent at full-load reducing to 25 percent at 300 MW) in NOX emissions. However, long-term tests indicate a maximum NOX 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. As shown in Figure 7, NOX emission variability was similar to that experienced during baseline testing. Mill performance during this phase was slightly better than during the baseline phase (Table 4).

3.3. Phase 3 - Low NOX 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 NOX burner system began in June 1991 and ended in January 1992. During the LNB test phase, the unit was operated according to FWEC instructions provided in the design manuals. A summary of these tests is shown in Table 3 and Figures 4 and 5. 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 NOX 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 NOX 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. NOx 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.
Long-term testing of the low NO\textsubscript{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\textsubscript{X} emission level was 0.53 lb/M\text{Btu} and the full-load, mean, NO\textsubscript{X} emission level was 0.65 lb/M\text{Btu} (Table 3 and Figure 4). As in the baseline long-term test period, NO\textsubscript{X} emissions generally increased with load; however, below approximately 275 MW, the converse is true and NO\textsubscript{X} emissions rapidly increase with decreasing load. In contrast, NO\textsubscript{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\textsubscript{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.

An important segment of the test program is to determine the impact of the low NOx combustion technologies on boiler performance. Boiler efficiency testing is performed as part of the performance tests and follows guidelines as set forth in ASME PTC 4.1. 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) higher carbon in ash values. The efficiency of the boiler is expected to decrease further when operating with LN Bs in conjunction with AOFA.

Results from this project indicate that operation with low NO\textsubscript{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. The impact of the LN Bs 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 utilized to improve the
precipitator collection efficiency, thereby allowing full-load operation and completion of this test phase.

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.

3.3.4. Task 3.3 LNB with AOFA Characterization

Due to the impact of the LNBs on electrostatic precipitator performance, testing cannot 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 NOx 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 NOx emissions for the baseline, AOFA, and LNB test phases were approximately 1.24, 0.94, and 0.65 lb/MBtu, 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 Table 4, mill performance was improved over that seen in previous test phases.

Approximately one week of long-term data was collected during March 1992. As shown
in Figure 9, NOx emissions were not highly dependent on load and exhibited only a slight "U" shaped NOx vs. load characteristic. In general, LNB+AOFA NOx emissions were less than the corresponding emission rates for LNBs alone; however at low loads the converse was true and LNB+AOFA NOx 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 fall 1992 and winter 1993.

FWEC operating instructions require that the AOFA flow be indexed to load (Figure 10). As can be seen in this figure, actual overfire air flow rates matched recommendations only approximately, especially at loads below 400 MW. The difference between recommended and actual flow rates is primarily the result of the AOFA system being manually controlled. Since the AOFA flow is manually controlled, this manner of operation may adversely impact the rate at which the unit can be automatically dispatched.

3.3.5. Burner Overheating

Three low NOx burners have been damaged due to excessive heat since the spring 1991 low NOx 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 (Figure 11). Two burners were damaged since resumption of unit operation following the spring 1992 outage.

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. 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.

On Sunday, May 31, 1992, a burner tip and inner barrel was damaged due to excessive heat. This burner is supplied coal by mill "F" and is located on the top, rear row of
burners (burner F-A). After discovery of the damage, the burner was isolated and unit operation continued until Friday, June 5, 1992. Following the shutdown, plant personnel repaired the damaged burner and the unit came back on-line on Monday, June 8, 1992. Repairs were facilitated by replacing the complete outer barrel/tip assembly. Plant process data collected during the failure by the project's data collection system is contained in Appendix A.

