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

Public Design Report
(Preliminary and Final)

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Executive Summary

This report incorporates the public design information utilized by the participants 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 technologies that were evaluated at this site are Foster Wheeler Energy Corporation's Advanced Overfire Air System (AOFA) and Controlled Flow / Split Flame low NO_x burners (LNB). In addition to these technologies, an advanced on-line optimization methodology, GNOCIS (Generic NO_x Control Intelligent System), was demonstrated.

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 primary objective of the demonstration at Hammond Unit 4 was to determine the long-term effects of commercially available low NO_x combustion technologies on NO_x emissions and boiler performance. In addition to the primary objective, it was the goal of the project to determine (1) the effects on other combustion parameters and unit operation and (2) the progressive cost effectiveness of the tested technologies.

Short-term and long-term baseline testing was conducted in an "as-found" condition from November 1989 through March 1990. Following retrofit of the AOFA system during a four-week outage in spring 1990, the AOFA configuration was tested from August 1990 through March 1991. The FWEC CF/SF low NO_x burners were then installed during a seven week outage starting on March 8, 1991 and continuing to May 5, 1991. Following optimization of the LNBs and ancillary combustion equipment by FWEC personnel, LNB testing commenced during July 1991 and continued until January 1992. Testing in the LNB+AOFA configuration was completed during August 1993. The outage during which the digital control system (DCS) was installed began in September 1993. The unit resumed operation in June 1994 and testing of the unit began thereafter.

This Public Design Report provides an overview of the test program including cost overview, host site and tested technology descriptions. A brief overview of the NO_x formation process is also included. Descriptions of the major equipment used during this project is provided.

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1. Introduction

1.1 Purpose of this Report

This Public Design Report presents the design criteria 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 MW) near Rome, Georgia. The technologies being demonstrated at this site include Foster Wheeler Energy Corporation's advanced overfire air system and Controlled Flow/Split Flame low NO_x burner. The DOE Cooperative Agreement Number for this project is DE-FC22-90PC89651.

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 (EPRI). 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 Program 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, conducted as cooperative agreements in which the industrial participant contributes at least fifty percent of the total project cost.

This report provides documentation on the design criteria used in the performance of this project as it pertains to the scope involved with the low NO_x burners, advanced overfire systems, and digital control system.

1.2 Overview of Project

1.2.1 Background of Project

The U.S. Department of Energy's Clean Coal Technology (CCT) Demonstration Program is a $7.1 billion cost-shared industry/government technology effort targeted at demonstrating a new generation of advanced coal-based technologies for both the domestic and international marketplace. DOE's share of the total project cost is approximately $2.4 billion (34 percent). As conceived by DOE, "the CCT Program has a key role in advancing three goals of the DOE Strategic Plan under the Energy Resource business line" , the goals being

- Reduce adverse environmental impacts associated with energy production, delivery, and use,

- Ensure reliable energy services with reduced vulnerability to energy price and supply volatility, and
- Enhance energy productivity to strengthen the U.S. economy and improve living standards.

The technologies being demonstrated through the CCT Program primarily target emissions of sulfur oxides, nitrogen oxides, greenhouse gases, hazardous air pollutants, and solid and liquid waste. The CCT Program has been implemented through a series of five solicitations conducted over a period of nine years. The first three solicitations (Rounds I through III) were aimed primarily at acid rain technologies while the latter two (Rounds IV and V) addressed post year 2000 energy supply.

In December 1987, Public Law No. 100-202, as amended by Public Law No. 100-446, provided $575 million to conduct cost-shared CCT Projects to demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. To that end a Program Opportunity Notice (PON) for Round II of the CCT Program was issued by DOE in February 1988, soliciting proposals to demonstrate technologies that are (1) capable of being commercialized in the 1990's, (2) more cost effective than current technologies, (3) capable of achieving significant reductions in sulfur dioxide (SO_2) and/or nitrogen oxide (NO_x) emissions from existing coal burning facilities, particularly those that contribute to transboundary and interstate pollution. In response to the PON, 55 proposals were received by the DOE and eventually 16 selected for funding. As one of the accepted proposals, Southern Company Services was awarded a contract for the project, "500 MW Demonstration of Advanced, Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers."

1.2.2 Project Objectives

The primary objective of the demonstration at Hammond Unit 4 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 was established for the project.

Specifically, the original objectives of the project are:

1. Demonstrate in a logical stepwise fashion the short-term NO_x reduction capabilities of the following advanced low NO_x combustion technologies:
    - Advanced Overfire Air (AOFA)
    - Low NO_x burners (LNB)
    - LNB with AOFA
2. Determine the dynamic, long-term emissions characteristics of each of these combustion NO_x reduction methods using 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.

To accomplish these evaluations, the project was partitioned into the following test phases:

- Phase 1 - Baseline
- Phase 2 - Advanced Overfire Air
- Phase 3A - Low NO_x Burners
- Phase 3B - Low NO_x Burners plus Advanced Overfire Air

Each of the phases of the project involved three distinct testing periods - short-term characterization, long-term characterization, and short-term verification. The short-term characterization testing established the trends of NO_x versus various parameters and establishes the influence of the operating mode on other combustion parameters. The long-term characterization testing (50 to 80 continuous days of testing) established the dynamic response of the NO_x emissions to all of the influencing parameters encountered. The short-term verification testing documented any fundamental changes in NO_x emissions characteristics that may have occurred during the long-term test period.

Over the course of the project, several tasks not part of the original project scope were included:

- Chemical Emissions Testing - Chemical emissions testing was conducted during Phases 2 and 3A
- Advanced Digital Control / Optimization - This task, added as Phase 4 of the project, evaluated advanced digital control and optimization techniques as applied to (1) reduction of NO_x emissions, (2) mitigation of adverse impacts of low NO_x burners and advanced overfire air system, and (3) improvement of boiler efficiency

1.2.3 Host Site Description

Georgia Power Company's Plant Hammond Unit 4 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. Hammond 4 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, FWEC Intervane burners. During the LNB outage, the existing burners were replaced with FWEC Control Flow/Split Flame burners. The unit was also retrofit with six Babcock and Wilcox MPS 75 mills during the course of the demonstration (two each during the spring 1991, spring 1992, and fall 1993 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, Hammond 4 was retrofit with a FWEC designed Advanced Overfire Air System. The unit is equipped with a coldside ESP and utilizes two regenerative secondary air preheaters and two regenerative primary air heaters. Designed for pressurized furnace operation, Hammond 4 was converted to balanced draft operation in 1977. The unit, equipped with a Bailey pneumatic boiler control system during the baseline, AOFA, LNB, and LNB+AOFA phases of the project, was retrofit with a Foxboro I/A distributed digital control system during Phase 4 of the project.

1.2.4 Project Schedule

Figure 1-2 shows the schedule for the project activities. Test instrumentation was originally installed during the third and fourth quarter 1989. Short-term and long-term baseline testing was conducted in an "as-found" condition from November 1989 through March 1990. Following retrofit of the AOFA system during a four-week outage in spring 1990, the AOFA configuration was tested from August 1990 through March 1991. The FWEC CF/SF low NOx burners were then installed during a seven week outage starting on March 8, 1991 and continuing to May 5, 1991. Following optimization of the LNBs and ancillary combustion equipment by FWEC personnel, LNB testing commenced during July 1991 and continued until January 1992. Testing in the LNB+AOFA configuration was completed during August 1993. The outage during which the digital control system (DCS) was installed began in September 1993. During this outage, a new precipitator was also installed on the unit.* The unit resumed operation in June 1994 and testing of the unit began thereafter.

1.2.5 Project Cost

The total estimated cost of the project is $15,853,890. The Participants' cash contribution and the Government share in the costs of this project are shown in Table 1-1. The costs quoted are those submitted in the most recent Cooperative Agreement modification. A summary of funding by contributor is shown in Table 1-2.

1.3 Report Organization

This Public Design Report is organized in the following manner:

- Section 1 - Introduction - Provides an overview of the project including funding and participants
- Section 2 - Unit Description - An overview of the unit
- Section 3 - Process Description - Describes the NO_x formation mechanism and provides a general overview of low NO_x burner and overfire air control technologies
- Section 4 - Equipment Description - FWEC Supplied Equipment - Briefly describes Foster Wheeler Energy Corporation's Controlled Flow/Split Flame Burner and Advanced Overfire Air System as installed at Hammond Unit 4. Further details are provided in Appendices A and B
- Section 5 - Equipment Description - Digital Control System
- Section 6 - Equipment Description - Instrumentation
- Section 7 - Equipment Cost Summary

In addition, the following information is provided as part of this report as Appendices.

Appendix A - FWEC Proposal to SCS

Appendix B - CF/SF Low NO_x Burners and Advanced Overfire Air Operating Instructions

Appendix C - List of Major Drawings Associated with LNB and AOFA Retrofit

* The precipitator installation was not part of the Wall-Fired project.

Appendix D - Digital Control System Scope

Appendix E - Digital Control System Interconnect Diagram

Appendix F - Control Processor Functional Arrangement

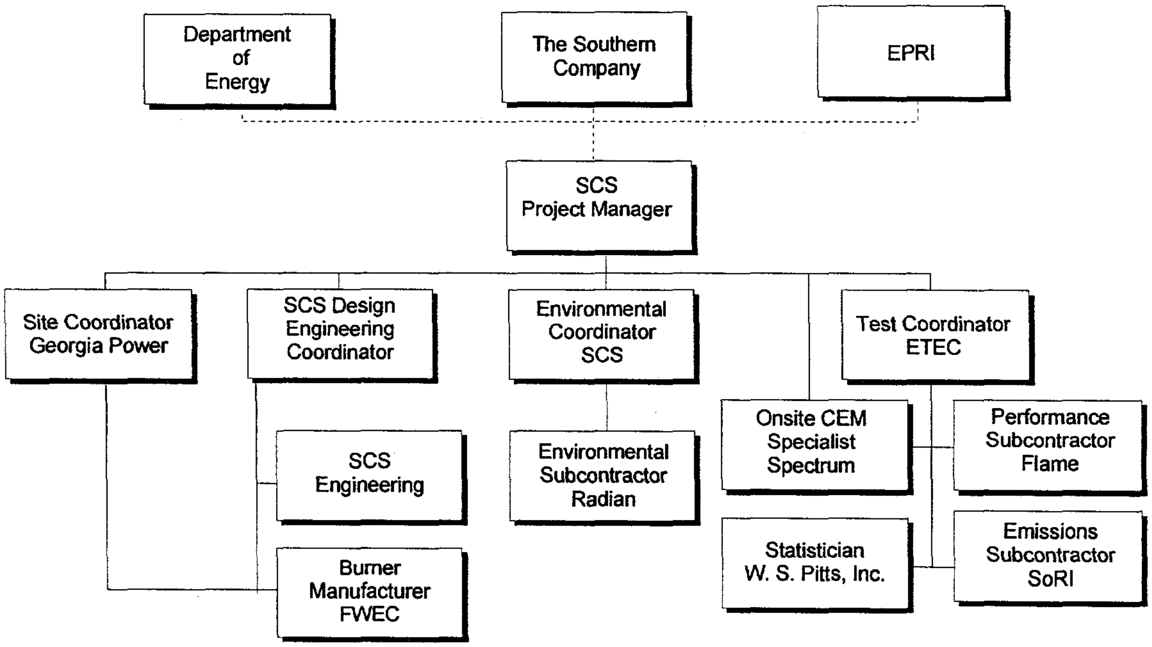


Figure 1-1: Project Organization

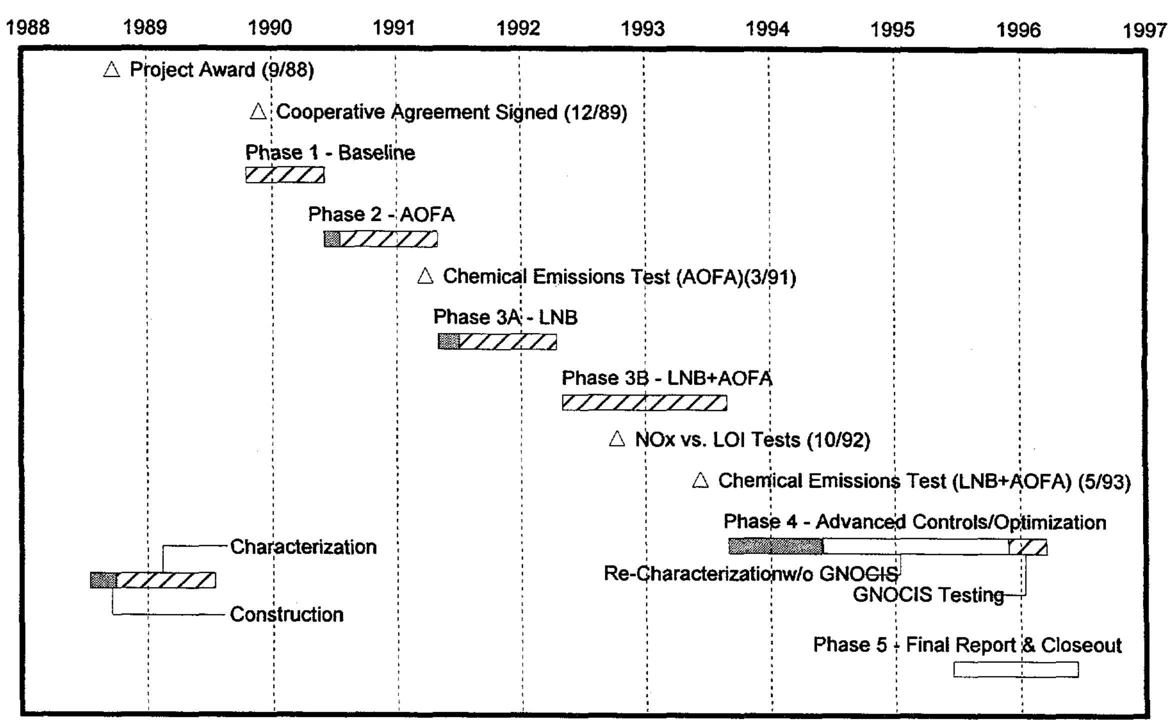


Figure 1-2: Overall Project Schedule

Table 1-1: Project Costs by Phase

Phase	Dollar Share ($)	Percent Share (%)
Phase 0 - Pre-Award		
Government	$122,311	41%
Participant	$179,637	59%
	$301,948	
Phase 1 - Baseline Testing		
Government	$660,426	45%
Participant	$813,739	55%
	$1,474,165	
Phase 2 - AOFA Installation and Characterization		
Government	$1,712,745	45%
Participant	$2,110,346	55%
	$3,823,090	
Phase 3 - LNB Installation and Characterization		
Government	$2,571,446	45%
Participant	$3,168,389	55%
	$5,739,835	
Phase 4 - Digital Control System		
Government	$1,076,000	30%
Participant	$2,522,338	70%
	$3,598,338	
Phase 4 - Project Close-out and Final Reporting		
Government	$410,598	45%
Participant	$505,915	55%
	$916,513	
Total Project Funding	$15,853,890	

Table 1-2: Project Funding by Participant

Participant	Dollar Contribution	Percent
DOE	$6,553,526	41.3
EPRI + Southern Company	$9,300,364	58.7
Total	$15,853,890	100

2. Unit Description and Pre-Retrofit Operating Characteristics

2.1. Unit Description

Georgia Power Company's Plant Hammond Unit 4 is a Foster Wheeler opposed wall-fired boiler, which started operating in 1970. The unit, shown in Figure 2-1, is rated at 500 MW with design steam conditions of 2500 psig and 1000/1000°F superheat and reheat temperatures, respectively. The boiler was originally designed for pressurized operation, but it was converted to balanced draft in 1977. As shown in Figure 2-2, the burners are arranged in a matrix of 12 burners (4 wide x 3 high) on the front and rear walls with each mill supplying coal to the four burners of each elevation. The original design characteristics of the unit are summarized in Table 2-1.

Table 2-1: Hammond Unit 4 Design Characteristics/Pre- Technology Retrofit

Unit Size	500 MW
Commissioning Year	1970
Firing System/Number of burners	Opposed wall-fired/24 burners
Vendor	Foster Wheeler Energy Corp.
Furnace	
- Configuration	Single Furnace
- Width X Depth (ft X ft)	52.5 X 40
- Burner Zone Liberation Rate (Btu/hr-sqft)	425,000
Windbox Design	
- Coal Elevation Spacing (ft)	8.5
- Top coal elev.-to-furn. outlet (nose) (ft)	55
Number of Mills/Mill Type	6 FWEC Planery Roller & Table Mills
Air/Fuel Ratio	2.1
Mill Transition Points	400 MW: E or B-MOOS
	300 MW:BE or EF-MOOS or AE-MOOS
Coal Type	Eastern bituminous
FC/VM	1.57
ESP (cold-side)	
- Specific collection area (ft^2)	161
- Fly ash resistivity (ohm-cm)	low-to-mid 10^{10}

As originally constructed and during baseling testing, six Foster Wheeler Energy Corporation (FWEC) planetary roller and table type mills provided pulverized eastern bituminous coal to 24 FWEC Intervane burners. During the test program although not part of it, the existing FWEC mills were replaced with B&W MPS 75 mills in phases; two mills were replaced in the Spring of 1991 and two more in the Fall of 1992. The last two mills were replaced in the Fall 1993/Spring 1994 outage.

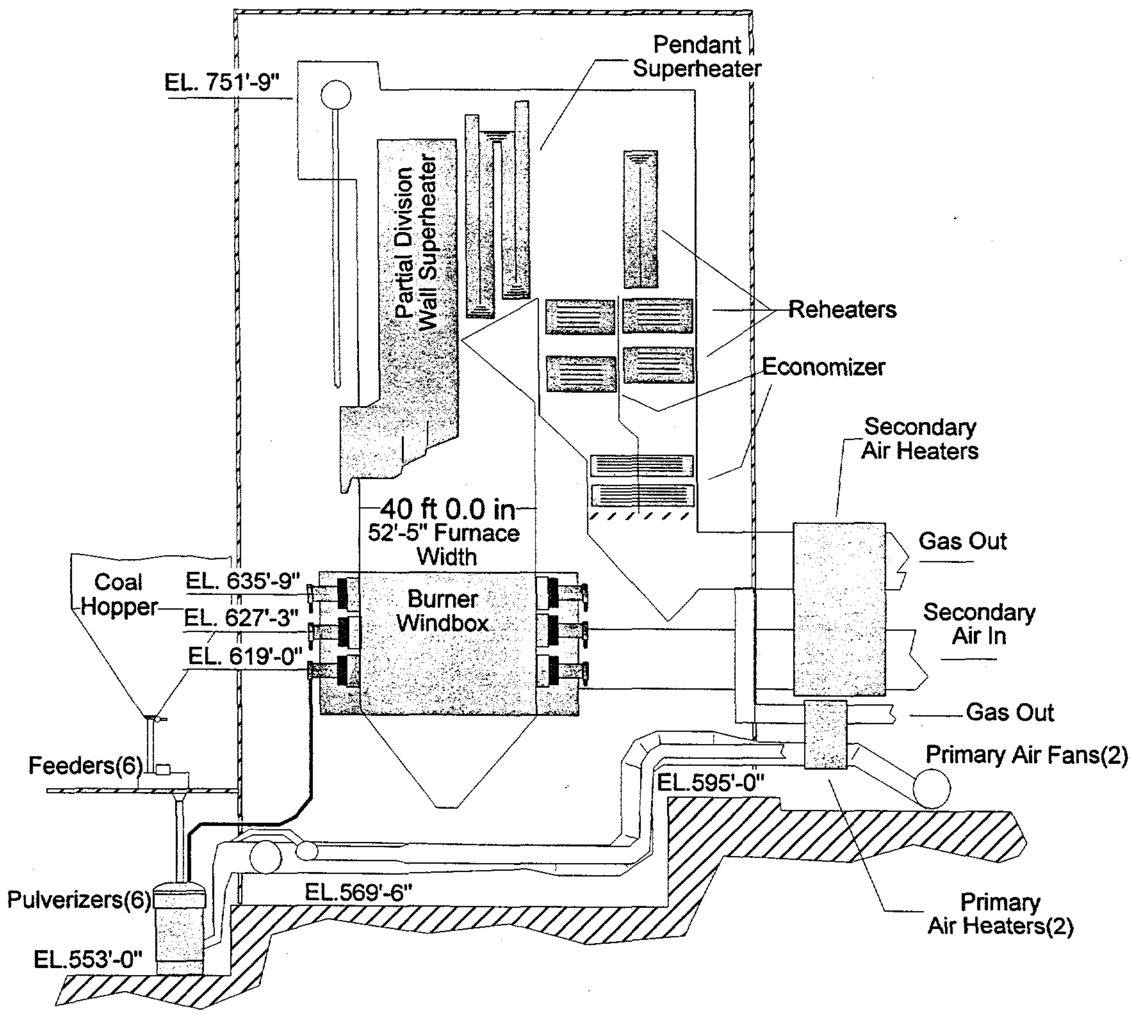


Figure 2-1: Hammond Unit 4 Side View / Pre-Retrofits

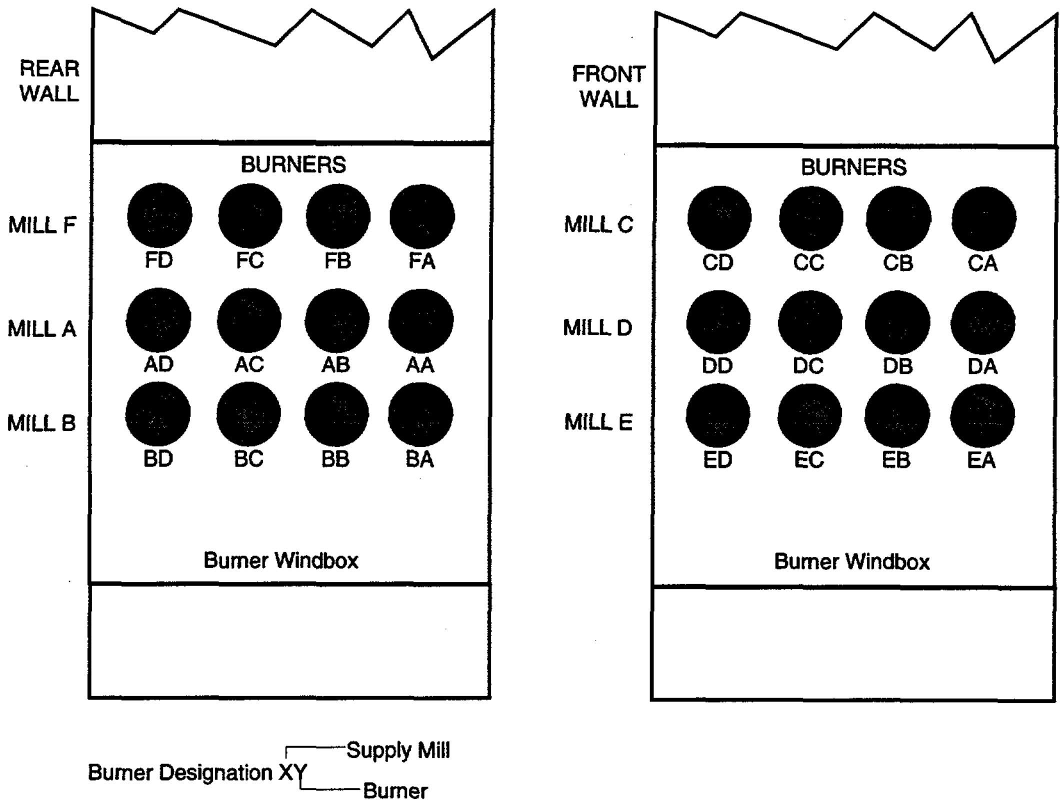


Figure 2-2: Burner Layout

As shown in Figure 2-3, the unit is equipped with a cold-side electrostatic precipitator (ESP) and Ljungstrom air preheaters; two secondary air and two primary air preheaters. The ESP capacity (original design of 161 SCA) was characterized as marginal under the baseline conditions.

In June of 1994, installation of a new electrostatic precipitator was completed for Hammond Unit 4. The new precipitators were furnished by Research Cottrell and are designed with an SCA of 213 ft^2/1000 acfm. The precipitators utilize a rigid discharge electrode design and have a design gas velocity of 5.15 ft/sec and collection efficiency of 99.65%.

The key features of Hammond Unit 4 which may impact the NO_x emission reduction with the low NO_x technologies and the applicability of the results to other wall-fired units are:

- High heat release rate
- Relatively small distance between the top burner elevation and the furnace outlet (55 ft)
- Marginal ESP capacity during Phases 1 through 3 of the test program; 9 fps velocity and 161 SCA
- The coal being burned at Hammond Unit 4 is a medium to low reactivity Eastern Bituminous coal

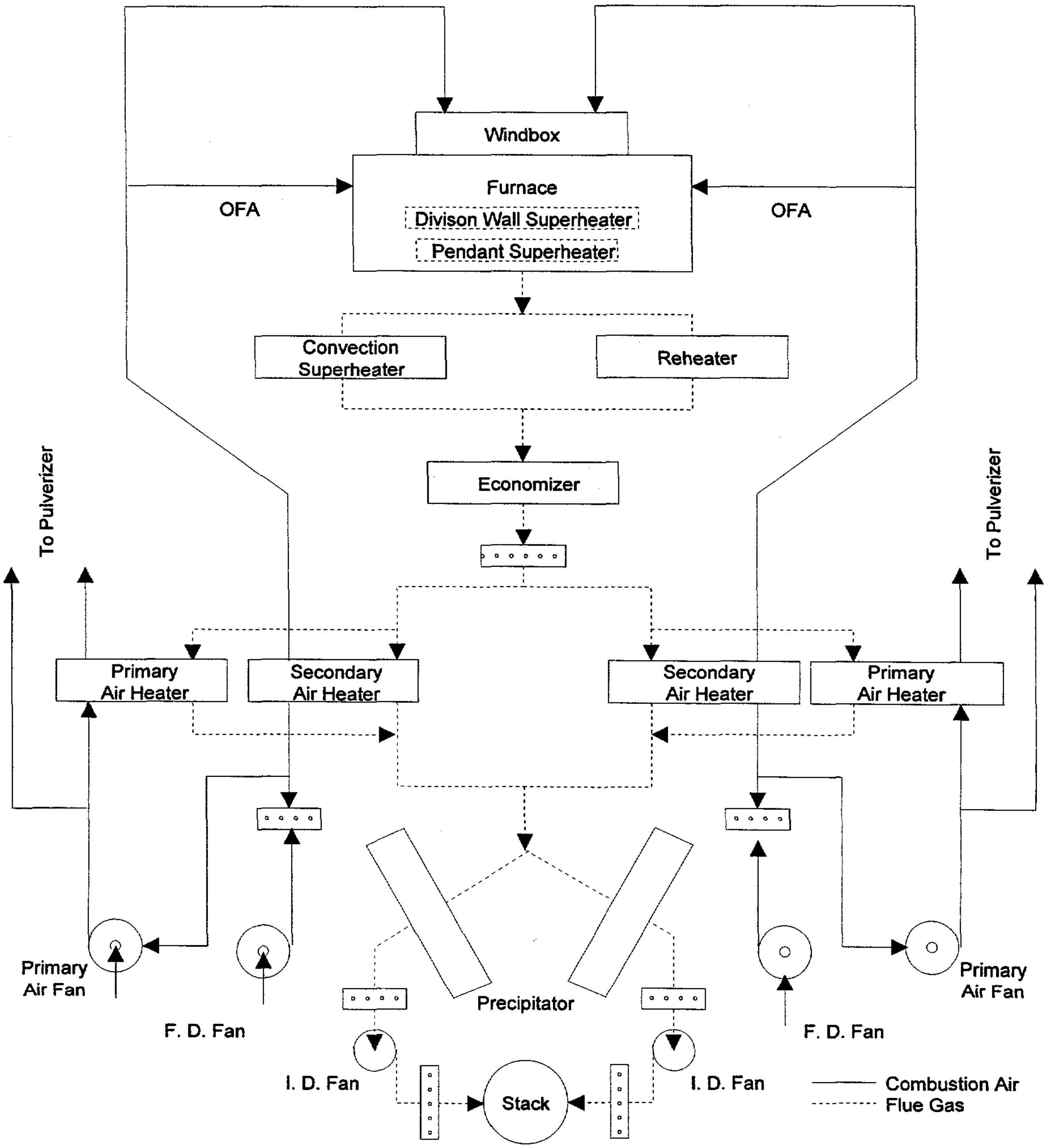


Figure 2-3: Layout of Combustion Air and Flue Gas Paths

The high heat release rate of the unit contributed to the higher than average baseline NO_x emissions (1.24 lb/MBtu long-term NO_x at full load). The heat release rate[a] for Hammond 4 is 425,000 Btu/hr-sqft as compared to the average heat release rate for opposed Foster Wheeler wall-fired units of 250,000 Btu/hr-sqft. However, it is not clear how the heat release rate will impact the (percentage) NO_x emission reduction.

The smaller than average distance from the top burner to the furnace outlet has limited the size and the location of the AOFA system, and potentially reduced the NO_x emission reduction potential. Also, due to the short distance from the top burner to the furnace outlet (furnace nose plane), the residence time of the coal particles will be reduced and the unburned carbon (LOI) may increase. However, the Hammond unit is not unique; there are many similar boilers designed in the 1960s, which face the same retrofit issues.

The boiler burns a medium to low volatility eastern bituminous coal with a typical analysis as shown in Table 2-2. As Figure 2-4 shows, the reactivity of the Hammond coal is similar to Illinois Bituminous B-type coals.

Table 2-2: Typical Hammond 4 Coal

Characteristic	Value
Constituents	
Ultimate	
Carbon	72.40 %
Hydrogen	4.69 %
Nitrogen	1.43 %
Sulfur	1.72 %
Oxygen	5.65 %
Moisture	4.28 %
Ash	9.77 %
Proximate	
Fixed Carbon:	52.70 %
Volatiles	33.50 %
Ash	9.77 %
HHV	12,900 Btu/lb

[a] FWEC uses burner zone liberation rate to indicate heat release. The area is calculated as follows: 2(W x H) + 2(D x H) + 2(D x W) where W = Width, D = Depth, and H = Height from knuckle to 10 feet above centerline of top row of burners. Other boiler manufacturers define heat release in a different manner.

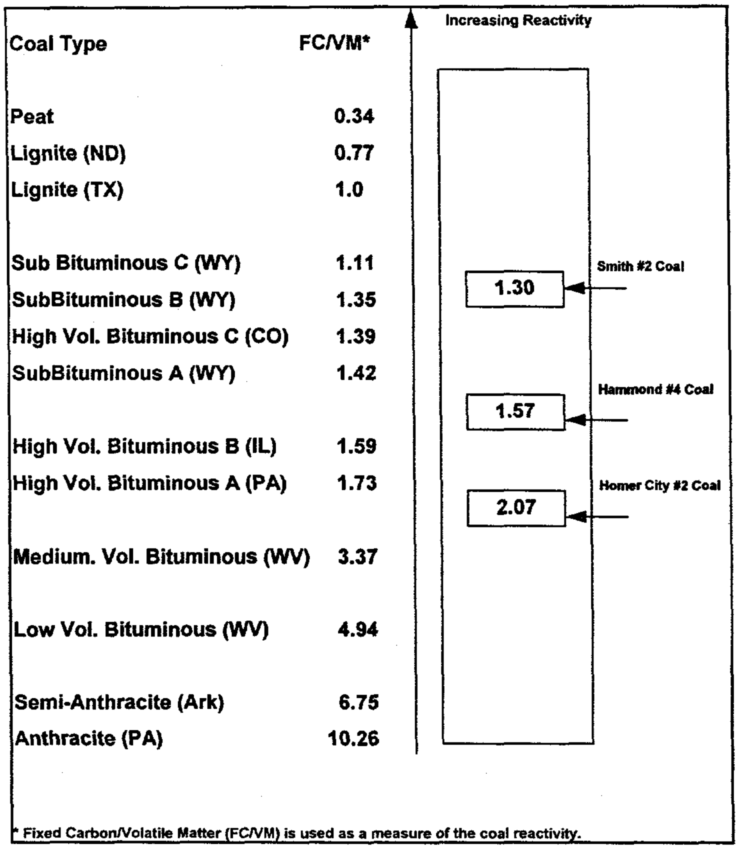


Figure 2-4: Comparison of Hammond Coal Reactivity to Other U.S. Coals

2.2. *Pre-Retrofit Operating Characteristics*

The main parameters characterizing the unit performance as it relates to this project are NO_x and CO emissions, required O_2, LOI, coal fineness, furnace slagging, backpass fouling, and performance of the ESP. The pre-technology values for these important operating characteristics are briefly discussed below.

NO_x Emissions

Pre-retrofit NO_x emissions at 480 MW load ranged from 1.1 to 1.45 lb/MBtu (750 to 1000 ppm) with O_2 of 2 to 5 percent as measured at the economizer outlet. The average full load long-term NO_x emissions at full load were 1.24 lb/MBtu at an average O_2 level of 2.6 percent. This emission level represents normal operation with the combustion system not optimized to reduce NO_x emissions prior to the commencement of the baseline testing. As shown in Figure 2-5, NO_x emissions decreased slightly with decreasing load. At 300 MW (control point), NO_x emissions were approximately 1.00 lb/MBtu.

CO Emissions

CO emissions were generally below 100 ppm over the load range. The CO level was adversely impacted by plant staff lowering operation excess O_2 levels in an effort to reduce stack particulate emissions.

Excess Oxygen

Excess O_2 (as measured at the economizer outlet) at full load ranged from 2 to 5 percent with an average of 2.6 percent. The lower limit was set to keep CO emissions from increasing while the upper limit was due to ESP capacity limitations.

Fly Ash Loss-on-Ignition

LOI at full load was 5 percent with average coal fineness of 63.0 percent through 200 mesh and 2.8 percent left on 50 mesh (Figure 2-6). This coal fineness does not compare favorably with the coal fineness recommended by most low NO_x burner manufacturers (higher than 70 percent through 200 mesh and less than 1.5 percent left on 50 mesh), but it established a basis for comparing the post-retrofit coal fineness and LOI. It should be noted also that the baseline testing was performed with all six original FWEC mills.

Air and Fuel Balancing

Significant air and coal flow imbalance was measured; O_2 ranged from 2 to 5 percent from the front to the rear wall of the furnace, respectively. The coal flow rate through each mill varied significantly, as well; even though the mills were set by the control room to approximately equal flow rates, up to 11 percent difference in flow rate was observed between mills.

Furnace Slagging

Prior to the retrofits, the unit could be considered to have moderate-to-high in-furnace slagging. This high slagging contributed to the extremely high furnace temperatures.

Steam Temperatures

Superheater outlet temperature was between 990 and 1000°F, while the reheat outlet was below 1000°F. The reheat temperature was particularly low (950-980°F) in the 250 to 420 MW load range.

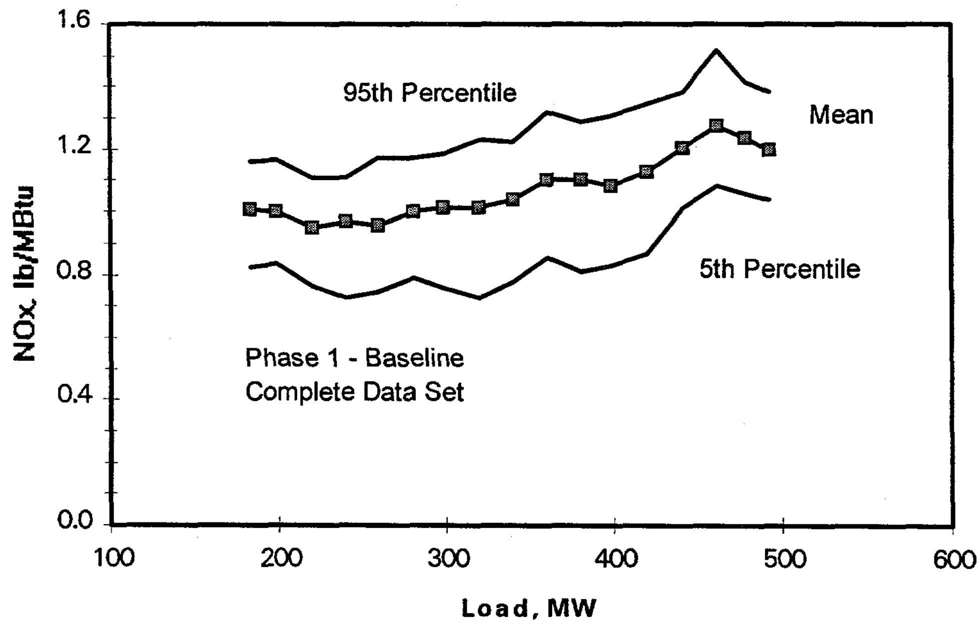


Figure 2-5: Pre-Retrofit NO_x Emissions

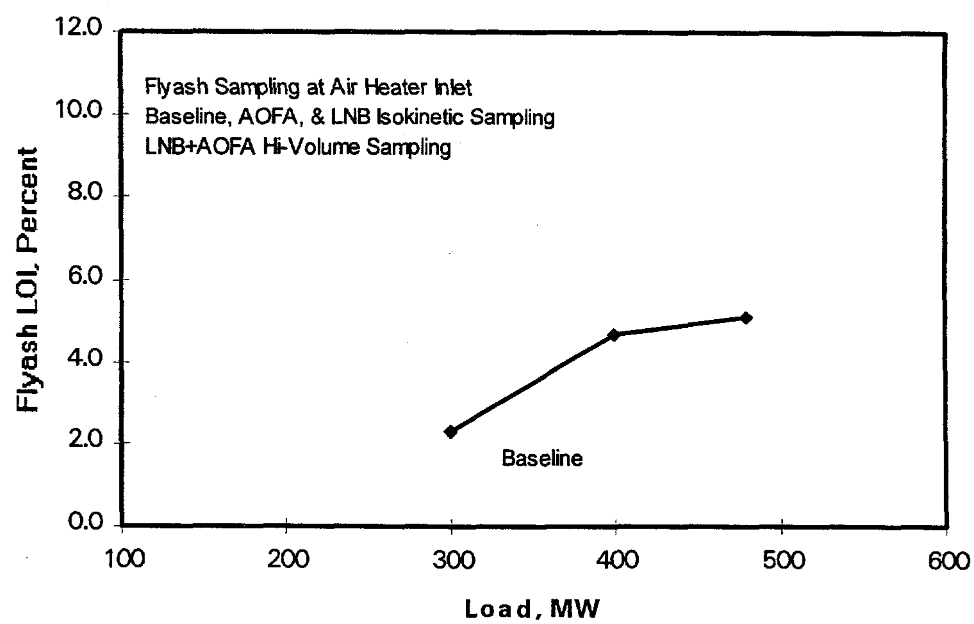


Figure 2-6: Pre-Retrofit Fly Ash Loss-on-Ignition

3. Process Description

The NO_x control technologies being demonstrated as part of this project rely primarily upon precise control of the combustion process to regulate the formation (and destruction) of NO_x within the combustion zone of the furnace. The following sections provide discussions of (1) the detailed descriptions of the fundamental chemical and physical mechanisms which control NO_x formation, (2) the processes by which each of the proposed technologies controls these mechanisms to minimize NO_x formation, (3) how these technologies might affect (positively or negatively) post-combustion NO_x control technologies, (4) how the proposed technologies compare to other alternative technologies, and (5) the potential effects of the proposed NO_x controls on other pollutant emissions.

