A DB RILEY TECHNICAL PUBLICATION

CONVERSION OF CHALK POINT UNIT 2 TO DB RILEY LOW NO_x BURNERS

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Presented at the
EDISON ELECTRIC INSTITUTE
PRIME MOVERS COMMITTEE
WASHINGTON, D.C.
October 24-26, 1994

RST-139

with modern, DB Riley low NO_x design burners with an overfire air system. As a part of the conversions, PEPCO elected to comply with National Fire Protection Association (NFPA) requirements. Therefore, the flame safeguards and boiler control systems were upgraded, due to age and obsolescence of parts, to a modern distributed controls system (DCS).

Boiler modifications were completed about ten days early. The plant was then required to be brought to full load and operated at that load for several weeks because of an East Coast power grid weather-related power emergency. Once the emergency was over, the boiler was released for burner system adjustments and testing.

The first tests were conducted before the burners were balanced or adjusted. These tests showed that the NO_x levels were unchanged from the preconversion emissions. After adjustments and balancing (as described herein), plant performance and emissions essentially matched those predicted. NO_x emissions had been reduced approximately 60 percent from a baseline of 1.35 lbs/mmBtu. Loss on ignition (LOI), however, increased from a baseline of 1 to 2 percent to 10 to 13 percent. Further burner adjustments and air and fuel flow balancing work is continuing to bring this unit in compliance with Title IV NO_x limits with acceptable LOI.

This paper describes the basic design criteria and approach, the rationale for adjustments to achieve the lowest practical NO_x, and the approaches of the participants to achieve this successful conclusion.

INTRODUCTION

Initially, the work had to be defined and some understanding of the requirements, methods, and costs established. The regulatory bodies (the state of Maryland and the U.S. Environmental Protection Agency) definitions of and the requirements for compliance to the CAAA were unclear, and the state-of-the-art of the available technologies was evolving.

Potomac Electric Power Company (PEPCO) and Stone and Webster Engineering Corporation developed a program to investigate available NO_x reduction alternatives. They also provided costs and development of economic parameters for what was perceived to be the Reasonably Available Control Technology (RACT) for this station. These results were discussed with the regulatory bodies, and the project scope was defined.

The project scope included conceptual design and space allocation for a possible future FGD system, replacement of the existing burners with low NO_x burners, replacement of the existing combustion control system with a new DCS system, replacement of the existing flame safeguards system, addition of an overfire air system, and adjustment of auxiliary plant systems to accommodate the new equipment. Fuel switching and blending were considered; the investigation included 72 different coals and natural gas. Baseline testing was performed, and a design accuracy boiler mathematical computer model[2,3,4,5,6] was prepared and calibrated to the test results. This model was then applied to determine the suitability of several coals and natural gas fuels, as well as performance predictions with different low NO_x burner designs, firing configurations, and biasing. As a result of applying the mathematic model, it was determined that the reduction in NO_x emissions which could be economically achieved for the first compliance phase could be as low as the 0.5 lb/mmBtu CAAA limit when the boiler was clean and calibrated properly. However, this performance would deteriorate between outages, and NO_x emissions would increase. These results, shown in Table 1, were presented to Maryland environmental authorities.

After the required equipment was selected, bids were received for the replacement burners, controls, and other equipment. Contracts were awarded for the equipment and installation. The DCS and flame safeguards systems were combined and awarded to Foxboro for both the Chalk Point and Morgantown stations. DB Riley was awarded the contract for Controlled Combustion Venturi (CCV®) low-NO_x burners for the Chalk Point boiler, which was originally supplied by Babcock & Wilcox.

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ABSTRACT

The modification of Potomac Electric Power Company's (PEPCO) Chalk Point Station Unit 2 (Babcock & Wilcox UP15) to comply with the U.S. 1990 Clean Air Act Amendments (CAAA) followed a unique plan. The objective of reducing emissions to meet the intent of the regulations at a reasonable cost and with minimum risk to plant integrity and reliability has been achieved thus far. The approach combined experience, sophisticated tools, boiler modeling and testing, and close cooperation between the owner, engineers, and equipment manufacturers.

PEPCO initiated CAAA compliance work simultaneously on the Morgantown and Chalk Point stations, both of which required comparable conversions. Although each project was awarded to a different engineering firm, the work required coordination and cooperation between the firms because both plants installed new controls systems purchased from the same vendor.

Both NO_x and sulfur dioxide(SO_2) emission reductions were considered. It was determined that emissions could be reduced by changing to lower sulfur eastern bituminous coal. To provide future fuel flexibility at Chalk Point, the units were converted to provide the capability to burn natural gas as a primary or partial fuel. In addition, a preliminary flue gas desulfurization (FGD) system design was prepared for additional future SO_2 reductions, if necessary, and all subsequent retrofit work was designed to accommodate the FGD arrangement and laydown space. Each boiler in each station was then analyzed for its ability to burn 72 different lower sulfur coals, many of which were harder coals which require pulverizer modifications or replacement. The analysis was performed using a computer boiler modeling program that predicted boiler performance and emissions levels for different fuels and boiler modifications. The intent was to determine common coals which could be burned with minimal impacts at both Chalk Point and Morgantown stations.

The coals found to be suitable for both stations were analyzed for boiler performance and auxiliary equipment impacts. A sophisticated engineering approach was used to provide performance costs and economic comparisons, as well as to document emissions predictions for various fuel and boiler physical changes. As a result of the boiler modeling and equipment impact assessment, it was determined that practical NO_x reduction could be achieved by replacing the existing B&W circular burners

Table 1 Boiler Performance Before and After Low NO_x Conversion
Pulverized Alpine Coal and Natural Gas Fuels

Subject	Actual Base-Line Test	Predicted Generic Low NO_x	Predicted Natural Gas
Boiler Load, Percent	100	100	100
Boiler Efficiency, Percent	89.88	90.22	85.54
Fuel Flow, lbs/hr	240,188	238,622	144,124
Coal Fineness, HGI	70	70	NA
Air Flow, lbs/hr	2,859,889	2,850,799	2,982,743
FEGT, ˚F	2376	2395	2339
Main Steam Flow, lbs/hr	2,370,600	2,370,600	2,370,600
Pressure, psig	3541	3541	3541
Temperature, ˚F	996	1000	995
Spray Water Flow, lbs/hr	0	0	0
1st Cold Reheat Steam Flow, lbs/hr	2,083,600	2,083,600	2,083,600
Pressure, psig	939	939	939
Temperature, ˚F	668	668	668
Spray Water Flow, lbs/hr	63,180	54,816	91,146
1st Hot Reheat Steam Flow, lbs/hr	2,146,789	2,146,780	2,174,746
Temperature, ˚F	1046	1050	1050
2nd Cold Reheat Steam Flow, lbs/hr	1,557,200	1,557,200	1,557,200
Pressure, psig	331	331	331
Temperature, ˚F	756	756	756
Spray Water Flow, lbs/hr	11,458	8,844	23,203
2nd Hot Reheat Steam Flow, lbs/hr	1,568,658	1,568,658	1,580,403
Temperature, ˚F	998	1000	1000
NO_x Emissions, lb/mmBtu	1.35	0.79	0.38
LOI in Flyash, Percent	1.9	4.7	–

Note: Predicted values are for low NO_x burner without OFA operation

DB Riley tested one of the primary Phase I coals, Alpine coal, in its test furnace. On the basis of the test results, it offered and guaranteed that the burners would satisfy the statutory limits on NO_x emissions, with overfire air, and with acceptable LOI levels.

During the detailed engineering and burner system design phase of the project, the burner front was modeled using a three-dimensional computer-aided design (CAD) program to develop the clearances, operability, and maintainability of various components. Close coordination between DB Riley and Stone & Webster during engineering design resulted in efficiency, lowest costs, and early completion of the design. Close cooperation between PEPCO instrumentation engineers, plant personnel, Stone & Webster, and the other engineering firms resulted in on-time completion of the DCS design and a well-functioning control system.

