Babcock Power

Technical Publication

Reducing NO_x Emissions to Below 0.15 lb/10^6 Btu on a 600 MW Utility Boiler with Combustion Control Only

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ABSTRACT

Riley Power Inc. (RPI), a subsidiary of Babcock Power Inc., completed the retrofit of a 600 MW_N opposed-wall fired utility boiler with new low-NO_X dual air zone coal burners and overfire air (OFA). The mid-western utility selected this approach as part of a comprehensive plan to bring their system-wide NO_X emissions into compliance with EPA requirements to avoid the more costly installation of SCR or SNCR at the plant. This application represents the use of the most up-to-date low NO_X coal burner technology combined with OFA, while burning Wyoming sub-bituminous Powder River Basin (PRB) coal. The retrofit project objective was the reduction of NO_X emissions to 0.155 lb / 10^6 Btu while maintaining carbon in flyash levels below 2%.

In pre-retrofit form the unit had four elevations of first-generation, low NO_X burners with several locations in the burner array void of burners. Baseline NO_X emissions averaged approximately 0.30 lb / 10^6 Btu while carbon in ash levels were below 0.1%. Modifications to the firing system were necessary to allow the addition of OFA including reconfiguration of the firing arrangement, without waterwall rebuilding, such that burners in the top elevation were redistributed to the lower three elevations and OFA could be installed in the uppermost windbox compartment. The project also included significant computational fluid dynamics (CFD) modeling of both furnace and burners. CFD results indicated that taking advantage of the existing, but unused, burner openings to compress and lower the burner array and create a fully separated OFA level would not increase FEGT significantly while giving sufficient furnace residence time for good carbon burnout. The CFD models indicated satisfactory OFA mixing so that the furnace exit oxygen distribution would be slightly better than before. Single burner CFD modeling gave burner settings for initial post-retrofit testing to reduce burner and unit commissioning time to reach the project NO_X targets. Actual post-retrofit performance demonstrated NO_X levels below 0.15 lb / 10^6 Btu with carbon in ash levels below 0.10% for a moderate amount of OFA (10-15%) depending on the number of mills in operation. This performance is one of the lowest NO_X emission levels achieved in the industry on a full-scale, wall-fired utility boiler burning sub-bituminous coal with only low NO_X burners and OFA. This paper reviews the design modifications and CFD analyses, and presents performance data from the low NO_X burner retrofit.

INTRODUCTION

To reduce NO_X emissions from pulverized coal fired utility boilers, Riley Power Inc. (RPI), a subsidiary of Babcock Power Inc., developed the Controlled Combustion Venturi (CCV®) burner in the early 1980's[1]. This burner design has evolved throughout the years, and is capable of achieving significant NO_X reduction in various types of applications, new and retrofit. To date, RPI has sold nearly 1,800 low-NO_X CCV® Burners with a total electrical generating capacity of 22,000 MW_E. Using the latest CCV® technology, NO_X emissions reductions from uncontrolled levels average more than 60% without overfire air (OFA) and can exceed 70% with OFA.

RPI supplied forty new coal fired low-NO_X Dual Air Zone CCV® Burners and an OFA system for installation into a 600 MW_N Utility Boiler. This technology incorporates the latest developments and was selected as an economically viable option for achieving system wide NO_X compliance. The objective of this retrofit project was to reduce NO_X emissions from a baseline of approximately 0.30 lb/10^6 Btu to 0.155 lb/10^6 Btu, while maintaining CO levels below 100 ppm and carbon in ash levels below 2%. A sub-bituminous, PRB coal is burned in this unit. The purpose of this project was to avoid the more costly installation of an SCR system at this plant.

To install these burners and OFA nozzles, modifications to the existing firing configuration were needed. These modifications included reconfiguring the burner arrangement such that the upper elevation of burners was redistributed throughout the lower three windbox compartments and the OFA was installed in the uppermost windbox compartment, as shown in Figure 1.