The last burner failure, the most severe of the three, occurred on Tuesday, June 16, 1992. In addition to burner tip, also damaged were the inner and outer barrel, burner register assembly, two adjacent burner registers, and the windbox. This burner is supplied coal by mill "C" and is located on the top, front row of burners (burner C-C). Also damaged were burners C-D and D-C. Following detection of the failure, the burner C-C was isolated and unit operation continued until Friday, June 19, 1992. Following unit shutdown, the damaged burner and register assemblies were removed from the furnace and repair of the windbox began. The plant had one complete burner assembly on site and this assembly was used to replace the severely damaged C-C burner. Using undamaged segments of the removed register assemblies from burners C-C and C-D, a working register assembly was pieced together and installed on burner C-D. As was the case during installation of the burners during spring 1991, limited access hindered repairs. All repairs were performed by the on-site maintenance contractor, Asea Brown Broveri-Combustion Engineering (ABB-CE). Approximately 10 craft personnel worked two 12 hour shifts for the duration of the outage. The unit resumed operation on Monday, June 29, 1992, however burner C-C remained isolated until repairs to the ignitor assembly could be performed. Plant process data collected during the failure by the project's data collection system is contained in Appendix B.

Although the root cause of these failures is at this time undetermined, the primary air and fuel delivery system performance - especially coal pipe velocities and primary air/fuel ratios - may have been an influencing factor. As shown in Figures 12 and 13, mill air to fuel requirements for the FWEC and the new B&W mills are different, with the air/fuel ratio at full load with all mills in service being 2.2 and 2.0 for the FWEC and B&W mills, respectively. Nominal full load coal flow on all mills is 65,000 lbm/hr and full load primary air flows for the FWEC and B&W mills are 143,000 lbm/hr and 130,000 lbm/hr, respectively. The minimum fuel rate requirement for the B&W mills is approximately 13,000 lbm/hr greater than the minimum for the FWEC mills. The B&W mills are currently running at the FWEC recommended primary air/fuel ratios. One deficiency of
differential pressure primary air-to-mill flow measurements are not temperature compensated. This deficiency can lead to errors in measured flow if the mill inlet temperature is substantially different than that for which the flow meter was calibrated. As discussed earlier, coal fineness has improved over baseline conditions and probably was not an influencing factor.

A study has been undertaken to determine the cause of these incidents and prevent future occurrences.

3.3.6. Burner Tip Cracking

Inspection of the burners during the spring 1992 outage revealed cracks in 17 of the 24 burner cast tips. The cracks are most severe on the upper elevation of burners. In many instances, the cracks were several inches long and multiple cracks are on each tip. At this time, the cracks do not seem to impact performance and FWEC recommends that no corrective action be taken. A study of the cracking problem has been undertaken by personnel from the DOE's Oak Ridge National Laboratory.

3.3.7. Ultramax Exploratory Experiment

Initial investigations by the Center for Electric Power at Tennessee Technological University into the development of digital control strategies as it relates to NOx emissions indicate that the Ultramax® optimization software may be suitable as the core of the NOx reduction strategy. Ultramax is an optimization package in which 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 its 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 testing of this package of this software package is planned for late July 1992. The proposed test plan can be found in Appendix C.

^ Ultramax is a registered trademark of Ultramax Corporation, Cincinnati, Ohio.
3.3.8. NDT Testing

During the spring 1992 outage, Georgia Power Company's Engineering and Construction Department performed a series of non-destructive tests (NDT) on the boiler waterwall tubes. Using ultrasonic techniques, eight bands along the girth of the furnace were tested to determine if any additional reduction of the water-wall tube surface had been caused by the use of the LNBs and AOFA (Figure 13). The summary of the results of these tests are given in Table 6. As can be seen from this table, no unusual wear occurred during the 6 month test period. Additional results of this testing are included in this report as Appendix D.
### Table 3: Baseline, AOFA, and LNB Long-Term Test Results

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

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

### Table 4: Mill Performance at Full Load

#### Mill Coal Flow Weighted Averages

<table>
<thead>
<tr>
<th>Phase</th>
<th>Left in 50 Mesh %</th>
<th>Passing 200 Mesh %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2.8</td>
<td>63.0</td>
</tr>
<tr>
<td>AOFA</td>
<td>2.6</td>
<td>66.5</td>
</tr>
<tr>
<td>LNB</td>
<td>1.3</td>
<td>66.5</td>
</tr>
<tr>
<td>LNB+AOFA*</td>
<td>1.3</td>
<td>73.6</td>
</tr>
</tbody>
</table>