The Unit 2 installation was completed 10 days early and under budget. Initial test results demonstrated that the boiler could be operated with satisfactory performance. Before detailed testing or calibration of the burners or fuel systems could be done, severe weather conditions caused a shortage of generating capacity in the east coast power grid that required that the unit be put into service. The unit was started quickly and successfully operated for more than one month at high load. The overfire air system was not used the first month of operation.

After several weeks of operation, preliminary tests were conducted which showed the pre-conversion NO_X level was unchanged, on the order of 1.2 to 1.4 lb/mmBtu. Some mechanical deterioration had occurred during the first two to three months of operation, and the lack of balancing resulted in heavy staging in some areas, including some of the overfire air ports and the lower furnace hopper. These problems have since been eliminated by a number of burner adjustments. Since these changes were made, the lowest consistently achievable NO_X, emissions have been reduced to 0.65 lb/mmBtu when the burners are operating at the specified conditions, although LOI levels increased considerably.

Some problems have been experienced thus far with fugitive dust from the coal pile and coal handling system, especially when the coal is dry. The fugitive dust has been linked to some of the Phase I lower sulfur coals, which have increased fines due to the washing process used to reduce ash and sulfur content.

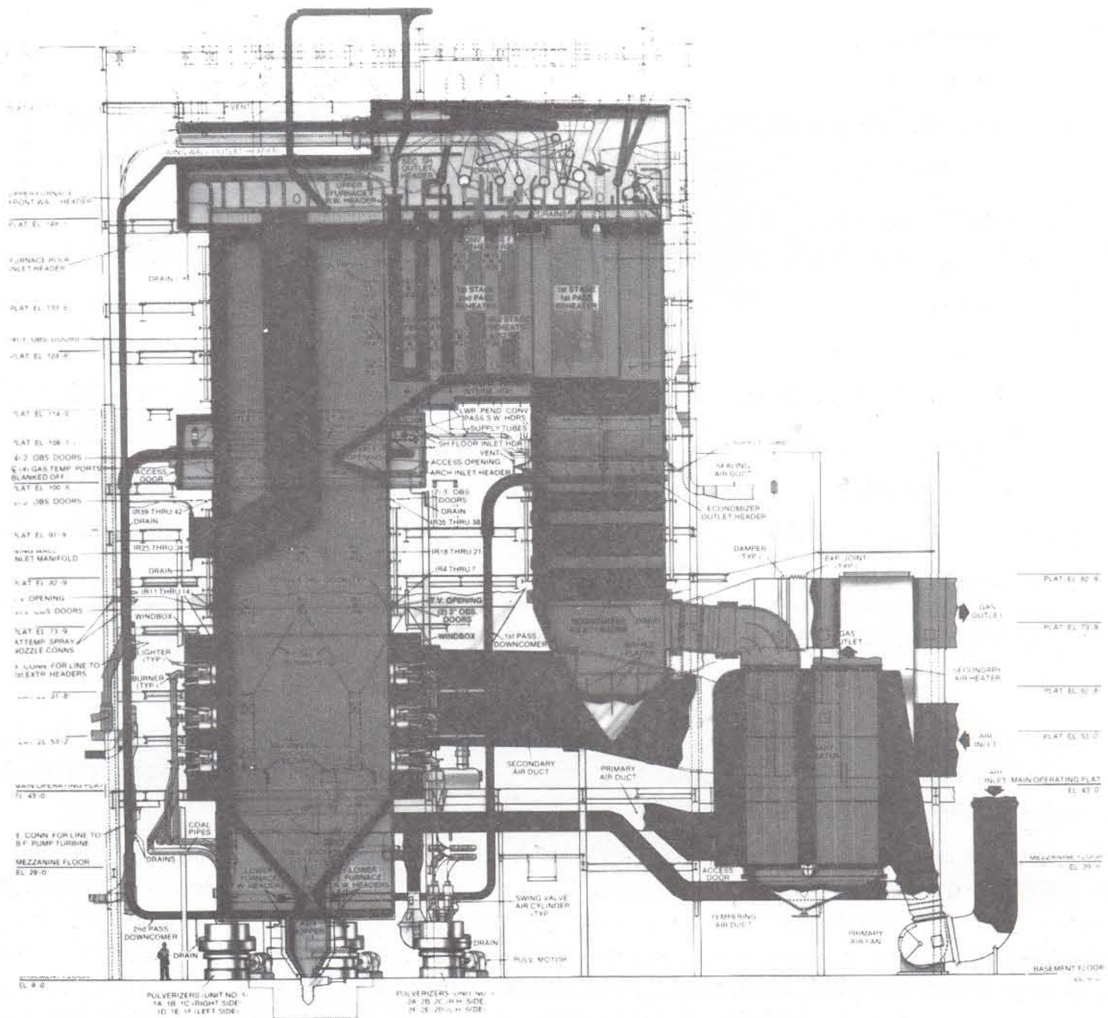

Figure 1 Chalk Point Units 1 and 2

BOILER DESCRIPTION

Chalk Point Generating Station is located approximately three miles southeast of Aquasco, Maryland, in Prince Georges County, at the confluence of the Patuxent River and Swanson Creek. Chalk Point Unit 2 is a pulverized coal, opposed wall-fired, dry bottom, double reheat, Babcock & Wilcox UP (supercritical) series boiler which entered service in 1965. Capacity is 355 MW, 2,500,000 lb/hr, 3,575 psig, 1,000°F/1,050°F/l,000°F (see Figure 1).

The boiler was previously converted from pressurized operation to balanced draft, and flue gas recirculation was removed. These excellent, highly efficient units are key base-loaded power producers in the PEPCO system.

BACKGROUND

Baseline testing found that existing boiler plant emissions were high, with NO_x emissions in the range of 1.2 to 1.4 lb/mmBtu. The CAAA regulations were interpreted to require that NO_x emissions from this boiler must be reduced to 0.5 lb/mmBtu. Conversion to this level was defined by the State of Maryland regulatory authorities as requiring installation of low NO_x burners with overfire air (RACT). The magnitude of the burner and controls modifications appeared to require the installation of a flame safeguards system to comply with NFPA codes, which PEPCO opted to meet.

These boilers have small furnaces for their rated steam output; therefore, a very high burner zone heat release rate, high flame temperature, and short retention time are required to achieve complete combustion and heat transfer. Significant furnace staging problems had been observed in the past, especially on the hopper slopes and the radiant wing walls. Bias firing (less fuel to the lower row and more fuel to the top row) of the original burners was required to control the lower furnace staging problem.

The opposed firing configuration creates flame turbulence which, although it improves carbon burnout, tends to produce more NO_x. These units currently burn a relatively soft coal (high Hardgrove Grindability Index, HGI) for which the mills produce coal fineness in excess of design requirements. The lower sulfur Phase I coals have approximately the same HGI, and thus will not affect the existing mills.

The lower sulfur coals being considered for the Phase I SO_2 reduction, however, often are harder to grind than those for which the boiler was designed and the pulverizers selected. Harder coals require larger mills to achieve the same grind size, which is necessary to minimize unburned carbon. The larger mills would require major plant auxiliary equipment changes at a high capital cost. As a result, the decision about this work was deferred and conversion for the Phase II harder coals was not considered at this time.

APPROACH

Preliminary Engineering

At the onset of this project, equipment impact and fuel selection studies were initiated for Chalk Point Units 1 and 2 to determine the most cost-effective approach to comply with Phases I and II of the 1990 CAAA.

One of the first activities consisted of extensive baseline testing of the boiler for use in the equipment impact study and the low NO_x equipment specification. This testing included furnace and fuel analyses and measurements, and boiler and emissions testing. These tests were supplemented with fuel and ash chemical and sieve analyses and LOI sampling. In addition to baseline emissions data, the tests provided the performance data needed to develop and calibrate the design accuracy boiler mathematic model.