3.1. Process Concept Description

To comprehend the chemical and physical processes governing the operation of the NO_x control technologies that are the subject of this proposal, a thorough understanding of the mechanisms by which NO_x is formed in combustion processes and the parameters that govern the formation or destruction of NO_x is imperative. Although many readers of this report will already have a comprehensive knowledge of this subject, it is thought to be useful to present in this document a concise overview of NO_x formation and control mechanisms for all readers. The discussion presented herein is a compendium of a large volume of public literature dating from 1947 (original Zeldovich equilibrium mechanisms) to present day papers presented at NO_x control symposia. The following discussion represents a widely held consensus on the mechanisms of formation and destruction of nitrogen oxides in fossil fuel combustion processes.

3.1.1. NO_x Formation Mechanisms

Nitrogen oxides are formed in combustion processes through the thermal fixation of atmospheric nitrogen in the combustion air producing "thermal NO_x," and the conversion of chemically bound nitrogen in the fuel producing "fuel NO_x". For natural gas and distillate oil, nearly all NO_x emissions result from thermal fixation. With residual oil, crude oil, and coal, the contribution from fuel-bound nitrogen can be significant and, in many cases, predominant.

Thermal NO_x

Nitrogen oxides (NO_x) are formed during combustion by the high temperature, thermal fixation of N_2. At high temperature, both N_2 and O_2 molecules in air are dissociated into their respective atomic states, N and O. The subsequent reduction of these atoms is described by the well known Zeldovich mechanism equations:

$$N_2 + O \leftrightarrow NO + N$$

$$N + O_2 \leftrightarrow NO + O$$

$$N + OH \leftrightarrow NO + H$$

Nitric oxide (NO) is the primary reaction product, even though NO_2 is thermodynamically favored at lower temperatures. The residence time in most stationary combustion processes is too short for significant oxidation of NO to NO_2.

In the flame zone itself, the Zeldovich mechanism with the equilibrium oxygen assumption is not adequate to account for experimentally observed NO formation rates. Several investigators have observed the production of significant amounts of "prompt" NO, which is formed very rapidly in the flame front, but there is no general agreement on how it is produced. Prompt NO is believed to stem from the existence of "super-equilibrium" radical concentrations within the flame zone which result from hydrocarbon chemistry and/or nitrogen specie reactions. To date, prompt NO has only been explicitly measured in carefully controlled laminar flames, but the mechanism almost certainly exists in commercial combustor flames as well. In an actual combustor, both the hydrocarbon and NO_x kinetics are directly coupled to turbulent mixing in the flame zone.

Experiments indicate that under certain conditions, the amount of NO formed in heated mixtures of N_2 and O_2 can be expressed by the following equation.

$$[NO] = k_1 \exp(-k_2/T)\,[N_2]\,[O_2]^{1/2t}$$

where [ ] = mole fraction

k_1, k_2 = constants

T = temperature

t = time.

Although this equation does not adequately describe NO formation in turbulent flames, it illustrates several points about thermal NO_x formation. First, it shows the strong dependence of NO formation on temperature (an inverse exponential function of 1/T, thus increasing with T). Also, NO formation is directly proportional to the square root of oxygen concentration.

Based on the above relations, thermal NO_x can theoretically be reduced by decreasing:

- peak temperature
- local nitrogen concentrations at peak temperatures
- local oxygen concentrations at peak temperatures
- residence time at peak temperatures

Since reducing N_2 levels is quite difficult, thermal NO_x control efforts have focused on reducing oxygen levels, peak temperatures, and time of exposure in the NOx producing regions of a furnace. Techniques such as lowered excess air and staged combustion have been used to lower local O_2 concentrations in utility boilers. Similarly, flue gas recirculation and reduced air preheat have been used on gas- and oil-fired boilers to control thermal NO_x by lowering peak flame temperatures. Flue gas recirculation also reduces combustion gas residence time, but its primary effect on thermal NO_x control is through temperature reduction. Neither flue gas recirculation nor air preheat reduction have been very successful in reducing NO_x on coal-fired boilers.

It is important to recognize that the above-mentioned techniques for thermal NO_x reduction alter combustion conditions. Although these techniques have all been relatively successful in reducing thermal NO_x, local combustion conditions ultimately determine the amount of thermal NO_x formed. These conditions in turn are intimately related to such variables as local combustion intensity, heat removal rates, and internal mixing effects. Modifying these secondary combustion variables requires fundamental changes in combustion equipment design.

Studies on the formation of thermal NO_x in gaseous flames have confirmed that internal mixing can have large effects on the total amount of NO formed. Burner turbulence, combustion air velocity, fuel injection angle and velocity, burner quarl shape, and confinement ratio all affect the mixing between fuel, combustion air, and recirculated products. Mixing, in turn, alters the local temperatures and specie concentrations which control the rate of NO_x formation.

Generalizing these effects is difficult because the interactions are complex. Increasing turbulence, for example, may increase entrainment of cooled combustion products (hence lowering peak temperatures) and increase fuel/air mixing (raising local combustion intensity). The net effect of increasing turbulence can be either to raise or lower NO_x emissions, depending on other system parameters.

The hierarchy of effects depicted in Table 3-1 describes local combustion conditions which promote thermal NO_x formation. Although combustion modification technology seeks to affect the fundamental parameters of combustion, modification must be made by changing the primary equipment and fuel parameters. Control of thermal NO_x, which historically began by altering inlet conditions and external mass addition, has moved to more fundamental changes in combustion equipment design.

Table 3-1: Factors Controlling the Formation of Thermal NOx

Primary Equipment and Fuel Parameters	Secondary Combustion Parameters	Fundamental Parameters
Inlet temperature, velocity		
Furnace design	Combustion intensity	
Fuel composition	Heat removal rate	Oxygen level
Injection pattern of fuel and air	Mixing of combustion products into flame	Peak temperature
Size of droplets or particles	Local fuel/air ratio	Exposure time at peak temperature
Burner swirl	Turbulent distortion of flame zone	
External mass addition	Reduction of flame temperatures by dilution	

Fuel NO_x

Fuel-bound nitrogen occurs in coal and petroleum fuels. However, the nitrogen-containing compounds in petroleum tend to concentrate in the heavy resin and asphalt fractions upon distillation. Therefore fuel NO_x is of importance primarily in residual oil and coal firing. The nitrogen compounds found in petroleum include pyrroles, indoles, isoquinolines, acridines, and prophyrins. Although the structure of coal has not been defined with certainty, it is believed that coal-bound nitrogen also occurs in aromatic ring structures such as pyridine, picoline, quinoline, and nicotine. The nitrogen content of most U.S. coals lies in the 0.5 percent to 2 percent range. Thus, fuel NO_x is a primary concern of coal combustion.

Although the precise mechanism by which fuel nitrogen in coal is converted to NO_x is not understood, certain aspects are clear. In a large pulverized coal-fired utility boiler, the coal particles are conveyed by an air stream into the hot combustion chamber, where they are heated at a rate in excess of 10,000°F/second. Volatile species containing some of the coal-bound nitrogen vaporize and burn rapidly (on the order of 10 milliseconds). This volatile combustion occurs homogeneously at some distance away from the original coal particle. Combustion of the remaining solid char is heterogeneous and much slower (on the order of 300 milliseconds). Nitrogen oxide can be produced from either the volatile or char fraction of the coal.

Figure 3-1 depicts a possible history of fuel nitrogen during this process. In general, volatile nitrogen evolution parallels evolution of the total volatiles except during the initial 10 to 15 percent volatilization in which little nitrogen is released. Both total mass volatilized and total nitrogen volatilized increase with higher pyrolysis temperature; the nitrogen volatilization increases more rapidly than that of the total mass. Pyrolysis temperatures can influence the ratio between volatile and char NO. However, at temperatures greater than 1800°K (2780°F), the char would be devoid of nitrogen, and char-produced NO would not exist. Coal type and pyrolysis temperature are both important in determining the amount of nitrogen devolatilized. For a given temperature, differences of up to 30 percent in volatile nitrogen yield can be seen. Thus, NO_x emissions may be different from coals with the same nitrogen content.

Although there is no absolute agreement on how the volatiles separate into species, it appears that about half the total volatiles and 85 percent of the nitrogenous species evolved react to form other reduced species before being oxidized. Prior to oxidation, the devolatilized nitrogen may be converted to a small number of common, reduced intermediates such as HCN and NH in the fuel-rich regions of the flames. The existence of a set of common reduced intermediates would explain the observation that the form of the original fuel nitrogen compound does not influence its conversion to NO. The reduced intermediates are then either oxidized to NO or converted to N_2 in the post combustion zone. Nitrogen retained in the char may also be oxidized to NO, or reduced to N_2 through heterogeneous reactions occurring in the post-combustion zone. The fraction of nitrogen remaining in the char can be high, although its conversion to NO is low compared to volatile nitrogen conversion to NO. This is probably due to the mechanism of char combustion. It is believed that char combustion involves internal burning with diffusion at or in the particulate being a controlling parameter. Because of the nature of char combustion, the conversion of nitrogen in the char to NO is not affected by near-burner aerodynamics. Thus, char NO can have significance in terms of the ultimate ability to reduce NO emissions.

Based on experimental and modeling studies, it is believed that 60 to 80 percent of the fuel NO_x results from volatile nitrogen oxidation. Conversion of char nitrogen to NO is generally lower, by factors of two to three, than conversion of total coal nitrogen, but is also relatively insensitive to load or overall stoichiometry.

Regardless of the precise mechanism of fuel NO_x formation, several general trends are evident. Fuel nitrogen conversion to NO is highly dependent on the fuel/air ratio for the range existing in typical combustion equipment. Oxidation of the char nitrogen is relatively insensitive to fuel/air changes, but volatile NO formation is strongly affected by fuel/air ratio changes. Thermal nitrogen is also affected by the fuel/air ratio.

In contrast to thermal NO_x, fuel NO_x production is relatively insensitive to small changes in combustion zone temperature. Char nitrogen oxidation appears to be a very weak function of temperature, and although the amount of nitrogen volatiles appears to increase as temperature increases, this is believed to be partially offset by a decrease in percentage conversion. Furthermore, operating restrictions severely limit the magnitude of actual temperature changes attainable in current systems.

Fuel NO_x emissions are a strong function of fuel/air mixing. In general, any change which increases the mixing between the fuel and air during coal volatilization will dramatically increase volatile nitrogen conversion and increase fuel NO_x. In contrast, char NO formation is only weakly dependent on initial mixing.

From the above discussions, it appears that, in principle, the best strategy for fuel NO_x abatement combines low excess air (LEA) firing, optimum burner design, and staged combustion. Assuming suitable stage separation, LEA may have little effect on fuel NO_x, but it may increase boiler efficiency. Before using LEA firing, the need to establish good carbon burnout and low CO emissions must be considered.

Optimum burner design ensures locally fuel-rich conditions during devolatilization, which promotes reduction of devolatilized fuel nitrogen to N_2. Staged combustion produces overall fuel-rich conditions during the first one to two seconds of combustion and promotes the reduction of NO to N_2 through reburning reactions. High secondary air preheat may also be desirable, because it promotes more complete nitrogen devolatilization in the fuel-rich initial combustion stage. This leaves less char nitrogen to be subsequently oxidized in the fuel-lean second stage. Unfortunately, it also tends to favor thermal NO formation, and at present there is no general agreement on which effect dominates.

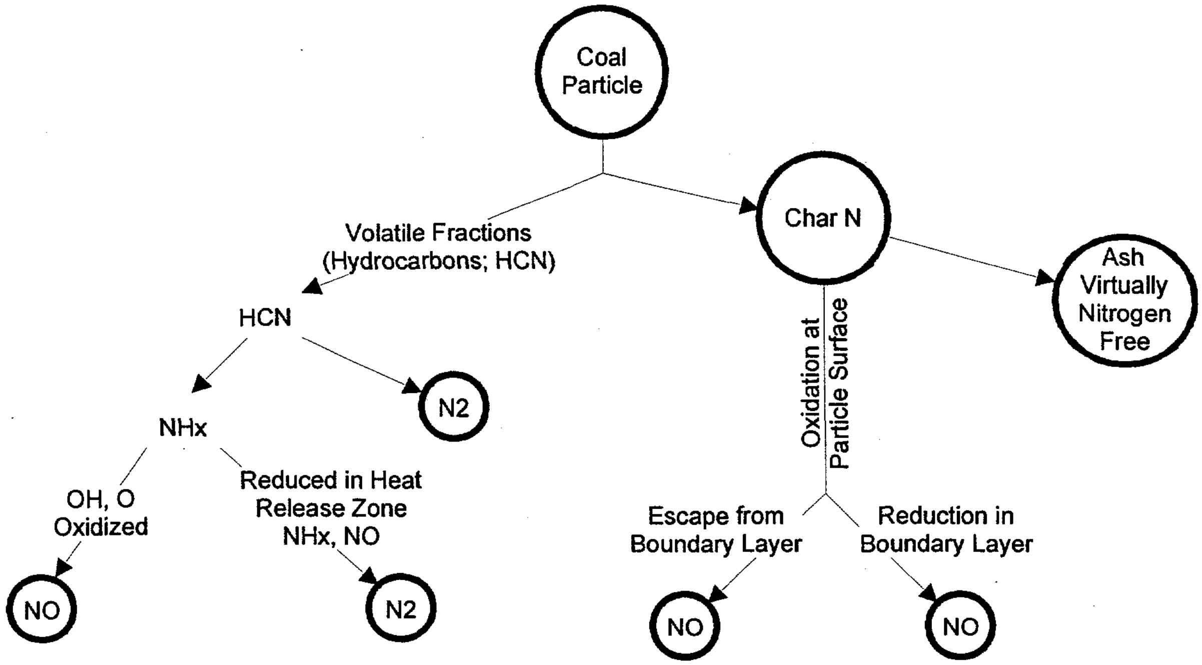


Figure 3-1: Possible History of Fuel Nitrogen

Summary

Both thermal and fuel NO_x are kinetically or aerodynamically limited in that their emission rates are far below the levels which would prevail at equilibrium. Thus, the rate of formation of both thermal and fuel NO_x is dominated by combustion conditions and is amenable to suppression through combustion process modifications. Although the mechanisms are different, both thermal and fuel NO_x are promoted by rapid mixing of oxygen with the fuel. Additionally, thermal NO_x is greatly increased by long residence time at high temperature. The modified combustion conditions and control concepts which have been tried or suggested to combat the formation mechanisms are as follows:

- Decrease primary flame zone O_2 level by
  - Decreased overall O_2 level
  - Controlled mixing of fuel and air
  - Use of fuel-rich primary flame zone
- Decrease time of exposure at high temperature by
  - Decreased peak temperature
  - Decreased adiabatic flame temperature through
  - Dilution with furnace gases
- Decreased combustion intensity

- Increased flame cooling
- Controlled mixing of fuel and air or use of fuel rich primary flame zone

- Decreased primary flame zone residence time

The primary techniques used to reduce primary zone O_2 levels and decrease the residence time at high temperatures, thereby reducing NO_x emissions, are low excess air (LEA), burners out-of-service (BOOS), overfire air (OFA), flue gas recirculation (FGR), and low NO_x burners (LNB). In many boilers, LEA is already employed to the extent possible for reasons of efficiency; therefore, little improvement in NO_x is likely to be possible. BOOS operation poses problems with furnace conditions (staging, corrosion), complicates operation of the coal fired system by requiring redistribution of coal to the burners, and may limit maximum load on the unit.

The following paragraphs describe the technologies that are applicable to this project. The proposed NO_x control technologies will reduce NO_x formation from both thermal and fuel nitrogen conversion mechanisms through control of flame stoichiometry, mixing and temperature. This is achieved by careful control of fuel and air injection mechanisms and localized staged combustion.

3.2. NO_x Control Technologies

The program employs two distinct approaches to NO_x reduction through combustion control. Each is capable of achieving substantial NO_x reduction if employed alone, but when the technologies are used in concert, even greater NO_x reductions are achieved. The following discussions present descriptions of the proposed technologies and some background as to their evolution to the current development status.

3.2.1. Advanced Overfire Air (AOFA)

Since NO_x formation is strongly dependent on the flame zone stoichiometry, as discussed above, a process which removes some of the "excess" air (above the stoichiometric quantity) from the burner flame zone and reintroduces it later in the combustion area, away from the high temperature flames, should reduce NO_x formation. This process was first documented in full-scale field tests with gas and oil fuels by leaving some upper level burners out of service (no fuel), but with the air flow to these burners unchanged. As a consequence, the stoichiometry at the in-service burners became less air rich, with less oxygen available for combination with nitrogen in the hot flame zone. The result was a reduction of about 50 percent in NO_x emissions at the highest degree of combustion staging. Subsequent development led to installation of separate overfire air (OFA) ports above the highest burner level, supplied with air from the windbox. This configuration resulted in similar NO_x emissions but allowed operation of all normal burners-in-service and some improvement in control of the staging process. When New Source Performance Standards (NSPS) regulations dictated reductions in NO_x emissions for new boilers, OFA technology was applied to coal-fired boilers (both wall-fired and tangential), with NO_x reductions on the order of 15-25 percent being typically achieved, depending upon furnace dimensions, burner configurations and location, fuel type, OFA port design, and degree of staging achievable. This process has been used on many boilers up to the present day as one means of NO_x control.

The primary limitations to increasing the effectiveness of NO_x control with OFA are the degree of staging which can be achieved without adversely affecting boiler operation, and the difficulty in achieving complete combustion by thorough mixing of the OFA with the partially combusted furnace gases from the burner zone.

The degree of staging achievable is potentially limited only by the provision of sufficient air to the burners to sustain stable combustion. However, extremely low stoichiometries can aggravate slag formation and other undesirable conditions in the furnace. A minimum stoichiometry of around 70-80 percent of theoretical is probably feasible. OFA staging has typically been limited to ensure that the overall burner zone stoichiometry is always above theoretical, so that local reducing conditions would not occur in the furnace. Reducing atmospheres, if allowed to persist adjacent to the furnace walls can result in a severe increase in corrosion of the tube metal. To avoid this condition OFA staging has been limited to approximately 10-20 percent of total combustion air and burner zone stoichiometrics in the range of 1.2 to 1.0.

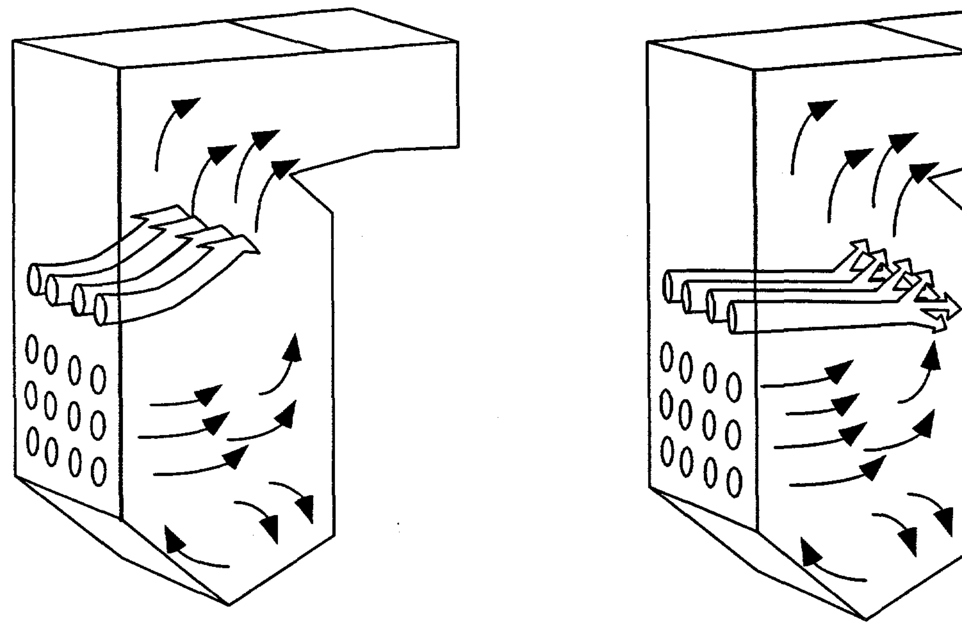
Since OFA operation results in combustion in the flame zone at stoichiometrics lower than would ordinarily occur, some incomplete combustion occurs, with the partially burned gases and carbon particles proceeding upwards from the flame zone. Completion of the combustion of these gases and carbon depends upon mixing with the remaining OFA at temperatures high enough to sustain the combustion, i.e., within the furnace volume. If any gases or carbon do not encounter oxygen molecules at the proper temperature prior to exiting the furnace, then an increase in combustible losses will occur. It is the function of the OFA design to ensure that mixing is sufficient to complete the combustion within the furnace. The effectiveness of the mixing is limited by the injection pressures (velocities) achievable with the windbox air supply provided. In addition to the concerns for flame zone reducing atmospheres cited above, the degree of staging possible with normal OFA designs has been further restricted by the limitations on achieving thorough mixing of the OFA with the combustion gases.

Because of the inherent limitations on OFA effectiveness and the potential for furnace corrosion, staging, etc. associated with OFA operation, in the mid-to-late 1970's manufacturers concentrated on development of the first generation of low NO_x coal burners, both to reduce the need for OFA and to address the more stringent NO_x NSPS requirements promulgated in 1979. Therefore, little advancement in OFA technology was made from that time until recently.

More recently, efforts have been directed toward increasing OFA effectiveness for use as an additional NO_x control technique in conjunction with other advanced control technologies, such as low NO_x burners and concentric firing techniques. Efforts have been aimed in two directions; first to permit greater degrees of staging to sub-stoichiometric conditions in the flame zone (called "Deep Staging") and second to improve mixing of the OFA with the sub-stoichiometric combustion gases.

Deep staging involves removing sufficient air from the burner zone so that the overall air/fuel ratio to the burners is sub-stoichiometric, i.e., less than the theoretically required air to complete combustion. Because of the high sensitivity of both thermal and fuel NO_x production to the flame zone stoichiometry substantial reductions in NO_x production can be achieved. However, as mentioned above, sub-stoichiometric (reducing) atmospheres can aggravate corrosion and staging on the furnace walls. To counteract this condition and provide protection to the wall tubes, some of the air diverted from the burners is directed along the furnace wall surfaces, providing, in effect, a "boundary" of air which maintains an oxidizing atmosphere close to the tube walls. In wall-fired units, this "boundary air" is provided by tertiary air ports located in the burner zone and close to the side walls. Air flows from the windbox through these ports and into the furnace. In tangentially-fired boilers that incorporate the Low NO_x Concentric Firing System (LNCFS) or a version designated Concentric Firing System, the "boundary air" is achieved as a natural byproduct of the injection of the fuel into a central core swirl within the furnace, and the air into an outer concentric swirl which sweeps the wall surfaces.

The second technique used in AOFA is to improve the mixing of the overfire air with the furnace gases so as to complete the combustion of the partially burned gases and carbon particles. This is achieved primarily by increasing the velocity of the OFA injection relative to upward furnace gas velocities. Higher injection velocities (and less diffuse air streams) can be achieved both by increasing the pressure of the air above normal windbox levels and by improved OFA port designs. The higher pressures are provided by booster air fans which extract air from either the windbox or its supply ducts. Figure 3-2 illustrates the concept of high velocity OFA mixing compared to normal OFA injection. Alternative methods of achieving high velocity OFA injection, other than providing booster fans, may produce equivalent or better mixing results at a much lower cost. For example, using a very small quantity of high pressure air to aspirate the large OFA volume into the furnace at high velocity may be an attractive alternative to booster fans. The implications of improved OFA mixing are three-fold. First, at normal staging rates (burner stoichiometry around 1.0 to 1.2), improving OFA mixing means that a lower overall stoichiometry (less total excess air) can be provided while still avoiding high unburned combustibles losses. Second, for a given total stoichiometry (excess air), deeper staging can be achieved without increasing combustible losses. This second feature, along with the protection of "boundary air," permits improved NO_x reductions compared to normal OFA operation. Finally, the increased mixing capability allows the AOFA ports to be placed higher in the furnace, away from the upper burners, without increasing combustible losses as depicted in Figure 3-3. Thus, the sub-stoichiometric conditions would persist for a longer time between leaving the flame zone and reaching the AOFA mixing zone. Recent studies have that NO_x production diminishes rapidly with time as the combustion products persist in a reducing (sub-stoichiometric) atmosphere. A residence time of one second can cause a reduction in NO_x level of 50 percent compared to the NO_x at the flame boundary. The combination of the three techniques, improved OFA mixing, deep staging, and boundary air constitutes the complete AOFA concept.



Furnace Flow Patterns with Low OFA Flow Furnace Flow Patterns with High OFA Flow

Figure 3-2: Effect of OFA Injection Velocity

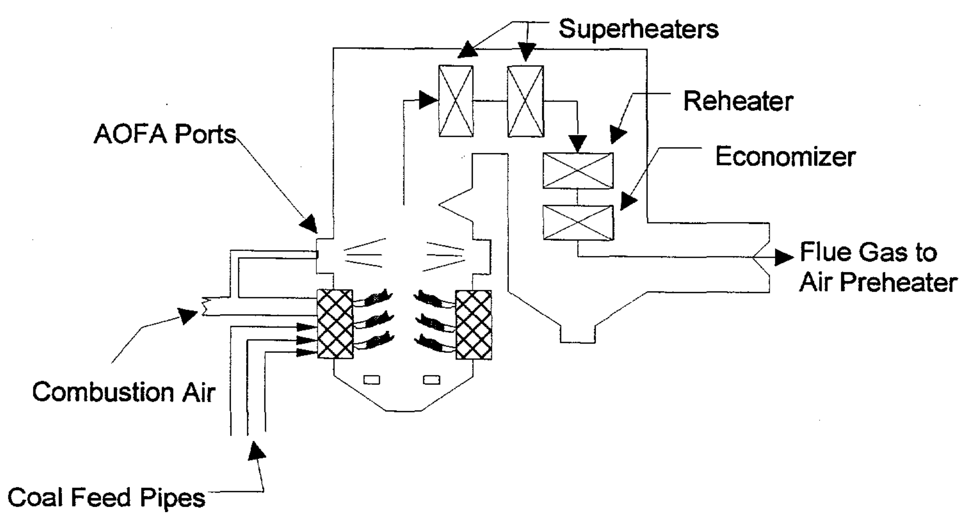


Figure 3-3: Advanced Overfire Air Concept

3.2.2. Low NO_x Burner System (LNB)

An alternative to the use of OFA as a means to control NO_x production through controlled fuel/air mixing (staged combustion) on a gross, furnace-wide basis, is to design the burner system to achieve the same combustion staging effects for localized, individual burner flames. To achieve this, the burner must regulate the initial fuel/air mixture, velocities and turbulence to create a fuel-rich flame core, with sufficient air to sustain combustion at a severely sub-stoichiometric air/fuel ratio. The burner must also then control the rate at which the additional air necessary to complete combustion is mixed with the flame solids and gases so as 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 combustion is completed at a low temperature. The fuel-rich flame gas provides a sustained, oxygen deficient region in which the fuel volatile nitrogen can be evolved and reduced to molecular nitrogen rather than NO. The remaining char nitrogen evolves in the extended flame zone where oxygen becomes available at a controlled mixing rate so as to minimize conversion of char nitrogen to NO. Thermal NO_x is also minimized as the controlled air mixing extends into the cooler regions downstream of the flame. All low NO_x burner designs utilize the same basic concepts of controlled fuel/air mixing in similar but unique ways.

3.2.3. Comparison To Other Technologies

Other than competing low NO_x burner designs, there are two alternative concepts for retrofit combustion NO_x control that have been demonstrated in wall-fired coal boilers. One is a fuel-stratification approach to stoichiometry control called "Reburning" and the other is a slagging combustor concept offered by TRW.

Reburning technology was developed by several companies in Japan and is in use in a number of Japanese boilers. NO_x reduction compared to uncontrolled emissions is reported to be approximately 50 percent. Reburning is intended primarily for new boilers but can be retrofit to some conventional tangentially-fired boilers.

Reburning consists of employing auxiliary fuel burners above the normal rows of coal burners and overfire air ports above the auxiliary fuel burners. The main coal burners are operated slightly air rich, thus producing high NO levels. The auxiliary burners inject a low-nitrogen fuel (natural gas, distillate oil, etc.) with no additional air, thereby producing a strong reducing atmosphere in the upper burner area. Overfire air is injected above the reburning zone to ensure complete fuel burn-out prior to exiting the furnace. The mechanism for NO_x reduction with reburning is that NO formed in the coal-burner zone is decomposed to N_2 and O_2 as it passes through the high temperature, reducing atmosphere of the reburning zone. The resulting low-NO_x levels are maintained as final combustion is completed in the overfire air zone because the bulk gas temperature has dropped well below the peak NO formation temperature. The several reburning concepts employed in Japan differ primarily in the arrangement of coal burners, auxiliary burners and overfire air ports with respect to each other, the stoichiometry control scheme and the reburning fuel(s) employed.

Reburning technology can be applied to both wall-fired and tangentially-fired boilers. However, expensive gas and light oils are used as reburn fuels which make the technology less cost-effective and less attractive.

Slagging combustors present still another alternative for emissions control. These devices are designed for conversion of oil and gas units to coal-firing. The emissions reduction potential of slagging combustors is viewed as being less than that of low NO_x burner systems.

3.2.4. Retrofit Impact On Other Emissions

The proposed retrofit technologies act through modification of the combustion process. It is, therefore, conceivable that emissions of species other than NO_x, which are products of, or influenced by the combustion process, might be increased or decreased in quantity or altered in character by the proposed technologies. The principal emissions which might be affected by combustion controls are solid particulates (ash), sulfur oxides (balance between SO_2 and SO_3) and hydrocarbons.

Particulates

The proposed technologies should not significantly affect the mass of particulate matter leaving the boiler; however, the character of the particulate could possibly be changed (compared to baseline) in three ways. First, if incomplete combustion products were to persist leaving the furnace, the carbon content of the emitted fly ash would be increased. Although the mass of the carbon emissions would not likely be a substantial fraction of total particulate emissions, due to low resistivity, carbon particles tend to be difficult to capture in electrostatic precipitators (ESP's). Therefore, carbonaceous particles might pass through the collector and could add to the stack emissions. Previous demonstrations of the proposed technologies has indicated that slight increases in carbon emissions can occur. If the particulate control system includes a fabric filter (baghouse) then no increase in stack emissions would be experienced, since carbon particles are as easily captured by filters as are any other particles.

Second, to some extent the particle size of fly ash emissions is affected by the combustion atmosphere in which they are formed. If the retrofit technologies were to decrease the average emitted particle size, then the efficiency of ESP, wet scrubber, or baghouse collectors might be reduced, and stack emissions increased. This is not considered to be a likely result; however, the program will document particle size distributions in the fly ash throughout the testing period.

Third, the resistivity of the fly ash leaving the boiler is influenced by the combustion atmosphere in the furnace (reducing or oxidizing) and by the presence of SO_3, which is also affected by the combustion conditions. If the average resistivity of the fly ash is substantially increased or decreased from the baseline value, then the collection efficiency of an ESP could be increased or decreased, depending upon the original design parameters. A scrubber or baghouse would not be affected by fly ash resistivity changes. The proposed program includes comprehensive ash resistivity measurements.

Sulfur Oxides

Because of the alteration of the furnace stoichiometry associated with the proposed technologies, the oxidation of fuel-borne sulfur could be affected by the retrofits. Fuel sulfur either combines with ash/slag elements (such as iron) to form solid sulfites or sulfides, or oxidizes to SO_2 or SO_3 and leaves the boiler in a gaseous state. The combustion modifications could affect the balance of the various sulfur forms and thereby either increase or decrease the sulfur oxide emissions. It is unlikely, however, that the proposed retrofits will significantly affect the total sulfur oxide emissions, (changes in SO_3 concentrations are in the order of 0.1 percent of the total SO_x) regardless of the type of sulfur emissions control employed (none, scrubber, spray dryer, etc.) The test program includes regular measurements of SO_2 and SO_3 emissions.

Hydrocarbons

It is highly unlikely that the proposed retrofits would significantly affect the level of hydrocarbon emissions. Nevertheless, the alteration of the furnace stoichiometry could conceivably result in some increase in uncombusted hydrocarbons. Regular measurements of hydrocarbon emissions are included in the test plan.

4. Equipment Description - FWEC Supplied Equipment

Based on a competitive solicitation, Foster Wheeler Energy Corporation (FWEC) was selected to provide the advanced overfire air system and low NO_x burners to be demonstrated at Plant Hammond Unit 4. FWEC proposed a commercially available version of their AOFA system and their Controlled Flow / Split Flame low NO_x burners, also commercially available. FWEC was responsible for the design, fabrication, installation, and commissioning of these systems at Hammond 4. A brief description of the major components are provided in the following paragraphs. More detailed information is provided in the FWEC proposal and operating instructions, excerpts of which are included in Appendix A and B, respectively.

4.1 Advanced Overfire Air System

As discussed in Section 3, 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 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 in greater quantities, with more control, and at higher pressures. The resulting system is capable of providing deep staging of the combustion process with accurate measurement of the AOFA airflow.

The FWEC AOFA system that is offered commercially utilizes a number of high velocity ports located at a higher elevation than the conventional OFA and uses a maximum of 20 percent of the total combustion air. As shown in Figure 4-1, the AOFA system diverts air from the secondary air ducts and introduces it through a number of overfire air ports in the front and rear wall. The Hammond Unit 4 boiler design characteristics and project requirements had an impact on the design of the AOFA system. The Hammond AOFA system differs from the standard FWEC AOFA design in the following two features:

- It utilizes four AOFA ports per wall instead of the six proposed originally by FWEC.
- It is located closer to the burners than FWEC would have liked (Hammond distance between the top burner and the bottom of the AOFA = 9' 2").

These two design features of the AOFA system are believed to have impacted the NO_x reduction potential, but they should not compromise the applicability of the tests results for other wall-fired units because many units are subject to similar limitations. The AOFA system operation at Hammond was not automated; a separate control panel was provided in the control room through which the operators manually controlled the AOFA dampers. However, the AOFA system has been automated for the Advance Optimization/Controls portion of the test program.

To insure optimum AOFA system performance, a burner/windbox air distribution system was also installed at the time of the installation of the AOFA system. The primary purpose of this system is to provide optimum distribution of combustion between the front and rear windboxes and to serve as backpressure dampers to enable sufficient flow to the AOFA system. A sketch of the installed system is shown in Figure 4-2.

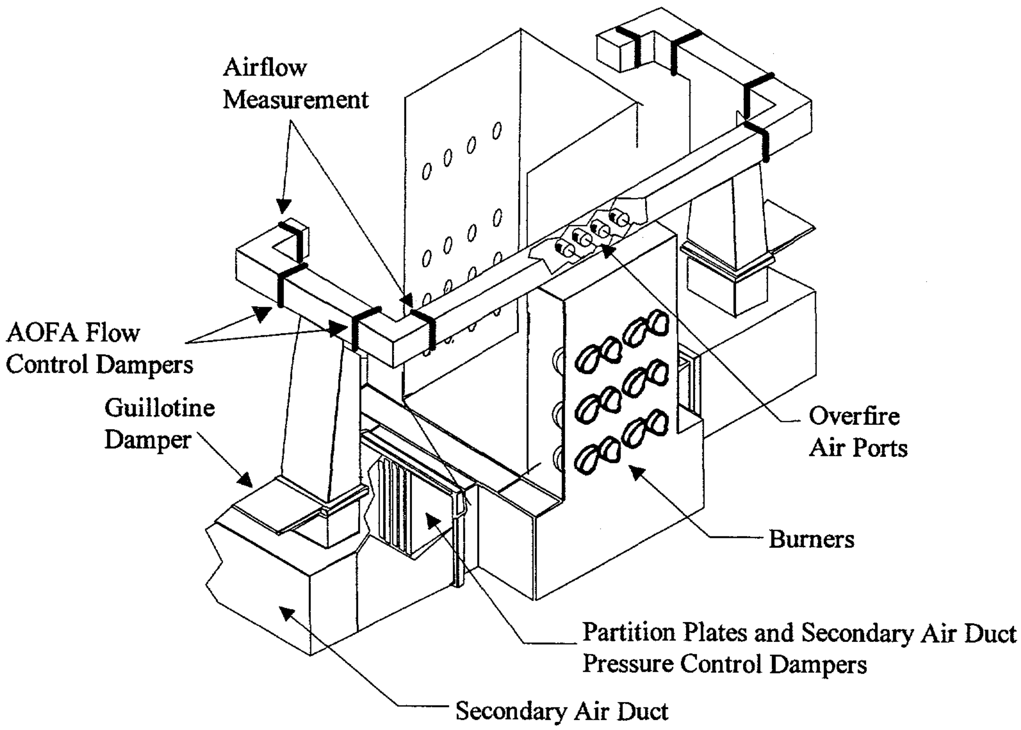


Figure 4-1: Advanced Overfire Air System

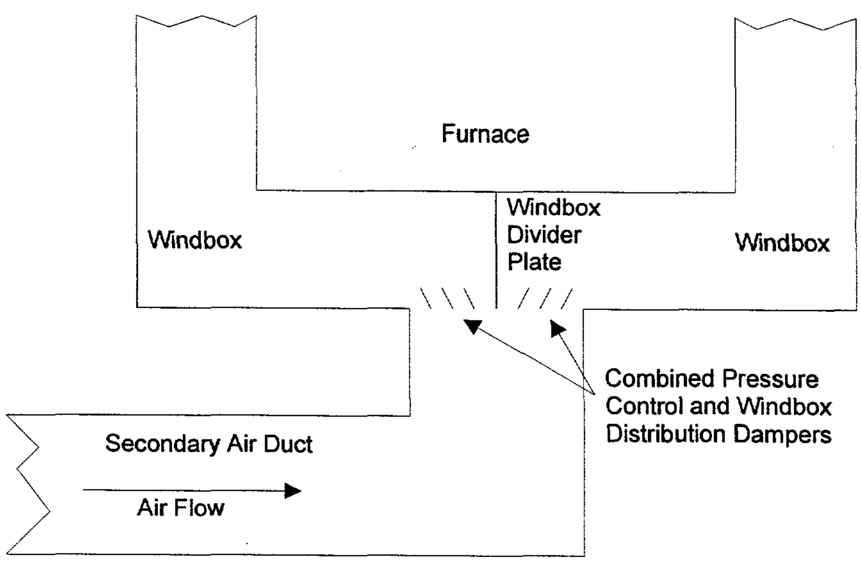


Figure 4-2: Windbox Inlet AOFA Pressure Control Dampers

In conjunction with the installation of the AOFA system, FWEC also installed a furnace boundary air system. The purpose of this system was to provide a passive means of maintaining an oxidizing atmosphere along the furnace sidewalls and in the furnace hopper zone. The boundary air system consists of airports, hopper airslots and sidewall airslots (Figure 4-3) designed to bias a small amount of air from the burners to the lower furnace walls. The Boundary air system does not supply additional air to the furnace and it does not increase the excess air requirement of the boiler.