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

### Table 5: Full Load Boiler Performance (Preliminary)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Test</th>
<th>Load MW</th>
<th>Total Fuel lb/hr</th>
<th>Total Air lb/hr</th>
<th>Excess O2 Percent</th>
<th>Excess Air% Percent</th>
<th>Flyash LOI Percent</th>
<th>Efficiency Percent</th>
<th>Change* Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>N/A</td>
<td>480</td>
<td>3.9E+05</td>
<td>4.2E+06</td>
<td>3.3</td>
<td>18</td>
<td>4.5</td>
<td>89.0</td>
<td>-</td>
</tr>
<tr>
<td>Baseline</td>
<td>Average</td>
<td>474</td>
<td>3.6E+05</td>
<td>3.7E+06</td>
<td>2.9</td>
<td>10</td>
<td>5.1</td>
<td>89.8</td>
<td>-</td>
</tr>
<tr>
<td>AOFAs</td>
<td>43-1.3</td>
<td>478</td>
<td>3.4E+05</td>
<td>3.8E+06</td>
<td>3.9</td>
<td>14</td>
<td>9.6</td>
<td>89.1</td>
<td>0.7</td>
</tr>
<tr>
<td>LNBs</td>
<td>Average</td>
<td>476</td>
<td>3.3E+05</td>
<td>3.9E+06</td>
<td>3.7</td>
<td>19</td>
<td>8.0</td>
<td>88.2</td>
<td>1.6</td>
</tr>
</tbody>
</table>

*Change relative to baseline average.

*Calculated using measured total air and fuel.

### Table 6: Post LNB Testing - Water Wall Tube Thickness

#### Nominal Wall Thickness = 0.288 in.

<table>
<thead>
<tr>
<th>Wall</th>
<th>Readings with Wall Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; .288 in</td>
</tr>
<tr>
<td>Left</td>
<td>1915</td>
</tr>
<tr>
<td>Rear</td>
<td>3195</td>
</tr>
<tr>
<td>Front</td>
<td>3054</td>
</tr>
<tr>
<td>Right</td>
<td>2114</td>
</tr>
</tbody>
</table>
1.60
NOx Comparison - All Phases
Baseline, AOFA, LNB Datasets Complete
LNB+AOFA Dataset Preliminary

Figure 4: NOx Emissions Comparison

Figure 5: Flyash Combustibles Loss-on-Ignition
Figure 6: Baseline Long-Term NOₓ Trend

Figure 7: AOFA Long-Term NOₓ Trend
1.60
Phase 3 - LNB
Complete Data Set

1.20
...................................................................................................................................................................

NOx, 95th Percentile

Ib

0.80

Mean

0.40

5th Percentile

0.00

100 200 300 400 500 600
Load, MW

Figure 8: LNB Long-Term NOx Trend

1.6

Phase 3B’ - LNB+AOFA
Partial Data Set
Preliminary

1.2

1.0

0.8

0.4

0.0

100 200 300 400 500 600
Load, MW

Figure 9: LNB+AOFA Long-Term NOx Trend - Preliminary
Figure 10: Recommended and Actual AOFA Flow