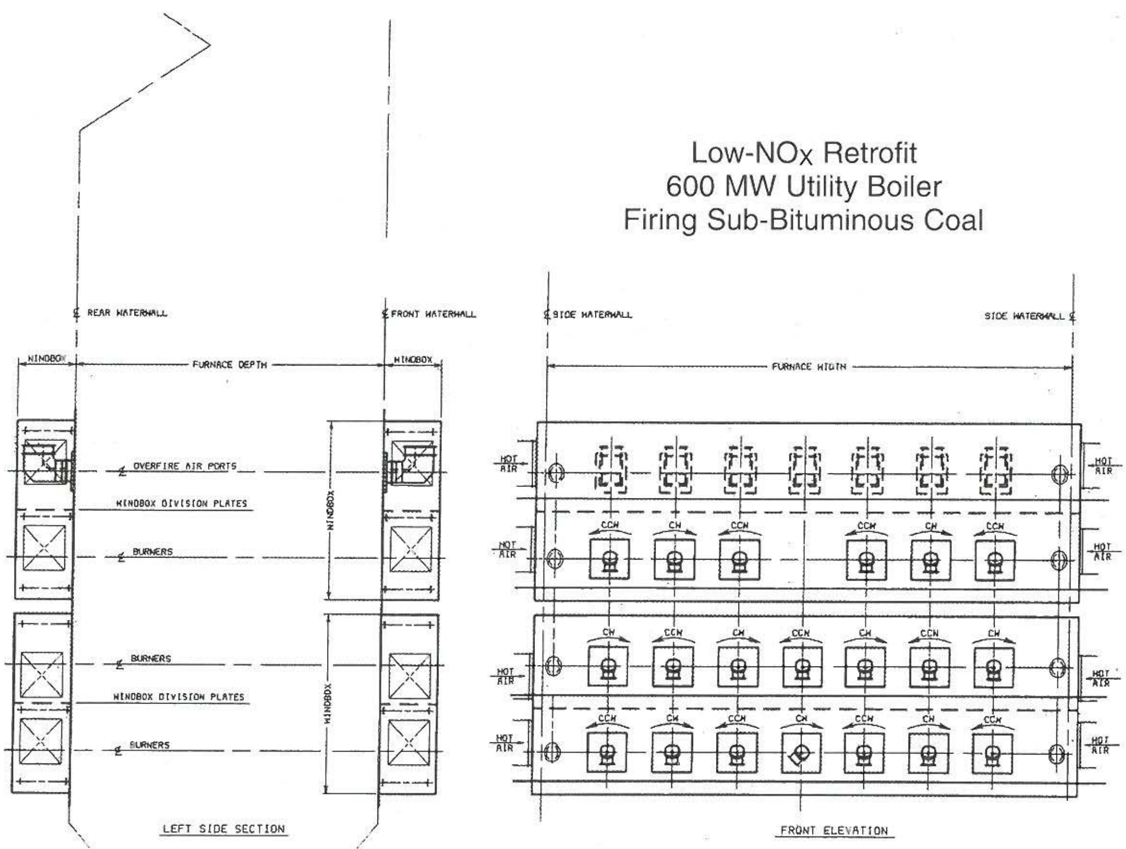

Figure 1 Low NO_X Utility Boiler Retrofit

Installation of the burners and the OFA system was completed in the spring of 2002 and performance testing was completed during the summer of 2002. This paper discusses the CCV® burner technology and CFD modeling utilized to achieve these reduced emission levels and presents results from the start-up and commissioning of this low-NOx combustion system.

UNIT DESCRIPTION

The subject utility boiler, shown in Figure 1, is an opposed-wall fired unit; burning 100% sub-bituminous PRB coal through up to four elevations of B&W's first generation low-NOX dual register burners. This unit was originally designed to generate 4,550,000 pounds per hour of main steam flow at 2,650 psig and 1005°F and 4,281,000 pounds per hour reheat steam flow at 602 psig and 1005°F. The original boiler design used eight B&W MPS 89 mills to supply pulverized coal to 56 burners. However, because of high furnace heat release rates during the original boiler startup, sixteen of the burners were removed from service (two per elevation). Full load boiler operation is 600 MW_N electric power output. Baseline NOx emissions averaged 0.30 lb/10^6 Btu and carbon in ash was typically <0.1%.

LOW NOx DUAL AIR ZONE CCV® BURNER TECHNOLOGY

CCV® Burners are used for reducing NOx emissions from fossil-fired utility and industrial boilers. Pulverized coal is the primary fuel burned using this design. However, with the proper equipment installed for dual fuel firing capability, oil and gas can also be burned. Figure 2 shows a schematic of the latest coal fired Dual Air Zone low NOx CCV® Burner technology, while Figure 3 shows photos of the actual burners delivered and installed. The patented venturi coal nozzle, low swirl coal spreader, and flame stabilizer ring produce a well attached, fuel rich flame, the fundamental condition necessary for minimizing the formation of both fuel and thermal NOx.