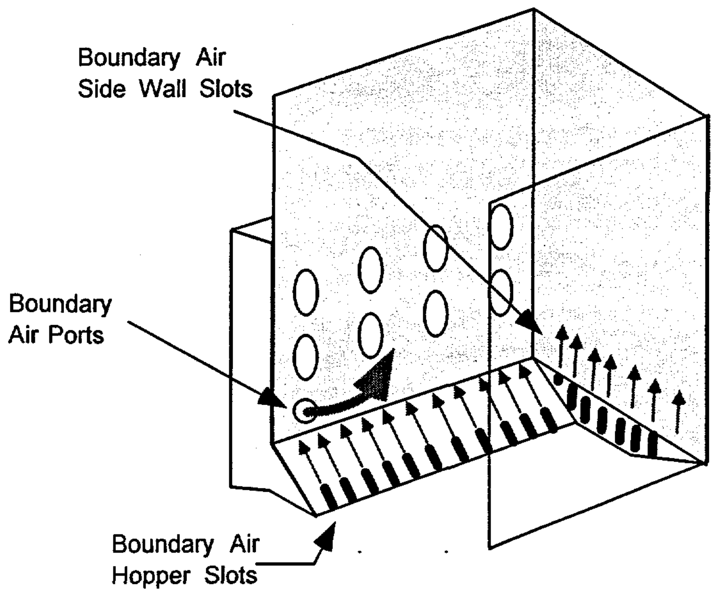


Figure 4-3: Boundary Air System

4.2 Controlled Flow / Split Flame Burners

Low NO_x burner systems attempt to stage 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 4-4 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.

The above two low NO_x technologies, AOFA and LNB, were also combined into the LNB+AOFA system.

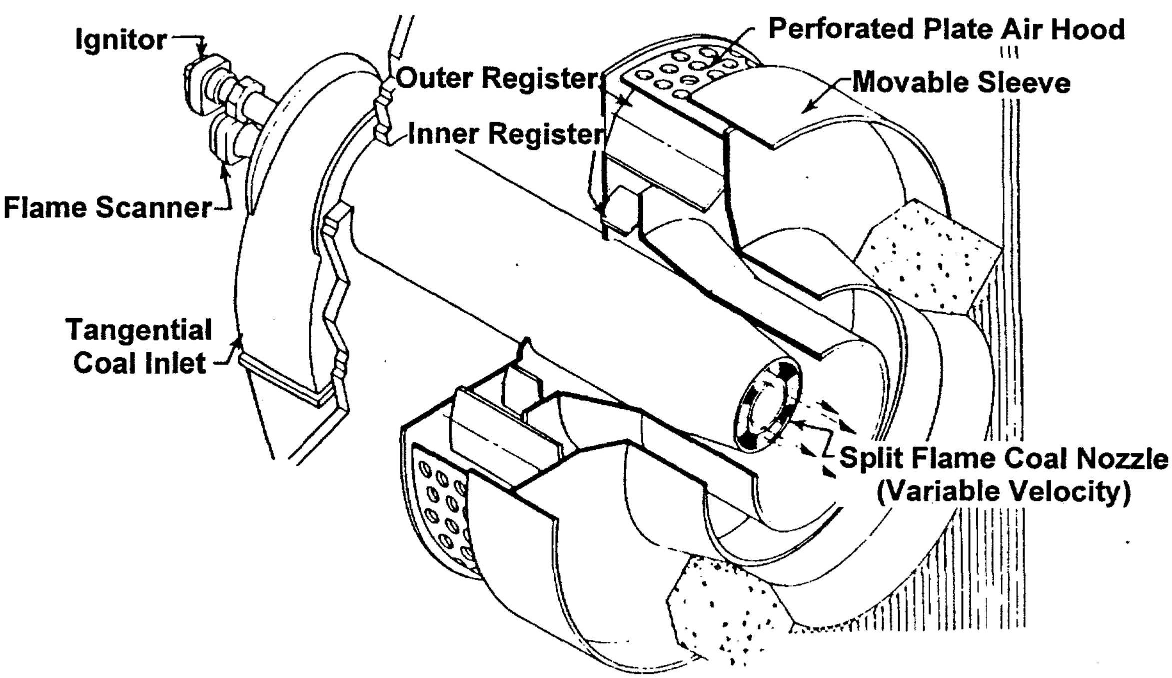


Figure 4-4: FWEC Controlled Flow/Split Flame Burner

5. Equipment Description - Digital Control System

The objective of Phase 4 of the project at Plant Hammond was to evaluate and demonstrate the effectiveness of advance digital control/optimization methodologies as applied to the NO_x abatement technologies installed at this site (LNB and AOFA). An integral part of Phase 4 of the project was the design and installation of a digital control system to be the host of the advanced control/optimization strategies being developed. SCS Engineering had overall responsibility for the following major activities:

- Preliminary engineering
- Procurement
- Detail engineering
- Digital control system configuration
- Installation and checkout

A list of the systems indicating the scope of the digital control system replacement can be found in Appendix D. In general, the system consisted of Unit Master, Fuel Control, Air Flow Control, Furnace Pressure Control, Feedwater Control, Steam Temperature Control, Condensate Control, Auxiliary Control*, DCA Heater Level Control, Ash Handling System*, Precipitator Energy Management System*,Precipitator Fire Protection*, and Burner Management System. In total, the digital control system was configured for 2352 input/output points consisting of 572 analog inputs, 116 analog outputs, 1032 digital inputs, and 632 digital outputs with the balance being allocated spares.

5.1 Foxboro I/A System

Based on a competitive evaluation, a Foxboro I/A Series System DCS was selected for this project. The Foxboro I/A Series System is a fully distributable, digital control system designed to address a broad range of application requirements. The DCS provides nodes of interchangeable hardware and software modules which can be matched to the process application. Although not necessarily unique to the Foxboro I/A System, the following are some of the important characteristics of this digital control system:

- Fully distributable, both functionally and physically, allowing installation of the control system hardware in the field (i.e. near the burner front and mills) -- no special environment for the control system hardware is needed.
- Extensive use of standard communication networks. I/A Series nodes communicate with each other using a MAP compatible network. Gateways are provided for communication to

* Not in Wall-Fired Project scope of work.

other devices via RS-232-C, RS-485, X.25, Modbus, Allen-Bradley Data Highway, IEEE 802.3 (CSMA/CD), IEEE 802.4 (token passing) and others.

- Open system architecture. The digital control system is built using the following constructs: (1) operating system - "VENIX", a version of "UNIX", (2) development language - "C", (3) relational data base - "INFORMIX", and (4) network - IEEE 802.3 and 802.4. Adherence to these standards facilitates software portability from and to other platforms and allows current software to be utilized as new hardware technology is introduced.
- Increased reliability from the use of sealed modules interconnected by serial communications and the application of redundant hardware modules on critical control loops.

An overview of the system installed at Hammond Unit 4 is shown in Figure 5-1 and specifics of the DCS installed at Hammond Unit 4 follows. A detail schematic of the digital control system interconnections as installed at Hammond Unit 4 can be found in Appendix E.

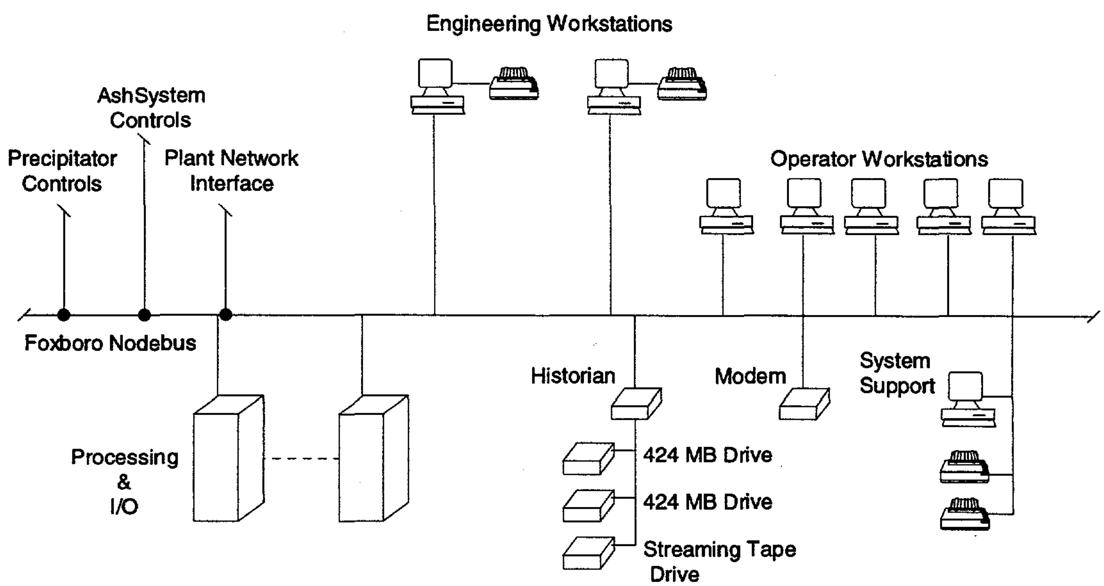


Figure 5-1: Unit 4 DCS Overview

Node

The I/A series architecture is based on the concept of a node. A node operates independently, performing automation-related functions. The DCS at Plant Hammond has three nodes:

- N0000E - Electrical Switchboard Node
- N00003 - Unit 3 Node
- N00004 - Unit 4 Node

All nodes connect to each other through the carrierband LAN (described below).

Modules

The I/A series consist of two basic types of modules (Table 5-1).

Table 5-1: Module Types

System Station	Fieldbus
Application Processors	Analog Modules
Control Processors	Digital Modules
Workstation Processors	
System Integrators/Gateways	
Tank Processors	

The Control Processor (CP) is a station that connects to a Nodebus and Fieldbus modules to perform:

- Regulatory, logic, timing , and sequential control
- Data acquisition, alarm detection, and notification

The DCS installed on Hammond 4 has seven CP-30, fault-tolerant, control processors (4CP001 - 4CP007) and one CP-10 control processor (4CP008) (see overview in Appendix E). The functions assigned to these processors at Hammond Unit 4 can be found in Appendix F.

The Application Processor (AP) is a station that connects to the Nodebus to perform computation intensive and file server functions. These processors are configured by software to perform system functions such as:

- System equipment management
- Database management
- Historical data collection
- Graphic display support
- Production control
- Configuration of software functions

- Application program development

Unit 4 has two AP-20s (4AP001 and 4AP002) and one AP-50 (4AP003). The latter system is based on Sun Sparc processor architecture. The specific functions of these Application Processors are shown in Table 5-2.

Table 5-2: Function of Application Processors

Application Processor	Function
4AP001	Main application processor used for production control, graphic display, equipment monitoring, and alarm processing
4AP002	Secondary application processor used as backup for 4AP001 and equipment tagout support
4AP003	Primary functions include historian, plant networking, reporting, and backup of 4AP001

Gateway

The I/A Series gateways are stations on a Nodebus that provide a communications link between an I/A Series node and other networks and devices, such as programmable controller networks. The Unit 4 system has three gateways: 4GW001 - Ash Handling Gateway; 4GW002 - Energy System Management Gateway; and 4GW003 - Sootblowing System Gateway. These gateways are monitored by the application processor 4AP003. The Ash Handling System and Sootblowing System gateways connect to Allen-Bradley Data Highways while the Energy Management System gateway connects to a Modicon system.

Fieldbus and Fieldbus Modules

The Fieldbus is a dual-redundant serial data communications bus that employs asynchronous protocol and conforms to the requirements of the EIA standard RS-485. All Fieldbus transactions are initiated by a master station and the Fieldbus Modules are slave devices. Error and failure protection schemes are utilized on the Fieldbus to prevent or reduce single-, double-, and odd-bit-number errors; burst errors; and single failure of a Fieldbus Module.

Fieldbus modules provide the interface between process sensors and actuators and the Fieldbus. The modules convert the electrical signals used by the field devices to a digital format suitable for use on the Fieldbus. The Fieldbus and Fieldbus Modules are arranged as shown in Appendix E. Unit 4 has the types of Fieldbus Modules as shown in Table 5-3.

5.2 Control Room Modifications

As part of this project, the control room was modified to accept the new Unit 4 digital control system. A plan drawing of the retrofitted Unit 1-4 control room is shown in Figure 5-2. As shown, the pre-existing Unit 4 benchboards were removed and replaced with a CRT based control panel. Also shown in this figure is the retrofitted Unit 3 benchboard which was upgraded during Fall 1993. In addition to the upgrades to Units 3 and 4, Georgia Power is also considering upgrading the digital control systems on Units 1 and 2. Figure 5-2 shows the control room as envisioned following upgrades on all four units. Digital control system and control room modifications for Units 1, 2, and 3 are not a part of the Wall-Fired Project. A schematic of the new Unit 4 benchboard is shown in Figure 5-3. As can be inferred from this figure, operator interaction with the digital control system will be almost exclusively through the operator displays.

Table 5-3: Fieldbus Module Descriptions

Fieldbus Module	Type
FBM01	Isolated interface for up to 8 analog 0-20 ma DC inputs
FBM02	Isolated interface for up to 8 thermocouple and/or millivolt inputs
FBM04	Isolated interface for up to 4 analog 0-20 ma DC inputs and 4 analog 0-20 ma outputs
FBM07A	High power isolated interface for up to 16 contact DC voltage inputs
FBM26A	High power isolated interface for up to 8 contact DC voltage inputs and 8 externally powered DC switch outputs
FBM26B	High power isolated interface for up to 8 contact sense inputs and 8 externally powered DC switch outputs
FBM09A	High power isolated interface for up to 8 DC voltage inputs and 8 externally powered DC switch outputs
FBM10	120 VAC isolated interface for up to 8 DC inputs and 8 output channels for 120 VAC with current overload protection

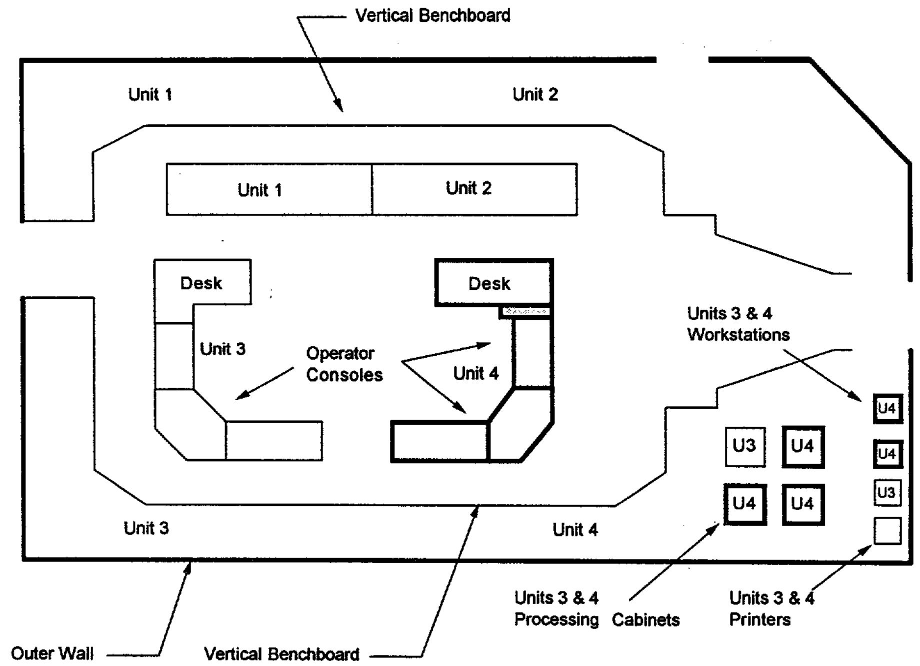


Figure 5-2: Unit 1-4 Control Room Layout as Currently Implemented

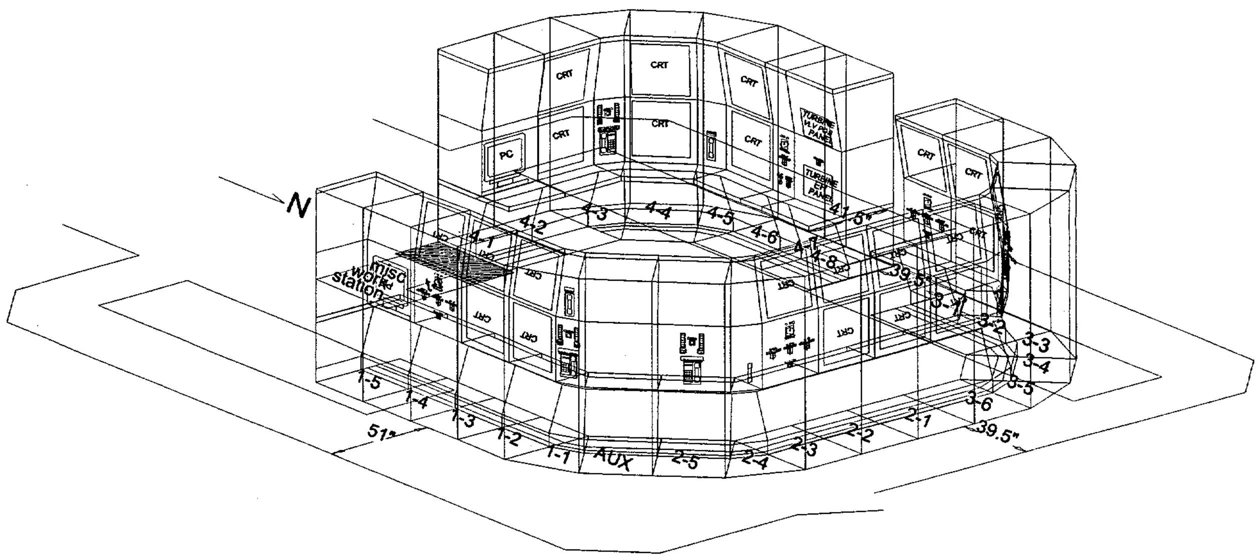


Figure 5-3: Unit 1-4 Control Room Layout (Planned)

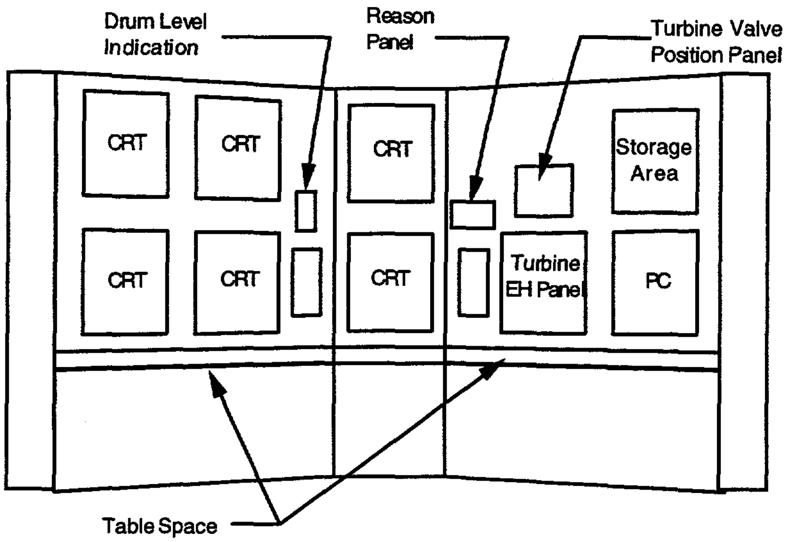


Figure 5-4: Unit 4 Benchboard

5.3 Networking

The Unit 4 DCS has been interfaced with the other DCS's at the site. As shown in Figure 5-5, Unit 3, Unit 4, and Electrical DCS systems are connected through a dual-redundant IEEE 802.3 (CSMA/CD) compliant local area network (LAN). Through this LAN, the three digital control systems are able to share process information and graphics. If for some reason either the A or B LAN fails, all digital control systems can maintain normal operation. An additional benefit of these LANs are the ability to share costly resources such as engineering consoles, historical drives, etc.

In addition to the inter-DCS network, the Unit 4 DCS (and the others also), are connected through a router to the plant's token-ring PC engineering and administrative LAN and the corporate wide area network (WAN) (Figure 5-6). The latter will enable remote access of process data and facilitate software maintenance. A Sun Sparcstation 5, hosting the advanced control/optimization software, will be connected to this network.

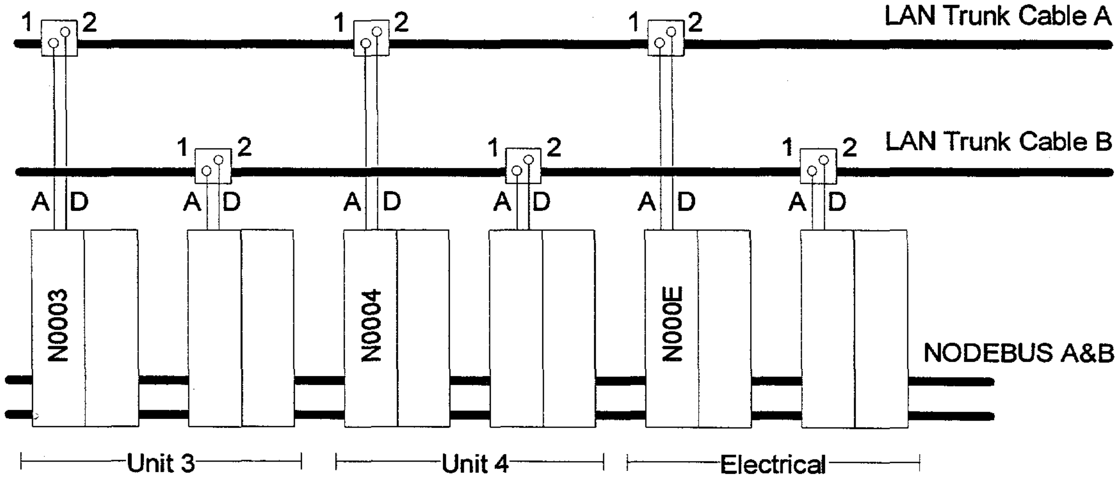


Figure 5-5: DCS Network

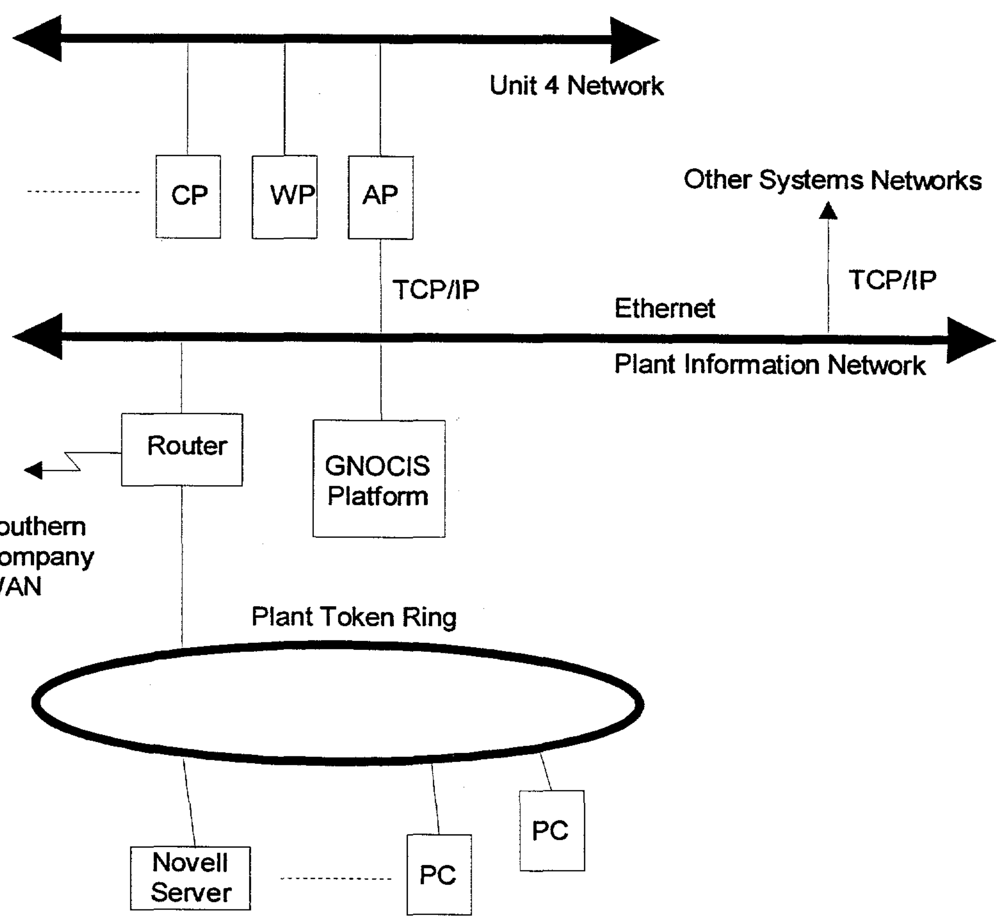


Figure 5-6: Hammond Plant Network

5.4 Operator Graphics

An extensive set of graphics have been developed for operator use. These displays are accessed at the operator consoles and are organized hierarchically. Using soft buttons on the displays, the top level display provide rapid control and observation of all major components. These push buttons have descriptions displayed on them which guide the operator or technician to the proper graphic. For example, one of the push buttons is labeled "MASTER SCREEN." From this graphic, the operator can access all major high level controls including Fuel Master, Feedwater Master, O_2 Compensator, ID Fan Master, and FD Fan Master. In addition, from the master menu, trends of process variables are readily obtained. An example of an operator graphic is shown in Figure 5-7. Approximately 300 graphics are available to the operator.

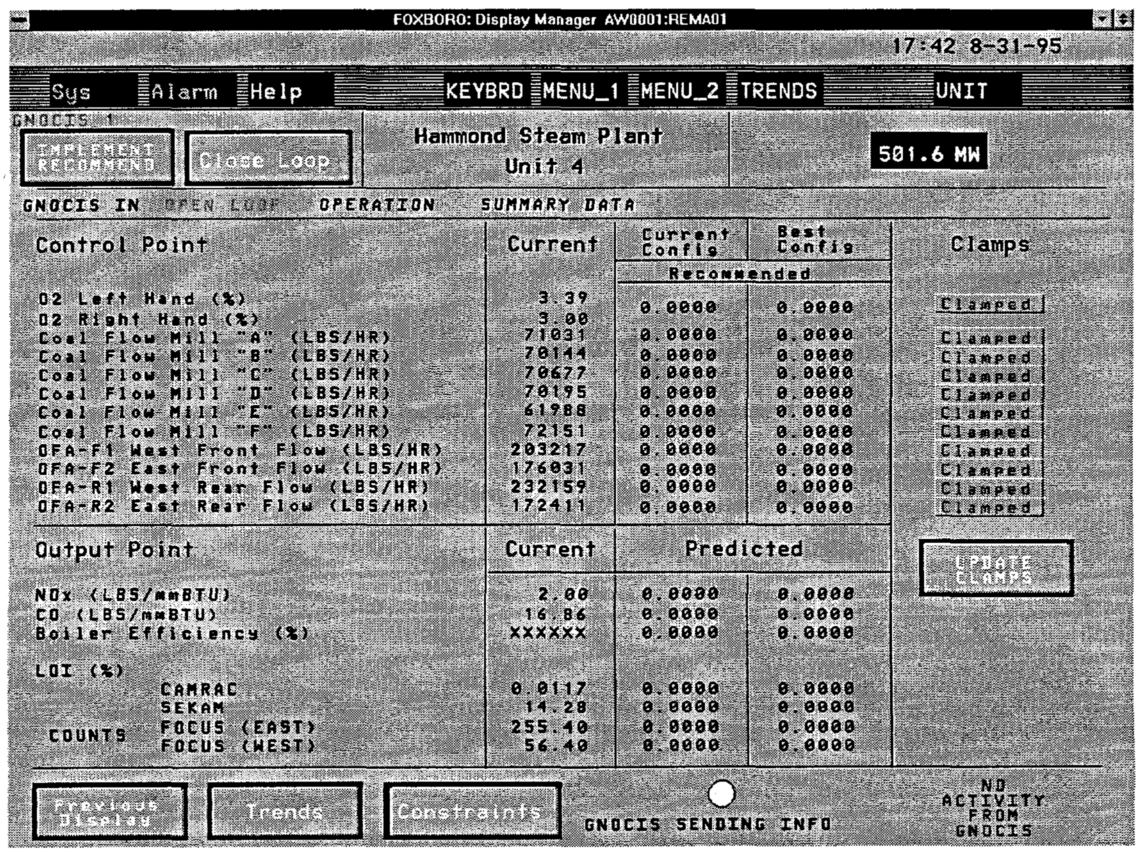


Figure 5-7: Typical Operator Graphic

5.5 Cabinet Locations

As mentioned previously, the cabinets are geographically dispersed throughout the plant to reduce cable runs. A general overview of the inputs and outputs to each cabinet is shown in Table 5-4. Due to this being a retrofit installation, the distribution of I/O and the minimization of cable runs is suboptimal to what may be achieved in a new "greenfield" installation.

Table 5-4: Cabinet Locations

Cabinet	Location	Inputs/Outputs
1	Upper boiler area; elevation 657'-3"; adjacent to acoustic pyrometer ports and project instrumentation trailer	Burners Sleeve Position , Main Steam, Reheat, Extractive CEM, Secondary Air Flows, Primary and Secondary Air Temperatures, Other Boiler Parameters
2	Control room area; behind Unit 4 benchboard	Turbine, Compliance CEM, Burner Flame Scanners (Coal), Mill Start/Stop
3	Control room area; behind Unit 4 benchboard	AOFA; Burner Ignitors; ID Fan; Flame Scanners (Oil Guns)
4	Control room area; behind Unit 4 benchboard	Boiler Feedpump Turbines, Condensate Pump
5	Lower boiler area near mills	Primary air to mills, Mill temperatures, Turbine extraction temperatures Feedwater heaters

5.6 Documentation

Documentation issued to the site included the following:

- Functional Control Diagrams
- Logic Drawings
- Cabinet Arrangements
- Instrument Rack Drawings
- Terminal Block Arrangements
- Termination Drawings
- Wiring Diagrams
- Elementary Diagrams
- Circuit Schedules

- Raceway Schedules
- Equipment Report
- Instrumentation and Controls Technicians Reference Manual
- Operators Manual

In total, in excess of 500 drawings were produced or revised as the result of the installation of the digital control system.

6. Equipment Description - Instrumentation

In order to achieve the goals of the project, instrumentation was installed to measure some specific parameters related to the combustion and thermal performance of the boiler, as well as selected gaseous pollutant emissions. These included combustion gas analyzers, pollutant emissions analyzers, an acoustic pyrometer system, heat flux transducers, and continuous ash samplers. The following paragraphs describes the major elements of the instrumentation system.

6.1 Extractive Continuous Emissions Monitoring System (ECEM)

A principal objective of this ICCT project is to evaluate the long term effectiveness of the installation of low NO_x burners and advanced overfire air with regards to the reduction of NO_x pollutants in the boiler exhaust gas. The ECEM was purchased from KVB to aid in the evaluation of combustion modifications. The system provides the means of extracting gas samples for automatic chemical analysis from sample points at strategic locations in the boiler exhaust ducts. The ECEM (Figure 6-1) is equipped with a manual valving system that permits the extraction of gas samples from any ECEM probe or combination of probes. Flue gas extraction points were located fore and aft of the secondary air heaters; prior to the primary air heaters, and in the ductwork leading from the precipitator to the stack (Figure 6-2). The probe arrangements are shown in Figure 6-3.

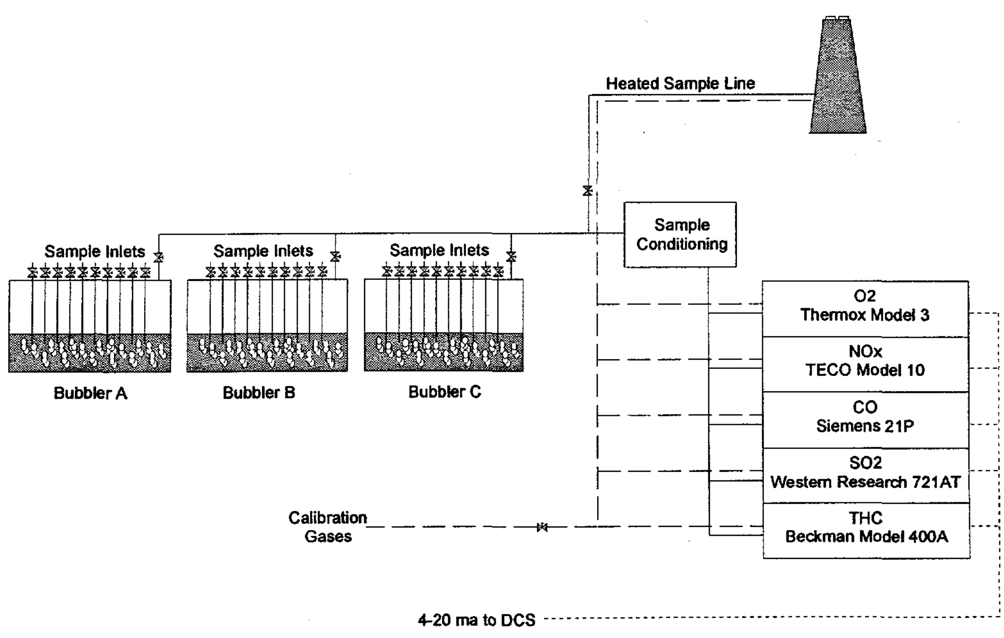


Figure 6-1: Extractive Gas Analysis System

The system quantitatively analyzes gas samples for NO_x, O_2, SO_2, CO, and total hydrocarbons (THC). The ECEM comprises sample probes and lines, a sample control system consisting of valves and sample distribution manifolds, pumps, sample conditioning (filters, condenser/dryer, pressure regulation and a moisture detector), flowmeters, gas analyzers and an automatic calibration system. The sample probes consist of 1/2" Hastelloy C pipes fitted with sintered stainless steel filters to prevent fly ash from entering the probes. Where appropriate one, two, or three probes penetrate a single port cap, extending vertically down into the duct to various depths. Polyethylene sample lines (3/8" OD) connect the probes to the ECEM sample selection valving. Exterior sample lines are heat traced and insulated for freeze protection. A Teflon sample line connected to a probe in the stack is heated to prevent moisture condensation. This line/probe is called the "continuous stack monitoring line."

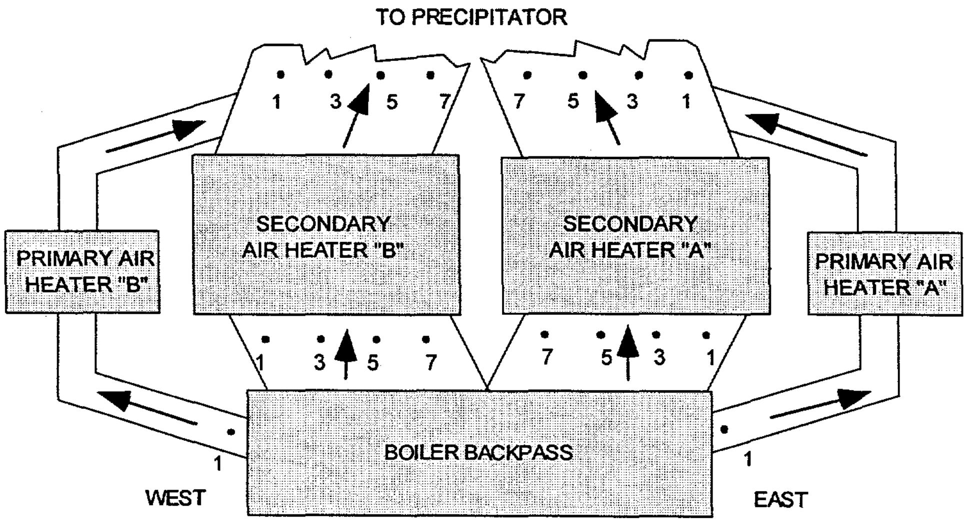


Figure 6-2: Extractive Gas Analysis System Probe Locations

With the exception of the continuous stack monitor probe line, all sample lines lead to individual flow control valves which are part of a sample distribution manifolding system. This arrangement allows the test personnel to sample selectively from any one probe, or any combination of probes, for analysis of the exhaust gases. The sample distribution bubblers act as simple flowmeters to ensure equal flow from each probe sampled. The use of the bubblers invalidates any SO_2 or THC readings from the duct probes due to partial solubility in the bubbler water. The valid SO_2 and THC data are acquired only through the heated stack probe/line.