Low NO_x burners and OFA were chosen to comply with RACT NO_x limits. For fuel flexibility reasons, the new burner system included the ability to burn natural gas in addition to coal. This cofiring ability required the addition of a natural gas piping system and associated controls and safety systems to the plant. Because of a lead time of approximately one year for a low NO_x burner system and distributed control system (DCS), as well as the scheduling of upcoming outages, procurement specifications were prepared in parallel with the preliminary engineering studies. The potential auxiliary equipment and boiler performance impacts for the low NO_x burner technology were factored into the equipment impact study with the impacts caused by compliance with SO_2 emission limits.

The emissions results of the baseline testing demonstrated that SO_2 emissions would have to be reduced. The technology initially selected for Phase I and II SO_2 reduction was fuel switching to a lower sulfur coal. Later, additional reductions for Phase II may require supplemental technologies for further $S0_2$ reduction. Conceptual engineering was performed to develop equipment arrangements for the possible future addition of a flue gas desulfurization (FGD) system. Laydown space and equipment "footprint" requirements for this conversion were reserved on the plant site, and it is intended that all present and future site work will accommodate these areas.

An availability study was performed to determine the available reserves and characteristics of eastern bituminous low-sulfur coals. These lower sulfur coals were found to be harder than the presently used coal, and provisions to upgrade the pulverizers were included in long-range planning.

The design accuracy boiler mathematic model was prepared and calibrated to reflect the results of baseline testing at various boiler loads. For the fuel selection study, the model was applied to determine the performance of this boiler when burning different coals and natural gas. Seventy-two different coals were reviewed, and special equipment modifications, such as the need for pulverizer modifications, were determined. For use with the equipment impact study and the evaluation of low NO_x burner bids, the model was modified to simulate boiler performance with a generic low NO_x burner design representative of those proposed by the major boiler manufacturers, burning Phase I coals. Testing and modeling results are shown in Table 1.

Detailed Engineering

Bids for the low NO_x burners and OFA system were solicited from five boiler manufacturers. Bids were submitted by ABB-Combustion Engineering, Babcock & Wilcox, Foster Wheeler Energy Corporation, and DB Riley. Based on price, guaranteed performance and technical merit, an order was placed with DB Riley. The contract for the burner system was awarded in June 1992, and detailed engineering commenced. At approximately the same time, an order was placed with Foxboro for the DCS and Burner Management System (BMS). Foxboro subcontracted the BMS to Detector Electronics. Detailed engineering was performed from June 1992 through August 1993, with the bulk of the equipment scheduled to arrive onsite in June 1993.

Detailed engineering of the burner front piping and electrical cable trays required the preparation of a three-dimensional CAD layout. Due to congestion at the burner front and the extensive amount of new piping (natural gas, atomizing and aspirating air, instrument air, etc.) and electrical wiring, a three-dimensional CAD layout was required to determine interferences, boiler movement impacts, and access for operations and maintenance. Perspective views of the layout from different reference angles were used to show the installation contractors how to install the various systems. The CAD layout was also instrumental in determining/specifying interface points with vendor equipment and laying out flex hose routings and sizings.

Low NO_x Burner System—Design Requirements

The low NO_x burner system provided by DB Riley is designed to bring Chalk Point Units 1 and 2 into compliance with the NO_x emissions provisions of Title IV of the 1990 CAAA. The guaranteed performance (see Table 2) was stipulated by DB Riley for all four compliance coals, utilizing low NO_x burners with OFA. DB Riley guaranteed that NO_x emissions would be reduced below the CAAA limit of 0.50 lb/mmBtu.

Table 2 Specification Requirements and Guaranteed Low NO_x Burner Performance

Parameter	Guaranteed Performance	Baseline
NO_x Emissions, Coal, lb/mmBtu	< 0.50	1.35
CO Emissions, Coal, lb/mmBtu	< 240	9
Unburned Carbon in Flyash, Percent	<= 5.0	1.9
Windbox to Furnace Pressure Drop, Inches W.G.	6.0	6.1
Excess Oxygen at Economizer Outlet, Percent	+/-10°	Minimal
Furnace Vibration	No change from baseline	
Lower Furnace (Burner Zone) Stoichiometry (OFA flow is limited to 15%)	>= 1.0	1.18 - 1.22

A pre-outage test was performed in conjunction with DB Riley to verify boiler operating conditions such as vibration, furnace staging, emissions, and unburned carbon. New ceramic tile burner throats were installed with the burners. New burner opening waterwall panels were also installed due to the age of the existing panels (which were scheduled to be replaced in five years). This saved the future cost of removing and replacing burner components and the tile throat to install new panels.

Ignitors

In addition to the low NO_x burners, new larger Class I, air atomized, dual fuel, retractable ignitors were supplied by Coen Company to replace the old Class III mechanically atomized ignitors and the old warm up guns. The poor atomization of the old ignitors produced unacceptably high opacity during startup. Precipitator problems were also being experienced with the old ignitors due to unburned oil droplets being carried over from the furnace and sticking to the collection plates.

The new ignitors are air atomized Model WS-1 and are designed to burn either No. 2 oil or natural gas. New dedicated atomizing air compressors and piping was added to support the ignitors. The new ignitors are designed for smokeless lightoff on a cold boiler and less than 10 percent opacity for continuous operation. The new ignitors are sized to provide sufficient fuel heat input for boiler warmup and to make up boiler load for the loss of one pulverizer.

The ignitors are incorporated into the DB Riley CCV® burner in the center of the coal nozzle, inserted down the coal spreader support tube. A significant feature of the Coen ignitor is the HEI spark rod, which oscillates in and out of the fuel spray several times a second to ensure quick ignition.

The lack of room at the burner front of these units made the WS-1 ignitor particularly difficult to accommodate. Clearance from the burner front plate to a row of main steam downcomers on the front wall of the boiler was less than 12 feet in a number of locations. This made the aisleways cramped and withdrawal of the new ignitors would have been impossible, not to mention egress across the burner front. To overcome this problem, Coen provided an ignitor body which is more compact than usual with a shorter retraction stroke. In addition, the fuel guns and spark rods included flexible portions so that the ignitor could be withdrawn in a shorter distance.

Burner Description

The DB Riley Controlled Combustion Venturi (CCV®) low NO_x burner with Model 90 register was retrofitted to Chalk Point Unit 2 and is planned to be retrofitted on Unit 1. The burner is designed to burn either coal or natural gas fuel for full-load operation. Six gas canes are provided which penetrate the burner through the secondary air annulus. The burner is shown on Figure 2.