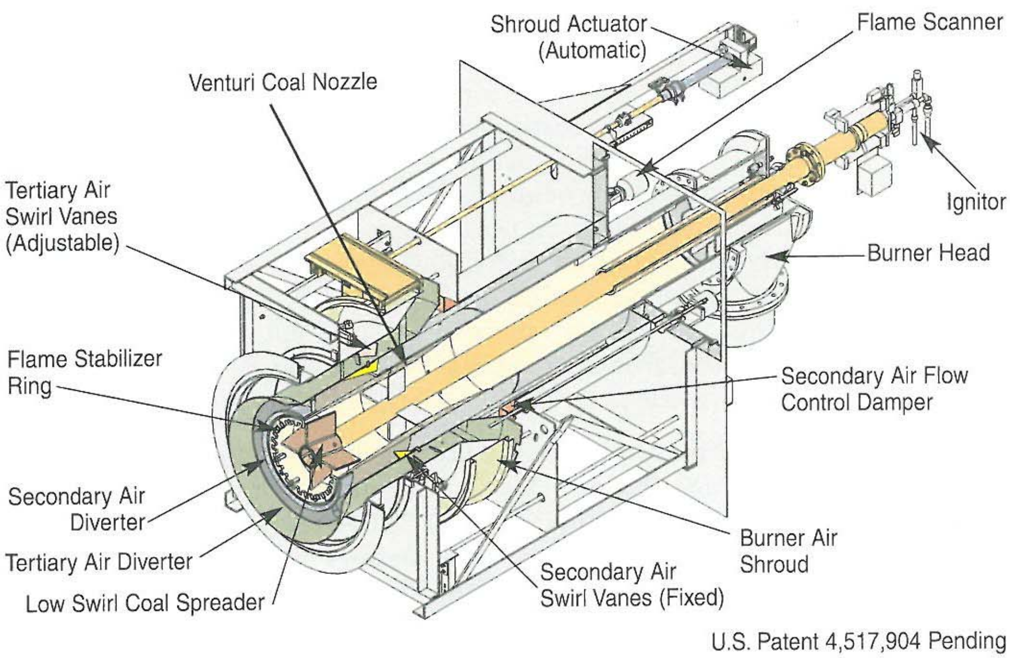

Figure 2 Low NOx Dual Air Zone CCV® Burner

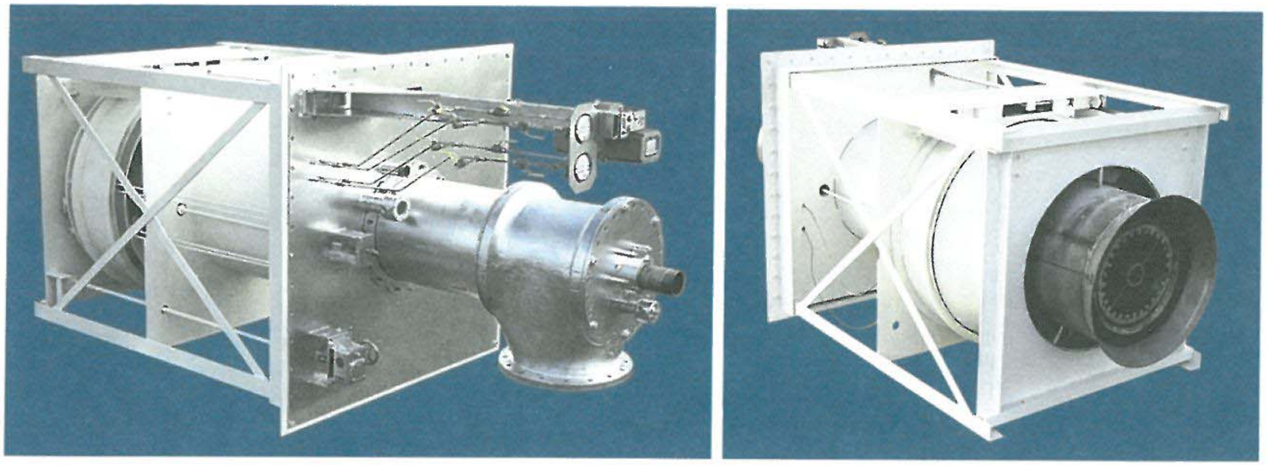

Figure 3 Coal-fired Low-NO_X Dual Air Zone CCV® Burner

Additional NO_x reduction can be achieved with the use of OFA to further stage the main combustion process. Typically, up to 25% of the combustion air can be diverted from the main combustion zone and introduced above the top elevation of burners. This reduces the stoichiometry at the main burner zone, thus creating a reducing environment for combustion. Airflow measuring devices monitor the desired level of air staging throughout the full range of boiler operation for minimum NO_x formation. Air staging is limited (or not used at all) when applied to boilers burning high sulfur coals and boilers designed for supercritical operation because of the potential concern for lower furnace corrosion.

The low-NO_x Dual Air Zone CCV® Burners supplied for this retrofit project were designed to meet the emissions target needed to bring this utility into compliance with their system-wide NO_x emissions limits. As previously noted, these burners included the latest technology upgrades[2,3]. These upgrades focused on maximizing NO_x emissions reduction while extending the wear life for critical burner components. Enhancements for minimizing the formation of NO_x emissions in this burner design included dual combustion air zones, low-swirl coal spreaders, and flame stabilizer rings. The dual air zones separate the combustion air into secondary and tertiary air passages, each containing swirl vanes for spin control. The Dual Air Zone CCV® Burner includes shrouds and dampers for independent control of the airflow to each passage, providing greater control of the stoichiometry at the burner discharge for additional flexibility in controlling NO_x emissions. The low swirl coal spreader disperses the pulverized coal as individual streams that enter the furnace in a gradual helical flow pattern, producing a longer, low-NO_x coal flame compared to shorter coal flames produced by higher swirl coal spreaders. The flame stabilizer ring produces a well attached, tubular-shaped coal flame for further NO_x emissions reduction. Each of these enhancements has a cumulative effect on reducing NO_x emissions in this burner design.