The sample acquisition/conditioning system consists of dual diaphragm type pumps, a refrigerated, water bath moisture condenser, filters, valves and a back pressure regulator. Moisture is removed from the sample gas within the condenser and drained automatically at set intervals. The back pressure regulator assures constant pressure supply to the analyzers to avoid measurement drifts associated with flow variations. The pumps draw roughly 1.0 cfm of sampled gas, of which a small portion is delivered to the analyzers and the remainder vented overboard. The high total sample rate is used to minimize the response time between the sample entering the probes and analysis.

Automatic (or manual) calibration is achieved by sequentially introducing certified gases of known zero and span value for each analyzer into the lines. The signal output of each analyzer for its respective zero or span gas is recorded by the control computer and translated into a linear calibration equation in engineering units. All of the analyzers have linear output response.

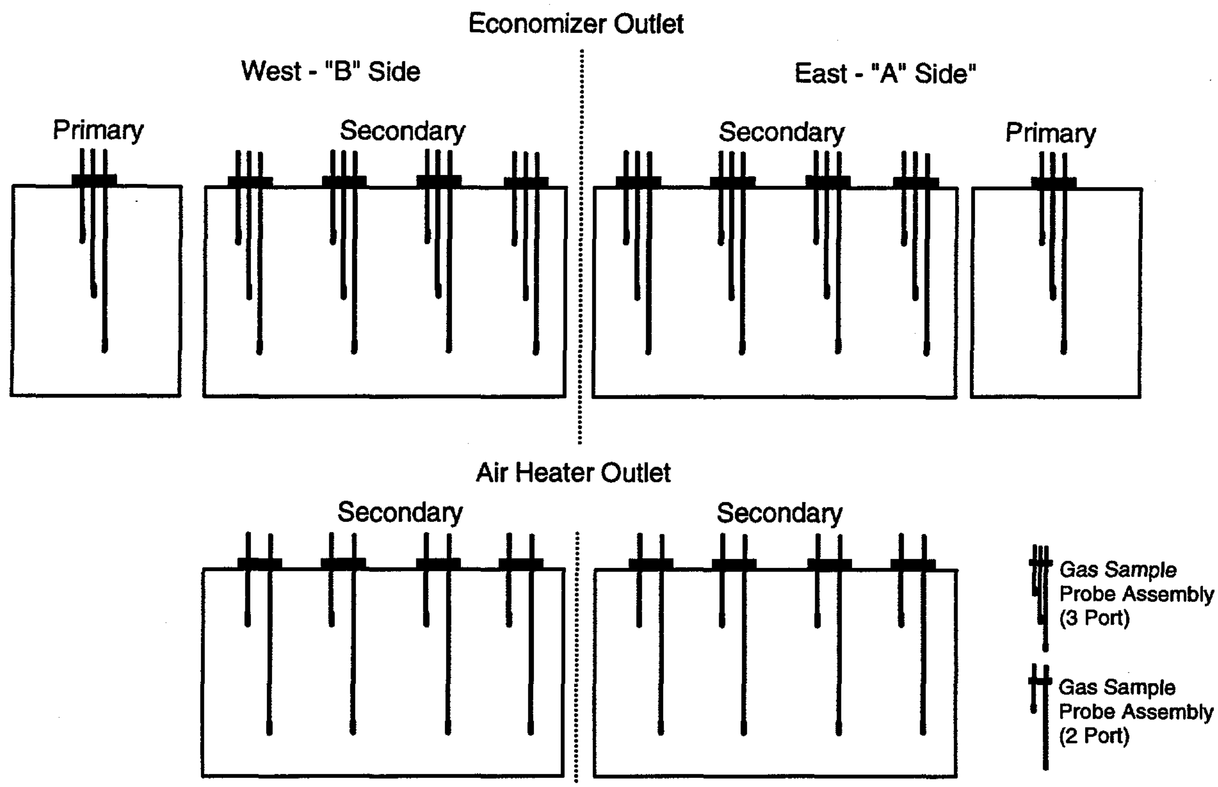


Figure 6-3: Extractive Gas Analysis System Probe Arrangement

6.2 Compliance Continuous Emissions Monitoring System (CCEM)

During spring 1994, just prior to Phase 4, a compliance continuous emission monitor (CCEM) was installed in the Hammond 4 stack. This system is a dilution-extraction type with analyzers for NO_x, SO_x, CO_2, and flue gas flow rate. This system is used as the secondary emissions monitor for this phase of the project.

6.3 LOI Monitors

A subsidiary goal of the Wall-Fired project is the evaluation of advanced instrumentation as applied to combustion control. Based on this goal, several on-line carbon-in-ash monitors were evaluated as to their:

- Reliability and maintenance
- Accuracy and repeatability
- Suitability for use in the control strategies being demonstrated at Hammond Unit 4

Three units are currently installed at this site: (1) Applied Synergistics FOCUS, (2) CAMRAC Corporation CAM, and (3) Clyde-Sturtevant SEKAM. The SEKAM unit samples from two locations at the economizer outlet while the CAM unit samples from a single location at the precipitator inlet (Figure 6-4). The FOCUS unit is a non-extractive system that utilizes two cameras located above the nose of the furnace. The following paragraphs briefly describe these devices.

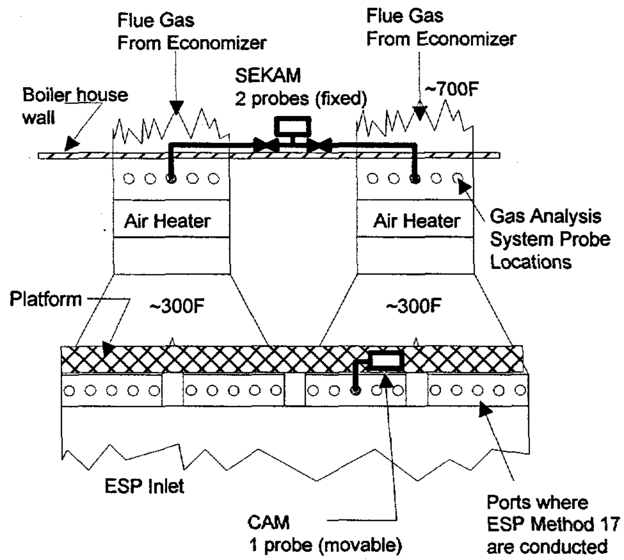


Figure 6-4: Extractive Gas Analysis System Probe Locations

Clyde-Sturtevant SEKAM. The SEKAM™ unit was developed by the UK Central Electric Generating Board (CEGB) with the SEKAM technology now transferred to Clyde-Sturtevant Engineering. A sketch of the SEKAM system is shown in Figure 6-5. The basis of the SEKAM device is the measurement of capacitance of the fly ash sample using a Kajaani cell which was developed by the Finish firm Kajaani Limited. Ash collected from the flue gas stream (or other locations) is deposited in a glass chamber of rectangular cross section measuring 150x70x20 mm (5.91x2.76x0.79 inches) placed between two capacitance sensors. The cell, flyash, and sensors are integrated into a circuit such that the output voltage of the circuit is a function of the measured capacitance. The device presumes a fixed relationship between the measured capacitance and carbon-in-ash. The installation at Hammond Unit 4 can sample from either the "A" or "B" side economizer outlet gas stream or from both probes simultaneously. It is expected that, except for short-term testing, the SEKAM will be configured to extract flue gas from both the "A" and "B" sides simultaneously thus shortening the sampling cycle time and improving the likelihood of obtaining a representative fly ash sample. Since the SEKAM device requires a relatively large fly ash sample (approximately 150 cm^3 ~ 375 g), in order to reduce the overall sampling time, the system samples super-isokinetically. An exhauster is used to supply the motive force to transport the flue gas and fly ash. Super-isokinetic sampling can have either a positive or negative impact on overall sampling accuracy. The SEKAM system was installed on Hammond 4 in Phase 4 during December 1994.

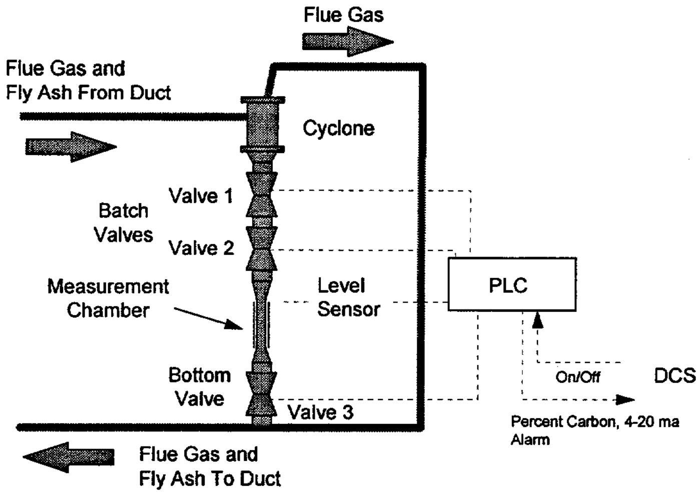


Figure 6-5: SEKAM Arrangement

CAMRAC CAM. CAMRAC Company's CAM (Carbon-Ash-Monitor) unit was developed during the 1980s by GAI Consultants (an affiliate of CAMRAC Company) with financial support from Allegheny Power Services Corporation, Duquesne Light Company, New England Power Services, NYSEG, Southern Company Services, Virginia Power, and EPRI. The CAM system uses the relative microwave absorbence between carbon and carbon-free fly ash to infer the carbon content of the sample. A schematic of a CAM system is shown in Figure 6-6. The installation at Hammond Unit 4 samples from one of twenty sample ports located at the inlet to the precipitator. The system has been designed such that vertical traverses of the flue gas stream can be conducted. During long-term testing, fly ash samples will be drawn from a single location. For short-term testing, several sample ports and depths will be used so that a spatial distribution of the unburned carbon can be obtained. The CAM system was installed on Hammond 4 during February 1995.

Applied Synergistic's FOCUS. The Applied Synergistic's FOCUS™ Unburned Carbon Module is a non-intrusive real-time device which provides a timely, continuous on-line indication of unburned carbon in fly ash. The device is based on the premise that unburned carbon particles and carbon laden ash particles exiting the furnace will be hotter than the surrounding background gases, carbon-free ash particles, and support structures, and therefore the carbon-laden particles will be higher emitters of radiant energy, especially in the infrared range. The primary sensing elements are one or more near infrared video cameras installed on the furnace. The hotter particles will be seen as white spots traversing the camera(s) field of view and these images are processed to determine the number of traverses in counts per minute. The assumption is then made that the carbon-in-ash (on a percent basis) is a function of these counts and unit load. Two cameras are utilized at Hammond 4. A sketch of the system is shown in Figure 6-7. The FOCUS Unburned Carbon Module was installed during July 1995.

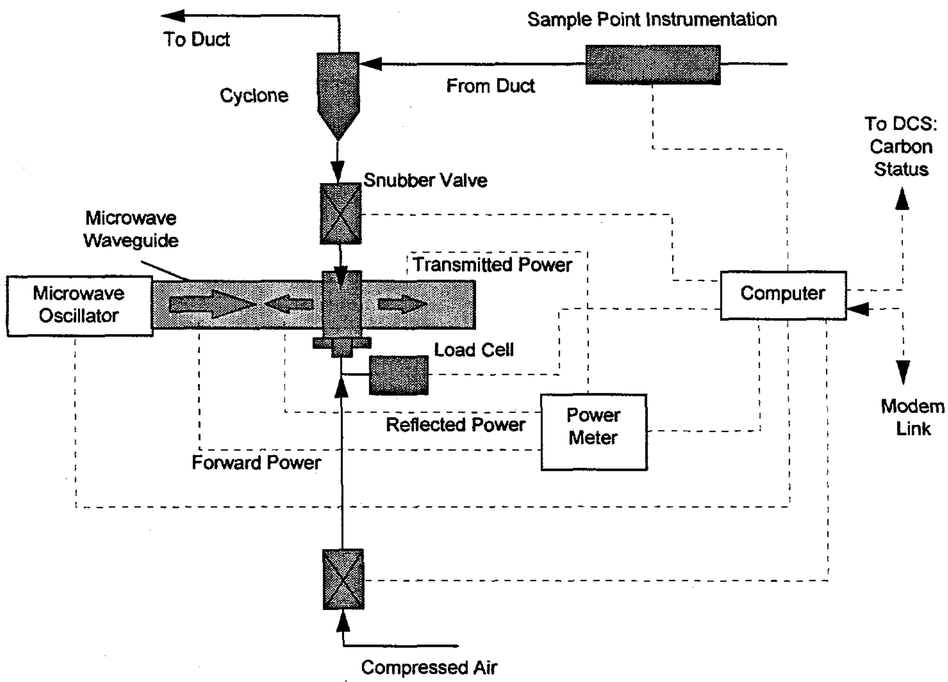


Figure 6-6: CAM Arrangement

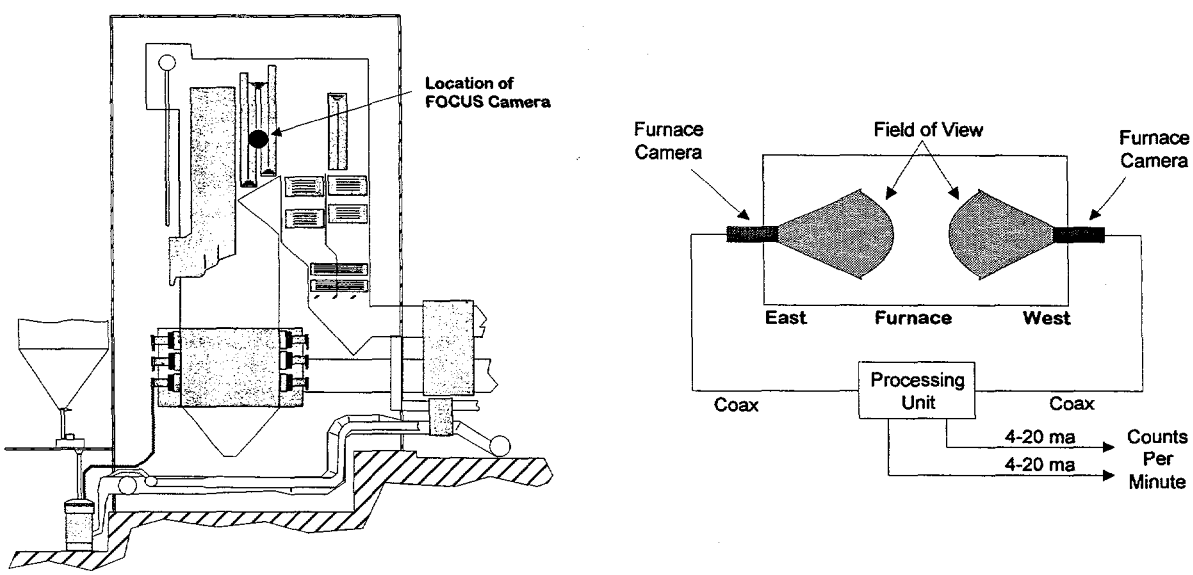


Figure 6-7: FOCUS Arrangement

6.4 Special Flue Gas Instrumentation

Excess O_2 Probes. In order to continuously monitor the excess oxygen levels at the economizer outlet and the air preheater outlet, in-situ monitors were installed in these locations. The purpose of these monitors was to allow detection of air preheater leakage through the seals and to provide excess oxygen data for the long-term data collection effort. The excess oxygen monitoring system uses zirconium oxide measuring cells located in the flue gas path. This in-situ method of measurement eliminates many of the maintenance problems associated with extractive systems. The zirconium oxide O_2 monitors used at Hammond are commonly used in power plant applications and provide an accuracy of ± 0.25 percent O_2. The installation includes six monitors at the economizer outlet and six monitors at the air preheater outlet (Figure 6-8).

Thermocouple Grids. Multi-point thermocouple grids were installed in the flue gas steam at the economizer outlet and the secondary air heater outlet (Figure 6-9).

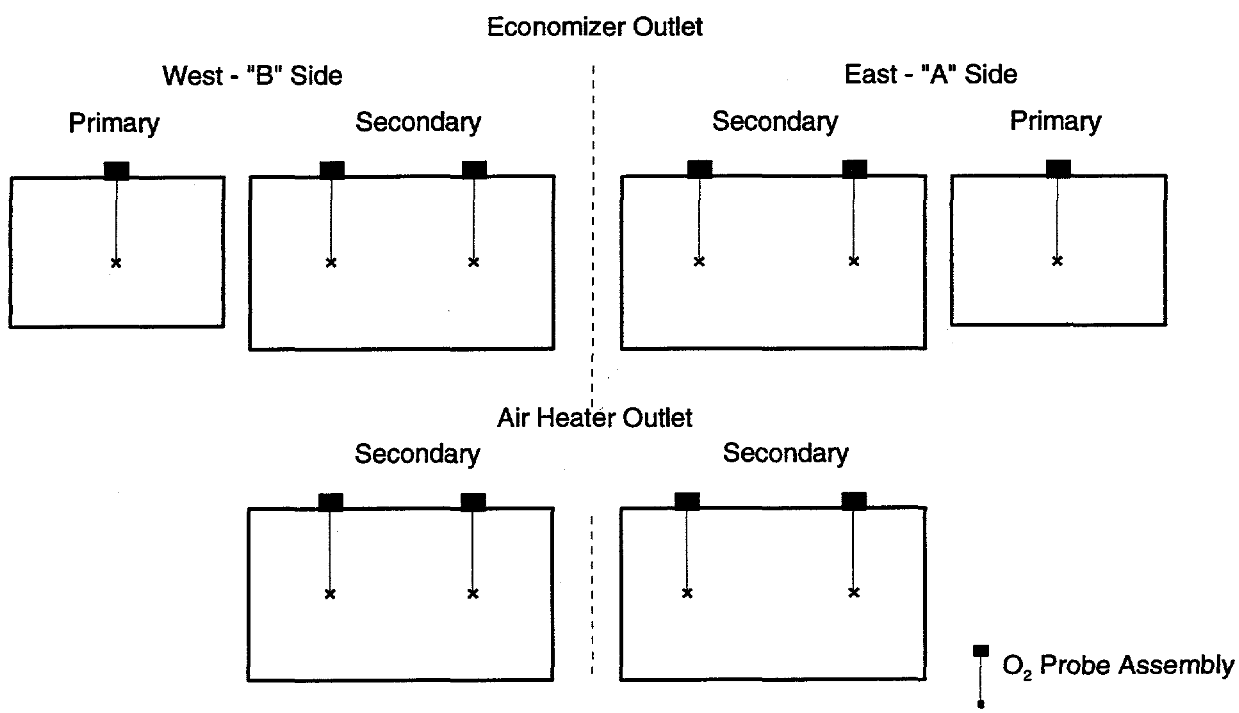


Figure 6-8: O_2 Probe Arrangement

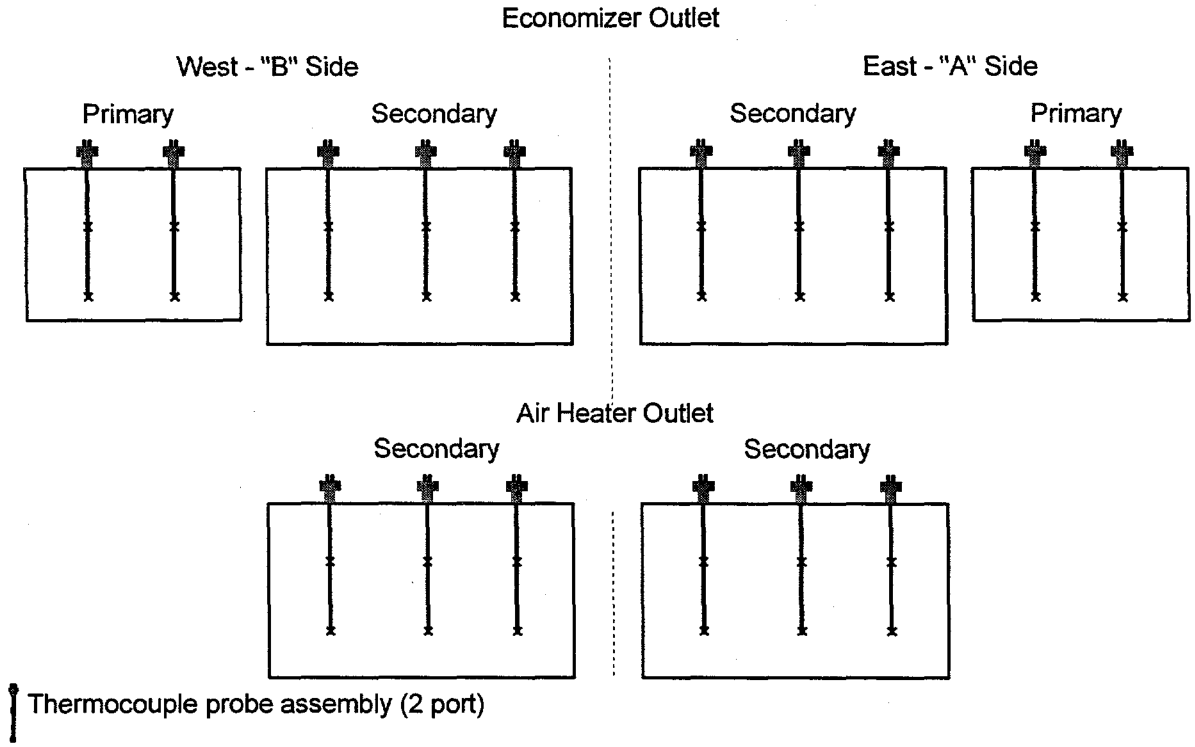


Figure 6-9: Thermocouple Probe Arrangement

6.5 Heat Flux Sensors

Heat flux sensors (from Land Combustion) were installed to detect changes in the heat absorption in the furnace combustion zone. The sensors consist of small metal cylinders welded to the fire side surface of a boiler tube. The shape, size and weld specifications of each cylinder are carefully controlled to assure exact dimensions in order to provide a specified heat path from the furnace/tube interface into the boiler tube. Two type-K thermocouples are embedded in each cylinder at prescribed depths. The temperature gradient detected by the thermocouples is proportional to the heat flux at the point of measurement. The arrangement of the flux sensors are shown in Figure 6-10.

6.6 Acoustic Pyrometer

The acoustic pyrometer package (from Scientific Engineering Instruments) provides furnace gas temperature data for the analysis of variations in the combustion process. The acoustic pyrometer is a micro computer controlled system that transmits and receives sonic signals through the hot furnace gas from multiple locations around the girth of the boiler furnace. The velocity of sonic pulses along multiple paths across the furnace can be computed and processed to provide an isothermal (contour) map of furnace temperatures at the level where the acoustic pyrometer transceivers are installed around the furnace. At Hammond, the horizontal plane that includes the transceivers is approximately 15 feet above the uppermost elevation of burners. The acoustic pyrometer's six furnace wall transceivers are located as shown in Figure 6-11.

The acoustic pyrometer provides average temperature data for straight line paths between any two transceivers not located on the same furnace wall (Figure 6-11). For the six transceiver configuration, a total of 12 paths are provided. The acoustic pyrometer computer provides eight 4-20 ma signals that can be programmed to represent any eight of the twelve temperature paths between transceivers. In addition, the acoustic pyrometer can display, on its color CRT, isothermal maps and three dimensional surface plots to allow engineers to evaluate heat profiles in the boiler. Print outs of CRT displays can be generated on demand at the plant.

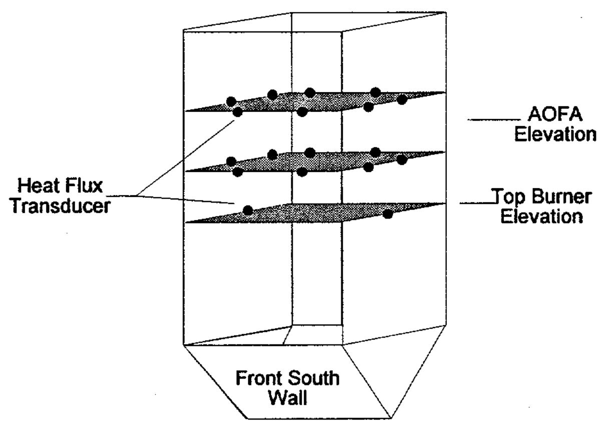


Figure 6-10:Arrangement of Heat Flux Sensors

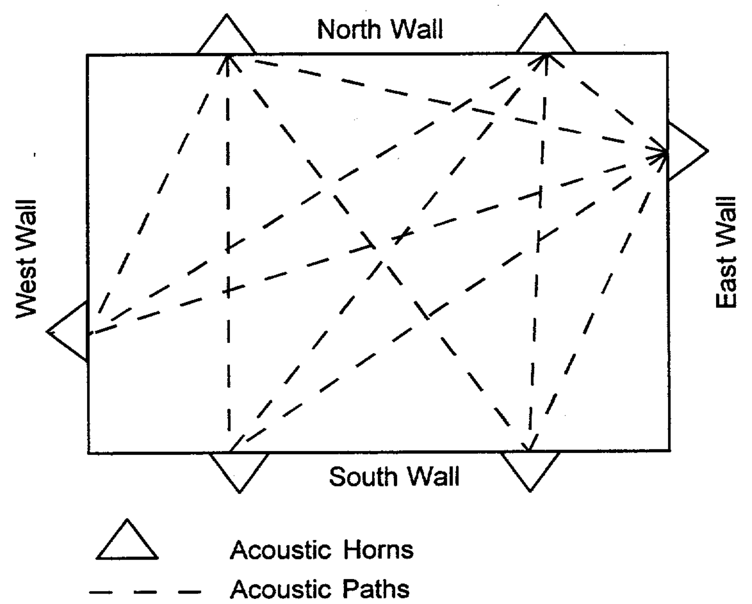


Figure 6-11: Acoustic Pyrometer

6.7 Data Acquisition System

Prior to baseline testing, a data acquisition system (DAS) was installed at the site. The DAS was used exclusively for Phases 1 through 3. For Phase 4, with the installation of the DCS, the majority of the inputs to the DAS were moved to the DCS. Approximately 150 inputs were terminated to the DAS including instrumentation installed around the air heaters, the ECEM, flux domes, acoustic pyrometers, and temperatures and pressures relating to the steam and feedwater cycle. The basic scan rate of the system is 5 seconds and the data is compiled into 5 minute averages for archival.

7. Equipment Costs Summary

A summary of the equipment costs for the Wall-Fired project is provided in Table 7-1. The quoted costs include all costs associated with engineering, procurement, installation, and start-up of the equipment. It does not include costs associated with the characterization of the equipment or project management. The costs as shown have not been escalated to current dollars.

Table 7-1: Approximate Equipment Cost Summary

Phase	Costs
Phase 1 - Baseline Instrumentation	$1,200,000
Phase 2 - AOFA Installation	$3,400,000
Phase 3 - LNB Installation	$4,000,000
Phase 4 - DCS Installation	$2,800,000

Appendix A

Proposal for Advanced Wall-Fired Combustion Modifications for
Reduced NO_x Emissions for
Plant Hammond Unit 4 of Georgia Power Company

Foster Wheeler Energy Corporation
June 6, 1989

CONFORMED

PROPOSAL

FOR

ADVANCED WALL-FIRED COMBUSTION MODIFICATIONS FOR REDUCED NOx EMISSIONS

FOR

GEORGIA POWER COMPANY
PLANT HAMMOND - UNIT NO. 4

PROPOSAL NO: 0-02-30063

JUNE 6, 1989

Issued By
Combustion & Environmental
Systems Department

FOSTER WHEELER ENERGY CORPORATION

(1480y)

Foster Wheeler Energy Corporation
Proposal No: 0-02-30063
June 6, 1989

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LIST OF FIGURES, DRAWINGS AND TABLES

(1480v)

Foster Wheeler Energy Corporation
Proposal No: 0-02-30063
June 6, 1989

:XECUTIVE SUMMARY

In response to Southern Company's Request for Proposal for a wall fired low NOx system demonstration, Foster Wheeler Energy Corporation is pleased to propose a multi-phase program. The proposed system represents a combination of a commercially-proven low NOx burner with an advanced overfire air arrangement. The following discussion summarizes these systems, the program phases and outlines FWEC's background in each area.

Background: Conventional Overfire Air Systems

Overfire air is the earliest form of combustion modification for NOx control. Conventional overfire air systems, utilized until the late 1970's, incorporated overfire airports within the burner windbox, typically about one burner elevation above the top burner row.

Although effective in achieving the 1971 New Source Performance Standard of 0.7 lb/million Btu, conventional overfire air is limited in its applicability. These limitations include:

- o Low port velocity, due to low windbox pressure, resulting in poor penetration of the overfire air flow into the furnace.
- o Increased unburned carbon if more than 20% of the total combustion airflow (TCA) is passed through the overfire airports.
- o Limited effectiveness, generally only 25-35% NOx reduction without causing increased unburned carbon levels.
- o Corrosion in the lower furnace could occur if a reducing atmosphere was produced when high sulfur coals were being burned.
- o Severe lower furnace slagging can result due to the reducing zone along the sidewalls.

Figure E-1 is a side-elevation view of a typical early 1970's NSPS unit equipped with turbulent burners and conventional overfire airports for NOx control. Typically NOx levels of 0.6-0.65 lb/million Btu were achieved with this system thereby complying with the original NSPS regulations.

FWEC's approach to reducing the above-listed adverse affects of overfire air, in steam generators designed <u>prior to</u> the development of our advanced low NOx burner, consisted of:

(1) Utilize a secondary air register design while incorporated a means, independent of the swirl-inducing register, to permit burner-to-burner air balance to be optimized. The Controlled Flow burner, shown in Figure E-2, contains dual registers surrounded by a sleeve damper and perforated plate. The sleeve dampers are adjusted until equal secondary air flows are achieved at all burners.

FOSTER WHEELER

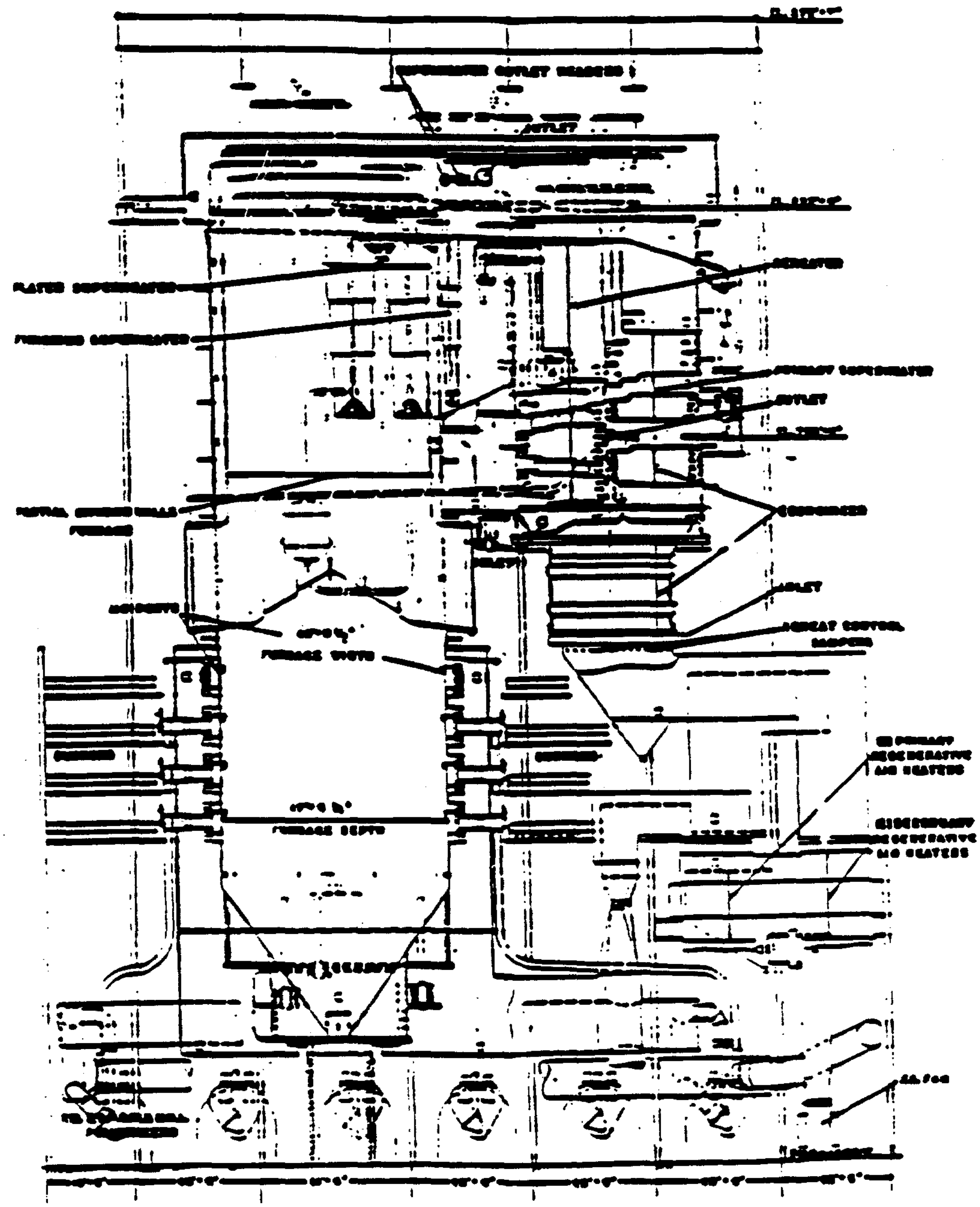

FIGURE E-1 Side Elevation - Vintage 1970 NSPS Unit

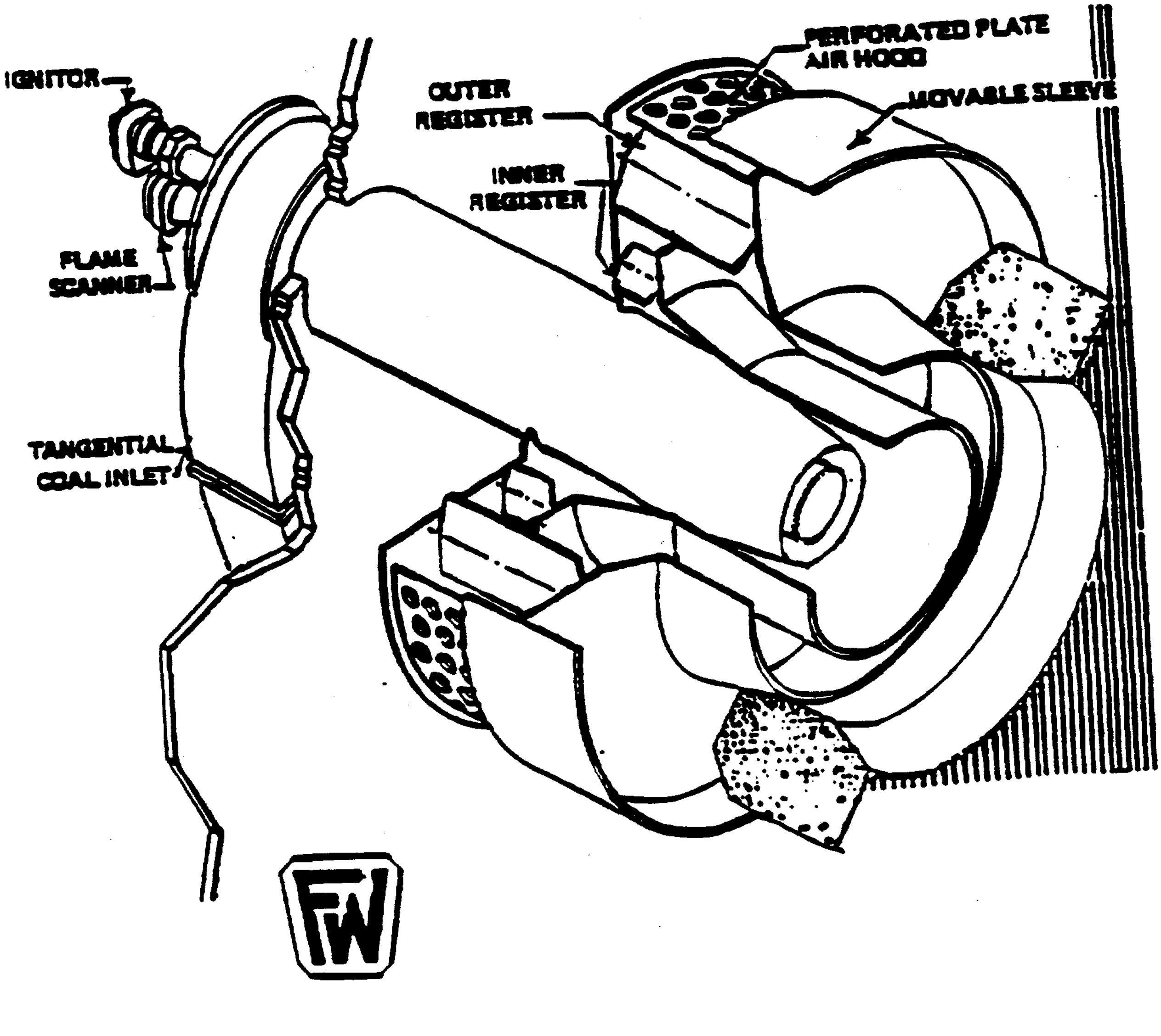

FIGURE E-2 Controlled Flow Burner

This secondary air balancing reduces unburned carbon under all operating conditions, particularly when overfire airports are open. Also, by closing the sleeve dampers sufficiently the windbox pressure can be raised such that satisfactory overfire air velocities can be attained. Consequently, penetration and furnace mixing are significantly improved, thereby minimizing unburned carbon losses.