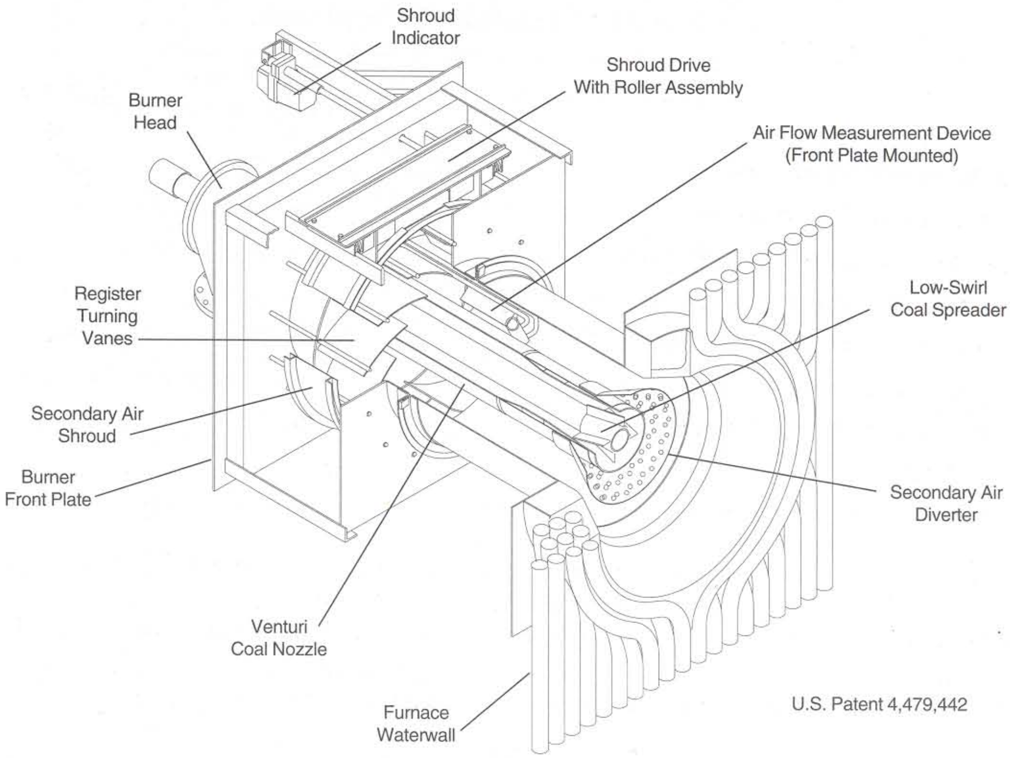

Figure 2 DB Riley Controlled Combustion Venturi (CCV®) Burner

NO_X emission reduction is achieved by the CCV® burner using only a single register, resulting in a mechanically simple design. A significant feature of the register design is the location of linkages and levers outside the windbox to minimize the exposure to secondary air temperatures. Only the turning vane shaft penetrates the burner front plate into the windbox.

New design developments are included in this burner. These changes include the design of a new coal spreader, implementation of heat- and wear-resistant materials, and development of a new secondary air diverter.

The key NO_X control element of the burner design is the venturi coal nozzle and low swirl coal spreader located in the center of the burner. The venturi nozzle concentrates the fuel and air in the center of the coal nozzle, creating a fuel-rich mixture. As this mixture passes over the coal spreader, the blades divide the coal stream into four distinct streams which enter the furnace in a gradual helical pattern, producing gradual mixing of the coal and secondary air. The coal spreader is available with blade angles of 15 and 30 degrees. The 30-degree spreader produces a shorter flame pattern with increasing mixing for reduced unburned carbon loss. The 15-degree spreader produces a longer flame with more gradual mixing to maximize NO_X emission reduction. This spreader is usually used with OFA.

The air register/shroud assembly provides independent control of swirl and secondary air flow. The backward curved, overlapping air register vanes provide excellent swirl control. The vanes are manually positioned using a direct-drive gear reducer for the proper degree of swirl during initial startup and locked into position for subsequent operation. Secondary air flow is controlled by a moveable shroud that slides over the vanes. An electrically-operated linear drive mechanism operates the shroud.

A secondary air diverter is located in the secondary air barrel to cause the secondary air initially to flow away from the primary combustion zone, thus creating an oxygen-lean zone at the burner discharge. This air flow gradually becomes re-entrained with the combustion process downstream of the primary combustion zone. Devolatilization of the coal in the fuel-rich mixture occurs at the coal nozzle exit in this oxygen-lean primary combustion zone, resulting in lower fuel NO_x conversion. Peak flame temperature is also reduced, thus suppressing thermal NO_x formation.

Independent control of the shroud and the vanes provides flexibility in controlling combustion, particularly at low loads.

Secondary air velocity across the register vanes is maintained by partially closing the shroud at low loads, retaining the high degree of swirl necessary for flame stabilization.

The burner includes a flow-measuring device installed in each burner barrel to provide a relative measure of the secondary air flow to each burner. This device, combined with the moveable air shroud, provides the capability of balancing secondary air flow to all burners. Balanced air flow, combined with balanced fuel flow, ensures that each burner is operating at similar stoichiometric conditions to produce optimum combustion performance during low NO_x operation.

Important aspects of the burner design for this project are:

- Burner throats are fitted with prefired silicon carbide tiles provided by York Linings of England. This tile design is affixed to the tubes with a stud which fits into a key in the back of the tile. This tile system is designed to produce excellent concentricity for better flame shape.
- Cast steel coal heads are provided with primary air/coal deflector vanes to eliminate roping in the coal nozzle and to provide uniform coal distribution. The deflector vanes for this installation are a wear-resistant ceramic material.
- High-grade temperature and wear-resistant alloys are used in critical burner components such as the venturi coal nozzle, spreader, and secondary air diverter to maximize burner reliability and wear life and minimize maintenance costs. The venturi nozzle is made of 310 stainless steel and Ni-hard. The secondary air diverter is made from stainless steel.
- Burner shrouds are designed to provide secondary air leakage to burners (for cooling) when they are out of service. Provision is made for auxiliary cooling air for the venturi and coal spreader (secondary air fed from the burner windbox) when firing natural gas.
- The burner design does not cause recirculation and coking in the coal nozzle. To prevent coal layout, the coal nozzles are designed to operate within acceptable velocity limits.
- The CCV® burner is designed to operate at a burner stoichiometric ratio between 0.90 and 1.20. This particular installation is operating at a stoichiometry of 1. 0 or greater as required by the specification.

OFA System Description

In addition to the low NO_x burners, an advanced overfire air system was added to provide an integrated approach to achieve further NO_x reduction. The combined burner and OFA system provides the control required to regulate the mixing of combustion air with the fuel by means of staging, which is needed for low NO_x and CO emissions operation.

The integration of an advanced OFA system allows staging of the combustion air, which results in higher NO_x emission reductions. Modifications to the furnace front and rear walls above the burners provided the required opening for the OFA ports. Modifications to the roof of the windbox and the platform above were required to accommodate the OFA ducts. The OFA system is intended to provide flexibility in NO_x emission control, with some variations in fuel characteristics.

Construction activities commenced in June 1993 with the mobilization of the piping contractor to start preoutage construction. Natural gas piping from the gas company's metering and reducing station to the powerhouse was one of the first activities to begin.

The Unit 2 outage began on September 6, 1993, and was scheduled for 19 weeks. The first outage activity started was asbestos abatement and burner area piping demolition. A significant amount of asbestos abatement was required on the boiler windbox and steam downcomers; this took approximately 10 days. Boiler and burner installation work commenced immediately after asbestos abatement. In addition to the burner and OFA port installation, new waterwall panels were installed for all burner nests as a scheduled maintenance item. Other boiler pressure part work performed included a significant number of other waterwall panels in the furnace, secondary superheater pendant assemblies, inlet header tube stubs, and mixwall headers. The significant amount of boiler work being performed required that the work be properly sequenced so as to maintain schedule without removing too many panels at any one time, which could affect the structural integrity of the boiler.

Burner front installation work required careful planning and scheduling due to the many crafts involved: electrical, instrumentation, mechanical piping, and boilermakers (burners and OFA ports). A significant amount of piping demolition was required before installation work could proceed.

The first boiler hydrostatic test was performed at the end of October. System checkouts were performed from the end of November into December, with the first firing of ignitors just after Christmas. After some initial problems with the ignitor oil system and the ignitors, the unit began firing coal and was declared commercially available on January 19, 1994.

RESULTS

Initial Startup

The initial firing of the ignitors was performed during the last week of December, 1993. Problems were experienced with the new oil and atomizing air systems controls, but these were gradually overcome by plant startup engineers. Initially, oil consumption by the new ignitors was insufficient to warm up the boiler, and ignitor opacity did not meet the 10 percent opacity guarantee. A series of modified atomizer tips was installed to correct these deficiencies.

The new low NO_x burners were initially started in January 1994, 10 days earlier than scheduled and during a power crisis caused by severe weather on the east coast which lasted several weeks. Because the need for power was essential, the unit was started without the overfire air in service or the low NO_x system balanced or tested. The skill of the operators and their ability to adapt to the new control system enabled the load to be carried at peak conditions during this period. The burners and the control system functioned well, and the boiler performed satisfactorily during the crisis. However, there was significant concern over slag deposits around some burners and on the hopper slopes.