To meet the requirement of being able to operate the low-NO_x burners maintenance free for up to four years between major plant outages, RPI also focused significant development effort on the design of the burner's wear components. The coal spreader was designed using high-grade cast alloy with a wear resistant weld overlay on the leading edge. Current designs utilize tungsten carbide for maximum wear life. The flame stabilizer ring materials are high wear with increased thickness for added wear life. In addition, ceramics were used to line the burner coal heads and nozzles, along with the coal spreader support tube. The burner design capacity for this project was 168×10^6 Btu/hr heat input, with the design coal shown in Table 1.

Table 1 Typical Coal Analysis

Proximate		Ultimate	
Fixed Carbon	40.5%	Carbon	54.3%
Volatile	31.2%	Hydrogen	3.8%
Moisture	24.1%	Nitrogen	0.7%
Ash	4.2%	Oxygen	12.5%
		Sulfur	0.4%
		Moisture	24.1%
HHV (Btu/lb)	9,550	Ash	4.2%

OVERFIRE AIR SYSTEM DESCRIPTION

In addition to low-NOx burners, an OFA system was provided for additional staging of the combustion air, which is needed for achieving further NOx reduction. In this case, for design purposes approximately 20% of the total combustion air is diverted from the main combustion zone and introduced through the OFA nozzles, which are located above the top elevation of burners. This results in a reduced lower furnace stoichiometry, which produces lower NOx emissions by providing a reducing environment for primary combustion to occur.

The OFA nozzles are located above each burner column, see Figure 1, and are designed using RPI's standard 1/3 – 2/3 nozzle design concept, see Figure 4. This design is based on extensive modeling and testing performed by RPI for EPRI in the mid 1980's to establish the design criteria for OFA Systems. Separate on/off dampers are used within each of these sections to control airflow through each of the compartments. This results in better control of

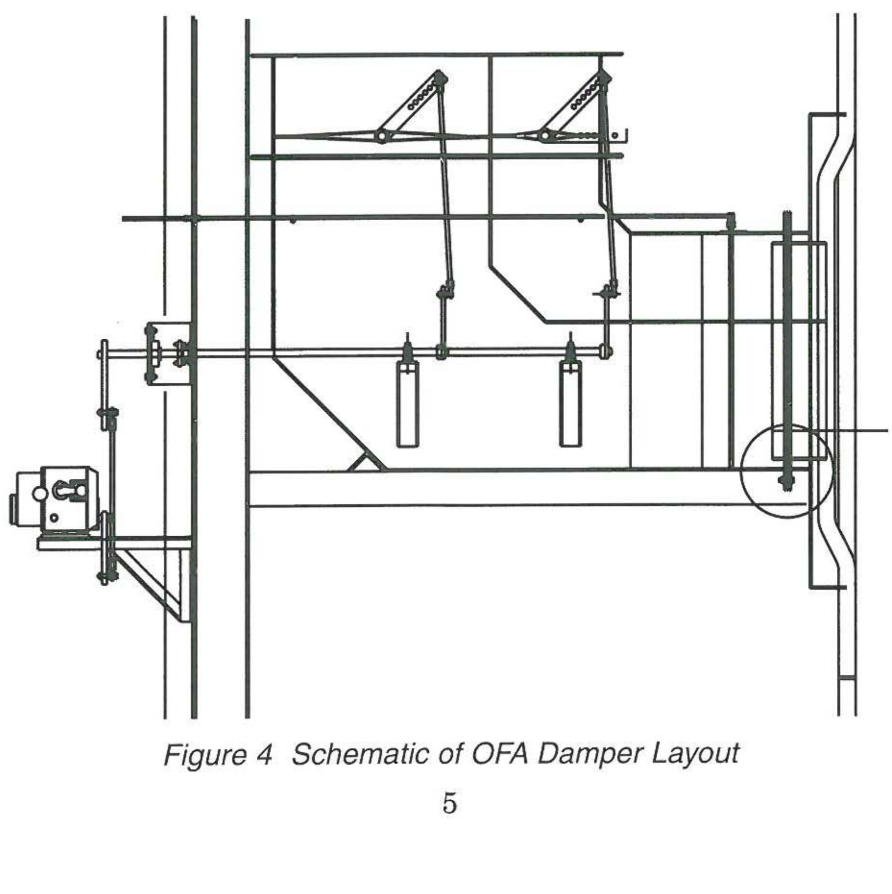

Figure 4 Schematic of OFA Damper Layout

the penetration and mixing of the overfire air over a range of operating loads, which is a key factor in achieving optimum combustion and minimizing CO production. The following items were also considered when this retrofit OFA system was designed:

- Adequate distance between the main burner and OFA zones to effectively reduce NOx.
- Proper OFA velocity for good penetration and mixing to produce efficient burnout of the remaining fuel.
- Proper distance between the OFA and furnace exit to provide adequate residence time for completing the combustion process.
- Independent control of the OFA from the burner air and independent control of each OFA port for balancing purposes.