(2) A Boundary Air system, shown in Figure E-3, was developed to blanket the sidewalls with air in order to maintain a constant oxidizing atmosphere between the sidewalls and wing burners. This has the effect of controlling sidewall corrosion and significantly reducing slagging. This system has been standard on all FWEC boilers sold since the late 1970's.

(3) FWEC developed an advanced low NOx burner, first used on a utility steam generator in 1979, which enabled the revised NSPS regulations (0.6 and 0.5 lb/million Btu) to be achieved without the use of overfire air. All FWEC units sold subsequent to this date incorporated this burner <u>without</u> the use of overfire air. Also, several industrial and utility units were retrofitted with this burner which achieves 50-60% NOx reduction.

(4) In anticipation of future need for greater NOx reduction FWEC continued to investigate the combined use of overfire air with our low NOx burner. The result of this investigation has been the development of an advanced overfire air system which does <u>not</u> rely on deep staging of the burners (we define deep staging as more than 25% of the TCA diverted to the overfire air. Field tests on two (2) utility steam generators, as well as testing on our 80 million Btu/hr Combustion and Environmental Test Facility, indicates that this advanced OFA system is twice as effective as conventional OFA with 20-25% of TCA to the overfire ports. NOx levels as low as 0.2 lb/million Btu have been obtained, representing an 80% reduction from uncontrolled turbulent burner NOx levels, when the advanced OFA is combined with our Controlled Flow/Split flame low NOx burner.

The Foster Wheeler advanced overfire air system schematically shown in Drawing LSK-893-7 Rev. A, is based upon increasing the residence time between the top burner level and the overfire airport level. [redacted] OFA ports will be located at the highest level since additional structural modifications, and consequent costs would be necessary to place the ports in the optimum location.

In addition, the following improvements have been made:

(1) Overfire airports are contained in a windbox separate from that of the burners. This eliminates burner air flow unbalances which occur when overfire airports are opened in a windbox common to both burners and ports.

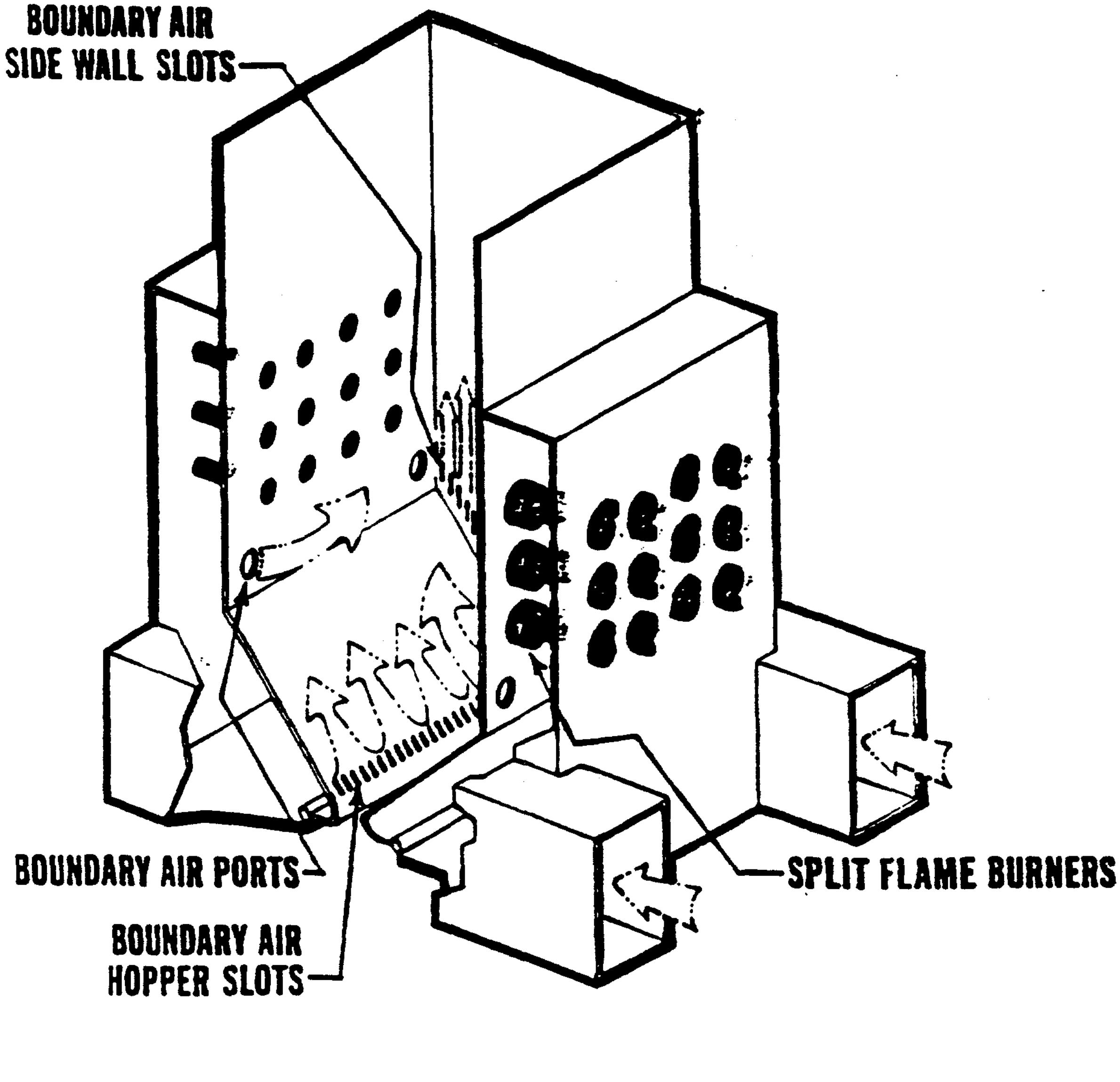

FIGURE E-3 Boundary Air System

(2) In addition to Boundary Airports providing air between the wing burners and sidewalls, an overfire airport is located above each burner. Thus, a unit which is four burners wide will have four overfire airports per firing wall: one port located above each burner column (for a total of four ports). This provides maximum coverage and mixing between furnace gases and staging air.

Coverage in the zone along the sidewalls is doubled by combined use of the boundary and wing overfire airports. This is the zone which is most susceptible to CO formation and stratification.

The effectiveness of this system in controlling CO and producing a uniform O_2 distribution across the furnace width is well documented.

(3) In order to maximize the available windbox pressure at the overfire air location, OFA supply ducts are run from the secondary air ducts.

Overfire Air Modeling

FWEC is proposing the following investigatory option for consideration. This will permit some system design optimization prior to final component design and fabrication.

Cold Flow Model of the boiler, secondary air ducts, windboxes and burners and overfire air system. A plexiglass, air-blown model will be utilized to evaluate the following:

- Front-to-rear windbox distribution with and without overfire air.
- Burner-to-burner secondary air unbalance with and without overfire air.
- Mixing between overfire air and furnace flow at 20% and 30% of TCA to the OFA ports.
- Evaluation of swirl/axial overfire air ratios, at 20% and 30% of TCA to the OFA ports, to determine most effective mixing pattern.

Although the cold flow model can provide useful information regarding air distributions and mixing patterns, it is nonetheless limited. Effects on combustion and boiler performance can only be inferred from the resultant data.

FWEC has used flow model and predictive computer programs in the past to design and locate overfire airports.

Foster Wheeler Energy Corporation
Proposal No: 0-02-30063
June 6, 1989

hase II: Low NOx Burner System

Foster Wheeler is proposing to supply twenty-four (24) Controlled Flow/Split-flame low NOx burners, shown in Drawing LSK-892-17 Rev. A, to be installed for the Phase II testing. This burner design is a fully commercial product which has been in utility field service since 1979. It is used in both retrofit and new steam generator applications.

Major advantages of this internally staged low NOx burner design are:

- Does not rely on delayed mixing concepts which produce long flames, higher Furnace Exit Gas Temperature and increased unburned carbon losses.
- Flame shape similar to that of existing turbulent intervane burner.
- Windbox-to-furnace pressure drop (without overfire air) [redacted]
- Typical NOx reductions [redacted] without overfire air.
- "Plug-in" retrofitability; not requiring pressure parts or structural modifications. Uses existing coal piping arrangements.
- Requires no special burner management system or flame scanning.
- Extensive experience with burners ranging in size from 30 to 300 million Btu/hr in both new and retrofit applications.
- Independent controls for secondary air flow (via an electrically actuated sleeve damper), flame shaping (using manually adjustable dual registers) and primary air/coal velocity (via a manually adjustable inner coal barrel tip). All manual adjustments are fixed after optimization.

The Controlled Flow/Split-flame burner should achieve [redacted] NOx reduction without overfire air and [redacted] total NOx reduction with the advanced overfire air system proposed. Boiler performance and efficiency effects should be minimal.

The low NOx systems we are proposing uses, to the maximum extent possible, commercially proven equipment and concepts. This philosophy should maximize NOx reduction, reliability and unit operability with minimum changes in unit operation, performance and efficiency.

Foster Wheeler Energy Corporation is prepared to work in close cooperation with Southern Company Services and Plant personnel to assure a smooth, efficient and successful program is undertaken.

Joel Vatsky, Director
Combustion and Environmental Systems

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FOSTER WHEELER ENERGY CORPORATION

Perryville Corporate Park

Clinton, N.J. 08809-4000

Proposal No. 0-02-30063 June 6, 1989

To: Georgia Power Company
(herein called the Purchaser)

Foster Wheeler Energy Corporation (herein called the Contractor) hereby proposes to furnish an Advanced Wall-Fired Combustion System consisting of equipment as outlined below. The following material, equipment and services are provided in accordance with the provisions of this proposal in response to the Purchaser's Request for Proposal No. GWO 9496 dated January 31, 1989.

1.0 SCOPE OF WORK

The scope of this proposal encompasses six (6) main tasks as follows:

- Low NOx Burner System
- Advanced Overfire Airport System
- Waterwall Air Protection System
- Burner Observation System
- Flame Scanner System
- Flow Modeling Study

Following is a task by task breakdown of the major equipment offered in this proposal.

1.1 Advanced Overfire Air System

1.1.1 Overfire Air Ports and Ducting

4 - Secondary Air Duct Pressure Control Dampers

4 - Overfire Air Duct Control Dampers

2 - Overfire Air Shutoff Dampers

1 - Overfire Air Duct System with associated platforms and flow measurement devices

8 - Can-In-Can Overfire Airport Injection Systems with replacement waterwall panels.

1.1.2 Waterwall Protection System

4 - Lower Furnace Airport Assemblies with replacement waterwall panels.

1 - Hopper Throat Air Slot System

1 - Hopper Slope Air Slot System

1.1.3 Burner Observation System

2 - Furnace Observation Port Waterwall Tube Penetrations

1 - Remote Flame Observation System

1.1.4 Flame Scanner System

24 - Main Flame Scanners

24 - Ignitor Flame Scanners

24 - Remote Flame Strength Indicators

1.2 Low NOx Burner System

24 - Low NOx Coal Injectors including outer sleeve with cast hi-temperature steel split flame coal nozzle, and inner barrel with cast hi-temperature steel adjustable tip and mounting flange.

24 - Coal Inlet Scrolls with ceramic lining.

24 - Controlled flow air registers including perforated plate air hood, sleeve damper, and air flow measuring device. For each of the dual air registers provide a manual drive for the inner and outer registers and an electric drive and associated drive shaft for the sleeve damper.

(24) Sets of Burner Thermocouples

1.3 Cold Flow Model Study

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3.0 LOW NOx BURNER DESCRIPTION

BACKGROUND

Foster Wheeler began development of low NOx burners for coal fired boilers with the promulgation of New Source Performance Standards (NSPS) in 1971. The first generation Controlled flow (CF) design burner was demonstrated in 1976. Three years later the second generation Controlled Flow/Split Flame burner (CF/SF) was commercially demonstrated at the 360 MW San Juan #1 unit. Both of these burners are commercially available. The CF burner is used as a general replacement for pre-NSPS burners. It is a modern flexible burner that can achieve low excess air, and low unburned combustibles with a short flame. Several thousand of these burners are in domestic and worldwide operation.

3.1 Design Philosophy

A fundamental design philosophy was strictly adhered to during the development of the CF/SF burner. Consequently, this burner has shown improved combustion, burner stability and boiler efficiency. This fundamental philosophy is as follows:

- Flame length and envelope to be equivalent to that of the turbulent burners that have been in historical use.
- Combustion airflow and swirl to each burner to be independently controllable.
- Adjustable primary air/coal velocity to insure optimum relation between primary and secondary air streams.
- Burner capacity to cover the complete range of industrial and utility use: approximately 30 to 300 million Btu/hr.
- Plug-in retrofitability, i.e., no pressure part changes, no conduit rearrangement and no major windbox modifications when installed on existing FW boilers.
- Primary and secondary air pressure drop in the same range as for the intervane burner, thus the existing fans can be used.

3.2 Design Features

Features included in the burner, shown schematically as an isometric sketch in Figure 3-1 and as a side elevation view drawing of the proposed Plant Hammond Unit No. 4 retrofit in FW Drawing Nos. LSK-892-17 and LSK-895-25, which enhance controllability and combustion are:

Perforated Plate with Movable Sleeve Damper: used to control secondary airflow on a per burner basis. By measuring the pressure drop across the perforated plate an index of airflow is obtained. The air distribution is thus optimized by adjusting the sleeve damper. This is a one-time optimization after which the "open" position is set. The limit

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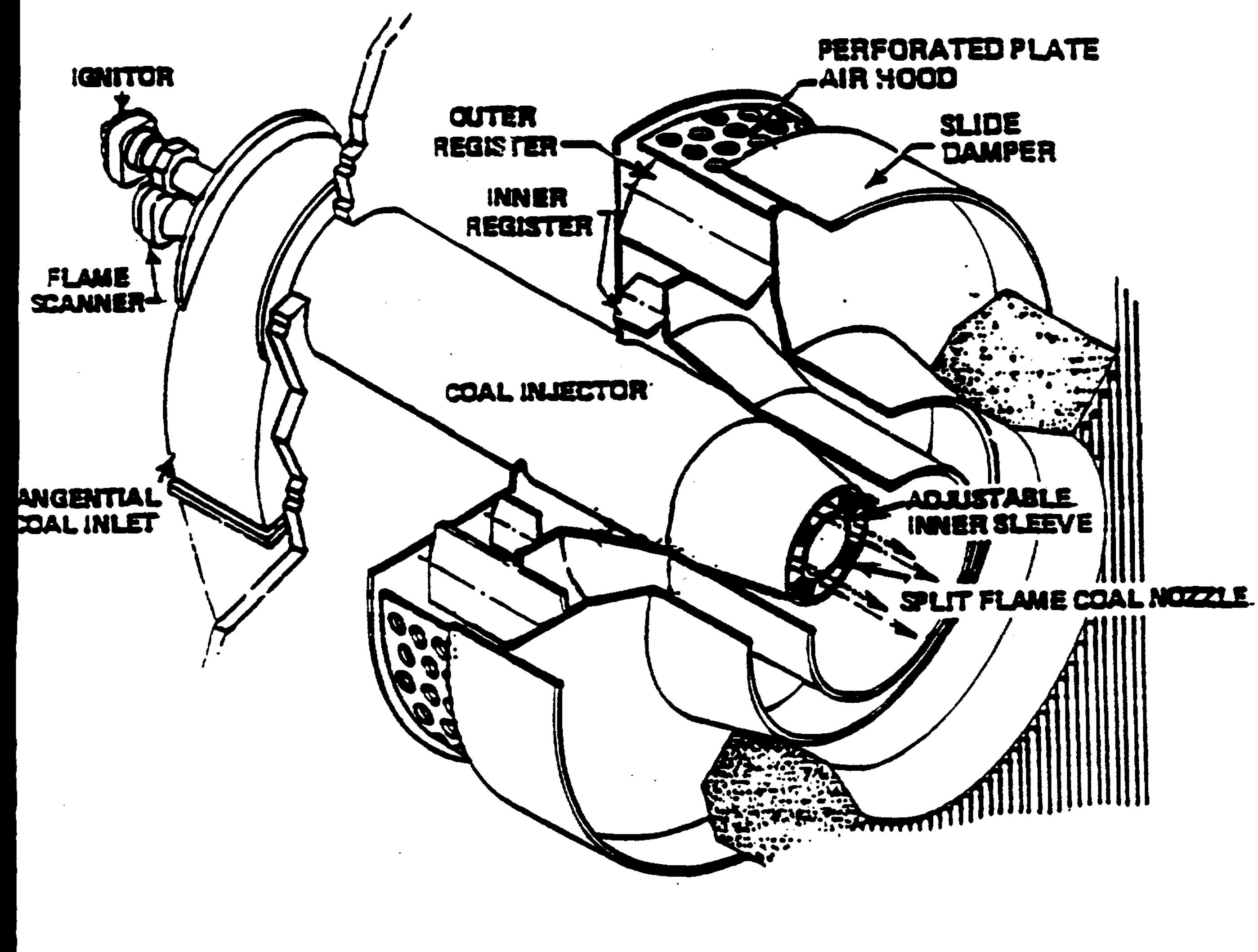

FIGURE 3-1 Controlled Flow Split Flame Low NOx Burner

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switches are adjusted for three positions: light-off, open and closed, and then the sleeve damper is used to shut off the air flow when the burner is out of service. The movable sleeve is not modulated with load.

- Dual Series Registers: provide improved flame shape control and NOx reduction by using a two-stage secondary air adjustment. A key reliability feature of this register configuration is that the blades and mechanisms are set back from the furnace wall and are well shaded from radiation. Consequently, they operate at windbox temperature and do not overheat or bind.

  Additionally, once the flame is optimized for proper flame shape and low NOx the registers can be fixed. They remain in their optimum position and are not modulated with load; they are not closed when the burner is out of service since the movable sleeve performs that function. Once optimized the register can be fixed and the burner essentially becomes a fixed register type.

- Adjustable Coal Nozzle: allows primary air/coal velocity to be optimized without changing primary airflow. The proper relationship between primary and secondary air is important for both NOx control and good combustion. The coal nozzle is adjusted during burner optimization; thereafter it remains fixed in the optimum position.

- Split Flame Nozzle: segregates the coal into four concentrated streams. The result is that the volatiles in the coal are driven out and are burned under more reducing conditions than otherwise would occur without the split flame nozzle. The volatiles contain a high percentage of fuel bound nitrogen and combustion under reducing conditions converts the bound nitrogen into N_2 substantially reducing NOx formation.

  These burners can be easily retrofitted to older boilers, usually on a "plug-in" basis, so that no pressure part or structural modifications are needed. Also, a significant operational advantage results from the fact that, after the burners' adjustable parameters are optimized, all but a single one are locked in place.

  Only the device used to shut off the secondary airflow is moved when the burners are taken in or out of service: the sleeve damper is used for this service in preference to the register. Thus, after optimization the burner becomes a fixed register type.

3.3 Register Operation

Each burner is equipped with two (2) separate registers each with its own separate adjustment mechanism. The registers are adjusted by manual operators external to the windbox. The operator applies torque to the primary register gear through a universal drive. The universal allows movement of the windbox relative to the register. The primary register gear engages a bull ring which drives a separate rack and pinion assembly for each vane. Each register vane is driven by a pinion gear that engages with a mating rack mounted on the bull ring assembly. Thus the bull ring is the rack and the pinion gear is the pinion in a circular rack and pinion assembly. Each pinion gear drives a shaft on which the corresponding register vane is mounted.

3.3.1 Inner Air Register

The inner air register regulates the degree of swirl imparted on the coal/air mixture in the near-throat area, regulates the supply of oxygen to the near-throat area and, in conjunction with the primary airflow, controls the point of ignition of the coal/air mixture.

By maintaining the near throat area in a reducing atmosphere, the NOx produced during the fuel devolatilization process can be minimized. In addition, the reduction in flame temperature associated with a near throat area reducing atmosphere will minimize the formation of thermal NOx. Thus, by adjusting the inner air register to control the near throat area stoichiometry the formation of NOx is minimized.

The inner air register is initially set at a nominal open position. During initial burner optimization the air register position will be fine tuned to locate the coal/air mixture point of ignition at the throat of the burner. By locating the point of ignition at the burner throat, the near throat coal/air mixture stoichiometry will be maintained at the desired level to achieve the NOx reductions indicated above.

It should be noted that the inner air register is used to fine tune the near-throat coal/air mixture conditions. Modifications to the primary air flow, air/coal ratio or inner air register vane position will produce changes in the near-throat coal/air mixture stoichiometry and flame ignition point and can affect NOx and CO production and the economizer outlet flue CO and O_2 distribution. Modifications to the inner air register vane position location should only be performed by qualified personnel under controlled test conditions.

Following the initial optimization of the inner air register, the vane position shall remain fixed unless changes in plant operation dictate that further optimization is required.

3.3.2 Outer Air Register

The outer air register arrangement divides the burner's secondary air stream into two concentric streams which independently vary air stream swirl. One air stream is routed through the inner air register assembly for the purposes noted above. The other stream of secondary air is directed by a flow divider to enter the furnace axially. This air stream then combines with the reducing atmosphere flame zone in the furnace to provide the remaining air necessary for combustion. The swirl on the secondary air stream promotes sufficient mixing of the two streams to ensure adequate carbon burnout prior to exiting the flame zone.

The outer register is initially set at a nominal open position. During initial burner optimization, the outer air register position will be fine tuned to produce minimum NOx and a balanced O_2 and CO distribution across the economizer exit flue. Following initial optimization of the outer air register, the vane position shall remain fixed.

3.4 Perforated Plate with Movable Sleeve Damper

The perforated plate and movable sleeve damper combine to control the burner to burner airflow distribution.

The perforated plate, installed around the circumference of the secondary air inlet area, aids in the burner circumferential air distribution. The result of this air distribution improvement is better air flow control through the air register assembly and into the flame zone. The perforated plate is a nonadjustable item.

The movable sleeve damper is the main airflow control device on the burner assembly. During normal operation, the sleeve damper is set at the open, light off, and closed positions depending upon the state of burner operation. During the initial full load burner optimization, the individual burner airflows are optimized by adjusting the movable sleeve dampers. This optimization determines each sleeve damper's open position.

The sleeve damper operator is an electric/manual linear drive that pushes/pulls the sleeve damper open or closed. The damper's rollers ride on two (2) rails that support it and keep it accurately aligned. The push rod from the linear operator pushes at a point equidistant from the two (2) rails such that the hood does not cock and jam. Limit switches on the operator, that are set during installation, stop the operator at the open, light off and closed position.

3.5 Inner Sleeve with Sliding Tip

The inner sleeve of the Controlled Flow/Split Flame burner's coal nozzle is equipped with an axially movable tip which provides a means for varying the primary air velocity while maintaining a constant primary airflow. The velocity adjustment is used to optimize the primary air/secondary air velocity ratio to minimize shear induced turbulence.

The optimum position of the sliding tip is determined during burner optimization testing by monitoring flue gas NOx and CO emissions and the igniter and coal flame conditions. This movable tip is adjusted manually and can be readjusted to account for different unit operation conditions. Therefore, if a major change in fuel characteristics occurs, tip adjustment can reoptimize NOx and CO. Note that this adjustment repositions the flame with respect to the burner throat. This adjustment is used in conjunction with the inner and outer register optimization to optimize the unit performance with respect to O_2 distribution, CO emissions, and NOx emissions. Note that once the optimum tip position is established it remains fixed.

3.6 Outer Sleeve with Split Flame Nozzle

The outer sleeve of the burner's coal nozzle, in conjunction with the inner sleeve described above, forms the opening through which the coal/primary air mixture flows. Attached to the discharge section of the outer sleeve is a split flame nozzle which channels the coal/air mixture into four concentrated streams, each of which forms an individual flame.

The chief design feature of the split flame nozzle is to control the mixing between the coal/air mixture and the secondary air stream. The combination of the concentrated coal streams and the staged secondary air produces near throat flame stoichiometries [redacted] up to about two throat diameters into the furnace (the total burner, however, is operating at normal boiler excess air). At that point, the swirling secondary stream from the outer portion of the throat annulus, containing the remaining combustion air, combines the four flames and provides sufficient mixing to ensure adequate carbon-burnout.

Uniform distribution of coal about the periphery of the coal nozzle's annular passageway is attained by use of the tangential coal inlet and the anti-roping bars mounted on the inside of the outer sleeve.

The result of the splitting up of the coal steam is that the volatiles in the coal are driven out and burned under a more reducing atmosphere than would occur without the split flame coal nozzle. The coal volatiles contain a high percentage of the fuel bound nitrogen that, when burned in an oxidizing atmosphere, would be converted to NOx. The split flame coal nozzle, by virtue of its operating in a reducing atmosphere, converts the bound nitrogen in the coal volatiles into N_2 thus substantially reducing NOx formation and emissions.

3.7 Description of Ancillary Equipment

3.7.1 Burner Metal Thermocouples

Four (4) burner metal thermocouples are provided with each burner for the purpose of monitoring the split flame nozzle and outer sleeve temperatures. Three (3) thermocouples are mounted at split flame nozzle tip and one (1) thermocouple is mounted on the outer sleeve, approximately one third the distance back from the nozzle tip. These thermocouples provide operators with a means of determining if a given burner is experiencing an upset temperature condition (i.e.: coking), allowing appropriate action to be taken to correct the problem. The operators will also know if the burner is cool enough to start coal flow.

3.7.2 Burner Air Flow Measuring Device

A local indication of secondary air flow is provided with each burner through the use of an air flow measuring device consisting of primary connection points at the sleeve damper perforated plate, piping to the exterior of the windbox and a magnahelic gauge (0" to 3" W.C.) panel assembly. Four (4) low pressure taps, located on the inboard side of the perforated plate and symmetrically positioned around its circumference, are combined outside the register front plate to yield an average low pressure reading. A single high pressure tap located on the outboard side of the perforated plate provides the high pressure reading. The differential pressure is displayed on the magnahelic gauge located on the gauge panel. The pressure drop across the perforated plate is dependent on the sleeve damper opening and the airflow; by knowing the hood percent open and the pressure drop the airflow can be approximated.

3.7.3 Burner Sleeve Damper Actuator

Each burner sleeve damper is equipped with an electric linear drive which moves the damper through the open, light-off and closed positions. The actuator is provided with open light-off and closed limit switches, torque switches for opening and closing, local and remote position indicators and position transmitters.

3.8 Manufacturing Method

Each major assembly is fabricated on a special jig which allows the entire assembly to be completed and tested as a unit.

The inner and outer registers are driven with a standard manual drive to assure proper operation. The sleeve damper is driven by a standard electric linear drive to assure that proper clearances, speed of travel and operation are attained. Manufacturing and testing the register assembly in this manner minimizes field installation time and precludes operational problems once installed. Subsequent to the quality control checks and operation test described above, the movable parts are blocked in place to prevent damage during shipment and to insure that the design tolerances will be maintained.

The inner sleeve movable tip is manually adjusted in the shop after assembly to the outer sleeve and coal inlet scroll. When ceramic liners are provided in the outer sleeve and the coal inlet scroll, the individual ceramic sections are shop assembled under close tolerance to assure correct fit. The complete assembly then becomes a plug-in module, easily mounted to the existing windbox front plate. This minimizes erection time at the jobsite and the complete shop assembly insures that all burner parts are correctly aligned, within tolerance, prior to shipment.

Miscellaneous parts including the air pressure measuring device, thermocouples, manual and electric drives and register drive shafts are shipped loose for field assembly. However, the two major burner components are completely shop assembled, resulting in better field fit-up, shorter erection time and greater operational reliability.

3.9 Burner History

The FW Controlled Flow/Split Flame burner was put in commercial service in 1979 at the San Juan #1 boiler of Public Service of New Mexico. This was the first commercial operation of the split flame coal nozzle; the balance of the burner (register, movable hood and the perforated air hood with air flow indicators) has been in commercial utility service since 1976 when the Controlled Flow burner was demonstrated. Table 3-1 shows a list of installations of the CF/SF burner.

San Juan #1 Operational History

The San Juan #1 boiler was retrofitted with CF/SF burners in 1979; the first installation in a utility size boiler. The NOx was reduced 60% to about 0.4 lb/10^6 Btu without overfire air; the CO measured 40 ppm at 4.0% excess O_2. No change in performance of the unit was found during testing.

In 1984 some of the original split flame tips fabricated from plate material were replaced with new cast tips to compare their operation. The cast tips have been in operation since 1984 with no problems.

Boardman #1 Operational History

The Boardman Unit #1 of Portland General Electric is a 525 MW opposed fired boiler. The unit was designed originally for intervane burners, but during erection CF/SF burners were installed. [redacted] No operational problems have developed since the unit was started up; burner components have not been replaced with new designs.

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Pleasants Operational History

The CF/SF burners were installed in Jan./Feb. 1986. After a two week optimization period the NOx measured [redacted] without overfire air; reduced from 1.0 lb/10^6. The CO measured 40 ppm and the [redacted] efficiency loss) levels equal to those measured during previous operation with the intervane burner. Primary air fan power consumption remained the same and the windbox to furnace pressure drop remained at 3.0 to 3.5 in W.C. Periodic visual observations of ash deposition patterns on furnace walls, superheater and convection pass tubing indicate no change. Changes in furnace absorption patterns have not been detected.

High temperature corrosion occurred on some split flame burner nozzles. These were replaced with new nozzles of higher temperature materials. After several months of operation the new material has shown no evidence of corrosion although other replacement nozzles installed at the same time but cast of the older material, had begun to deteriorate.

Modification Summary of Three Units:

- Public Service of New Mexico, San Juan #1

  1976 Initial start-up with turbulent intervane burners.

  1979 Retrofit with CF/SF burners (split flame nozzles fabricated from steel plate).

  1984 Replacement of some split flame tips with cast tips.

- Portland General Electric, Boardman #1

  1981 Initial start-up with turbulent intervane burners.

  1982 Retrofit with CF/SF burners.

- Allegheny Power Systems, Pleasants #2

  1981 Initial start-up with turbulent intervane burners

  1986 Retrofit with CF/SF burners.

  1987 Replacement of some tips with higher temperature resistance than original.

Table 3-1 deleted at the request of Foster Wheeler

4.0 OVERFIRE AIR SYSTEM DESCRIPTION

Background

In order to demonstrate the long term effects of overfire air on NOx emissions reductions and boiler performance FWEC is proposing to install a state-of-the-art overfire air system at the Hammond Station. Installation of the proposed system will allow overfire air performance to be determined for the various unit loads and operating conditions typically experienced in a large, central generating station such as Plant Hammond Unit No. 4.

Following is a brief description of the design-philosophy and various components of the offered system.

4.1 Design Philosophy

The primary design philosophy was to create an overfire air system which is fully integrated with current technology while providing flexibility in the overfire air design for research potential. FWEC has developed a cost efficient design which utilizes a maximum of the currently available technology. Following is a brief description of the design philosophy used.

- Overfire air system mass flow [redacted] of the Total Combustion Air Flow. By reducing the air to fuel ratio in the burner zone, the fuel bound nitrogen will be forced to combine with other fuel bound nitrogen, thus avoiding harmful NOx emissions. When a large amount of the combustion air is taken out of the burner zone, the temperature at the burner front tends to decrease. This reduces the amount of thermal NOx produced from the combustion reaction. On past furnace applications (both experimental and industrial) it has been demonstrated that the best operating range for overfire air is to limit total AOFAP flow [redacted] of the Total Combustion Air Flow.

- The proposed overfire air system allows for the diversion of a portion of the combustion air from the burner windbox to the AOFAP windbox. As explained above, this creates an atmosphere which reduces both thermal and fuel NOx. In order for the reactions to have time to progress as completely as possible, the overfire air system will be placed as far up in the furnace as possible. This will maximize the pre-overfire air residence time and allow for the optimum NOx reduction to be obtained.

- A problem associated with the use of overfire air is to assure even distribution over the furnace cross section. The proposed design includes four (4) overfire airports per side with each port having a can-in-can damper arrangement which will allow injection air to be balanced or biased to reducing areas.

- Obtaining good overfire air penetration into the hot flue gas stream is another design priority. The proposed design is for a [redacted] AOFA injection velocity at the overfire airport throats when using [redacted] of the total combustion air. The system also has the flexibility to produce AOFA injection velocities of up to [redacted]

- Because current methods for NOx reduction require lower burner zone temperatures and longer sub-stoichiometric residence times, the unit efficiencies as well as combustion efficiencies tend to drop. The proposed design is flexible in that proper amounts of combustion air can be biased between the burner zone and the overfire air to achieve low NOx emissions while still operating at optimum unit efficiency. With the proposed system, normal burner operation during overfire air testing will be maintained.

4.2 Design Features

Schematics of the individual port and can-in-can damper are shown on FW Drawing No. LSK-893-7. A plan view of the proposed ducting is shown on FW Drawing No. LSK-895-19-B. And an elevation of the AOFAP and LNB's is found in FW Drawing No. LSK-895-25.

Following is a brief description of the major components of the overfire air system.

4.2.1 Secondary Air Duct Pressure Control Dampers

In order to obtain the required static head to allow for AOFA injection velocities of up to [redacted] a pressure control damper will be installed just downstream of each secondary air duct overfire air takeoff. This damper, in combination with a windbox divider plate, will also be used as a windbox air distribution control device. (See Section 1.2.2 below.) The damper will be of a parallel louver type and will be installed at the secondary air duct to windbox inlet plane.

By closing down on the pressure control dampers the required AOFA System pressures and flows can be obtained while maintaining the burner windbox flows and pressures at a normal level. This is necessary to assure that the burner operation is representative of normal burner operation so that a true analysis of the effects of overfire air can be determined.

The use of the secondary air duct pressure control dampers is made possible due to the Hammond Station, Unit No. 4 being originally designed as a Forced Draft Boiler but run as an Induced Draft Boiler. Figure 4.1 shows the fan curves generated by Southern Company with the test block and the expected operating point for the FD fans while the AOFA system is in use. As seen from this curve the proposed static pressure and flows for the AOFA system are well below the test block flow and maximum static pressure capabilities of the fans.

Analysis of the ductwork has found that the proposed operating pressures are well within the design constraints of the ducts so that no duct stiffening is required. However, provisions for inspection of the existing duct to determine if repairs are necessary to return the duct to a design state have been made.

4.2.2 Burner/Windbox Air Distribution System

In order to insure optimum AOFA system performance a Burner/Windbox Air Distribution system has been included in this proposal. This system is broken down into two (2) main parts. First is the ability to assure optimum air flow distribution between the front wall and rearwall windboxes. Second is the ability to control the air flow to each burner to optimize the burner combustion process.

The method proposed to optimize the front to rear windbox air distribution is to install secondary air pressure control dampers (as noted above) and a windbox divider plate. By installing these dampers with vertical shafts and parallel vanes as shown in Fig. 4.2 and by installing a windbox divider plate as also shown in Fig. 4.2, the front to rear windbox distribution can be controlled for optimum burner performance.

These combined duty dampers perform their function by having opposite stroke directions for the left and right side dampers. (See Fig. 4.2.) The dampers are essentially acting as a variable position turning vanes which direct the flow towards the respective front or rear windbox. The windbox divider plate acts as a flow baffle to minimize the air biasing between the front and rear windbox, thus allowing the dampers to operate with a maximum effectiveness. It is important to note that the windbox baffle plate is not an air tight baffle. The intent of its use was to minimize the air flow biasing between the front and rear windbox and not to preclude any flow between the front and rear windbox.

It is strongly believed that this step will aid the flame zone combustion process and will allow the AOFA NOx reduction system to perform to the best of its ability. Two of the major detriments of using an overfire air system are its potential to increase unburned carbon levels in the ash and increase unit CO emissions levels. Proper air flow balancing between each windbox and between each burner, along with correct airflow introduction into the flame zone, will minimize the potential increase in UBC levels and CO emissions levels when using overfire air.

4.2.3 Overfire Air Duct System

The proposed overfire air duct routing is found in FW Drawing No. LSK-895-19-B. As shown in this drawing, the overfire air ducts are taken off the secondary air duct just before the secondary air duct connects into the burner windbox. The overfire air ducts extend a vertical distance of approximately 20 feet. The overfire air ducts then split to supply front and rear ducting to overfire air windboxes. A flow control damper is located just down stream of the split for each overfire air duct. A combination of two dampers per side allows the overfire air to be biased between the front and rear overfire air windboxes. Positive AOFA duct flow shutoff dampers will be installed in the vertical takeoff from the Sec Air Duct.

The AOFA duct routing was designed to minimize interferences with existing equipment. The existing sidewall waterwall blowers will not have to be removed. However, the front and rearwall waterwall blowers will be removed to allow for installation of the AOFA system.

The front to rear OFAP air flow distribution shall be controlled by use of the flow control dampers.

4.2.4 Overfire Airport System

The proposed advanced overfire airport system is FWEC's standard [redacted] diameter throat (refractory to refractory) OFAP. The can-in-can dampers are supplied by air from the front and rear AOFA ducts. FW Dwgs. LSK 893-7, LSK 895-25 and LSK -895-26 show details of the proposed system.

4.2.5 OFA Port Locations

The offered overfire air system is comprised of eight (8) individual ports. These ports are arranged four per wall; one port located above each burner column (for a total of four ports).

4.2.6 Overfire Air System Indication

The AOFA duct sections will have flow indication systems installed upstream of the AOFA port windbox inlet. The flow measurement devices shall be of a flow straightener and pitot tube grid type.

5.0 WATERWALL PROTECTION SYSTEM (FURNACE BOUNDARY AIR SYSTEM):

The Boundary Air System provides a passive means of maintaining an oxidizing atmosphere along the furnace sidewalls and in the furnace hopper zone. During unit operation it is not necessary to modulate any dampers as load changes or as mills are taken out of service.

The Boundary Air System consists of airports, hopper airslots and sidewall airslots (Figure 5-1) designed to bias a small amount of air from the burners to the lower furnace walls. The Boundary Air System does not supply additional air to the furnace and it does not increase the excess air requirement of the boiler.