Figure 11: Damaged Burner Locations
Figure 12: Mill Air/Fuel Ratios

Figure 12: Mill Air and Coal Flows
4. **FUTURE PLANS**

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

<table>
<thead>
<tr>
<th>Quarter</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Third Quarter 1992</td>
<td>• Advanced Digital Controls Testing</td>
</tr>
<tr>
<td></td>
<td>• Begin Long-Term LNB+AOFA Test</td>
</tr>
<tr>
<td>Forth Quarter 1992</td>
<td>• Diagnostic Tests of the LNB's+AOFA</td>
</tr>
<tr>
<td></td>
<td>• Post Retrofit Chemical Emissions Tests</td>
</tr>
<tr>
<td></td>
<td>• Continue Long-Term LNB+AOFA Test</td>
</tr>
<tr>
<td>First Quarter 1993</td>
<td>• Complete Long-Term LNB+AOFA Tests</td>
</tr>
<tr>
<td></td>
<td>• Performance Tests of the LNB's+AOFA</td>
</tr>
<tr>
<td></td>
<td>• Verification Tests of the LNB's+AOFA</td>
</tr>
<tr>
<td>Second Quarter 1993</td>
<td>• Begin Final Reporting</td>
</tr>
<tr>
<td></td>
<td>• Begin Disposition</td>
</tr>
<tr>
<td>Third Quarter 1993</td>
<td>• Continue Final Reporting</td>
</tr>
<tr>
<td></td>
<td>• Continue Disposition</td>
</tr>
<tr>
<td>Forth Quarter 1993</td>
<td>• Complete Final Reporting</td>
</tr>
<tr>
<td></td>
<td>• Complete Disposition</td>
</tr>
<tr>
<td></td>
<td>• Project Completion</td>
</tr>
</tbody>
</table>
5. ACKNOWLEDGEMENTS

The following project participants are recognized for their dedicated efforts toward the success of the wall-fired low NO$_X$ demonstration: Mr. Ernie Padgett, Georgia Power Company, and Mr. Mike Nelson, Southern Company Services, for their coordination of the design and retrofit efforts and Mr. Jose Perez, full-time Instrumentation Specialist from Spectrum Systems, Inc. Also Messrs Jim Witt and Jimmy Horton of Southern Company Services for design, procurement, and installation of the instrumentation systems. The following companies have provided outstanding testing and data analysis efforts: Energy Technology Consultants, Inc., Flame Refractories, Inc., Southern Research Institute, W. S. Pitts Consulting, and Radian Corporation. Finally, the support from Mr. Art Baldwin, DOE ICCT Project Manager, and Mr. David Eskinazi, EPRI Project Manager, is greatly appreciated.
APPENDIX A
Burner Failure May 31, 1992 / Pre and Post Failure Data
HAMMOND UNIT FOUR
BURNER FAILURE 31 MAY 92

Approximate time of burner failure.
HAMMOND UNIT FOUR
BURNER FAILURE 31 MAY 92

INCHES OF WATER (DP)

SEC AIR FLOW "A" SIDE
SEC AIR FLOW "B" SIDE

TIME

10:00:00
10:10:00
10:20:00
10:30:00
10:40:00
10:50:00
11:00:00
11:10:00
11:20:00
11:30:00
11:40:00
11:50:00
12:00:00
12:10:00
12:20:00
12:30:00
12:40:00
12:50:00
13:00:00
13:10:00
13:20:00
13:30:00
13:40:00
13:50:00
14:00:00
APPENDIX B
Burner Failure June 16, 1992 / Pre and Post Failure Data
HAMMOND UNIT FOUR
BURNER FAILURE 16 JUN 92

"B" Transmitter out of service.
APPENDIX C
Ultramax Exploratory Experiment
ULTRAMAX EXPLORATORY EXPERIMENT

PURPOSE

The purpose of this experiment is to investigate the application and performance of ULTRAMAX software at Plant Hammond, Unit 4. ULTRAMAX will be tested with an experiment consisting of the control of secondary air flow to the windbox and the biasing of overfire air flow to the front and rear of the boiler. At the same time, ULTRAMAX is expected to monitor other variables and attempt to reduce the NOx emissions to comply with EPA regulations.

EXPERIMENTAL SET-UP

Hardware Required:
- ULTRAMAX and compatible computer
- Data Acquisition System
- Plant Hammond Boiler

Operators involved:
- Data Acquisition Operator
- ULTRAMAX Operator
- Control Room Operator

The control room must be equipped with the portable computer. The portable computer will be loaded with ULTRAMAX software and will be used to generate advice for the settings of the controlled variables. As more data points are typed into the model, ULTRAMAX will upgrade its model coefficients in order to minimize the emission of NOx levels while maintaining the "important results" variables within the specified constraints. Note that each data point consists of a set of values for all the active variables in the ULTRAMAX model. See appendix 1 for the variables listing.