Initial Testing

When the power crisis ended, the boiler was released to DB Riley for formal startup and testing. Initially, the NO_x was found to be approximately the same as it was at the original baseline testing, about 1.26 Lb/mmBtu when burning the low volatile coal typical for this unit. The initial testing program results at boiler full load (355-360 MW) with 30-degree coal spreaders, as recommended by DB Riley, are listed in Table 4. Slag accumulation on the hopper slopes was quite severe, causing the test program to be delayed while the slag was removed by water lances. Burner biasing was required to keep the staging under control, which resulted in higher NO_x emissions.

The following reasons appeared to cause the poor results:

- Overfire air was not functioning properly. The dampers to three of the OFA ports were not opening properly due to a bound linkage.

Table 4 Initial Testing Results
30 Degree Coal Spreaders

Test Description	OFA Flow, Percent	Register Vane Position	Excess Oxygen, Percent	NO_x Emissions, lb/mmBtu
Baseline, no OFA	0	35°	4.0	1.27
Baseline, -O_2	0	35°	3.5	1.31
Increased O_2	0	35°	5.0	1.29
Spreader Inserted 2" Into Furnace	0	35°	4.1	1.33
Spreader Retracted 6" Into Nozzle	0	35°	4.3	1.47
Lower Burner Row Negative Coal Bias	0	25°	4.1	1.64
Repeat, Open Vanes	0	40°	4.3	1.41
Excess slag buildup on the lower hopper slopes had to be cleared before testing could be resumed				
Baseline Retest	0	35°	4.0	1.26
1/3 OFA Open	33.3	35°	4.5	1.25
2/3 OFA Open	66.7	35°	4.5	1.24
Full OFA	100	35°	4.5	1.24
Sootblowing	0	25°	4.2	1.10
Reduced O_2	0	25°	3.0	1.03
Full OFA, lower O_2	100	25°	2.9	0.90 - 0.95
Full OFA, Repeat	100	25°	2.8	0.81 - 0.85

- The burner spreaders installed were 30-degree, which resulted in a shorter, more compact flame with increased mixing. SWEC estimates translate this to an increase of about 150°F in flame temperature from the baseline, which results in higher NO_x emissions.
- Tests of the burner coal/air flow, i.e. dirty air, showed imbalances of up to 28.8 percent, resulting in an imbalance in flame temperatures.
- Slag accumulation on the lower hopper slopes appeared to stem from the lower row burner flames licking the slopes.

The only test parameter which appeared to reduce NO_x emissions was lowering excess air levels. The sensitivity to excess oxygen and the lack of sensitivity to burner adjustments established that the reduction in furnace stoichiometry was the key to NO_x reduction in this furnace. The potential for reducing atmosphere corrosion exists and must be carefully considered for long-term operation.

Burner Adjustments

Based on DB Riley's recommendations, the unit was shut down in early April for a short maintenance outage to replace the 30-degree coal spreaders with 15-degree to improve NO_x reduction. After the 15-degree spreaders were installed, initial testing showed that under the specified operating conditions, NO_x could be reduced significantly to as low as 0.50 to 0.53 lb/mmBtu with OFA. The 15-degree coal spreaders produced a longer, narrower flame which resulted in more gradual mixing of the coal and secondary air, thus reducing NO_x emissions. This narrower flame significantly reduced the flame impingement on the lower furnace hopper slopes. The staging problems in the lower furnace were virtually eliminated. However, LOI levels were quite high, in excess of 11 percent with OFA in use. LOI levels in bottom ash were observed to be less than those of the flyash. These high levels of LOI prompted an investigation of the coal fineness from the mills. Coal fineness was found to be quite poor, with coal fineness through 200 mesh averaging 42 percent. Within one week, the mills were tuned and coal fineness improved dramatically, as shown below:

COAL FINENESS
(Average of Six Mills)

	% through 50 mesh	% through 200 mesh
Before tuning	99.9	42.0
After tuning	99.6	75.6

After mill tuning, the NO_x emissions increased to 0.60 to 0.66 lb/mmBtu (13 to 24 percent increase), while the LOI was reduced below 10 percent.

After the mills were tuned, DB Riley proceeded to tune the burners and OFA system to find the optimum settings for lowest NO_x emissions and LOI in flyash. The following adjustments were tried:

- Lowering excess oxygen resulted in lower NO_x and higher LOI (0.65 lb/mmBtu and 9.7 percent respectively). The opposite trend occurs at higher excess oxygen levels (see Figure 3) .
- The burner air register vanes for swirl control were adjusted to 25-, 30-, and 35-degree open. The best NO_x results were achieved at 30-degree open (0.63 lb/mmBtu) (see Figure 4).
- NO_x emissions were reduced by 16 percent (down to 0.53 lb/mmBtu) by increasing the primary air (PA) flow by 10 percent. Further increases in PA flow (+15 to 20 percent) did not result in further NO_x emission reductions (see Figure 5) .