Boundary Air is an adjunct to the low NOx burner system. It does not directly lower NOx but allows lower NOx levels to be achieved by permitting lower excess air levels to be used before the onset of sidewall slagging or excessive CO formation. The system consists of hopper airslots, sidewall airslots, and four (4) lower furnace airports. The secondary air flow through the airports and airslots can be adjusted to optimize the system. Once the system is optimized the control damper manual operators are locked in place and need not be changed.

The Boundary Air System redirects combustion air from the windbox to the region between the sidewalls and the outer burner columns thereby increasing the sidewall excess oxygen level. The effect of using the Boundary Air System is summarized in Figure 5-2. This Figure shows the O_2 and CO levels across the width of a 500 MW boiler (as measured at the economizer exit). The upper curve represents the as found, unbalanced O_2 and CO levels. The center curve shows the improvement obtained by adjusting the sleeve dampers to achieve equal pressure drops across the burner perforated plates. It should be noted that normalizing the burner perforated plate pressure drops does not necessarily result in equal burner stoichiometries. The lower curve, showing a nearly flat O_2/CO distribution, results from the use of the Boundary Air System.

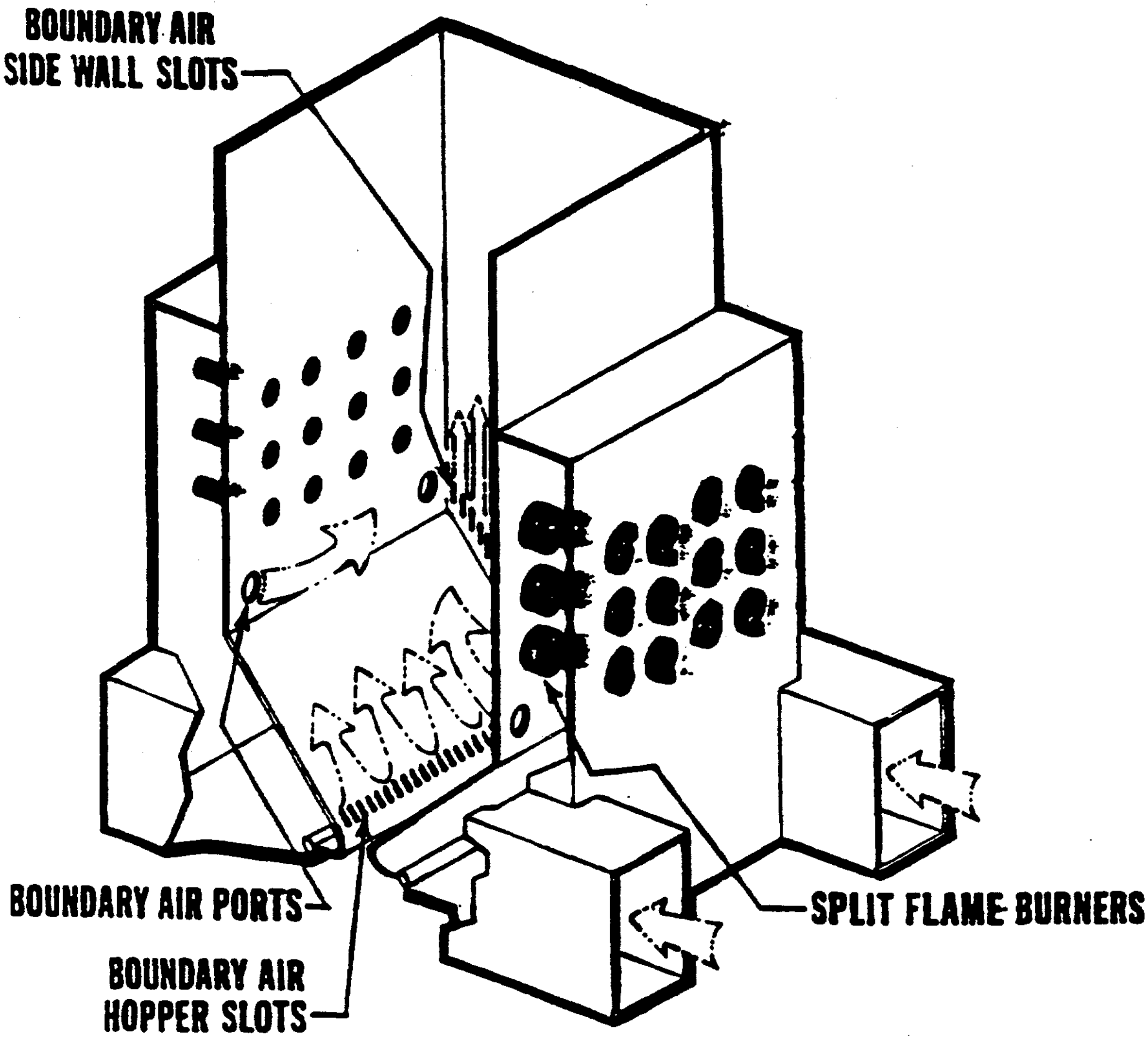


FIGURE 5-1 Boundary Air System

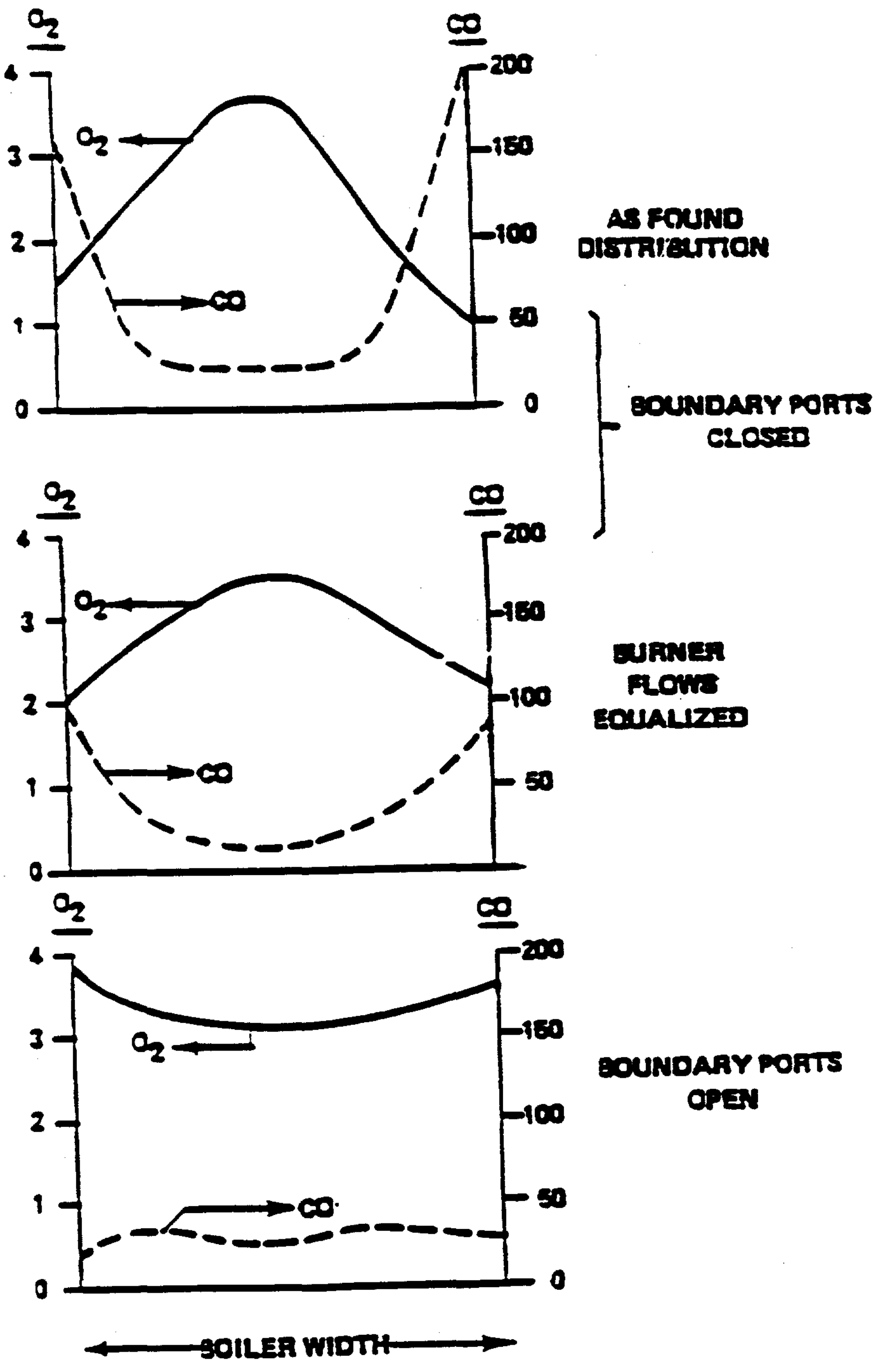


FIGURE 3-2 Effectiveness of Boundary Air and Secondary Air Balancing

6.0 BURNER OBSERVATION SYSTEM

Following is a brief description of the various Burner Observation System Components.

6.1 Furnace Observation Port Waterwall Tube Penetration

FW is proposing to install two (2) tube penetrations above the burner zone so that two (2) CCTV cameras can be installed.

6.4 Remote Flame Observation Systems

In order to insure that all eight (8) top row burners may be viewed remotely, FWEC is proposing to install two (2) remote flame observation camera assemblies. Each assembly will be a self contained, cooled, flame observation system.

FOSTER WHEELER

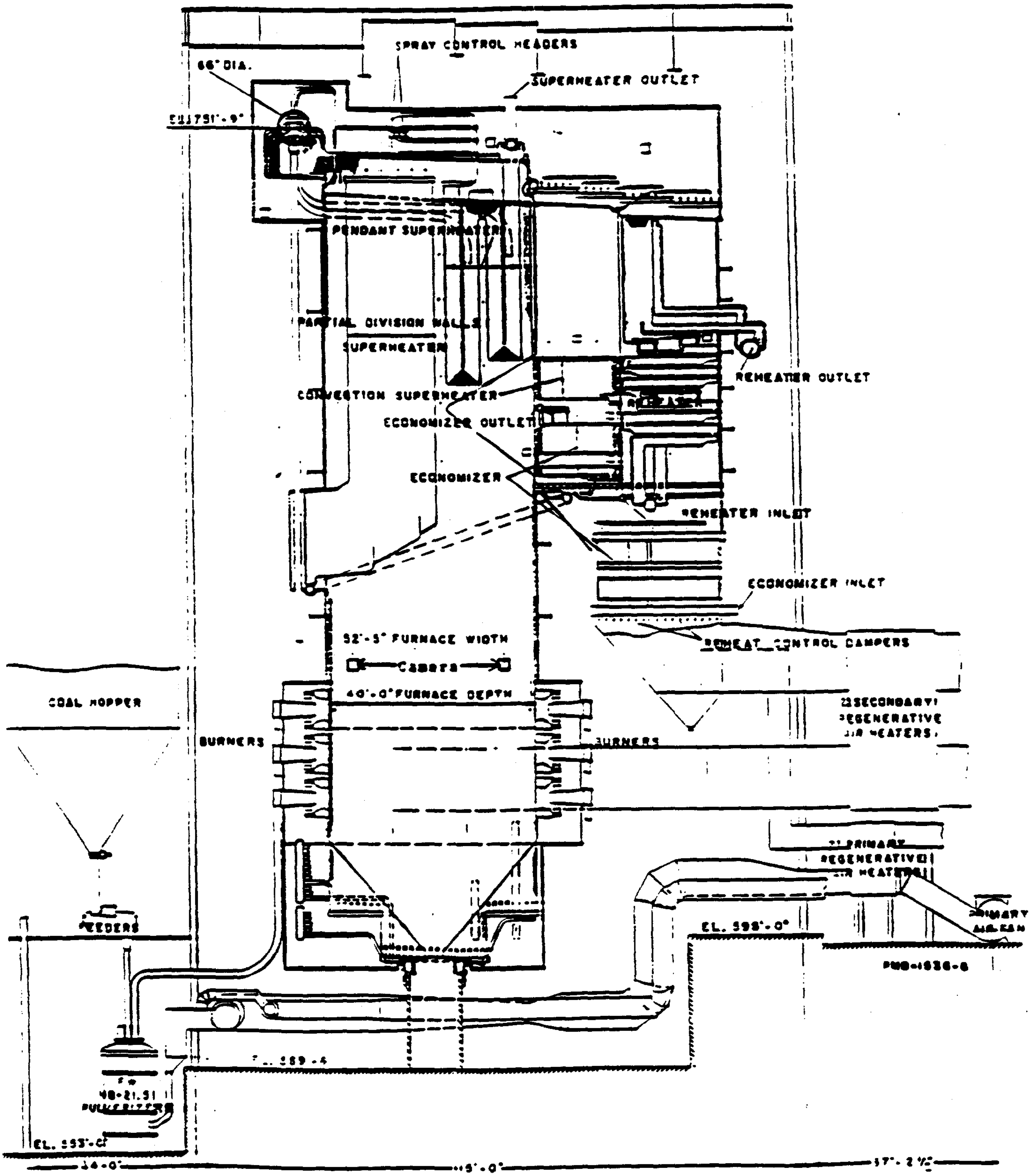


FIGURE 6-1 Burner Observation System Installation Location

7.0 FLAME SCANNER SYSTEM

In order to assure safe, reliable unit operation during the different phases of the Low NOx Demonstration Project, FWEC is offering to upgrade the existing ignitor flame scanner system, add a main flame scanner system, and provide a basic fuel safety system. Following is a brief narrative on each of these systems. A more detailed description of the overall system may be found in Appendix B.

7.1 Main Flame Scanner System

FWEC is proposing to supply a main flame scanner system for each burner (total of 24) so that the burner flame strength under the various Demonstration Project test phases may be monitored. A general listing of the offered equipment is as follows:

- Mounting Tubes with Manual Isolation Valves
- IDD-II Main Coal Flame Detector Heads
- Main Coal Detector Amplifier Systems
- Transfer Cables to Unit Control Room
- All Necessary Junction Boxes, Miscellaneous Wiring, etc.
- All Required Hook-Up to Cooling Air

The design and installation of the above noted equipment will be performed by Forney Engineering Company in conjunction with FWEC so that an integrated, reliable system shall be supplied.

7.2 Ignitor Flame Scanner System

FWEC is proposing to supply replacement IDD-II ignitor flame detector heads to replace the existing ignitor detector heads. The replacement heads will be fully compatible with the existing ignitor scanner system.

7.3 Advanced Overfire Air Control System

An Advanced Overfire Air Control System is being offered so that the various AOFA dampers and flows can be monitored and controlled from the unit control room. This system will supply the necessary AOFA system readouts to allow a accurate demonstration of the AOFA concept. In addition, the system will monitor the Main Coal Flame Scanner signal strengths.

8.0 COLD FLOW MODEL STUDY

FWEC proposes to have performed a comprehensive cold flow model study to define the proposed AOFA System operating parameters and to allow for design modifications to optimize the system prior to field installation. Following is a brief description of the proposed model testing as broken down by system.

8.1 Scope of Study

To construct and test a 3-dimensional 1/10-scale model of the boiler furnace and combustion air system, the system will be tested to demonstrate that the model system produces the same flow patterns that occur in the full-size system. After confirmation, the model will be tested to determine the necessary internal changes to ensure even air distribution to each burner, optimum location and performance of the overfire air system, and minimum draft loss.

8.2 Model Construction

The model, geometrically similar to the full-size system, will be constructed from clear acrylic plastic. It will extend from the outlets of the two secondary air preheaters thru the secondary air ducts, venturis, wrap around windbox and individual burners to the outlet of the furnace section of the boiler. The primary air duct take-offs and the AOFA system will also be included in the model.

All internal expansion joints, dampers, structural members, trusses and gusset plates deemed to have an effect on the gas distribution will be modeled in detail and included in the model.

The 24 existing burners will be fabricated from acrylic plastic in great detail to include air registers, simulated ignitors, flame scanners and observation tubes, where applicable, and included in the model.

The 24 low NOx burners will be scaled for size and resistive devices installed in them to provide the appropriate pressure drop across them.

The velocity distributions through the outlet flanges of the secondary air preheaters will be simulated in the model by representing the combustion air flow paths through the air preheaters with eggcrating of the appropriate shape in fixed locations.

Flow through the model will be provided under positive pressure by two single inlet centrifugal fans to produce full-scale velocities in the model.

8.3 Instrumentation

For validation of full-scale velocity distribution and draft loss tests, the model will be tested at the exact same test locations as used in the field, with data recorded by the exact same type of instrumentation. To calculate volume flows in the model for comparison with field data the same assumptions and calculation methods will be used.

Optimization testing in the model will be conducted using the following equipment:

(a) Velocities in the ductwork and thru the burners

- 2-dimensional, wedge-type pneumatic sensor. This instrument will determine true static pressure, maximum vector of velocity pressure, and the yaw angularity (relative to the duct boundaries) of measured flow streams.

(b) Volume flows through the burners

- Electronic direct reading vane-type anemometer with a tube fitted with anti-spin devices to straighten the flow leaving the burners. The tube will be so designed as to provide no additional pressure loss across the burner it is attached to.

(c) Velocity distributions in the furnace

- Linearized hot-wire anemometer with attached cotton tuft for flow direction.

(d) Flow visualization

- Smoke generator to supply white smoke to individual burners or overfire airports to view circulation patterns and/or jet penetrations in the furnace.
- VHS color video camera for documentation of flow patterns and jet penetrations.

8.4 Similitude

The model will be constructed using a natural linear scale of 1/10.

For complete gas flow modeling it is theoretically necessary to simultaneously maintain geometric, kinematic and dynamic similarity and the combustion process, which is not possible in a cold model.

The most important scaling parameter of accurate geometric similarity ensuring reliability of measurements can be maintained when a sufficiently large scale is used. A 1/10-scale model of the boiler and ductwork is considered sufficient to satisfy this criteria and give representative results, yet be economic to build and test.

8.4.1 Ductwork Windbox and Burner Testing

Kinematic similarity is dependent on the Reynolds Number and has no significant influence if this number is maintained above an approximate value of 20,000, the minimum to ensure that the gas flow is fully turbulent. If velocities equal to those in the prototype are used in the model, the typical Reynolds Numbers for the prototype and model satisfy the above criterion. These velocities allow velocity distributions and pressure losses to be accurately measured in the model and be representative of those in the prototype under the same load conditions.

In this model of uniform air density, the forces of gravity are negligible, compared with the inertia forces. Therefore, it is not necessary to maintain dynamic similarity.

8.4.2 AOFA Penetration and Furnace Circulation Pattern Testing

Furnace volume flow scale factors will be consistent with equal momentum ratios in the model and prototype. These represent the ratio of overfire air momentum to the upward flue gas momentum and thus give a representative simulation of the nozzle flow penetrations into the boiler furnace provided the model Reynolds Number is sufficiently high to ensure fully turbulent flow conditions.

All air entering the model will be at constant temperature (ambient). To simulate the effect of combustion on the gas flow patterns, the momentum of the upward flowing air from the model burners will be increased to simulate the increase in temperature and volume associated with fuel combustion.

8.5 Test Procedures

In the ductwork and windbox, the air velocities will be measured at discrete points located at the centers of equal areas of a duct section. The test locations will be positioned to examine the volume flow balances through the system.

The gas velocities and directions will be measured using the wedge-type pneumatic probe mentioned above.

The velocity distributions at the test locations within the boiler furnace will be measured at discrete points located at the centers of equal areas using the hot-wire anemometer. Flow direction will be determined by a cotton tuft attached to the tip of the velocity probe. The distributions will be presented in normalized format with respect to the mean velocity at each test section.

The gas flow patterns will be recorded on video tape and sketches of the salient features of these patterns will be prepared from the video tapes.

8.6 Test Program

The model testing will be carried out in four (4) phases.

Phase 1 Existing burners - Confirmation of model against field test data.

Phase 2 Existing burners with AOFA ports and supply system.

Phase 3 New low NOx burners - No AOFA ports.

Phase 4 New low NOx burners with AOFA ports and supply system.

The data obtained from the model will be used to evaluate the following:

- o Front-to-rear windbox distribution with and without overfire air.
- o Burner-to-burner secondary air unbalance with and without overfire air.
- o Mixing between overfire air and furnace flow at 20% and 30% of TCA to the AOFA ports.
- o Evaluation of swirl/axial overfire air ratios, at 20% and 30% of TCA to the AOFA ports, to determine most effective mixing pattern.

10.0 SCHEDULE FOR DESIGN, FABRICATION AND DELIVERY

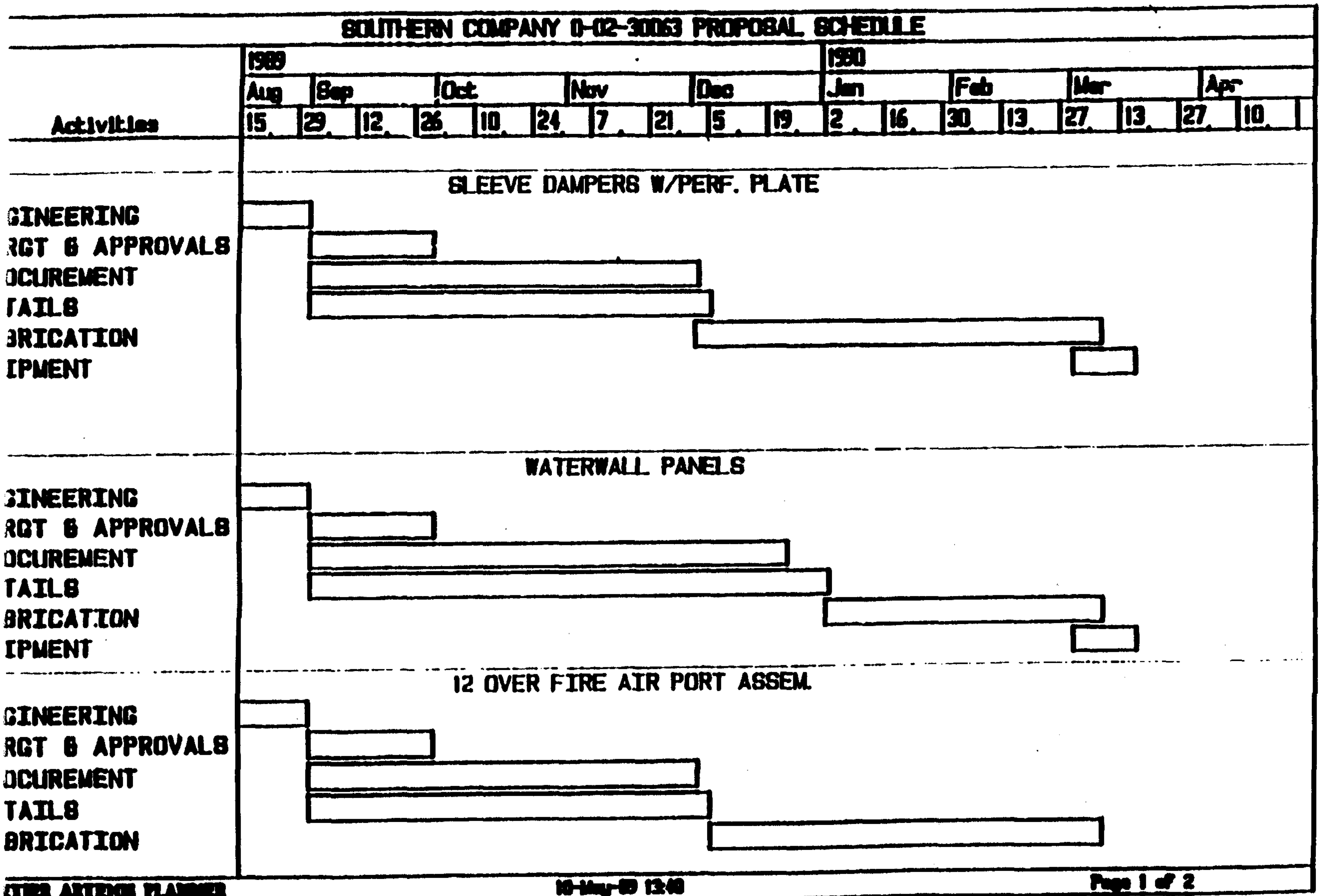
On the following page is a detailed bar chart which identifies the engineering, design (general arrangement drawing development), detailing (detail shop drawing development), procurement of material for fabrication and vendor supplied material, fabrication and shipment (AOFA only).

Also, following this section, is a preliminary listing of the anticipated documentation to be provided in connection with this contract. Please note that the number of drawings and titles may change during the course of the contract, but this list represents our best estimate at this time.

Drawing No.	Title
-5-650	Arrangement of Low NOx Burner
-5-651	Arrangement of Burners with Equipment
-5-652	Assembly of Dual Register Gear Type, Intervane Reversible
-5-658	Assembly of Sleeve Damper w/drive
-4-663	Air Pressure Measuring Device
-5-800	Arrangement of Refractory Setting at Burner Throat
By Vendor	Sleeve Damper Drive Outline Drawing
By Vendor	Sleeve Damper Drive Wiring Diagram
By Vendor	Inner & Outer Register Manual Actuator
By Vendor	Burner Thermocouple with Flexible Leads
By Vendor	Burner Bayonet Spring-Loaded Assembly
By Vendor	Tertiary Air Damper Outline
By Vendor	Tertiary Air Handlever Assembly
Later	Overfire Air Windbox
Later	Overfire Air Ductwork
Later	Overfire Airport Opening (Tubes)
Later	Detail & Assembly OFA Airport Wallbox
Later	Arrangement of Overfire Airports

Drawing No.	Title
Later	Arrangement of Lower Furnace Airports
Later	Arrangement of Underfire and Hopper Slope Air Slots
Later	Detail and Assembly Lower Furnace Airport Wallbox
Later	Lower Furnace Airport Opening (Tubes)
Later	Equipment Parts List
Later	Main Flame Scanner Drawings (Forney)
Later	Ignitor Flame Scanner Drawings (Forney)
Later	Advanced Overfire Air System Controls (Forney)
Later	Overfire Air Control Damper
Later	Overfire Air Shutoff Damper
Later	Pressure/Flow Control Damper
Later	Electric Motor Data Sheet-Sleeve Damper Drive
Later	Electric Motor Data Sheet-Control Damper Drive
Later	Electric Motor Data Sheet-Shutoff Damper Drive
---	Logic Diagram (s) (Forney)
---	Recommended Spare Parts List (including pricing)
---	Instruction Books
---	Construction Schedule

(1480y)


SOUTHERN COMPANY 0-02-30063 PROPOSAL SCHEDULE
Activities
1989
1990
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
Apr
15 29 12 26 10 24 7 21 5 19 2 16 30 13 27 13 27 10
SLEEVE DAMPERS W/PERF. PLATE
GINEERING
RGT & APPROVALS
OCUREMENT
TAILS
BRICATION
IPMENT
WATERWALL PANELS
GINEERING
RGT & APPROVALS
OCUREMENT
TAILS
BRICATION
IPMENT
12 OVER FIRE AIR PORT ASSEM.
GINEERING
RGT & APPROVALS
OCUREMENT
TAILS
BRICATION
Page 1 of 2

SOUTHERN COMPANY 0-02-30063 PROPOSAL SCHEDULE

Activities	1989 Aug 15	Sep 29	12	Oct 26	10	Nov 24	7	Dec 21	5	19	1990 Jan 2	16	Feb 30	13	Mar 27	13	Apr 27	10
SHIPMENT																		
ELCCTRIC DRIVES, DUCTING, ETC.																		
ENGINEERING																		
ARRGT & APPROVALS																		
PROCUREMENT																		
DETAILS																		
FABRICATION																		
SHIPMENT																		
BEGINS 3/30/90 END 4/27/90																		
ERECTION																		

11.0 Predictions & Guarantees

The following are offered under the specified conditions:

11.1 Emissions Predictions

A. Advanced Overfire Air: NOx Boiler performance predictions will apply to overfire air flow up to [redacted] of total combustion air flow only. With the ports located below the [redacted] elevation the prediction will be [redacted] reduction (See Figure 11-1).

B. Low NOx Burners: NOx will be reduced [redacted] from the baseline condition at full load with all burners in service. The NOx emission will not increase above this level within the normal unit control range (See Figure 11-1).

(1480y)

Foster Wheeler Energy Corporation
Proposal No: 0-02-30063
June 6, 1989

100% MCR

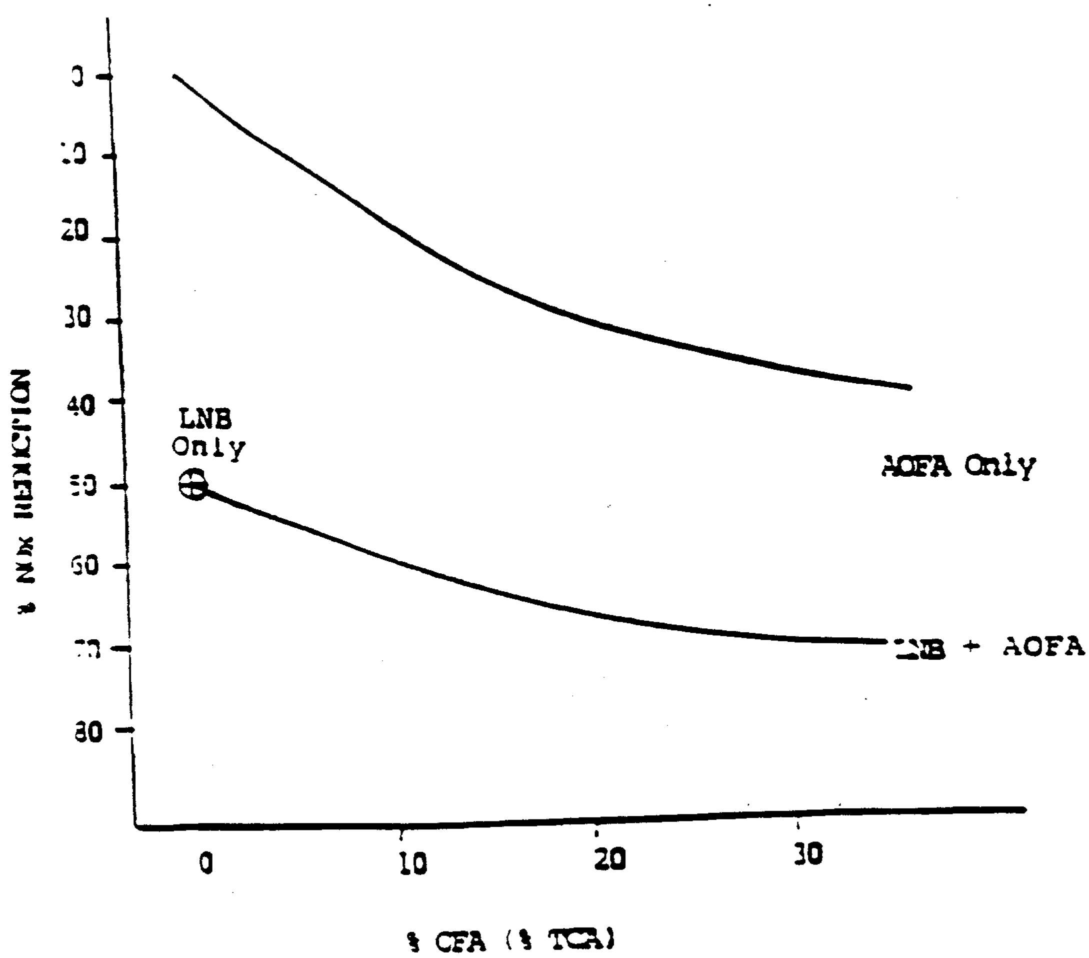


FIGURE 11-1 NOx Reduction with AOFA and Low NOx Burner (Valid for Baseline NOx Level Between 800 and 1200 ppm @ 3.5% O_2) Predicted Reductions Only

Vendor Proprietary Information Contained on This Page in Original Document
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12.0 QA/QC SUMMARY

All materials, workmanship and testing supplied by FWEC will be handled in accordance with the ASME approved Foster Wheeler Energy Corporation Quality Control System. All non-destructive examination procedures will be in accordance with ASME Code Section V and acceptance standards will be in accordance with Section I.

CONFORMED

PROPOSAL

FROM

Foster Wheeler Energy Corporation

PERRYVILLE CORPORATE PARK CLINTON NJ
(Vendor's name and address to be inserted here)

FOR

ADVANCED WALL-FIRED FIRED COMBUSTION MODIFICATIONS

FOR REDUCED NO_x EMISSIONS

PLANT HAMMOND - UNIT NO. 4

OF

GEORGIA POWER COMPANY

Mr. S. M. Wilson
Southern Company Services
P. O. Box 2625
Birmingham, AL 35202

1.0 **SCOPE**

In accordance with your inquiry inviting proposals for combustion modifications for reduced NO_x emissions for Plant Hammond Unit 4 and subject to all conditions and requirements of your Specifications, all related attachments and accompanying documents in connection therewith, we propose to furnish, deliver, and install the subject equipment for the prices quoted herein. "Option" is understood to be Purchaser's option.

Vendor Proprietary Information Contained on These Pages in Original Document
Page(s) 2 through 13 Deleted from Public Design Report

8.13 Shipping weights:

Component	Material
LATER	

9.0 PERFORMANCE DATA

9.1 AOFA Characterization

	6 Mills I/S	5 Mills I/S	4 Mills I/S	2 Mills I/S
A. Boiler load	100%	75%	50%	25%
B. Boiler efficiency	89.01	89.81	90.26	91.17
C. Air flows - lb/hr				
F.D. fan discharge	4,852.500	3,828.400	2,781,000	1,589.000
Tempering and sealing air	266.000	188.400	98.000	14,000
Entering air heater, primary and secondary	4,586.500	3,640,000	2,683,000	1,575,000
Leakage through air heater, primary and secondary	346,500	330,000	293,000	282,000

	Leaving air heater, primary and secondary	4,240,000	3,310,000	2,390,000	1,293,000
	Primary air entering furnace	684,000	540,000	348,000	189,000
	Secondary air entering furnace	2,920,800	2,258,700	1,642,400	856,600
	AOFA system air entering furnace	901,200	699,700	497,600	261,400
D.	Air temperature leaving air heater - °F	575	545	505	410
E.	Air velocity leaving AOFA ports - ft/sec (Inner/Outer)	[redacted]	[redacted]	AOFA May or May not be used at these loads	
F.	Furnace gas velocity at AOFA port level - ft/sec	[redacted]	[redacted]	AOFA May or May not be used at these loads	
G.	Furnace exit gas temperature - °F *	1840	1703	1546	1242
H.	Air pressure drop from steam coil air heater to burners - inches of water				
	Ducts & Dampers & AOFA	7.00	4.80	3.52	1.50
	Dampers	—	—	—	—
	Steam coil	0.80	0.49	0.26	0.07
	Air heater	4.95	3.30	1.80	0.75
	Air meter	1.00	0.61	0.32	0.09
	Required at burners	4.00	3.00	2.60	1.20
	Total pressure drop from steam coil to burners	13.75	9.20	5.90	2.41
I.	Excess air leaving boiler - °F %	18	18	23	40
J.	Fuel burned - lbs/hr	389,000	303,000	210,000	99,600
K.	Heat losses - BTU/lb fuel as fired				

* 1) As defined by specifications

2) Actual values to be developed during baseline testing prior to conversion

3) OFA can either cause an increase or decrease in FEGT depending on quantity

Due to combustible in refuse	45.6	33.6	30.0	23.8
Due to dry gas to stack	492	414	357.6	278.8
Due to water in fuel and water from combustion of hydrogen in fuel	567.6	556.3	547.[illegible]	578.0
Due to moisture in air	12.0	9.6	7.7	6.0
Due to radiation	21.6	29.9	16.3	30.0
Due to unconsumed hydrogen, carbon and hydro-carbons	Negligible	Negligible	Negligible	Negligible
Manufacturer's margin	180.	180	180	180
Total loss	1318.8	1222.9	1168.9	1059.6
L. Heat release in furnace - BTU/hr/cu ft. (Note - Vendor shall include drawing showing volume included)	17,250	13,[illegible]	9,[illegible]	6,410
M. Heat release in furnace - BTU/hr/sq ft. (Note - Vendor shall include drawing showing area included)	2,220,000	1,774,000	1,202,000	570,000
N. Flue gas flow - lb/hr				
Entering air heater	4,595,000	3,585,000	2,599,000	1,380,000
Leaving air heater	4,952,000	3,920,000	2,882,000	1,660,000
O. Flue gas temperature - °F				
Entering air heater	708	636	587	480
Leaving air heater	282	253	244	272
P. Emissions entering air heater				
NO_x - ppm 20/30% TCA	∠600/550	∠450/425	∠450	∠450
CO - ppm	∠200	∠200	∠200	∠200
SO_2 - ppm	1850	1850	1780	1570

O_2 - %	3.3	3.3	4.0	6.1
HC - ppm	< 5	< 5	< 5	< 5

Q. Emissions leaving air heater: Volumetric values to be as in P diluted by air heater leakage

NO_x - ppm	___	___	___	___
CO - ppm	___	___	___	___
SO_2 - ppm	___	___	___	___
Particulates - lb/10^6 BTU	7.46	7.46	7.46	7.46
O_2 - %	___	___	___	___
HC - ppm	___	___	___	___
LOI - %	< 5	< 5	< 5	< 5

9.2 LNB Characterization

	6 Mill I/S	5 Mills I/S	3 Mills I/S	2 Mills I/S
A. Boiler load	100%	75%	50%	25%
B. Boiler efficiency	89.01	89.81	90.26	91.17
C. Air flows - lb/hr				
F.D. fan discharge	4,852,500	3,828,400	2,781,000	1,589,000
Tempering and sealing air	266,000	188,400	98,000	14,000
Entering air heater, primary and secondary	4,586,500	3,640,000	2,683,000	1,575,000
Leakage through air heater, primary and secondary	346,500	330,000	293,000	282,000
Leaving air heater, primary and secondary	4,240,000	3,310,000	2,390,000	1,293,000
Primary air entering furnace	684,000	540,000	348,000	189,000
Secondary air entering furnace	3,822,000	2,958,400	2,140,000	1,118,000
AOFA system air entering furnace	n/a	n/a	n/a	n/a

D.	Air temperature leaving air heater - °F	575	545	505	410
E.	Air velocity leaving AOFA ports - ft/sec	n/a	n/a	n/a	n/a
F.	Furnace gas velocity at AOFA port level - ft/sec	n/a	n/a	n/a	n/a
G.	Furnace exit gas temperature - °F *	1840	1703	1546	1242
H.	Air pressure drop from steam coil air heater to burners - inches of water				
	Ducts & Dampers	1.81	1.12	0.62	0.22
	Dampers	—	—	—	—
	Steam coil	0.8	0.49	0.26	0.07
	Air heater	4.95	3.30	1.80	0.75
	Air meter	1.00	0.61	0.32	0.09
	Required at burners (Max.)	4.00	3.00	2.60	1.20
	Total pressure drop from steam coil to burners	12.56	8.52	5.60	2.33
I.	Excess air leaving boiler - °F %	18	18	23	40
J.	Fuel burned - lbs/hr	389,000	303,000	210,000	99,600
K.	Heat losses - BTU/lb fuel as fired				
	Due to combustible in refuse	45.6	33.6	30.	28.8
	Due to dry gas to stack	492	414	357.6	238.8
	Due to water in fuel and water from combustion of hydrogen in fuel	567.6	556.8	547.2	528.
	Due to moisture in air	12.0	9.6	7.2	6.0

* 1) As defined by specifications

2) Actual values to be developed during baseline testing prior to conversion

	Due to radiation	21.6	28.8	46.8	78.0
	Due to unconsumed hydrogen, carbon and hydro-carbons	Negligible	Negligible	Negligible	Negligible
	Manufacturer's margin	180	180	180	180
	Total loss	1318.8	1222.8	1168.8	1059.6
L.	Heat release in furnace - BTU/hr/cu ft (Note - Vendor shall include drawing showing volume included)	17,250	13,420	9,300	4410
M.	Heat release in furnace - BTU/hr/sq ft (Note - Vendor shall include drawing showing area included)	2,230,000	1,734,000	1,202,000	570,000
N.	Flue gas flow - lb/hr				
	Entering air heater	4,595,700	3,585,000	2,589,000	1,380,000
	Leaving air heater	4,952,200	3,920,000	2,882,000	1,660,000
O.	Flue gas temperature - °F				
	Entering air heater	708	636	587	480
	Leaving air heater	282	263	244	222
P.	Emissions entering air heater				
	NO_x - ppm	< 430	< 325	< 250+	< 250+
	CO - ppm	< 200	< 200	< 200	< 200
	SO_2 - ppm	1850	1850	1780	1570
	O_2 - %	3.3	3.3	4.0	6.1
	HC - ppm	< 5	< 5	< 5	< 5
Q.	Emissions leaving air heater: Volumetric values to be as in P diluted by air heater leakage				
	NO_x - ppm	___	___	___	___
	CO - ppm	___	___	___	___
	SO_2 - ppm	___	___	___	___

+ To be determined by Mills Out of Service and their pattern.