CFD MODELING

Computational fluid dynamics (CFD) modeling involves solution of the conservation equations of mass, momentum (Navier-Stokes equations), energy, and chemical species in a grid of small cells filling the volume of the burner or furnace in this case. Simulation results are descriptions of gas flow inside the device in terms of velocities, turbulence, temperature, pressure, density, and local chemical composition. RPI has been using Fluent, the world leader in commercially available CFD software, for 19 years to solve flow problems in power generation equipment.

This project required two types of steady-state models to achieve the project goals. Modeling of single burners was needed for three reasons: 1) To fine tune the retrofit burner design since the existing burner throat was different from RPI standard CCV® sizes, 2) To obtain correct burner air flow boundary values for inputs into the subsequent furnace models, and 3) To obtain burner settings giving the desired low NOx flow patterns for use as initial settings during burner and unit shakedown to reduce re-commissioning time. Modeling of the entire furnace concentrated on three issues: 1) OFA design and performance in terms of upper furnace oxygen distribution, CO and carbon burnout, 2) The effect of different configurations of mills out of service on furnace and OFA performance, and 3) Possible approaches for boundary air design to reduce or eliminate sidewall corrosion if it should develop.

Burner Modeling

As noted above, single burner CFD modeling was done for burner design purposes and initial start up settings as well as a necessary first step for the furnace modeling. To reduce model calculation times and maximize the number of simulations possible in a given project duration, the burner modeling approach was kept simple. Burner models were 2-D simulations using aerodynamics only, i.e. no combustion, of a single burner in an idealized tunnel furnace representing the equivalent firing wall region of an outside burner. This approach gives a tunnel diameter similar in size to the actual firing environment but without flame-to-flame interactions which will dominate the flow behavior several throat diameters from the wall.

Aerodynamics-only is sufficient for all three goals of the burner modeling: design refinement, boundary values for input to furnace models, and suggestions for initial start up settings for optimization testing. Figures 5a and 5b display simulation results in the form of streamline plots for both pre- and post-retrofit burner designs respectively. Streamlines are

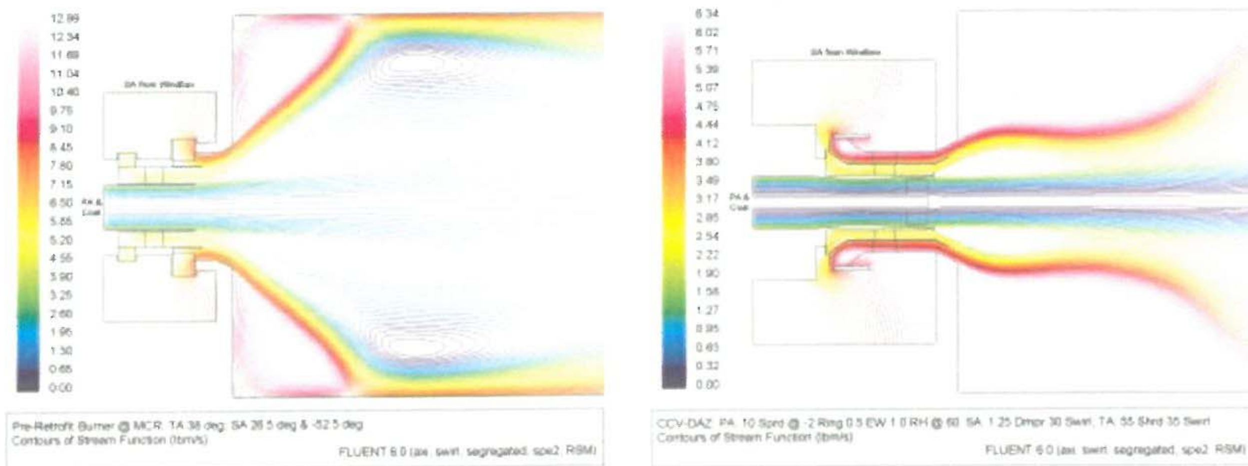

Figure 5 CFD-Computed Single Burner Aerodynamics-Only Streamlines for a) Pre-Retrofit Burner and b) Post-Retrofit Burner

useful because they mark the path of the steady state motion. Streamlines forming loops in the figures show recirculation zones, which are important for flame attachment and controlling the mixing of devolatilizing coal and secondary air oxygen, and thus the formation of NO_X. The flow patterns in Figure 5a indicate a well attached, broad, bushy flame. However, streamlines within the quarl show that primary air (PA) and secondary air (SA) streams interact strongly with rapid mixing driven by the high SA swirl relative to the axial PA flow, so that excess oxygen enters the primary ignition zone and NO_X will be high. The flow patterns in Figure 5b, which are expected to be enlarged slightly by the high reactivity of the PRB coal, indicate a longer, thinner flame will be attached strongly to the burner tip. The flow pattern delays final mixing of SA and tertiary air (TA) into the flame core and thus reduces NO_X emissions. More importantly, the streamlines in the near-burner region indicate an aerodynamic "seal," formed by recirculated PA, that blocks off early mixing of SA into the primary ignition zone, thus leading to low NO_X emissions.