The Data Acquisition System consists of: a) Instrumentation and Process Inputs, b) Data Acquisition Package (DAP), c) Field Wiring, and d) Instrumentation room. The DAP is an integrated system developed for IBM PC's and compatibles which collects about 150 analog inputs and a mixture of high level and low level signals. A data tabulation program provides access to process data where up to 30 variables can be viewed at one time.

For extensive information on the DAP refer to the "PHASE I BASELINE TEST REPORT" Sec. 3.2.1, pp. 3-6,3-9.

The data acquisition operator is in charge of obtaining the proper data values from the analyses made by the data acquisition system. This task involves the selection of the required measurements from the different probes, the addition or averaging
of different probe readings and the hand-over of variable values to the ULTRAMAX operator through a communications link.

The ULTRAMAX operator is in charge of proper model building using ULTRAMAX and adequate interpretation of the results. His task consists of introducing the new variable values into the software, running the Learn/Achieve cycles, and obtaining an "advice" for the control variables.

The control room operator is in charge of manipulating the controls once the advice given by ULTRAMAX has been evaluated. His task consists of the adjustment of the controls desired to produce a figure for the secondary air flow and OFA biasing as close as possible to that given by ULTRAMAX. With the present control system the resolution of setting the controlled variables will be limited. The OFA flows (front and rear) have remote manual control of damper position as opposed to flow control loops.

EXPERIMENTAL PROCEDURE

The procedure to be used for the implementation of ULTRAMAX and its results into the control cycle for the NOx emissions reduction at Plant Hammond is as follows:
1.- Model construction
2.- Optimization procedure

The construction of the model is made by disturbing the control variables in order to generate data points scattered through an "Area of Confidence". For assumed constant operating conditions and steady state operation the variable values will be transmitted from the instrumentation room to the control room by the data acquisition operator. The data acquisition operator will determine the moment when steady state is being reached and communicate the variable values to the ULTRAMAX operator. The ULTRAMAX operator, in turn, will introduce the new values into the program and execute a Learn cycle.

By previous agreement with the control room operator the following steps will be given to the control variables. Up or down does not make a difference at this point since the purpose of the step is to create a new set point for ULTRAMAX to construct its model more rapidly instead of doing its own guessing.
- Step the OFA at the front of the boiler
- Step the OFA at the rear of the boiler
- Return the front and rear OFA flows to the initial positions and step them in different directions
- Return the front and rear OFA flows to the initial positions and step the total amount of air to all the OFA ports.

Note that the magnitude of the step must be large enough so that a noticeable change in the steady state of the system occurs.

---

1. For simplicity and accuracy of assumptions, it is suggested that the boiler be at full load with all mills in service. This configuration reduces the possibility of misinterpretation of the OFA biasing due to more burners active on one side of the boiler than in the other.
but small enough so that the system is not upset beyond the normal operation of the plant. The judgement of the control room operator will be used to determine the magnitude of the step.

The data acquisition operator will maintain transmission of the data to the control room and will advise the ULTRAMAX operator at the moment that steady state is approaching so that the values can be entered into the software. This procedure is intended to provide ULTRAMAX with a distribution of variable values for different set points and expedite the model building process. As more data points are used the model is updated to fit the new values and the advice given approaches more the optimum.

The optimization of the control variables will be done following ULTRAMAX advice as long as it does not conflict with the normal operation settings. The procedure is similar to that of the model generation with the exception that instead of given predetermined step inputs to the control variables, these will be changed as advised by ULTRAMAX. Appendix 2 lists the ULTRAMAX parameters that have been changed in order to assist the optimization process.

Appendix 3 has the current ULTRAMAX formulation and the variable relation to the probes of the data acquisition system.
APPENDIX 1. Variable definitions for the exploratory experiment at Plant Hammond using ULTRAMAX.