		6 Mills	5 Mills	3 Mills	2 Mills
	Particulates - lb/10^6 BTU	7.46	7.46	7.46	7.46
	O_2 - %				
	HC - ppm				
	LOI - %	< 5	< 5	< 5	< 5

9.3 AOFA and LNB Characterization

		6 Mills I/S	5 Mills I/S	3 Mills I/S	2 Mills I/S
A.	Boiler load	100%	75%	50%	25%
B.	Boiler efficiency	89.01	89.81	90.26	91.17
C.	Air flows - lb/hr				
	F.D. fan discharge	4,852,500	3,828,400	2,781,000	1,589,000
	Tempering and sealing air	266,000	188,400	98,000	14,000
	Entering air heater, primary and secondary	4,586,500	3,640,000	2,683,000	1,575,000
	Leakage through air heater, primary and secondary	346,500	330,000	293,000	282,000
	Leaving air heater, primary and secondary	4,240,000	3,310,000	2,390,000	1,293,000
	Primary air entering furnace	684,000	540,000	348,000	189,000
	Secondary air entering furnace	2,920,800	2,258,700	1,642,000	856,600
	AOFA system air entering furnace	901,200	699,700	497,600	261,400
D.	Air temperature leaving air heater - °F	575	545	505	410
E.	Air velocity leaving AOFA ports - ft/sec (Inner/Outer)	[redacted]	[redacted]	AOFA May or May not be used at these loads	
F.	Furnace gas velocity at AOFA port level - ft/sec	[redacted]	[redacted]	AOFA May or May not be used at these loads	
G.	Furnace exit gas temperature - °F *	1840	1703	1546	1242

* 1) As defined by specifications

2) Actual value to be developed during baseline testing prior to conversion

... depending on

H.	Air pressure drop from steam coil air heater to burners - inches of water				
	Ducts, Dampers & AOFA	7.00	4.80	3.52	1.50
	Dampers	—	—	—	—
	Steam coil	0.80	0.49	0.26	0.07
	Air heater	4.95	3.30	1.80	0.75
	Air meter	1.00	0.61	0.32	0.09
	Required at burners	4.00	3.00	2.60	1.20
	Total pressure drop from steam coil to burners	13.75	9.20	5.90	2.41
I.	Excess air leaving boiler - °F %	18	18	23	40
J.	Fuel burned - lbs/hr	389,000	303,000	210,000	99,600
K.	Heat losses - BTU/lb fuel as fired				
	Due to combustible in refuse	45.6	33.6	30.0	28.8
	Due to dry gas to stack	492.0	414.0	357.6	238.8
	Due to water in fuel and water from combustion of hydrogen in fuel	567.6	556.8	547.2	528.0
	Due to moisture in air	12.0	9.6	7.2	6.0
	Due to radiation	21.6	28.8	46.8	78.0
	Due to unconsumed hydrogen, carbon and hydro-carbons	Negligible	Negligible	Negligible	Negligible
	Manufacturer's margin	180.0	180.0	180.0	180.0
	Total loss	1318.8	1222.8	1168.8	1059.6

L.	Heat release in furnace - BTU/hr/cu ft (Note - Vendor shall include drawing showing volume included)	17,250	13,420	9,300	4,410
M.	Heat release in furnace - BTU/hr/sq ft (Note - Vendor shall include drawing showing area included)	2,230,000	1,734,000	1,202,000	570,000
N.	Flue gas flow - lb/hr				
	Entering air heater	4,595,700	3,585,000	2,589,000	1,380,000
	Leaving air heater	4,952,200	3,920,000	2,882,000	1,660,000
O.	Flue gas temperature - °F				
	Entering air heater	708	636	587	480
	Leaving air heater	282	263	244	222
P.	Emissions entering air heater				
	NO_x - ppm [redacted]	∠300/260	∠300/260	∠300/260+	∠300/260+
	CO - ppm	∠200	∠200	∠200	∠200
	SO_2 - ppm	1850	1850	1780	1570
	O_2 - %	3.3	3.3	4.0	6.1
	HC - ppm	∠ 5	∠ 5	∠ 5	∠ 5
Q.	Emissions leaving air heater: Volumetric values to be as in P diluted by air heat leakage				
	NO_x - ppm	___	___	___	___
	CO - ppm	___	___	___	___
	SO_2 - ppm	___	___	___	___
	Particulates - lb/10^6 BTU	7.46	7.46	7.46	7.46
	O_2 - %	___	___	___	___
	HC - ppm	___	___	___	___
	LOI - %	∠ 5	∠ 5	∠ 5	∠ 5

10.0 ALTERNATES AND PRICING

The Vendor is requested to address alternate proposals by including either of the following statements: "Having complied with the bidding requirements of your specifications and attachments, we request due consideration to the attached alternate proposals, complete with prices and descriptive data for comparison to the base proposal" or "Having complied with the bidding requirements of your specifications and attachments, we do not offer an alternate proposal"

11.0 EXCEPTIONS

Exceptions shall be noted in accordance with Paragraphs 11.1 and 11.2.

11.1 We have reviewed your Specifications and all Related Attachments. Unless specific exceptions are listed below (or attached to our proposals and referenced below), it is understood that all of the provisions contained therein are acceptable to us:

__________ without exception

XXX with exceptions as outlined below:

See Proposal.

11.2 The Vendor Submittal Schedule has been reviewed and the required documentation and submittal dates (time frames) are acceptable to us unless listed below:

If there are no exceptions, state "No Exceptions".

12.0 SIGNATURE Don Kaurech TITLE Sect. Manager, Combust & Environmental Syste

13.0 NAME OF COMPANY Foster Wheeler Energy Corporation

14.0 TELEPHONE NUMBER (201) 730-5466

15.0 DATE June 6, 1989

MON/ab/mns
0546S
1/25/89

Appendix B

Instructions for the Care and Operation of the Controlled Flow Split Flame Low NO_x Burners, Furnace Boundary Air System, and Advanced Overfire Air System Installed for Georgia Power Company, Plant Hammond Unit No. 4 Rome, Georgia

Foster Wheeler Energy Corporation
April, 1992

FOSTER WHEELER

SUPPLEMENTARY

INSTRUCTIONS

for the

Care and Operation

Of

CONTROLLED FLOW SPLIT FLAME LOW NO_x BURNER SYSTEM,

FURNACE BOUNDARY AIR SYSTEM

AND

ADVANCED OVERFIRE AIR SYSTEM

INSTALLED FOR:

GEORGIA POWER COMPANY

PLANT HAMMOND, UNIT NO. 4

ROME, GEORGIA

PURCHASE ORDER NO.: 195-89-042

FOSTER WHEELER CONTRACT NO.: 2-30-5729 (2-79-514)

THIS COPY OF INSTRUCTIONS IS

ISSUED TO: SOUTHERN COMPANY SERVICES INCORPORATED

DATE: JANUARY 1991; REVISED: APRIL 1992

NUMBER: 6

WITH THE UNDERSTANDING THAT IT IS RETURNABLE UPON REQUEST

Form No. 156-31

Form No. 156-31

Form No. 156-31

LIST OF ILLUSTRATIONS

Drawings/Figures are located at the end of their respective parts within this manual. The Drawings and Figures are listed in order of their first appearance within the text of this manual.

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INTRODUCTION

This Operating Instruction Manual addresses the Controlled Flow-Split Flame Low NO_x Burner System (Part I), the Furnace Boundary Air System (Part II) and the Advanced Overfire Air System (Part III) supplied by Foster Wheeler Energy Corporation (FWEC). This manual is to be used in conjunction with the Operating Instruction Manual for the Natural Circulation Reheat Type Steam Generator (Georgia Power Company PO Ham 4-2), FWEC Contract No. 2-79-514 issued in June 1969 and last revised November 1977.

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PART I

CONTROLLED FLOW-SPLIT FLAME LOW NO_x BURNER SYSTEM

SECTION 1
DESCRIPTION

1.1 GENERAL DESCRIPTION

This section is a general description of twenty four (24) coal burners at Georgia Power Company's Plant Hammond, Unit No. 4, retrofitted with Foster Wheeler Energy Corporation's (FWEC) Controlled Flow-Split Flame Low NO_x (CF/SF) burner system.

The general arrangement of the retrofitted burner is shown on Drawing Nos. 30-5729-5-650, 30-5729-5-651 and Figure 1-1. There are twenty four (24) burners in the furnace; these burners are on the front and rear furnace walls. Each firing wall is arranged in three (3) horizontal rows, with four (4) burners per row. Each burner is equipped with a Foster Wheeler controlled flow dual air register, a perforated plate with an adjustable sleeve damper, and a coal injector consisting of an outer barrel with split flame coal nozzle and an inner barrel with a sliding tip. Each burner front plate is equipped with cleanout connections and inspection openings. The burner incorporates ignitor and main flame detectors. Four (4) burner tip thermocouples and one (1) mid-sleeve thermocouple, for monitoring burner temperature, are mounted on the coal burners. The burner also incorporates air pressure measuring instrumentation. See Figure 1-2 and Drawing 30-5729-4-663 for additional information on the foregoing instrumentation. The thermocouple instrumentation is shown in Figure 1-3.

A pulverized coal/primary air mixture, supplied from a coal pulverizer, is introduced tangentially in the annulus between the inner and outer sleeves of the coal injector. As the mixture travels down the annulus, the spiral motion imparted to the stream by the tangential inlet is greatly reduced by the anti-roping bars mounted on the inside of the outer sleeve. The coal/air mixture is then injected axially into the furnace in four concentrated streams formed by the split flame nozzle and through the annulus formed between the split flame tip and the inner barrel sliding tip.

A tertiary air connection introduces hot windbox air into the inner sleeve of the coal injector. The tertiary air pipe from the windbox incorporates a waffer valve. Refer to Olson Technologies drawing in the Appendix for further details on this valve. This tertiary air purges the burner's center section, keeping it free of coal accumulation and providing additional combustion air for the ignitor, while maintaining proper burner tip temperature.

Centered around the discharge end of each burner is the dual air register through which the secondary (windbox) air required for combustion is admitted to the furnace. Each register is equipped with adjustable vanes for use in varying the airflow. The outer and inner registers are positioned by manual operators mounted on the front of the windbox. The register vanes are designed to impart a rotational motion to the air. The flame front and flame shape are adjusted by positioning the two (2) registers. The inner and outer registers are manually set and are not modulated; the optimum settings being determined during initial burner optimization. Additional control is achieved by axially moving the inner sleeve adjustable tip, which positions the flame with respect to the burner throat and aids in controlling the flame shape.

CAUTION

SEE REVISED WORDING ON PAGE 2-4.
MDH
5/11/92

~~WHEN THE INNER SLEEVE SLIDING TIP IS ADJUSTED, ANY IGNITORS WITHIN THE INNER SLEEVE MUST BE MOVED (RE-SET) EQUAL TO SLEEVE MOVEMENT. MAKE SURE THAT FLAME IMPINGEMENT IS NOT ON ANY BURNER COMPONENT.~~

Perforated plates are installed around each dual air register assembly to aid in the equalization of the circumferential air distribution. Surrounding the perforated plates are movable sleeve dampers with electric linear actuators mounted outside the windbox wall. Each damper is operated at the closed, light-off and open positions which are set by limit switches. The "open" (operate) position is found during initial burner optimization and is fixed thereafter.

Figure 1-1 deleted at the request of Foster Wheeler

Figure 1-2 deleted at the request of Foster Wheeler

Figure 1-3 deleted at the request of Foster Wheeler

PART I

SECTION 2

CONTROLLED FLOW/SPLIT FLAME BURNER DESCRIPTION AND INITIAL SETTINGS

2.1 GENERAL

The components of the Controlled Flow/Split Flame burners are described below. In addition, adjustment guidelines for optimizing the air register component operation are also provided.

2.2 INNER AIR REGISTER (FWEC DRAWING NO. 30-5729-5-652)

The inner air register regulates the degree of swirl imparted on the coal/air mixture in the near-throat area and, in conjunction with the primary air flow, controls the point of ignition of the coal/air mixture.

By maintaining the near throat area in a reducing atmosphere, the NOx produced during the fuel devolatilization process can be minimized. In addition, the reduction in flame temperature associated with a near throat area reducing atmosphere will minimize the formation of thermal NOx. Thus, by adjusting the inner air register to control the near throat area stoichiometry, the formation of NOx is minimized.

The inner air register is initially set at a nominal 20% open position. During initial burner optimization the air register position will be fine tuned to locate the coal/air mixture point of ignition at the throat of the burner. By locating the point of ignition at the burner throat, the near throat coal/air mixture stoichiometry will be maintained at the desired level to achieve the NOx reductions indicated above.

It should be noted that the inner air register is used to fine tune the near-throat coal/air mixture conditions. Modifications to the primary air flow, air/coal ratio or inner air register vane position will produce changes in the near-throat coal/air mixture stoichiometry and flame ignition point and can affect NOx and CO production and the economizer outlet flue CO and O_2 distribution. Modifications to the inner air register vane position location should only be performed by qualified personnel under controllea test conditions.

Following the initial optimization of the inner air register, the vane position shall remain fixed unless changes in plant operation dictate that further optimization is required.

2.3 OUTER AIR REGISTER (FWEC DRAWING NO. 30-5729-5-652)

The outer air register arrangement divides the burner's secondary air stream into two concentric streams which independently vary air stream swirl. One air stream is routed through the inner air register assembly for the purpose noted above. The other stream of secondary air is directed by a flow divider to enter the furnace axially. This air stream then combines with the reducing atmosphere flame zone in the furnace to provide the remaining air necessary for combustion. The swirl on the secondary air stream promotes sufficient mixing of the two streams to ensure adequate carbon burnout prior to exiting the flame zone.

The outer register is initially set at a nominal 50% open position. During initial burner optimization, the outer air register position will be fine tuned to produce minimum NOx and a balanced O_2 and CO distribution across the economizer exit flue. Following initial optimization of the outer air register, the vane position shall remain fixed.

In general, as the outer air register is progressively opened, it transforms the coal fire from a bushy, relatively short flame to a longer, narrower flame.

2.4 MOVABLE SLEEVE DAMPER (FWEC DRAWING NO. 30-5729-5-658)

The perforated plate and movable sleeve damper combine to control the burner air flow distribution.

The perforated plate, installed around the circumference of the secondary air inlet area, aids in the burner circumferential air distribution. The result of this air distribution improvement is better air flow control through the air register assembly and into the flame zone. The perforated plate is a nonadjustable item.

The movable sleeve damper is the main air flow control device on the burner assembly. During normal operation, the sleeve damper is set at the open, light off, and closed positions depending upon the state of burner operation. During the initial full load burner optimization, the individual burner air flows shall be optimized by adjusting the movable sleeve dampers. The optimization determines the sleeve damper open positions. The method used to perform this task is noted in Section 10 of this Part.

NOTE

> All burner adjustments are, to varying degrees, dependent upon one another. For example, positioning of the outer air register can effect the CO profile. As a result, burner adjustments should be done slowly and only by personnel aware of the potential results of such manipulation.

2.5 INNER SLEEVE WITH SLIDING TIP (FWEC DRAWING NO. 30-5729-5-650)

The inner sleeve of the Controlled Flow-Split Flame Low NO_x Burner's coal nozzle is equipped with an axially movable tip which provides a means for varying the primary air velocity while maintaining a constant primary air flow. The velocity adjustment is used to optimize the primary air/secondary air velocity ratio to minimize shear induced turbulence.

The optimum position of the sliding tip is determined during burner optimization testing by monitoring flue gas NOx and CO emissions and the coal flame conditions. The movable tip is adjusted manually and can be readjusted to account for different operating conditions on the unit. Therefore, if a major change in fuel characteristics occurs, tip adjustment can reoptimize NOx and CO. Note that this adjustment repositions the flame with respect to the burner throat. This adjustment is used in conjunction with the inner and outer register optimization described in Section 10 of this Manual to optimize the unit performance with respect to O_2 distribution, CO emissions, and NOx emissions. Note that once the optimum tip position is established it remains fixed.

CAUTION

WHEN THE INNER SLEEVE SLIDING TIP IS ADJUSTED, ENSURE THAT THE IGNITOR IS ADJUSTED TO BE 2" BACK FROM THE NEW INNER SLEEVE POSITION. MAKE SURE THAT THERE IS NO FLAME IMPINGEMENT ON ANY BURNER COMPONENT.

2.6 OUTER SLEEVE WITH SPLIT FLAME NOZZLE (FWEC DRAWING NO. 30-5729-5-650)

The outer sleeve of the burner's coal nozzle, in conjunction with the inner sleeve described above, forms the opening through which the coal/primary air mixture flows. Attached to the discharge section of the outer sleeve is a split flame nozzle which channels a portion of the coal/air mixture into four concentrated streams, each of which forms an individual flame.

The chief design feature of the split flame nozzle is to control the mixing between the coal/air mixture and the secondary air stream. The combination of the concentrated coal streams and the staged secondary air produces near throat flame stoichiometries in the [redacted] range up to about two throat diameters into the furnace (the total burner, however, is operating at normal boiler excess air). At that point, the swirling secondary stream from the outer portion of the throat annulus, containing the remaining combustion air, combines the four flames and provides sufficient mixing to ensure adequate carbon-burnout.

Uniform distribution of coal about the periphery of the coal nozzle's annular passageway is attained by use of the tangential coal inlet and the anti-roping bars mounted on the inside of the outer sleeve.

The result of the splitting up of the coal steam is that the volatiles in the coal are driven out and burned under a more reducing atmosphere than would occur without the split flame coal nozzle. The coal volatiles contain a high percentage of the fuel bound nitrogen that, wnen burned in an oxidizing atmosphere, would be converted to NOx. The split flame coal nozzle, by virtue of its operating in a reducing atmosphere, converts the bound nitrogen in the coal volatiles into N_2 thus substantially reducing NOx formation and emissions.

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SECTION 3
OPERATION

3.1 GENERAL

The following burner operating procedures should be used in conjunction with the boiler and auxiliary equipment operating procedures.

3.2 START-UP

a. After preparing the boiler for burner light-off (that is, fans, and all other auxiliary equipment in start-up condition), place the sleeve damper in the light-off position.

NOTE

The sleeve damper light-off, open and closed positions are set during initial start-up and optimization of the burners, and the sleeve damper drive limit switches are set accordingly. Also, the inner and outer register positions are set during initial start-up and optimization, and remain fixed thereafter. No further adjustments are required after optimization.

b. If the burner had been operating prior to this light-off, a fifteen minute burner tip cool down period shall be completed prior to establishing coal flow to the burner. This shall be accomplished by establishing purging air flow (cold air flow) through the pulverizer/conduit system with the coal feeder out of service. During this period, the burner thermocouples should be monitored to ensure that the burner nozzle tip temperatures have dropped to below 850°F or that the rate of temperature drop, due to the effects of the cooling air, has slowed significantly. Following the burner cool down period, coal flow may be established following normal coal pulverizer start-up guidelines.

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c. The secondary air flow should be set at not less than 25% of full load air flow.

d. Confirm that ignitors are operable and ready for operation. If an ignitor or coal burner is inoperable, it is recommended that the entire pulverizer not be started.

e. Select the burners to be initially placed into service.

(1) Light the ignitors for the selected burners and confirm ignition. Refer to the ignitor manufacturer's instructions.

(2) Refer to pulverizer start-up procedures.

(3) Light the burners with in-service ignitors, while following the pulverizer instructions.

CAUTION

DO NOT LIGHT ANY BURNER FROM AN ADJOINING BURNER AT ANY TIME OR UNDER ANY CIRCUMSTANCES. THE IGNITOR SHOULD ALWAYS BE USED FOR LIGHTING ITS CORRESPONDING BURNER.

(4) Remove the ignitors from those burners initially placed into service when flame and furnace conditions at those burners are stable and the unit is above the minimum unsupported coal firing rate.

(5) Raise firing rate and air flow as required by load or start-up conditions. The sleeve damper should be moved from the light-off to the open (operating) position.

f. Repeat the above procedures for placing additional burners into service.

3.3 NORMAL OPERATION

3.3.1 Precautions

During the normal operation procedures, paragraph 3.3.2, the operator must inspect for hazardous conditions such as burner overheating and burner coking. This can be done by periodically viewing through the inspection ports. If left unchecked, severe damage to equipment and possible injury to personnel could result. If such a condition occurs during these procedures, refer to paragraph 3.3.3, Hazardous Conditions.

3.3.2 Procedures

a. Observe the fires periodically to be certain that there is no heavy flame impingement on any of the furnace heating surfaces. This may occur due to improper burner adjustments or pulverizer operation.

b. The fuel-air mixture temperature leaving the pulverizer should be maintained at the temperature required for stable burner operation. This exit temperature is determined by observing flame stability characteristics during actual operation. Initially set the exit temperature at 150F. Depending on the fuel being burned, pulverizer exit temperature may vary between 125F and 150F with resulting acceptable stable flame conditions at the burners.

c. It is desirable to keep as many burners in service as the boiler load will permit. However, when the load is to be decreased below the stable minimum output for burners, burners should be taken out of service. At low capacity operation, it is important that burner operation be watched closely to insure stable combustion conditions during this period.

NOTE

If operation is to be at less than 30% of boiler load, ignitors should be placed in service for flame stabilization.

Place ignitors into service for those burners which are to be taken out of service. If there is evidence of instability due to some abnormal condition of operation or fuel quality, it may be desirable to use ignitors for all burners.

All burners from the same pulverizer should be taken out of service before taking burners out of service from another pulverizer. With this approach, pulverizers can be shut down when not required to maintain boiler load.

CAUTION

AFTER A PULVERIZER IS SHUT DOWN, THE PULVERIZER, COAL CONDUITS AND BURNERS MUST BE PURGED OF ALL COMBUSTIBLES.

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3.3.3 Hazardous Conditions

a. During operation, if any burner becomes overheated, it is recommended that the burner be shut down and the cause determined immediately and corrected. The overheated area should be cooled, using procedures recommended below, before the burner is placed back in service.

b. During operation, it will be necessary to shut off the temperature detecting system for the idle burners because the temperatures will probably rise above the value established as the safe limit of operation.

c. Before placing a burner in service, determine if any part of the burner has become overheated by radiation from adjacent operating burners or any other cause. Observe burners periodically through the inspection ports for evidence of coking. If coking occurs, the condition should be corrected immediately, otherwise severe burner and/or windbox damage could result. A burner that has become overheated by radiation only can be cooled by passing cold primary air not containing any coal, through it. However, if the overheating is caused by a smoldering fire, the burner must be cleaned out by air lancing or mechanical lancing before any primary air can be permitted to pass through the burner.

CAUTION

USE FIRE RESISTANT CLOTHING, INCLUDING COVERING FOR HEAD, HANDS AND FEET DURING LANCING TO PROTECT AGAINST FLARE-BACK FROM THE BURNERS.

CAUTION

THE USE OF WATER FOR BURNER LANCING CAN BE CONSIDERED, BUT IT MAY CAUSE QUENCHING DAMAGE TO BURNER BARRELS AND THROAT REFRACTORY. THE POSSIBILITY OF STEAM FLARE-BACK REQUIRES THAT EXTREME CARE BE TAKEN TO ENSURE PERSONNEL SAFETY.

CAUTION

DO NOT ATTEMPT TO RETURN A COKED BURNER TO SERVICE UNTIL THE FOLLOWING PROCEDURES HAVE BEEN COMPLETED.

To handle a coking burner, proceed as follows:

(1) Ascertain that there is a coking burner. The thermocouple will indicate a sharp increase in burner

temperature. With a coal burner in operation, normal burner temperature may vary from 300F to 800F depending on thermocouple location. When temperatures increase steadily over 850F, the burner should be removed from service.

(2) Remove the affected burner from service making sure that the burner shut-off damper closes. Also, make sure the pulverizer cold tempering air regulating damper opens.

(3) If coking has progressed to the coal inlet scroll and coal conduits, try to cool the conduit and scroll with a fire hose until they have stopped glowing.

(4) Check the burner thermocouples and make sure that the temperature has come down before attempting to inspect the burner. It may take at least two hours for the burner to cool.

(5) After the burner has cooled, the burner should be cleaned with an air lance to remove any unburned coal. Access is through a clean-out plug on the burner and coal is blown into the furnace. A heat resistant suit or other suitable protection should be worn when this is done.

(6) If there is doubt about the cleanliness of a conduit before returning it to service, a quick check can be made by taking all coal off the pulverizer and, with only air passing through the conduits, perform an air flow distribution check by inserting a pitot tube in the coal sampling connection.

(7) If there is an indication of a conduit being plugged that will require an outage, then the burner should remain out of service.

d. Prior to shutting down a pulverizer, cold tempering air flow should be increased to the maximum amount possible while maintaining stable pulverizer conditions. This may be started a half-hour before shutting down a pulverizer.

e. Continue pulverizer grind-out until it is proven empty by observing that no coal fires exist for the related burners.

3.4 SHUT-DOWN

a. Reduce the firing rate to the minimum for stable operation.

b. As each burner is about to be shut down, place ignitors into service for the burner to be shut down.

c. Remove burners from service in the reverse order of the start-up procedures specified in Paragraph 3.2 and using the pulverizer shut-down procedures specified in the pulverizer operating instructions.

CAUTION

AFTER A PULVERIZER IS SHUT DOWN, THE PULVERIZER, COAL CONDUITS AND BURNERS MUST BE PURGED OF ALL COMBUSTIBLES.

d. Adjust air flow as necessary to maintain minimum air requirements.

e. Repeat steps a through d for remaining burners.

SECTION 4
MAINTENANCE AND LUBRICATION REQUIREMENTS

4.1 GENERAL

This section contains all the maintenance and lubrication requirements for controlled flow split flame burner components. The requirements are defined under each component's title below.

4.2 LIMITORQUE ELECTRIC DRIVE FOR MOVABLE SLEEVE DAMPER

Refer to Limitorque L-120 Instruction and Maintenance Manual for lubrication requirements including frequency of lubrication applications, lubricant type and quantity of lubricant. This Limitorque Maintenance Manual is located in the Appendix (Auxiliary Equipment) section of this Manual.

4.3 BURNER INNER AND OUTER REGISTER MANUAL DRIVES

"Never-Seez" lubrication compound (Never-Seez Compound Corp., Broadview, ILL. 60155) or equivalent, should be applied periodically to the manual drive shaft grease fitting to insure ease of operation. The lubrication interval is to be determined based on periodic inspections and lubricant is to be applied as required.

4.4 BURNER SLEEVE DAMPER

a. Any moving parts for the sleeve damper assembly should be lubricated during each maintenance outage with Molykote 321-R (Dow Corning Corp., Midland, Mich. 48640) or equivalent.

b. Each sleeve damper is equipped with a pair of trap doors, located in the perforated plate at the 6 o'clock position inside the damper sleeve travel area. These trap doors have been installed to allow for periodic dumping of any accumulated ash. During each maintenance outage, starting at the top row of burners and proceeding down to the bottom row, the trap doors should be opened to discharge any buildup of ash. After trap doors are closed, a trial run of the damper sleeves should be made to ensure unobstructed movement.

4.5 BURNER INNER AND OUTER REGISTERS

During maintenance outages, each control ring should be checked to ensure that it does not hang-up or skid on the roller assembly. By stroking each manual inner and outer register and observing the operation of the control ring, check to see if the rollers are running free and not skidding. If any binding or skidding is observed, the eccentric cam should be adjusted to reset the gap for the tolerances shown on FWEC Drawing 30-5729-5-652. This adjustment is made on each of twelve (12) cams by breaking the tack welds. Once the adjustments are made, the nuts should be tack welded.

4.6 IGNITOR

The CF/SF burner utilizes a customer supplied ignitor. The customer has ignitor instructions supplied directly from the manufacturer.

4.7 FORNEY MAIN FLAME AND IGNITOR FLAME DETECTORS

Forney Contract No. H-2036, entitled Flame Detector System is included in the Appendix (Auxiliary Equipment) of this manual. This pulication contains specific maintenance information applicable to the main flame and ignitor flame detectors furnished under this contract. Refer to this document prior to performing any maintenance on the equipment.

In general, a maintenance and repair log should be kept for all maintenance and repair operations performed. Close review of this log will help isolate problem areas and reduce trouble-shooting time.

SECTION 5

LIST OF PARTS AND PART NUMBERS

5.1 GENERAL

The following Bills of Material contain the part numbers, quantities and names of all parts used to assemble the burner. The drawing on which the specific part is shown has also been included in the listing; these drawings follow Section 11 of this part.

The contents of this section have been removed from the Public Design Report.

SECTION 6

RECOMMENDED SPARE PARTS

6.1 GENERAL

The following list contains the recommended spare parts for the burner. As indicated at the end of the list, all of these spare parts can be identified on Foster Wheeler Drawings 30-5729-5-650, and 30-5729-5-652. These drawings follow Section 11 of this part.

The contents of this section have been removed from the Public Design Report.

SECTION 7
COMPONENT WEIGHTS AND CLEARANCES

7.1 GENERAL

The weights and component-to-component clearances are as indicated on the drawings following Section 11 of this part.

SECTION 8
SPECIAL TOOLS

8.1 GENERAL

There is a special tool used to adjust the inner moveable burner tip. See the -650 drawing.

There are no other special tools required to assemble, disassemble, or maintain the Controlled Flow/Split Flame burners; a set of common mechanic's tools will suffice.

SECTION 9
ASSEMBLY AND DISASSEMBLY

9.1 GENERAL

Assembly and disassembly of the Controlled Flow-Split Flame Low NO_x Burner shall be accomplished in accordance with the drawings following Section 11 of this part. Erection and general notes on the drawings, as well as the dimensional layout, define the method of assembly (and therefore disassembly).

9.2 SLEEVE DAMPER ELECTRIC DRIVES

Refer to the Limitorque Instruction and Maintenance Manual in the Appendix of this manual for the "Installation Tips" applicable to these drives.

SECTION 10

BURNER OPTIMIZATION PROCEDURE

10.1 GENERAL

Following the initial Controlled Flow-Split Flame Low NO_x Burner startup, a burner optimization procedure, as outlined below, is required. The purpose of this procedure is to optimize the unit performance with respect to minimizing NOx and producing a balanced O_2 and CO distribution across the economizer exit flue. The actual procedure to perform this task is included in paragraph 10.3. It is important to note that this procedure should only be performed by qualified Foster Wheeler personnel under controlled test conditions.

10.2 INSTRUMENTATION

In order to perform Controlled Flow-Split Flame Low NO_x Burner optimization, the following instrumentation is required:

- o Sleeve damper position indicator
- o Individual air register pressure drop measuring devices
- o An economizer outlet flue gas sample grid, which measures exit gas O_2, CO and NO_x on a per point basis.

10.3 PROCEDURE

The burner optimization procedure consists of two parts: 1) Flame Optimization and 2) System Balancing. The first step in optimization is to obtain the air register settings that produce the best flame shape and the proper flame ignition point. This is generally accomplished by a series of tests that utilize visual observation of the flames and economizer exit flue gas O_2, CO and NO_x readings to determine the flame shape that best fits the furnace.

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Once the best flame shape has been determined, the overall system is then balanced. Balancing is accomplished by adjusting the burner sleeve dampers, while monitoring the sleeve damper perforated plate differential pressures and the economizer outlet flue gas O_2 and CO levels. The purpose of the system balancing phase of the burner optimization program is to balance the O_2 and CO levels across the economizer exit flue gas probes. In conjunction, the inner sleeve sliding tip should be adjusted to position the flame to achieve minimum NOx.

The burner sleeve damper positions that produce balanced flue gas O_2 and CO levels are considered the preliminary "open" positions. It is important to note this position on each burner as the initial reference point. Upon completion of this preliminary balancing phase, the flames shall be observed and air register position modifications* shall be performed to return the flame shape to the optimum conditions. Once again, these final air register and sleeve damper positions shall be noted for future reference.

The final part of the system optimization is to check the flame shape and flue gas O_2 and CO, while firing the unit in a pulverizer-out firing configuration. Should this part of the test produce an unacceptable flame shape or flue gas O_2 and CO side-to-side distribution, some of the initial "optimum" burner system settings should be fine-tuned to return the system to its optimum condition.

Following completion of the pulverizer-out test series, the unit shall be returned to full load, all-pulverizer operation for a final check and fine-tuning. The burner air register, sleeve damper and sliding tip positions found following the fine tuning are the final optimum positions for the burner system. At this time, the sleeve damper drive limit switches shall be set and all the positions noted for future reference. Also, the inner sleeve sliding tip positions should be noted and fixed.

* A typical air register test matrix is presented in Figure 1-4. Start testing in matrix at A-25 and then progress to testing at e.g. A-24 or A-26 while checking for minimum NO_x, balanced O_2 and CO across the economizer exit flue (and proper flame shape) is the process by which optimization is attained. Continued testing in the "direction" of the optimized register setting will yeild the actual optimum position.

10.4 Purpose/Intent

It is very important to note that the purpose of the burner optimization procedure is to obtain the best overall furnace fires to balance or normalize the economizer exit flue gas O_2 and CO distributions, and to minimize the NOx levels leaving the economizer. It is not the intent or the purpose of this optimization program to equalize the air flows through each burner. Due to differences in conduit-to-conduit coal distribution and the nature of air flow in the furnace, an equalizing of the burner-air flows may not produce optimum flame shape and balanced flue gas constituent distribution. For this reason the above testing should only be performed by qualified Foster Wheeler personnel who are fully conversant with the CF/SF Low NO_x Burner system components and their affect on furnace fires and flue gas constituents.

It is intended that station personnel will work closely with the Foster Wheeler Service Engineers during the start-up and burner optimization process. In this way they will become fully acquainted with the equipment and the procedures used to adjust and modify the combustion process.

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SECTION 11

RECEIVING, INSPECTION, STORAGE AND HANDLING

11.1 GENERAL

Material and equipment provided under this contract is being furnished to support an erection schedule which is due to begin within approximately one month of material/equipment receipt at the job site. As a result, short term storage, as opposed to long term storage, is applicable. Specific receiving, inspection, storage and handling procedures are listed below for each of the auxiliary equipment items furnished by Foster Wheeler's subcontractors.

11.2 SLEEVE DAMPER ELECTRIC DRIVES

Upon receipt at the job site, the Limitorque electric sleeve damper drives should be removed from the packing cases, counted and checked for breakage and/or shortages. The drives should then be stored safely in a clean, dry, protected warehouse free from excessive vibration and rapid temperature changes. If actuators must be stored outdoors, the drives should remain in the packing cases. Further, the cases must be stored off the ground, high enough to prevent their being immersed in water or buried by snow.

Connect internal heaters (when supplied) or place desiccant in the limit switch compartment. Replace all plastic caps or plugs with pipe plugs. Ensure all covers are tight.

Unit should be stored with motor and limit switch compartment horizontal or vertical above unit centerline. Failure to comply with Limitorque Corporation's recommended storage procedure will void their warranty.