Beyond burner design verification, aerodynamics-only single burner modeling led to a cost savings in the project's burner shakedown and furnace re-commissioning phase. After the burner design was finalized, CFD burner simulations covering a range of burner settings with acceptable flow behavior led to the practical operational range for the burner and also highlighted the burner settings for the best low NO_X Dual Air Zone CCV® Burner flow patterns while having the correct wind-box-to-furnace pressure drop. This suggested setup was used as the starting point for burner tuning. During startup only minor changes in swirl settings were made during the seven day shakedown period to finalize the tuning of the 40 burner installation before the unit passed acceptance testing.

Furnace Modeling

CFD furnace modeling was performed to evaluate the impact of OFA on furnace mixing, FEGT and CO emissions. Figures 6a and 6b show the 3-D furnace models for the pre-retrofit and post-retrofit configurations, respectively. In these figures, the front and left-side walls are transparent to show more clearly the burner array configurations. In the figures, red ovals are in service burners, blue rings are out of service burners with only cooling air thus acting as low effectiveness OFA, and blue rectangles denote true OFA ports. Figure 6a highlights the 30 burners in the bottom three rows most typically in service, the unused spaces in the burner pattern including two mills out of service, and the use of the top row of out of service burners as a type of low effectiveness OFA system. Figure 6b highlights the re-use of the unused burner spaces to create a true separated OFA level built within the windbox and the 40 burners in service.

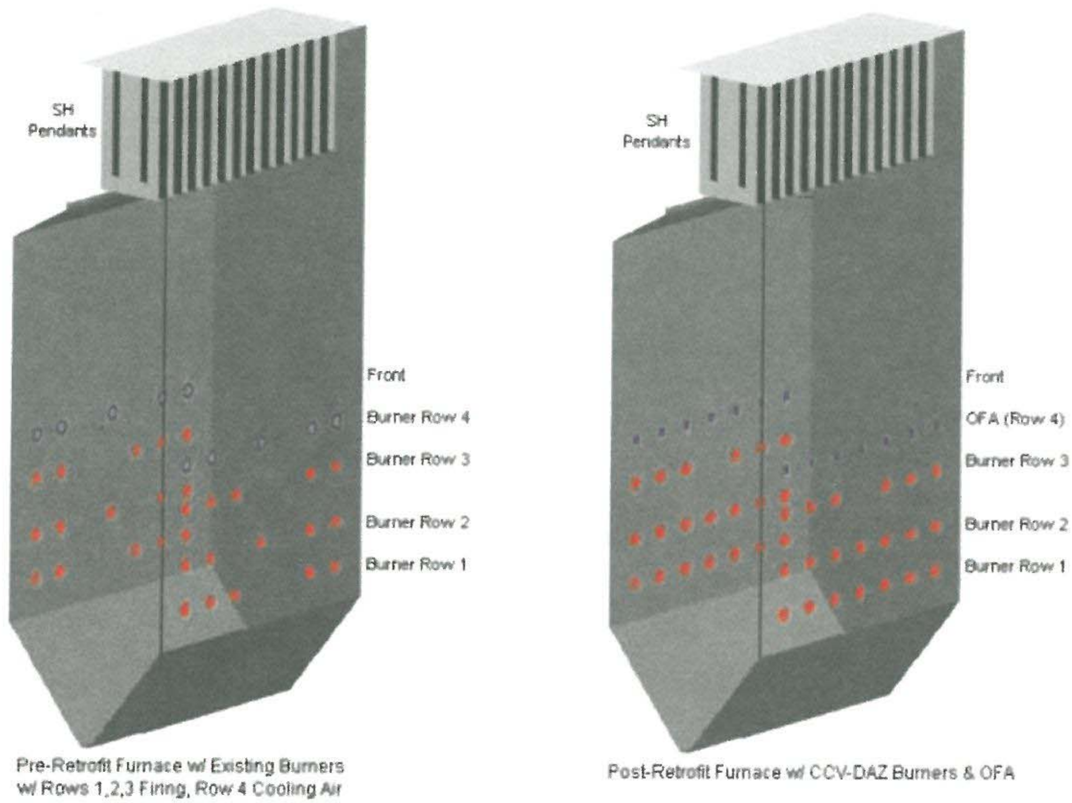

Figure 6 CFD 3-D Models of a) Pre-Retrofit and b) Post-Retrofit Furnaces

Because of left-to-right asymmetry of burners in or out of service, the furnace models are full furnace width from left sidewall to right sidewall, and each model contains over 860,000 brick-like cells in the 82 ft wide by 51 ft deep by 184 ft high furnace volume. Over 2/3 of the cells are concentrated around the burner openings to capture reasonable detail of burner flow patterns, flame structures, and their interactions. Farther away from the burners, the furnace flow patterns are larger scale than near the burners and are captured in sufficient detail with larger cell sizes. The single burner aerodynamic modeling provided detailed profiles of velocity components to map as input boundary conditions on the burners shown in Figures 6a and 6b. Such detail is necessary because the specifics of the PA, SA, and TA flows leaving the burner tips, combined with combustion effects, govern the shape of the flames and general flow to the furnace.