The variables used with ULTRAMAX are classified in 8 types:
0  Miscellaneous - not used in the ULTRAMAX analyses
1  Controlled - adjusted by the user
2  External - measurable, but cannot be affect by the user
3  Ruled - user-defined rules (or functions) govern their values
4  Results - of interest only
5  Important Results - constrained or used in "CALC"
6  Measure of Performance - the "objective" to optimize, one quantity only
7  Average Performance - the average of "type 6" for all data points in disk memory

For this experiment the dependent and independent variables are divided as follows:

**Independent Variables**

CONTROLLED - Type 1
- Total OFA (kpph)
- Front OFA (kpph)
- Rear OFA (kpph)

EXTERNAL - Type 2
- Total Coal Flow (kpph)
- Load (MW)

**Dependent Variables**

RESULTS - Type 4
- SO₂ (ppm)
- THC (ppm)

IMPORTANT RESULTS - Type 5
- Opacity
- O₂ (pct)
- CO (ppm)

MEASURE OF PERFORMANCE - Type 6
- NOx (ppm)
APPENDIX 2. The following ULTRAMAX parameters have been changed from their default values.

Parameters which change the OPERATION:

PAR(10) = 2.0 Standard distance which defines the limit of the area of confidence. The smaller PAR(10), the less is the risk from bad extrapolation, and slower the performance improvements. 2.2 is the maximum allowed standard distance; 1.8 is considered conservative, good for ongoing, very low risk operations.

PAR(11) = 2 Factor of PAR(10) which is the allowed limit in "TRAVEL" from the last run point when doing exploration.

PAR(40) = 0 Removes the limitation of the "OPTIMUM ESTATE" and "ADVICE" to be within the area of confidence.

PAR(45) = 1 Do "LOCAL MODELS" with fixed discrimination parameters.

Parameters which affect the INPUT/OUTPUT:

PAR(38) = 1 All information on the screen is printed to files.
PAR(48) = 3 For displaying all curvatures.
APPENDIX 3. ULTRAMAX variable formulation and Data Acquisition System correlation.

<table>
<thead>
<tr>
<th>Variable #</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Total OFA = FT605A + FT605B + FT605C + FT605D</td>
</tr>
<tr>
<td>2</td>
<td>Front OFA = FT605A + FT605B</td>
</tr>
<tr>
<td>3</td>
<td>Rear OFA = FT605C + FT605D</td>
</tr>
<tr>
<td>4</td>
<td>Total Coal Flow = FT510 + FT520 + FT530 + FT540 + FT550 + FT560</td>
</tr>
<tr>
<td>5</td>
<td>Load = JT001</td>
</tr>
<tr>
<td>6</td>
<td>SO₂ = KVBSO2</td>
</tr>
<tr>
<td>7</td>
<td>THC = KVBTHC</td>
</tr>
<tr>
<td>8</td>
<td>Opacity = Read from dial at control room</td>
</tr>
<tr>
<td>9</td>
<td>O₂ = KVBO2</td>
</tr>
<tr>
<td>10</td>
<td>CO = KVBCO</td>
</tr>
<tr>
<td>11</td>
<td>NOx = KVBNOX</td>
</tr>
</tbody>
</table>

NOTE: The prior regions and the constraints listed in the problem formulation are subjected to change upon recommendation of the control room operator.
### ULTRAMAX PROBLEM FORMULATION

**PLANT HAMMOND, ULTRAMAX EXPLORATORY EXPERIMENT**  
07:50 FRI, 29 MAY 1992

<table>
<thead>
<tr>
<th>AR #</th>
<th>NAME</th>
<th>UNITS</th>
<th>TY</th>
<th>MO</th>
<th>TR</th>
<th>PRIOR</th>
<th>REGION</th>
<th>CONSTRAINTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TOTAL OFA</td>
<td>KPPH</td>
<td>1 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>900.</td>
<td>0.</td>
</tr>
<tr>
<td>2</td>
<td>FRONT OFA</td>
<td>KPPH</td>
<td>1 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>450.</td>
<td>0.</td>
</tr>
<tr>
<td>3</td>
<td>REAR OFA</td>
<td>KPPH</td>
<td>1 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>450.</td>
<td>0.</td>
</tr>
<tr>
<td>4</td>
<td>TOTAL COAL</td>
<td>KPPH</td>
<td>2 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>300.</td>
<td>0.</td>
</tr>
<tr>
<td>5</td>
<td>LOAD</td>
<td>MW</td>
<td>2 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>300.</td>
<td>500.</td>
</tr>
<tr>
<td>6</td>
<td>SO2</td>
<td>PPM</td>
<td>4 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>500.</td>
<td>1250.</td>
</tr>
<tr>
<td>7</td>
<td>THC</td>
<td>PPM</td>
<td>4 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>500.</td>
<td>0.</td>
</tr>
<tr>
<td>8</td>
<td>OPACITY</td>
<td>PPM</td>
<td>5 A</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5.</td>
<td>10.</td>
</tr>
<tr>
<td>9</td>
<td>O2</td>
<td>PPM</td>
<td>5 A</td>
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<td>0</td>
<td>0</td>
<td>75.</td>
<td>10.</td>
</tr>
<tr>
<td>10</td>
<td>CO</td>
<td>PPM</td>
<td>5 A</td>
<td>0</td>
<td>0</td>
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**MINIMIZING** variable # 11 NOX (Type 6)