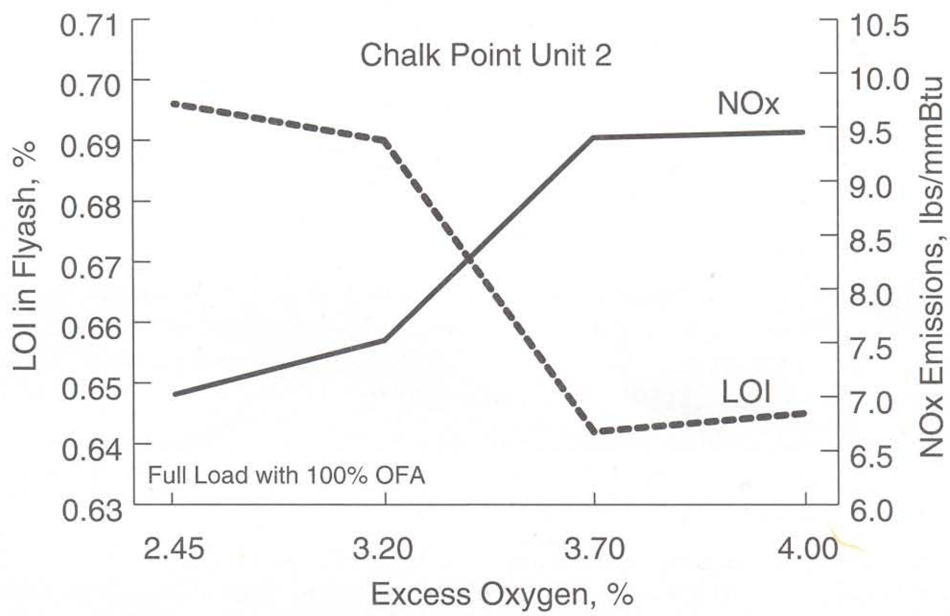

Figure 3 NO_x and LOI vs. Excess Oxygen

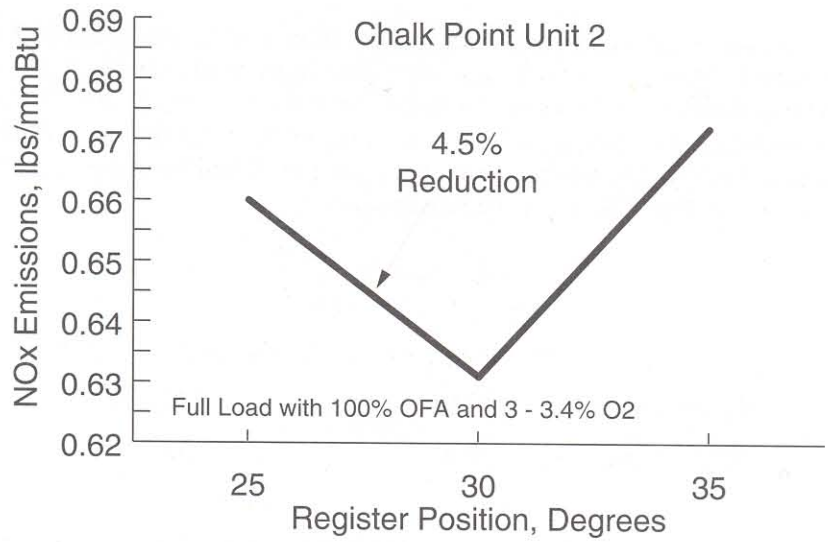

Figure 4 NO_x vs. Burner Register Position

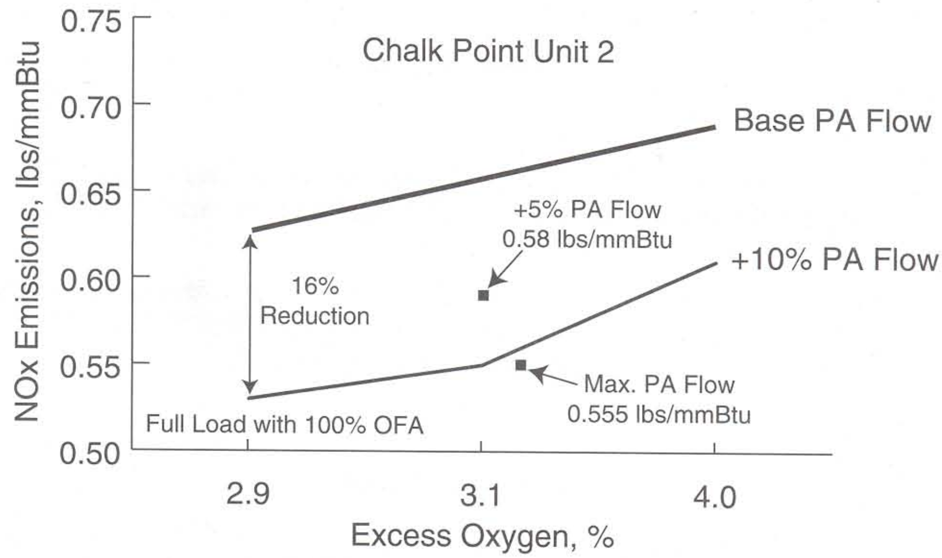

Figure 5 NO_x vs. Increased PA Flow

- NO_x emissions proved to be sensitive to windbox-to-furnace pressure drop, while LOI showed no effect. The lowest NO_x emissions (0.52 lb/mmBtu) were achieved at a windbox-to-furnace pressure drop of 3.6 to 4.0 inches W.G., a reduction of 11 percent from the 6 inches W.G. pressure drop (see Figure 6) .
- NO_x and LOI trends versus excess oxygen with increased primary air flow proved to be very linear, with NO_x varying from 0.58 to 0.61 lb/mmBtu with LOI in flyash ranging 10 to 15 percent, respectively (see Figure 7).
- At full boiler load with optimum burner settings, NO_x and LOI with no OFA flow ranged between 0.75 to 0.80 lb/mmBtu and 5 to 6 percent, respectively. With OFA on, NO_x and LOI ranged between 0.52 to 0.59 lb/mmBtu and 8 to 10 percent, respectively.

- NO_x emissions at lower loads showed an increasing trend for low NO_x burners with OFA operation. The total NO_x reduction from the baseline for low NO_x burners with OFA is 60 percent and for low NO_x burners only is 44 percent (see Figure 8) .
- NO_x emissions have shown a sensitivity to furnace cleanliness. Where NO_x has increased as the furnace slags up. The lowest NO_x emissions (0.48 lb/mmBtu at full load) have been achieved on a clean furnace or just after sootblowing. However, this