To balance calculation time against fine flow detail, the furnace models separated the pulverized coal streams from the burners into three size bins of small, medium, and large coal particles to capture most of the different flow behavior of the various coal particle sizes. Devolatilization rate and volatiles composition were adjusted for the reactive PRB coal type. A 2-step volatiles to CO to CO_2 reaction system allowed furnace CO levels to attain realistic values from furnace bottom to furnace exit. Carbon in ash (CIA) values were calculated and small adjustments in the char burnout reaction rate were made as the base case simulation progressed so that furnace exit flyash CIA remained close to field data. These reaction rate values were held constant for all subsequent furnace models so that model-to-model comparisons and trends from all model results would have value, at least on a relative basis, if not an absolute value basis.

Field measured values of FEGT or upper furnace gas temperatures and composition were not available, so furnace model validation could not be done by direct comparison of the base case results to field measurements. Instead, indirect validation was made by comparison against the results of another pre-retrofit furnace model with a burner configuration known to give high FEGT as deduced by high steam temperatures and high spray flows. The FEGT results for the two CFD cases gave a difference commensurate with the back-end heat transfer calculations for the regular and high FEGT field setups. No CFD-based NO_X calculations were made. RPI prefers to rely on NO_X emissions regression analysis calculations based on field-measured values for over 150 coal-fired utility units.

Figures 7a and 7b and 8a and 8b show the computed furnace gas temperature and oxygen distribution fields for the pre- and post-retrofit cases corresponding to the geometries in Figures 6a and 6b. The temperature plots indicate that the retrofit does not create any unusual temperature disturbances anywhere in the furnace compared to the temperature history in the pre-retrofit case. The post-retrofit model FEGT increment over the pre-retrofit model FEGT is less than the 50°F desired by the plant to maintain control of upper furnace ash buildup. The oxygen plots indicate that, although the post-retrofit OFA system makes major re-distributions of combustion air and oxygen as part of the NO_X reduction process, the oxygen distribution in the upper furnace and particularly the furnace exit is more uniform for the post-retrofit case. Issues of reduced oxygen content in the lower furnace and burner zone are discussed below.

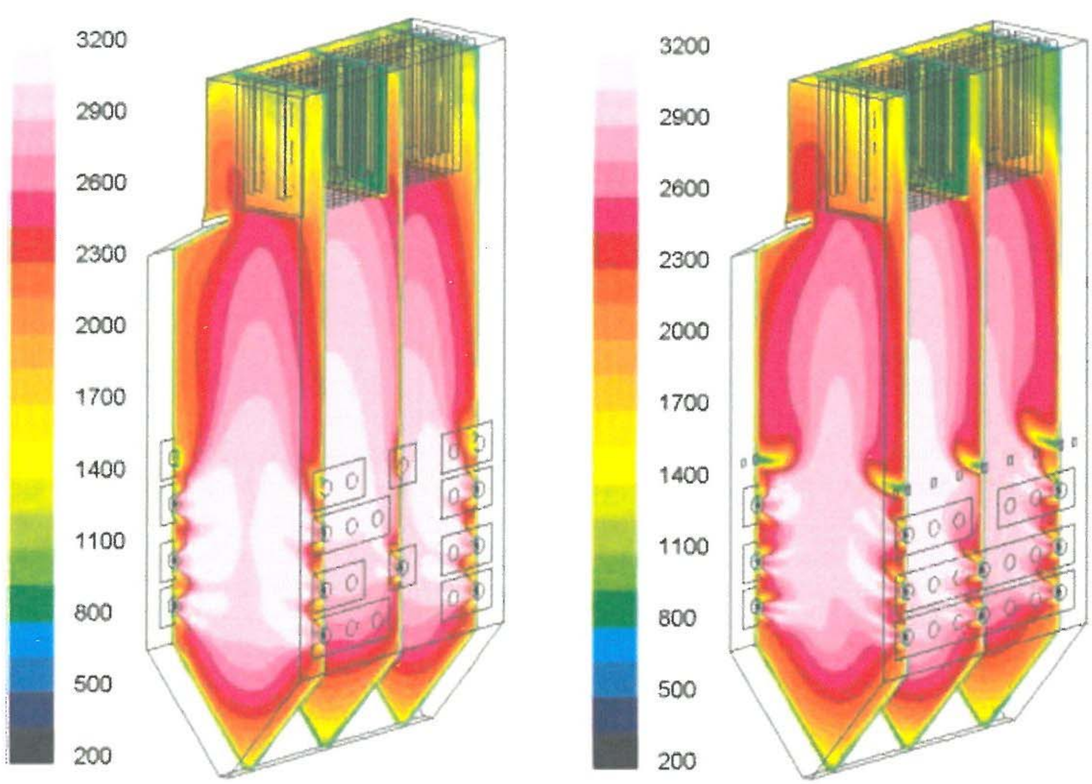

Figure 7 Computed Gas Temperatures [°F] for a) Pre-Retrofit and b) Post-Retrofit Furnaces