FIGURE 1-4

TESTS TO DEFINE OPTIMUM NOx WITH THE CF/SF BURNER*

Outer Register**	Inner Register** 0	5	10	15	20	25	30
15	A-8	A-9	A-10	A-11	A-12	A-13	A-14
30	A-15	A-16	A-17	A-18	A-19	A-20	A-21
45	A-22	A-23	A-24	A-25	A-26	A-27	A-28
60	A-29	A-30	A-31	A-32	A-33	A-34	A-35
75	A-36	A-37	A-38	A-39	A-40	A-41	A-42

* Note: For a particular coal only 10 - 12 tests from this matrix are typically performed. In addition, at the optimum register settings 3 - 4 positions of the coal nozzle's adjustable inner tip are tested.

** Degrees open from closed position.

PART II

FURNACE BOUNDARY AIR SYSTEM

SECTION 1
DESCRIPTION

1.1 GENERAL

The Boundary Air System consists of special lower furnace airports and hopper slope/hopper throat sidewall slots (see FWEC Drawings 30-5729-5-370, 30-5729-5-371, 30-5729-5-375 and Figure 2-1) designed to shift a small amount of air from the burner combustion zone to the lower furnace walls. Ducts to shift windbox air to the hopper and sidewall slots are shown on Drawings 30-5729-5-371 and 30-5729-5-375. This system does not provide additional air to the furnace and as such does not increase the excess air requirement of the boiler; the system provides redistribution of air.

Boundary air is an adjunct to the low NOx burner system. It does not directly lower NOx, but allows lower NOx levels to be achieved by permitting lower excess air to be used prior to the onset of sidewall slagging or excessive CO formation. The system consists of four (4) special lower furnace air ports, two (2) on the front wall and two (2) on the rear wall, and the hopper slope/hopper throat sidewall slots. (See Figure 3-2 at the end of Part III for typical lower furnace airport damper configuration). The secondary air flow through the lower furnace air ports can be adjusted for optimization. Once the system is optimized, the manual operators on the four lower furnace air port dampers remain in place and need not be changed.

Combustion air from the windbox is directed along the hopper slope via the boundary air hopper throat slots, along the two sidewalls via the boundary air hopper slope slots and through the lower furnace air ports thereby increasing the local excess oxygen level adjacent to all of the walls and hopper slope. See Figure 2-1.

SECTION 2

OPERATION

2.1 GENERAL

Under normal conditions, there are no special techniques required to operate the boundary air system. Following the initial optimization, the boundary air system operates "automatically" because the four lower furnace airport dampers remain in place and the hopper and sidewall slots are "set" due to their design configuration.

SECTION 3
MAINTENANCE AND LUBRICATION REQUIREMENTS

3.1 GENERAL

The only maintenance requirement is general boiler cleanliness to ensure that the slots and ports remain free of ash and other contaminants. Sufficient "Never-Seez" lubricant (Never-Seez Compound Corp., Broadview, ILL. 60155) or equivalent, should be applied to the four lower furnace airport damper grease fittings to ensure freedom of damper sleeve movement, should readjustment ever be required. Apply Never-Seez to grease fitting until clean lubricant is expelled from the packing gland. The lower furnace airport dampers should be stroked once a month to prevent flyash buildup. In that ash and corrosive environments vary from boiler to boiler, it is necessary that an inspection schedule be established to see how often lubrication is required. If this lubrication is not applied, the lower furnace airport dampers could freeze in their set position, virtually eliminating any future adjustment capability.

PART II

SECTION 4
LIST OF PARTS AND PART NUMBERS

4.1 GENERAL

The following Bill of Material pages contain the quantities and part numbers of the lower furnace airport components (as well as for the windbox access doors supplied on this contract). The component parts for the lower furnace airports are shown on FWEC Drawing 30-5729-5-370.

The contents of this section have been removed from the Public Design Report.

SECTION 6
ASSEMBLY AND DISASSEMBLY

6.1 GENERAL

Assembly and disassembly of the lower furnace airport dampers shall be accomplished in accordance with FWEC Drawing 30-5792-5-370. The dimensional layout and notes on this drawing delineate assembly of this component.

The contents of this section have been removed from the Public Design Report.

PART III
ADVANCED OVERFIRE AIR SYSTEM

SECTION 1

DESCRIPTION

1.1 GENERAL SYSTEM DESCRIPTION

1.1.1 System Overview

The Foster Wheeler Advanced Overfire Air System (AOFA) installed at Plant Hammond, Unit No. 4 reflects state-of-the-art AOFA design. See Figure 3-1. Foster Wheeler has determined that significant reduction in oxides of nitrogen (NO_x) formations can be achieved by proper design and location of an overfire air system without increasing the detrimental side effects associated with conventional overfire air systems.

NOTE

The Advanced Overfire Air System will be optimized during the initial start-up following system installation as indicated in Section 3.

1.1.2 Design Philosophy

By diverting a large amount of the total combustion air (TCA) to the overfire air system, a fuel-rich region is created in the burner zone of the furnace. The substoichiometric burner zone (oxygen starved) causes fuel nitrogen to bond with itself to form N_2 instead of NO_x. The overfire air is introduced to the furnace at an elevation well above the upper burner level, thus allowing the combustion reaction to progress and the combustion reactants to cool prior to the introduction of overfire air. When introduced, the overfire air completes the combustion process; however, the combustion reactants are now at a lower temperature than when in the burner zone, thereby reducing the formation of thermal NO_x.

The overfire air system installed at Plant Hammond incorporates four (4) rotating sleeve style damper assemblies per wall at the overfire airports on the front and rear walls. The rotating sleeve dampers are designed to inject air axially into the furnace to penetrate the flue gas for optimum mixing. The rotating sleeve dampers are normally fully open or closed; however, in extreme cases these dampers can be modulated to aid in balancing the overfire airflow across the furnace.

1.2 SYSTEM FEATURES

The following is a brief description of the major components of the overfire air system.

1.2.1 Secondary Air Duct Pressure Control Dampers

In order to obtain the required static head for overfire air injection velocities and to aid burner windbox front-to-rear distribution, pressure control dampers have been installed in the horizontal ductwork at each entrance in the crossover ducts between the front and rear wall windboxes. A vertical partition plate has been incorporated just downstream of each pressure control damper to segregate secondary air flow to the front and rearwall windboxes. Refer to FWEC Drawing 30-5729-5-301. As shown on the drawing, each partition plate forms a vertical partition from the center of the damper running inboard to each sidewall.

The design purposes for each pressure control damper are 1) to create the required back pressure in the secondary air duct (upstream of the damper) to ensure that desired overfire air system flows can be achieved and 2) to function as secondary air turning vanes (on each side of the partition plate) directing flow to either the front or rearwall windbox. Damper design permits the separate alignment of the front and rear half parallel louvers to accomplish the aforementioned directional capability. The locations of this damper within the AOFA system are shown on drawings 30-5729-5-300 and 30-5729-301.

1.2.2 Overfire Air System Ducting/Dampers

The general arrangement of the AOFA system ducting is shown on the following drawings: 30-5729-5-300, 301. As shown, the overfire ducts take air from the secondary air duct just downstream of the venturi. A guillotine type damper is provided just above the take-off point (both sides) to allow complete isolation of the AOFA system in an emergency. The guillotine dampers are located in the vertical duct section that feeds the AOFA plenum. A flow control damper is located in the plenum just downstream of the vertical feed duct (see drawing 30-5729-5-300). A combination of two pressure control dampers per side allows the overfire air to be biased between the front and rear overfire air windboxes.

NOTE

The guillotine dampers must never be closed except in case of emergency. The guillotine dampers should remain open no less than 6 inches so that the overfire airport dampers do not experience an overheat condition.

1.2.3 Rotating Sleeve Dampers (See Figures 3-2 and 3-3)

The AOFA system installed at Plant Hammond is comprised of eight (8) individual ports. Airflow through each port is controlled by the rotating sleeve damper assembly (drawing 30-5729-5-373, at the end of this section). The rotating sleeve damper assemblies are actuated by a remotely operated electric drive and require only ¼ turn from closed to full open. The rotating sleeve dampers are designed to be set in either the fully opened or fully closed position. In the event of an exceptionally poor O_2 distribution across the furnace, the rotating sleeve dampers can be modulated to bias individual airports flows to compensate for an inherent O_2 distribution problem.

1.2.4 Measurement Of Overfire Airflow

Four (4) duct airflow measuring devices are installed upstream of the AOFA plenums to provide remote indications of overfire airflow. The flow measuring devices consist of a honeycomb panel upstream of a multi-point pitot tube traverse station. A calibrated temperature compensated transducer measures the differential between the total and static pressures. The transducer converts the measured differential pressure to a 4-20 MADC electronic signal which is linear and proportional to velocity pressure. A digital readout of overfire airflow (lbs/hr) is provided in the control room.

1.3 MAINTENANCE

1.3.1 Overfire Air Port (OFAP) Dampers and Overfire Air Isolation Dampers

Sufficient "Never-Seez" lubricant (Never-Seez Compound Corp., Broadview, IL, 60155) or equivalent, should be applied to all OFAP shafts to ensure freedom of movement. In that ash and corrosive environments vary from boiler to boiler, it is necessary that an inspection schedule be established to see how frequent lubrication is required. If this lubrication is not applied, the damper shafts could freeze in their set positions.

The overfire air isolation (guillotine) dampers and overfire air port dampers should be stroked monthly so as to prevent flyash build-up.

SECTION 2

OPERATION

2.1 PROCEDURE PRIOR TO STARTING FD, PA AND ID FANS

2.1.1 Checks to be Performed

a. Check that all overfire air pressure control dampers CD-F1, CD-F2, CD-R1 and CD-R2 are in the 0% open position. ~~If these dampers are not open, open them to the 0% open position.~~

b. Open the overfire isolation (guillotine) dampers and confirm that the open-lights are illuminated.

2.2 START-UP (AFTER REACHING STABLE OPERATION AT 300 MEGAWATTS OR ABOVE)

2.2.2 Overfire Air Pressure Control Damper Initial Settings

a. Slowly open air pressure control dampers CD-F1, CD-F2, CD-R1 and CD-R2 as indicated below:

(1) Open all four dampers, one at a time, an additional 15%.

(2) Wait five minutes. Open all four dampers, one at a time another 15%.

(3) Repeat again until all four dampers are at the 50% open position.

2.3 NORMAL LOAD CONTROL OPERATION

2.3.1 Damper and Excess Oxygen Settings

a. The following procedure is conservative in that NO_x emission levels will be reduced with relatively little or no CO levels being experienced.

Page 2-2 and 2-3 deleted at the request of Foster Wheeler

opening. This is partially explained by system resistance pressure changes. It is therefore imperative, that changes be made in a timed/balanced manner in an effort to minimize operational upsets.

b. OFA dampers are to be opened to recommended settings following completion of an upramp.

c. OFA dampers are to be preset to projected load settings prior to a downramp.

d. These dampers are to be brought into position systematically while watching O_2 and CO levels.

2.4 SHUTDOWN

2.4.1 Closing Overfire Air Pressure Control Dampers

a. Slowly close the overfire air flow control dampers CD-F1, CD-F2, CD-R1 and CD-R2 as indicated below:

(1) Close all four dampers, one at a time, down to 50% open.

(2) Wait five minutes and close all dampers, one at a time, an additional 15%.

(3) Continue to reduce damper opening as in step (2) above, until the 10% open position is reached. Then close an additional 10% after waiting five minutes to obtain a 0% open position.

CAUTION

THE CLOSED POSITION OF THE OVERFIRE AIR (GUILLOTINE) DAMPERS IS CONSIDERED TO BE AT THE SIX INCH OPEN POSITION. THESE DAMPERS MUST NEVER BE CLOSED WITH THE UNIT RUNNING.

SECTION 3
ADVANCED OVERFIRE AIR SYSTEM OPTIMIZATION PROCEDURE

3.1 GENERAL

Following the initial Advanced Overfire Air System (AOFA) System start-up, as noted in Section 2.0, Part III, a AOFA System Optimization procedure, as outlined below, is required. The purpose of this procedure is to assure that the overfire air system is optimized to reduce unit NO_x emissions, while maintaining acceptable unit O_2, CO, and performance levels and safe unit operation. When optimization is completed, the secondary air duct pressure control dampers and the rotating sleeve overfire airport dampers are in their set positions and need not be moved unless circumstances require reoptimization. The actual optimization procedure is delineated in paragraph 3.3. It is important to note this procedure should only be performed by qualified Foster Wheeler personnel under controlled test conditions.

3.2 INSTRUMENTATION

In order to perform the AOFA System Optimization Procedure, the following instrumentation should be installed and must be in proper working order.

- Secondary Air Duct Pressure Control Damper Position Indicators.
- AOFA Flow Control Damper Position Indicator.
- AOFA Flow Measurement Indicator.
- AOFA Rotating Sleeve Damper Position Indicators.
- Economizer Outlet Flue Gas Sample Grid, which measures flue gas O_2, CO and NO_x emissions on a per point basis at the economizer outlet.
- Indicator for Total Combustion Air Flow to the Unit.

3.3 PROCEDURE (See Figure 3-4)

AOFA System Optimization consists of the following procedural steps.

- Flow Biasing

- Flow Balancing
- OFAP Optimization (if required)

3.3.1 Flow Biasing

The first step in optimizing the AOFA System is to obtain the required airflow to the AOFA ports by adjusting the secondary air duct pressure control dampers. Closing down these dampers will increase the secondary air duct pressure at the AOFA system takeoffs, thereby increasing the AOFA flow as shown below:

a. Prior to adjusting the secondary air duct pressure control damper, the remaining AOFA system dampers should be in the following positions:

  - Secondary Air Duct Pressure Control Dampers - 100% Open
  - Guillotine Shut-off Damper - 100% Open
  - AOFA Flow Control Dampers (CD-F1, CD-F2, CD-R1 and CD-R2) - 50% Open
  - AOFA Rotating Sleeve Dampers - 100% Open
  - AOFA Flow Measurement Devices - In Service

b. With the AOFA system dampers positioned as indicated above, determine the total combustion air flow (TCAF) to the unit (by monitoring control room indications), the AOFA system total flow (by totaling readings taken from the four flow measurement devices) and the economizer exit flue gas O_2, CO and NO_x emissions profile. Ensure that O_2 is at design level and continue to monitor NO_x.

c. If the measured AOFA flow is equal to [redacted] of the unit's total combustion air flow (TCAF) and if CO emissions are acceptable, proceed to paragraph 3.3.2 Flow Balancing.

d. If the AOFA is less than [redacted] attempt to obtain [redacted] TCAF before exceeding acceptable CO. This may be accomplished by beginning to close down the secondary air duct pressure control dampers in 10% increments (followed by step e, if necessary) to obtain step c. values. Start with the 90% open position. Wait for 15 minutes for the system to settle out after each 10% damper shutdown, and take measurements in step b. again. Prior to the next 10% damper closing, perform step e.

e. If after reducing the secondary air duct pressure control dampers 10%, the AOFA flow is still less than [redacted] of the unit's TCAF, readjust the AOFA flow control dampers (CD-F1, CD-F2, CD-R1 and CD-R2). Adjustment should be made to obtain approximately equal air flows through the four measuring devices. Wait for a 15-minute settling out period. Begin again to take the readings in step b. above; if these readings result in values in step c., proceed to paragraph 3.3.2, Flow Balancing. If the values are still unacceptable, repeat steps d. and e. again with the secondary air duct pressure control damper set at the next lower 10% opening. Continue to adjust the secondary air duct pressure control dampers and the AOFA flow control dampers, in the above sequence, until the AOFA flow and CO levels in step c. are attained. However, if acceptable CO values are exceeded while in the process of trying to obtain [redacted] TCAF with acceptable CO, proceed to step f.

f. In the event that acceptable CO values are exceeded (at a particular reduced damper setting), increase the secondary air duct pressure control damper opening (one 10% increment, or until CO is just within acceptable values). At this point, even though [redacted] TCAF has not been attained, proceed to paragraph 3.3.2 Flow Balancing.

3.3.2 Flow Balancing

Once the AOFA system air flow corresponds to [redacted] of the TCAF, or the unit CO emissions have limited the AOFA system flow to a maximum allowable level (based on the above noted criteria), the AOFA system shall be balanced by adjustment of the AOFA system flow control dampers. The first step in the AOFA system flow balancing is to move all four flow control dampers to the 50% open position. Following a 5 minute settling out period, the four AOFA flow indicators should be read. If the four flows are within plus/minus 5% of each other and the total AOFA system air flow is still [redacted] of the unit's TCAF, proceed to paragraph 3.3.3. If the four individual AOFA flow measurements are not within plus/minus 5%, adjust by opening the flow control dampers with the lowest indicated flows until the four flows are balanced to plus/minus 5%. Following a successful balanced plus/minus 5% distribution, compare the total AOFA system air flow to the unit's TCAF. If the AOFA system air flow is [redacted] of the unit TCAF and the unit's CO emissions are at an acceptable level, note the AOFA flow control damper positions for use as the full open damper position and then optimize the overfire airports as indicated in paragraph 3.3.3. If the AOFA system airflow is less than [redacted] of unit TCAF, refer to paragraph 3.3.1 to obtain correct flow.

3.3.3 AOFA Port Optimization

If required, the AOFA ports may be biased to optimize the economizer exit O_2, CO and NO_x distribution to eliminate any localized reducing atmospheres or localized areas of high CO levels. This biasing should only be performed by FWEC personnel under controlled test conditions.

* Or at the value limited by acceptable CO.

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SECTION 4
MAINTENANCE AND LUBRICATION REQUIREMENTS

4.1 GENERAL

This section contains all the maintenance and lubrication requirements for the advanced overfire air system components. The requirements are defined under each component's title below.

4.2 LIMITORQUE ELECTRIC DRIVE FOR AOFA FLOW CONTROL AND ROTATING SLEEVE DAMPERS

Refer to Limitorque LY series Instruction and Maintenance Manual for lubrication requirements including frequency of lubrication applications, lubricant type and quantity of lubricant. This Limitorque Maintenance Manual is located in the Appendix (Auxiliary Equipment) section of this Manual.

4.3 SHUTOFF (GUILLOTINE) DAMPER

Refer to the ACDC Service Manual in the Appendix for all phases of maintenance for the shutoff (guillotine) damper. Lubrication of the shutoff damper is also depicted in the aforementioned Service Manual.

4.4 FABRIC EXPANSION JOINTS

Refer to the Dynex installation instruction in the Appendix for alignment, installation and operating techniques for the expansion joints.

4.5 OVERFIRE AIRPORT (ROTATING SLEEVE) DAMPER

Where the driveshaft penetrates the plenum outboard casing, a grease fitting is provided to lubricate the packing gland. Never-Seez (Never-Seez Compound Corp., Broadview, Illinois 60155) is to be used for lubricant at this location. Apply Never-Seez until clean lubricant is expelled from the packing. The overfire airport dampers should be stroked once a month to prevent flyash buildup. In that ash and corrosive environements vary from boler to boiler, it is necessary that an inspection schedule be established to see how often lubrication is required. If this lubrication is not applied, the overfire airport dampers could freeze in their set position, virtually eliminating any future adjustment capability.

SECTION 5
LIST OF PARTS AND PART NUMBERS

5.1 GENERAL

The following Bills of Material contain the part numbers, quantities and names of all parts used to assemble the overfire air system. The drawing on which the specific part is shown has also been included in the listing; these drawings follow at the end of Part III.

The contents of this section have been removed from the Public Design Report.

Figure 3-1, Figure 3-2, Figure 3-3, and Figure 3-4

deleted at the request of Foster Wheeler

Appendix C

List of Major Drawings Associated with LNB and AOFA Retrofit

DRAWINGS

TITLE	DIMENSIONS AND DESCRIPTIONS	DRAWING NUMBER	DATE REVISED
	FOSTER WHEELER		
AIR PORT OPENINGS	3" O.D. TUBE BENDS 37" D THROAT	30-5729-4-191	03-01-90
AIR PORT OPENINGS	3" O.D. TUBE BENDS 29" D THROAT	30-5720-4-192	03-01-90
WALL OPENING FOR TV CAMERA	3"O.D. TTUBES ON 3 3/4" CTRS	30-5729-4-193	12-18-89
DETAIL/ASSEMBLY AIR PORT WALLBOX	37" D THROAT OPENING	30-5729-4-268	03-01-90
DETAIL/ASSEMBLY AIR PORT WALLBOX	29" D THROAT OPENING	30-5729-4-269	03-01-90
ARRANGEMENT OF OVERFIRE AIR DUCT	R.S. ELAV, 1/2 FRONT & REAR VIEWS	30-5729-5-300	04-18-90
ARRANGEMENT OF OVERFIRE AIR DUCT	PLAN VIEW	30-5729-5-301	01-17-90
ARRANGEMENT OF SECONDARY AIR DUCT	AND PARTITION PLATE	30-5729-5-330	12-22-89
ARRANGEMENT OF OVERFIRE AIR DUCT		30-5729-5-360	01-02-90
ARRANGEMENT OF OVERFIRE AIR DUCT		30-5729-5-361	01-02-90
ARRANGEMENT OF OVERFIRE AIR DUCT		30-5729-5-362	01-02-90
WINDBOX MODIFICATIONS		30-5729-5-363	05-02-90
ARR OF LOWER FURNACE AIR PORTS		30-5729-5-370	12-26-89
ARR OF UNDERFIRE AIR DUCTS		30-5729-5-371	02-23-90
ARR OF AIR PORT DAMPER		30-5729-5-373	01-08-90
ARR OF HOPPER SLOPE AIR DUCTS		30-5729-5-375	02-23-90
DETAIL CONTROL DAMPER OFA DUCTS		30-5729-5-500	01-16-90
DETAIL CONTR DAMPER LR FURN AIR PORTS		30-5729-5-501	01-16-90
ARR OF LOW NOx BURNER	45" D THROAT COAL FIRED	30-5729-5-650	04-26-90
ARR OF BURNERS WITH EQUIPMENT		30-5729-5-651	04-09-90
ASSEMBLY OF GEAR TYPE, INTERVANE REV	5'-9 3/4/3'-11 PITCH D DUAL REG	30-5729-5-652	04-29-90
ASSEMBLY OF SLEEVE DAMPER	W/DRIVE PITCH D OUTER REG HOUSING	30-5729-5-658	04-24-90
AIR PRESSURE MEASURING DEVICE		30-5729-4-663	03-26-90
ARR OF OFA DUCT PLAN VIEW	LOADS TO CUSTOMER STEEL	30-5729-5-1002	10-10-89
ARR OF OFA DUCT	R.S. ELEV, 1/2 FRONT & REAR VIEWS	30-5729-5-1001	10-10-89
PROPOSED INNER SLEEVE ARRANGEMENT		LSK-904-11	04-06-90
BURNER COAL INLET FLANGESEALS		L-862-23	09-16-86
Arrg't of Low NOx Burner	45" Dia throat coal fired	30-5729-5-650	10-19-90
Assembly of 5'-93/4/3'-11 pitch	Dual regist Gear Type Intervane Rev	30-5729-5-652	10-19-90
Ass of sleeve damper w/drive	Pitch dia outer regis housing	30-5729-5-658	5-25-90
Air Pressure Measuring Device		30-5729-4-663	6-29-90
	LIMITORQUE		
ENCLOSURE NEMA4X OR NEMA 4		02-484-0081-2	01-00-89

LY-101 ASSEMBLY	W/14x12x6 CNTRL CABNT & SPEC BORE	03-459-0059-3	03-26-90
	GEORGIA POWER CO.		
HAMMOND #4-GEN ARRG'T	CROSS SECTIONAL ELEV LOOKING NORTH	10-201-H-4101	05-03-68
HAMMOND #4-GEN ARRG'T	BURNER PLATFORM ELEV. 619'0"	10-201-H-4106	01-24-68
HAMMOND #4-GEN ARRG'T	BURNER PLATFORM ELEV. 627'-3"	10-201-H-4107	01-30-68
HAMMOND #4-PIPING DIAGRAM	LIGHTER OIL AND AIR TO BURNERS	10-201-H-4126	09-30-69
HAMMOND #4-PIPING	LIGHTER OIL AND AIR TO BURNERS	10-201-H-4185	06-16-70
HAMMOND #4-ELEC EQUIP AT BOILER	BURNERS-SH. 1	10-201-H-4618	08-04-70
HAMMOND #4-ELEC EQUIP AT BOILER	BURNERS-SH. 2	10-201-H-4619	08-04-70
HAMMOND #4-COMMUNICATIONS BURNER	PLATFORMS EL-619'0" & 610'-0"	10-201-H-4963	12-08-69
HAMMOND #4-COMMUNICATIONS BURNER	PLATFORMS EL-627'3" - 635'-9"	10-201-H-4964	12-08-69
HAMMOND #1,2,3,4-GEN PLT ARRG'T		E-PS-3061-14	07-02-74
	FORNEY INTERNATIONAL INC.		
HAMMOND #4-COAL FLAME AMPLIFIER		C-358270-01	02-21-90
EXT. WIRING DIA. COAL FLAME DETECTORS		D-358272-01	02-21-90
CONTROL PANEL		D-358512-01	02-26-90
COAL FLAME DETECTOR AMPLIFIER CAB	NEMA 4	C-358513-00	02-26-90
JUNCTION CABINET NEMA 4		C-358514-01	02-26-90
CABLE ASS-IDDII	FOR 1/2" FLEXIBLE SEALTITE PVC	D-358676-00	2-27-90
	LENOX INSTRUMENT		
INST/OUTLINE MOTOR IRIS FURN LENS SYS		100D800	02-13-90
	AIR MONITOR CORP		
VELTRON 7000AZ			
MF-2 STATION W/THERMOCOUPLE MANIFOLD		03171000	12-19-89
THERMOCOUPLE MANIFOLD		03171001	12-19-89
	DYNA-TORQUE INC.		
MANUAL ACTUATOR WA 80-30		FW0204	
	DYNEX		
ICCT W/F LOW NOX COMBUS DEMON-RING		1659-00	12-27-89

SAME AS ABOVE-GEN ARANG'T OF FABRIC	EXPANSION JOINT-TAG EJ-1	1659-01	12-27-89
SAME AS ABOVE- TAG EJ-2		1659-02	12-27-89
SAME AS ABOVE- TAG EJ-3		1659-03	12-27-89
	EFFOX INC.		
PARALLEL LOUVER DAMPER	171X142-1/2H	124200-1	01-31-90
	ACDC INC		
OVERFIRE AIR ISOLATION DAMPER		AC-3381-1	01-26-90
	CANNON		
	CCTV SYS INSTALLATION INSTRUCTIONS		
CCD COLOR VIDEO CAMERA MODULE			
COLOR VIDEO MONITOR CT-1331Y			
VORTEC HOOK-UP FIGURE 2		SK-A-828	03-08-83
AIR FILTER ASSEMBLY		100-B-361	12-10-89
THERMAL SWITCH HOOK-UP		SK-A-829	03-08-89

Appendix D

Digital Control System Scope

PLANT HAMMOND UNIT 4
PLANT DIGITAL CONTROL SYSTEM
SCOPE 12/8/93

SYSTEMS

I. UNIT MASTER

II. FUEL CONTROL
- A. Feeder Speed
- B. Primary Air Flow Control
- C. Primary Air Temperature Control
- D. Mill Outlet Temperature Control

III. AIR FLOW CONTROL
- A. Air/Fuel Ratio Control
- B. Secondary Air Control
- C. Burner Sleeve Damper Control
- D. Overfire Air Damper Control
- E. Overfire Air Flow Control
- F. Forced Draft Fan Inlet Vanes
- G. Forced Draft Fan Outlet Dampers
- H. Forced Draft Fan Logic

IV. FURNACE PRESSURE CONTROL
- A. Induced Draft Fan Inlet Vanes
- B. Induced Draft Fan Outlet Dampers
- C. Induced Draft Fan Logic

V. FEEDWATER CONTROL
- A. Drum Level Control
- B. Boiler Feedpump Minimum Flow Control

VI. STEAM TEMPERATURE CONTROL
- A. Superheat Steam Temperature Control
- B. Reheat Steam Temperature Control

VII. CONDENSATE CONTROL

A. Hotwell Level Control

B. Deaerator Level Control

VIII. AUXILIARY CONTROL

IX. DCA HEATER LEVEL CONTROL

X. ASH HANDLING SYSTEM

XI. PRECIPITATOR ENERGY MANAGEMENT SYSTEM

XII. PRECIPITATOR FIRE PROTECTION

XIII. MOTOR BREAKER/START-STOP LOGIC

XIV. BURNER MANAGEMENT SYSTEM

A. Furnace Purge Logic

B. Master Fuel Trip Logic

C. Ignitor Trip Logic

D. Pilot Oil Torch Trip Valve Control

E. Coal Ignitor Control Interface

F. Pulverizer Control

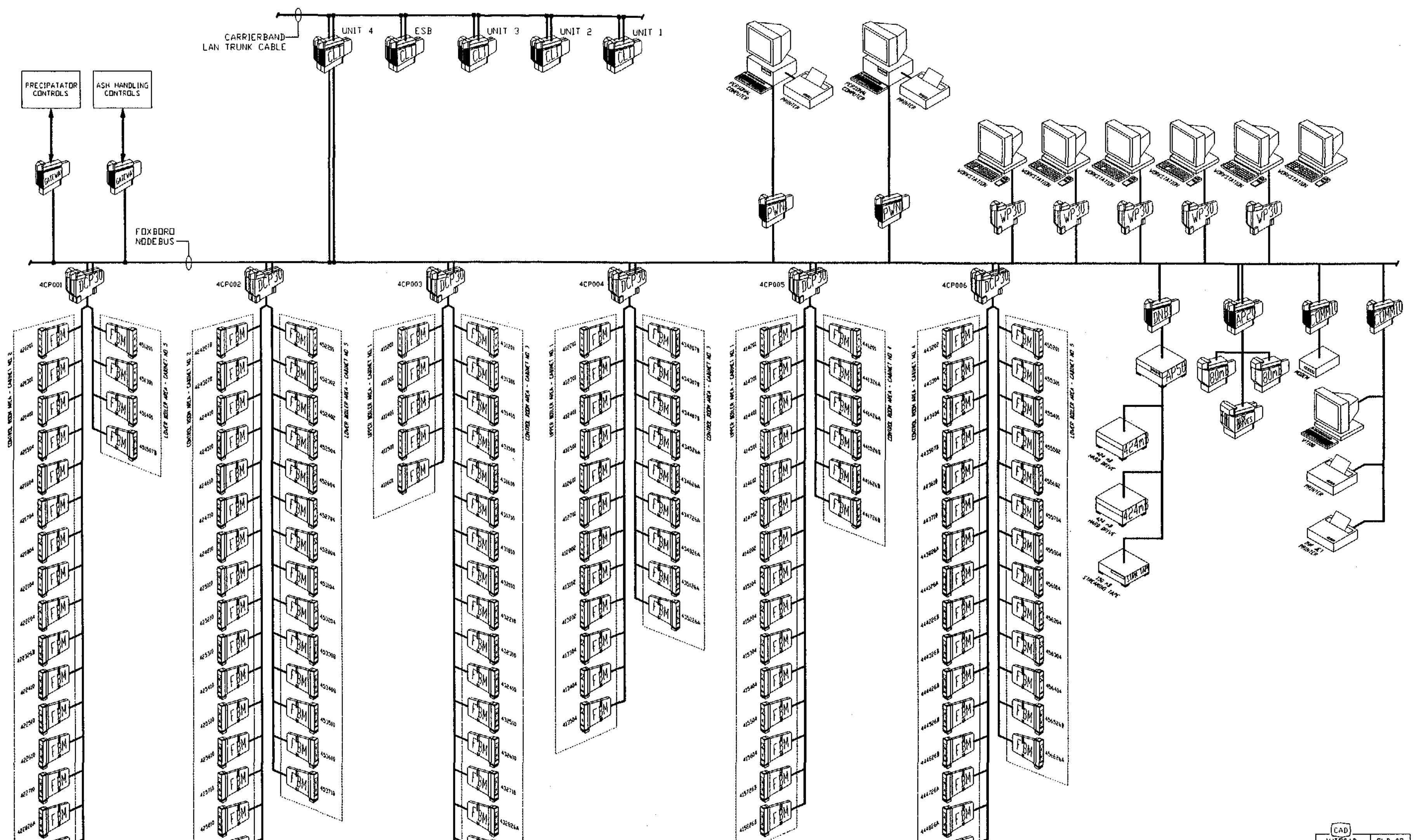
I/O

1. Spares - 605
2. AI's - 572
3. AO's - 116
4. DI's - 1032
5. DO's - 632

TOTAL - 2352

Appendix E

Digital Control System Interconnect Diagram



(CAD) AUTOCAD | FLB-02

Southern Company Services, Inc.
FOR
Georgia Power Company

PLANT HAMMOND - UNIT NO. 4
INSTR & CONT - CONTROL SYSTEM REPLACEMENT
ARRGT OF FOXBORO LAN/ NODEBUS WITH FBM'S

H4NTWPX2.DWG

Appendix F

Control Processor Functional Arrangement

Hammond Unit No. 4
Control System Replacement
Control Processor Functional Arrangement

Control Processor 1

Unit Master Analog Control
Unit Master Digital Control
AGC Analog/Digital
Fuel Control Analog/Digital
Feeder Control Analog/Digital
Air Cross Limiting Analog/Digital
Rundown logic
Runback logic
Throttle Pressure median select
First stage pressure median select
Mill amps (possible feeder rundown)
Megawatt input
Turbine vibration inputs
Turning gear motor start/stop
Turning gear oil pump start/stop
Turning gear engage/disengage
Feeder start/stop logic
Turbine trip logic
Lighter oil pump start/stop
Main turbine EHC oil pump start/stop
Air side seal oil pump start/stop
Hydrogen side seal oil pump start/stop
Emergency bearing oil pump start/stop
Emergency seal oil pump start/stop
HP seal oil pump back-up start/stop
Governor valve status inputs
Turbine drain valve cutout
Miscellaneous turbine analog inputs
Precipitator alarms - digital inputs
Feeder auxiliary relay

Hammond Unit No. 4
Control System Replacement
Control Processor Functional Arrangement

Control Processor 2

Mill differential pressure analog inputs
Mill primary air differential inputs
Mill coal/air temperature inputs
Mill air flow control analog/digital
Mill temperature control analog/digital
Mill start/stop logic
Mill lube oil pump 1 start/stop
Mill lube oil pump 2 start/stop
Mill seal air fan start/stop logic
Mill burner gate open/close logic
Mill primary air gate open/close logic
Mill shut off gate open close logic
Mill coal flame scanner inputs/alarm/trips
Mill lube oil temperature alarms
Mill lube oil pressure alarms
Mill seal air dampers open/close
Lighter oil tank indication
Loss of fuel logic
Master fuel tripping logic
Flame scanner cooling air fan start/stop

Hammond Unit No. 4
Control System Replacement
Control Processor Functional Arrangement

Control Processor 3

Digital logic for total control of 24 ignitors
Low NOx burner sleeve damper control
Sulfur injector start/stop
Ignitor oil flame inputs/logic
OFA damper controls
OFA isolation damper control
OFA air flow inputs
Pilot oil valve open/close logic
CEMs inputs
Opacity input

Hammond Unit No. 4
Control System Replacement
Control Processor Functional Arrangement

Control Processor 4

Temperature compensated total air flow measurement
Air flow control analog/digital
Fuel cross limiting analog/digital
FD inlet vane control analog/digital
FD outlet damper control analog/digital
FD fans start/stop
FD fan damper/vane limit switch status
Fan brakes control
FDFX auxiliary relay logic
O_2 measurements
O_2 control signal selection logic
O_2 control analog/digital
Furnace pressure median select inputs
Furnace pressure control analog/digital
ID fan inlet damper control analog/digital
ID fan outlet damper control analog/digital
ID fan directional blocking logic
ID fan MFT logic
ID fan tripping logic
ID fan MFT kicker analog control
ID fan start/stop
ID fan speed changer logic
IDFX relay logic
Primary/secondary air heater temperatures
Primary/secondary air heater differentials
Primary/secondary air heater start/stops
ID/FD damper logic (mft, fan trip, fan isolation)

Hammond Unit No. 4
Control System Replacement
Control Processor Functional Arrangement

Control Processor 5

LH superheat/reheat pass damper control analog/digital
RH superheat/reheat pass damper control analog/digital
LH lower superheat spray valve control analog/digital
RH lower superheat spray valve control analog/digital
LH upper superheat spray valve control analog/digital
RH upper superheat spray valve control analog/digital
RH economizer bypass control analog/digital
LH economizer bypass control analog/digital
Reheat spray valve control analog/digital
Reheat spray block valve control
BFPT vibration analog inputs
Primary air inlet vane control analog/digital
Primary air fan outlet damper control logic
Primary air fans start/stop logic
PAFx relay
Primary air heaters inlet damper control analog/digital
Economizer feed stop valve open/close
Cond. vacuum breaker open/close
Gland steam exhauster open/close
Vapor ext loop seal start/stop
Furnace probes control
Superheat power relief safety valve control
Steam seal valves control
Mass blowdown valve control
Feedwater flow temperature compensation
Drum level pressure compensation
Feedwater valve control

Hammond Unit No. 4
Control System Replacement
Control Processor Functional Arrangement

Control Processor 6

Boiler fill start/stop
Boiler fill valve control
Single element drum level control analog/digital
Three element drum level control analog/digital
BFPTs feedwater control analog/digital
BFPs minimum -low control
BFPTs turbine controls interface
BFPTs turning gear control
BFPT drains indication
BFPTs turbine gear oil pump start/stop
BFPTs EH fluid oil pump start/stop
BFPTs MBOP start/stop
BFPTs EBOP start/stop
BFPTs ABOP start/stop
BFPTs lube oil temperature control
Feedwater heater DCA/Level control analog/digital
Feedwater heater extraction check valve solenoids
Heater drain pumps start/stop
Deaerator level control analog/digital
Hotwell level control analog/digital
Condensate pumps start/stop
Condenser quick fill valve control
Main turbine oil temperature control
Misc. BFP analog input signals
Generator hydrogen temperature control

Hammond Unit No. 4
Control System Replacement
Control Processor Functional Arrangement

Control Processor 7

Boiler Annunciator Points
Turbine Annunciator Points
Hydrogen Annunciator Points
BFPT Annunciator Points
Event Recorder Points