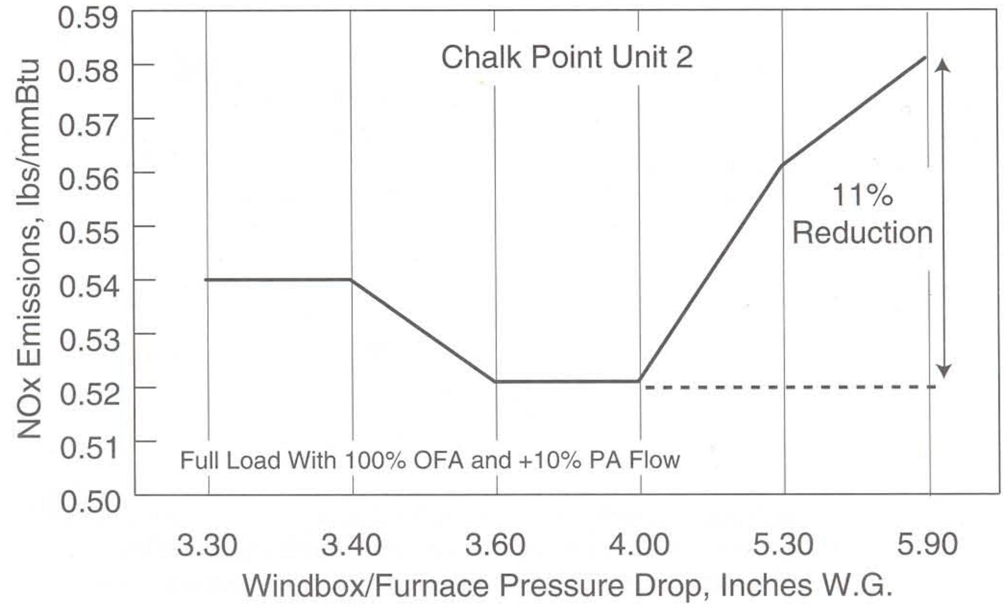

Figure 6 NO_x vs. Windbox/Furnace Pressure Drop

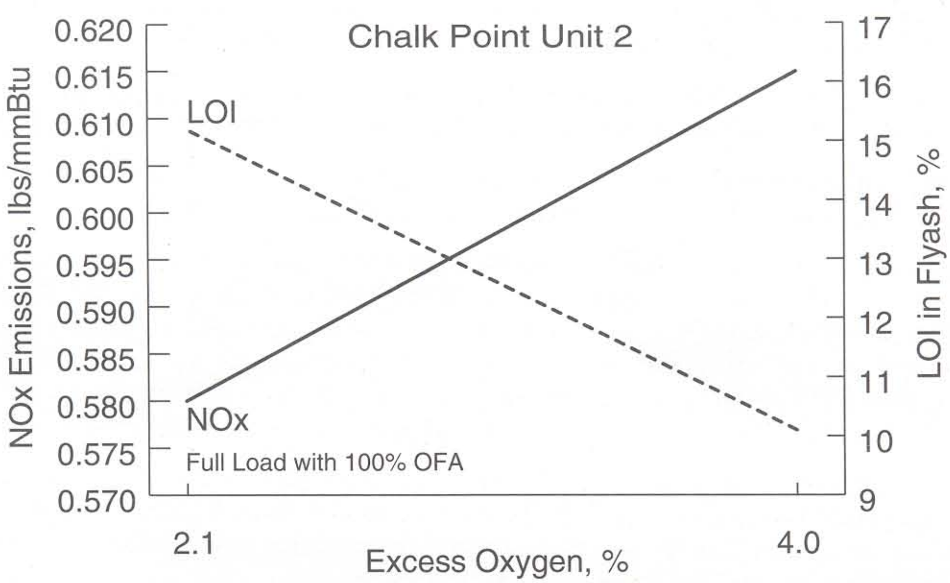

Figure 7 NO_x and LOI vs. O_2, +10% PA Flow

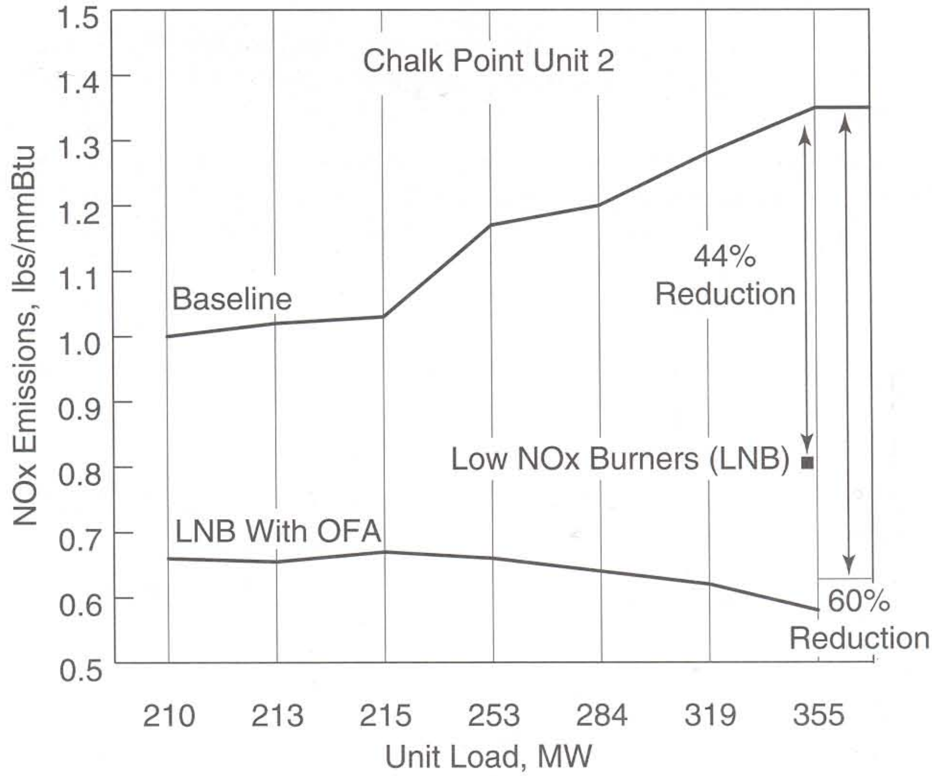

Figure 8 NO_x Emissions vs. Load

has been shown to be a very transient condition and is not repeatable. Continuous furnace sootblowing has been tried to determine its effect on NO_x emissions, and the results so far have been negligible. After a number of days of boiler operation, NO_x emissions settle out at 0.52 lb/mmBtu and higher, regardless of sootblowing. The lowest NO_x emissions levels have been achieved at lower excess oxygen levels (2.8 to 3.3 percent), which result in higher LOI (11 to 15 percent).

- Retracting the coal spreader back into the venturi coal nozzle was tried and proved to be unsuccessful. NO_x emissions increased to 0.60 to 0.61 lb/mmBtu. The optimum NO_x reduction occurs with the spreaders set flush (zero retraction).
- Biasing of OFA flows from the front to the back wall and biasing air flows from the bottom to the top row of burners was tried and had minimal effect on NO_x and LOI.

During testing, the following operating anomalies were observed on this unit. They may be affecting the NO_x emission and, LOI performance of the burners.

- Excess oxygen levels become imbalanced from side to side of the unit when the OFA ports are opened. Adjusting the burner air registers and OFA damper settings does not correct the imbalance. DB Riley analyzed the ductwork and windbox airflow distribution with a computational fluid flow program to determine the root cause and found the airflow distribution to be relatively uniform. They theorize that fan balance or control problems are the root cause of the problem, but this remains to be proven.
- Coal flow balance, pipe to pipe, appears to be poor (as high as +62 to 730 percent from average) even though the primary air flows have been balanced within +/- 10 percent pipe to pipe. Further testing will be performed in the future to determine the extent of the imbalance and the corrective action to balance the flows.

Boiler Model Predictions

Stone & Webster used a mathematic boiler model to analyze the effects of the low NO_x burners firing CAAA compliance coals on this boiler. The predicted boiler performance is presented in Table 1. The actual performance of the low NO_x burners (without OFA) appears to trend closely to the model results.

	Predicted	Actual
NO_x emissions, lb/mmBtu	0.79	0.75 to 0.80
LOI in flyash, %	4.3	5.0 to 5.4

The model did predict that lower NO_x emissions could be achieved by more intense staging of the air and fuel at the burners. However, this may not be achievable on this boiler due to lack of residence time in the furnace for more delayed combustion and other contract limitations on performance parameters. The proximity of the furnace wingwalls to the OFA port/burner region also limits the amount of staging possible on this boiler. LOI in flyash predictions were based on balanced fuel and air flows and the specified fineness (70 percent through 200 mesh and 99.5 percent through 50 mesh).

In most cases the furnace exit gas temperature appeared to be lower than the model had predicted, i.e., with spray flows of about 13,000 to 32,000 lb/hr and 8,000 to 13,000 lb/hr for the two reheats, respectively, compared to the 55,000 to 60,000 and 8,800 to 10,500 lb/hr calculated. These flows were consistent with the model results when considering the differences in operating excess air levels and furnace cleanliness with those in the model.

Table 3 Baseline and Phase I Coals

Parameter	Baseline Coal A	Phase I Coal B	Phase I Coal C
Higher Heating Value, Btu/lb	13,262	12,969	13,016
Ultimate Analysis, Percent			
Carbon	75.31	74.4	74.38
Nitrogen	1.13	1.56	1.56
Sulfur	1.51	1.38	1.57
Oxygen	2.79	2.71	3.47
Hydrogen	4.37	2.71	2.94
Moisture	4.50	7.27	4.39
Ash	10.38	9.97	11.69
Fixed Carbon	65.86	64.80	64.15
Volatile Matter	19.25	17.96	19.77
FC/VM Ratio	3.42	3.61	3.24
Grind, HGI	95	89 - 97	83
Ash Fusion Temperature, °F Reducing (Softening Temperature)	2700	2640	2500

Phase I Compliance Coal Impacts

Both the Chalk Point and Morgantown units receive a mixture of eastern bituminous coals from various mines in southwestern Pennsylvania, West Virginia, and western Maryland. The baseline (pre-CAAA) coals are characterized as Class II, Group 2: bituminous, medium volatile coals with maximum sulfur content of 2.0 percent (ultimate analysis). A typical analysis of the baseline coal is shown in .

The Phase I coals have a maximum specification limit on sulfur of approximately 1.6 percent to meet the CAAA sulfur dioxide emission limit of 2.5 lb/mmBtu. The analysis of typical Phase I compliance coals currently being delivered to Chalk Point is also shown in Table 3. A number of mines from which PEPCO was purchasing baseline coals are able to meet the current Phase I sulfur specification limit by refining the coal at the mine. This refining consists of sizing the coal, washing the coal at the mine to remove some of the sulfur and ash, and drying it for shipment.

Thus far, the impact of the Phase I coals on boiler performance and auxiliary equipment has been negligible. Steam temperatures, tube metal temperatures, and spray flows have been unaffected. Slagging and fouling of the boiler have been unaffected by the coal switch. Lower furnace staging actually improved from preoutage levels, but this is believed to have been caused by the burners. Problems have been experienced in the coal handling system and on the coal pile with fugitive dusting of some Phase I coals.

Coal Dusting Problems

Several shipments of the Phase I coals received at Chalk Point from December 1993 to April 1994 were burned in both the Unit 1 (no low NO_x burners installed) and Unit 2 (low NO_x Burners installed) boilers. These coals were from mines in West Virginia and Pennsylvania.

Excessive dust levels were experienced at the rotary car dumper during the unloading of these coals. Dust clouds were also observed from the coal pile after the coal had been stacked out and the surface of the pile dried for a few days. Windy weather conditions cause visible clouds of dust to blow off the coal pile. Excessive dusting also presented a problem for operators working in the tripper room inside the boiler house.