**IST 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)** = 2. Size of AREA OF CONFIDENCE
- **PAR(11)** = 2. Factor of PAR(10) to limit TRAVEL
- **PAR(38)** = 1.
- **PAR(40)** = 0. Do not limit ADVICE to AREA OF CONFIDENCE
- **PAR(45)** = 1. Local models with fixed selection rule
- **PAR(48)** = 3. Display all Curvatures
- **PAR(55)** = 2. Terminal: NORMAL MODE (Needs ANSI.SYS Driver)
- **PAR(56)** = 0. Line printer: LPT1
- **PAR(57)** = 1. Reports saved automatically

**IST of GLOBAL FACTORS (if any)**
APPENDIX D
Non-Destructive Testing Report
Locations for Sandblasting

- Sand Blast
- Wall Blowers
- 3" Overfire Air Ports
- Sand Blast
- Burners
- Sand Blast
- Burners
- 29' Lower Furnace Air Ports
- Sand Blast
- Truss Centerline
- Sand Blast
- Sand Blast
- Sand Blast

DOE/Southern Company Services, Inc
Innovative Clean Coal
Technology Project
Plant Hammond Unit Four

April 12, 1990
GEORGIA POWER COMPANY
ENGINEERING AND CONSTRUCTION DEPARTMENT
TECHNICAL SERVICES

PLANT HAMMOND - UNIT # 4  DATE - 04/92
DESCRIPTION - FRONT WALL  TUBE DIAMETER - 3.00
NOMINAL WALL - 0.288

BLACK - READINGS GREATER THAN .288  3054
BLUE - READINGS BETWEEN .2 AND .288  531
RED - READINGS LESS THAN .2  0

3585 READINGS TAKEN

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PLANT HAMMOND - UNIT # 4
DESCRIPTION - REAR WALL
NOMINAL WALL - 0.288

DATE - 04/92
TUBE DIAMETER - 3.00

BLACK - READINGS GREATER THAN .288 3195
BLUE - READINGS BETWEEN .2 AND .288 144
RED - READINGS LESS THAN .2

3339 READINGS TAKEN

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GEORGIA POWER COMPANY
ENGINEERING AND CONSTRUCTION DEPARTMENT
TECHNICAL SERVICES

PLANT HAMMOND - UNIT # 4
DESCRIPTION - LEFT WALL
NOMINAL WALL - 0.288
TUBE DIAMETER - 3.00

DATE - 04/92

BLACK - READINGS GREATER THAN .288
BLUE - READINGS BETWEEN .2 AND .288
RED - READINGS LESS THAN .2

2178 READINGS TAKEN

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GEORGIA POWER COMPANY
ENGINEERING AND CONSTRUCTION DEPARTMENT
TECHNICAL SERVICES

PLANT HAMMOND - UNIT # 4         DATE - 04/92
DESCRIPTION - RIGHT WALL          TUBE DIAMETER - 3.00
NOMINAL WALL - 0.288

BLACK - READINGS GREATER THAN .288  2114
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RED - READINGS LESS THAN .2

2463 READINGS TAKEN

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DATE FILMED

3/115/93