In order to produce coals which meet the lower sulfur specification for CAAA compliance, coal suppliers are washing the coals, which creates more dust (smaller) particles than the raw coal coming from the mine. The washed coals are also sized and thermally dried at the mine, which increases the amount of coal particles in the small size fraction and reduces the moisture content. The typical washed Phase I coals contain 25 to 30 percent particles smaller than 28 mesh. By comparison, unwashed coals contain less than 15 percent particles smaller than 28 mesh.

The coal (or fugitive) dusting problem with low sulfur, washed eastern coals has also been noted at other power stations on the east coast. Fugitive dusting usually is observed when the coal moisture content drops below a certain limit, typically during transit from the mines and storage on the coal pile during long periods of dry weather.

The Chalk Point station is currently not equipped with adequate dust suppression equipment on the coal handling system to deal with the fugitive dusting problems. A significant capital expenditure would be required to upgrade existing or install new equipment.

At present, PEPCO is dealing with the fugitive dusting problem by investigating portable, spray-type water/surfactant systems. The surfactant is mixed with water and serves as a wetting agent that coats the coal particles. This temporary solution will be used on the coal pile and at the rotary car dumper area until a permanent system can be installed.

Equipment Performance

The installation of the DB Riley low NO_x burner system has had no negative effect on boiler thermal performance, in contrast to some experience in the industry. However, the higher LOI in flyash levels are a concern for PEPCO. Day-to-day operation of the boiler has been relatively unaffected compared to the preoutage baseline. The addition of the burner management system has caused more frequent burner trips due to loss of flame signals. No. 2 oil consumption has increased due to the larger Class I ignitors brought in on main burner trips. Lower furnace staging has been virtually eliminated, which eliminates the need for PEPCO to bias fire the burners for slag control.

Operation of the Foxboro DCS and Detector BMS has been excellent, with no problems noted in the first 7 months of boiler operation.

A high temperature furnace observation camera was used to videotape the burner flames when operating with OFA. It was observed that slag "eyebrows" were building above the OFA ports, especially on the outboard wing OFA ports. Eyebrow formation on the burners appeared to be minimal, but some slag formation which had not been observed before the outage is now being observed around the bottom of the burner throat. Burner eyebrow formation was a problem before the low NO_x burners were installed.

During a short unit outage to repair the secondary electrostatic precipitator (ESP) in May 1994, the burners were inspected from inside the furnace and the following items of concern were noted:

- A number of secondary air diverters had slag accumulation which was blocking the perforations through the shroud. This accumulation makes it difficult for the main flame scanner to sense flame on these burners. Also, the slag is accumulating on the gas cane tips, causing plugging of the cane.
- The gas cane tips were inspected and cleaned during a recent forced outage in July 1994. A number of tips had deteriorated severely, requiring replacement. Also, poor welds between the tips and canes resulted in a number of tips falling off during cleaning. All gas cane tips are being rewelded to address this problem. Ash and slag plugging was observed several inches up the gas canes and ash was found in the burner gas plenum. This necessitated cleaning of the gas plenum and canes during the outage.
- OFA port boot steel is warping and deteriorating on the furnace end due to burn back. DB Riley has theorized that differential thermal expansion of the boiler wall to OFA boot connection is causing the warpage. DB Riley has recommended upgraded materials (446 stainless steel) to solve the problem. The upgraded material will be installed on Unit 1.
- Coal spreaders and their support tubes have exhibited some deformation on the furnace end. It is believed that recirculation of the flame (caused by the secondary air diverters) is responsible for the deformation. DB Riley is considering an upgraded stainless steel support tube end to retrofit the coal spreaders which have exhibited deformation.

Additional problems which have been noted are:

- A number of ignitor spark rod power pack failures have been experienced. Coen has provided a redesigned power pack.
- A significant increase in the flyash removal frequency is being experienced due to the increased amounts of flyash being generated on Unit 2. Increased LOI, lower coal higher heating value, and the slightly higher ash content of Phase I coals have caused the amount of flyash generated by the unit to increase considerably. A recent maintenance outage to repair the ESP has minimized flyash removal problems.

LESSONS LEARNED

To improve the execution of future low NO_x burner system retrofits, a number of items are noted below based on the experience gained at Chalk Point.

- The startup, calibration, and testing time originally scheduled for the burner system was 30 days. Testing and calibration have taken over 6 months and are still in progress. Unforeseen adjustments required on the burners have prolonged testing.
- Potential fugitive dusting problems must be addressed with washed, lower sulfur coals before compliance coals are scheduled to be delivered. This may require installing appropriate dust suppression or collection devices if the plant is not already equipped.
- The field service representative for the new ignitors should have been onsite during the boiler startup phase. This would have reduced the time to resolve initial problems on the ignitors.
- The precipitator must be in optimum operating condition after a fuel switch to a lower sulfur coal and retrofit of low NO_x burners (due to increased LOI). Overhauls of the precipitators should be performed during the burner installation outage in anticipation of increased flyash flows.
- Mill overhauls and adjustments should be made during the burner installation outage.. Balancing of both clean (primary) and dirty (coal and primary) air should be performed on the mills during the calibration phase of the burner system. Properly orientated test ports on the coal pipes should be installed during the outage to perform the clean and dirty air tests. The burner vendor should be consulted regarding the preferred location of the test ports.
- Both pre- and post-outage test plans and procedures should be agreed to as part of the burner system contract negotiations. The details of the test plans, such as types of tests, location of test ports, amount of testing, types of instruments to be used, personnel required, etc., should be worked out to the greatest extent possible before an order is placed. This will ensure that verification of guaranteed performance is done to the satisfaction of both parties involved.
- The availability and use of the continuous emissions monitoring (CEM) systems was of great benefit during the testing and calibration of the burner system. This avoided the cost of testing equipment and personnel during the lengthy testing program.

STATUS OF PROJECT

At present, the unit has not met the guaranteed simultaneous NO_x emission limit (which is also the Title IV CAAA limit) and the LOI in flyash limit with the specified 4.0-percent excess oxygen. The LOI in flyash guarantee also has not been achieved simultaneously with 4.0 percent excess oxygen with either low NO_x burners alone or with OFA. Testing and calibration of the burner system is ongoing to determine the optimum burner settings for low NO_x operation. DB Riley is investigating a number of equipment upgrades which, it is hoped, will eliminate some of the equipment performance problems previously mentioned.

Balancing of coal flows pipe-to-pipe in an effort to reduce LOI requires further testing before a plan of action is determined. Windbox airflow distribution has been studied to determine whether it plays a role in the NO_x and LOI performance of the burner system. This analysis determined that combustion air flows were relatively balanced; however, DB Riley recommended that certain air baffles which had been removed on Unit 2 be left in place on Unit 1.

DB Riley recommended the removal of the secondary air diverters from the burners to alleviate staging problems on the gas canes and also improve flame discrimination. This diverter was removed during a recent outage. DB Riley estimates that removal of the diverter will improve NO_x reductions slightly.

Gas cane tips were not attached using a full penetration weld to the cane. All gas cane tips had to be rewelded and some tips had to be replaced. Ash plugging of the gas canes and plenum is a concern, especially during long periods of non-use. DB Riley believes this plugging is exacerbated by the removal of the secondary air diverter.

Relocation of the main flame scanners is being considered to improve the sight path and improve flame discrimination.

Temporary measures are being installed to address fugitive dusting problems in the coal handling system. More permanent measures are scheduled for the future.

The natural gas system is fully operational and ready for testing. As of this time the unit has not fired natural gas. Initial operation of the natural gas system has been deferred until at least the fourth quarter of 1994 for economic reasons and concerns over the cleanliness (slag and ash buildup) of the gas canes.

The Unit 1 outage is at present scheduled for November 1994 for the low NO_x burner system and DCS retrofit.

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