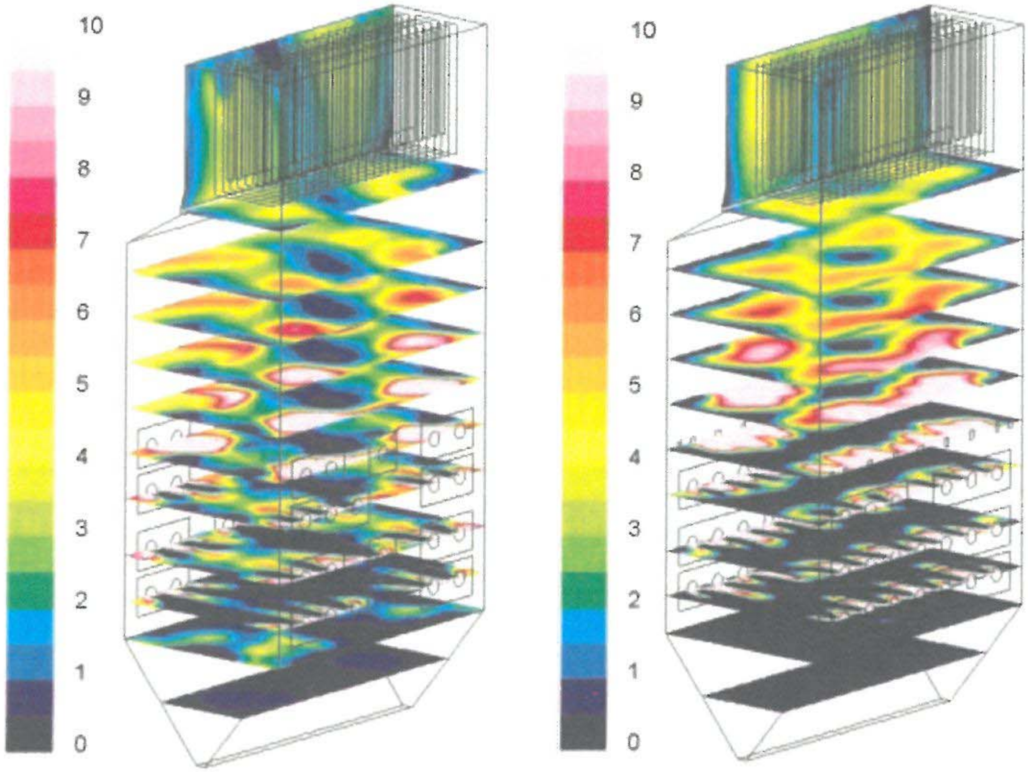

Figure 8 Computed Gas Oxygen [%] for a) Pre-Retrofit and b) Post-Retrofit Furnaces

CFD furnace modeling addressed potential problems that might surface from the burner zone air staging RPI expected was required to meet the project's NO_X reduction goal. It is well known that opposed-fired utility furnaces can suffer sidewall corrosion even without air staging, i.e. without OFA, primarily in the middle of the sidewalls at the upper burner elevations. Although sidewall wastage had not been a problem at this unit, since burner zone air staging is part of the NO_X reduction strategy, the potential for sidewall corrosion may become more severe in the post-retrofit situation, and some plan for minimizing this potential must be ready. Figures 9a and 9b display the computed sidewall heat flux for the pre- and post-retrofit furnaces, while Figures 10a and 10b display the computed gas oxygen content at the sidewalls. Figures 10a and 10b show that the historical regions of corrosion correspond to the zones of little or no oxygen on the wall coupled with the highest wall heat flux. Thus, it is clear these two factors plus high CO levels adjacent to the sidewalls increase the rate of wall wastage. Figure 9b compared to Figure 9a indicates the post-retrofit firing arrangement decreases the peak sidewall heat flux magnitude and affected area of highest heat flux while increasing the area of elevated heat flux due to the spreading out of the combustion process by the OFA. This is not sufficient to protect against potential wall wastage because a comparison of Figures 10a and 10b indicates the post-retrofit system will have no greater, and potentially lower, sidewall oxygen levels on the critical wall regions. Thus a boundary air system may be necessary if wall wastage becomes a problem.

Since this unit has membrane wall construction, two different approaches to boundary air are possible: sidewall slots (cutting the membrane away to allow air to bleed in) and small ports on the firing walls between outboard burner columns and the sidewalls. Figures 11a and 11b and Figures 12a and 12b shows the CFD-computed performance of preliminary slot and multi-port boundary air designs in terms of sidewall oxygen and CO levels, respectively. The figures indicate the port approach cannot reach all the way to the critical side-

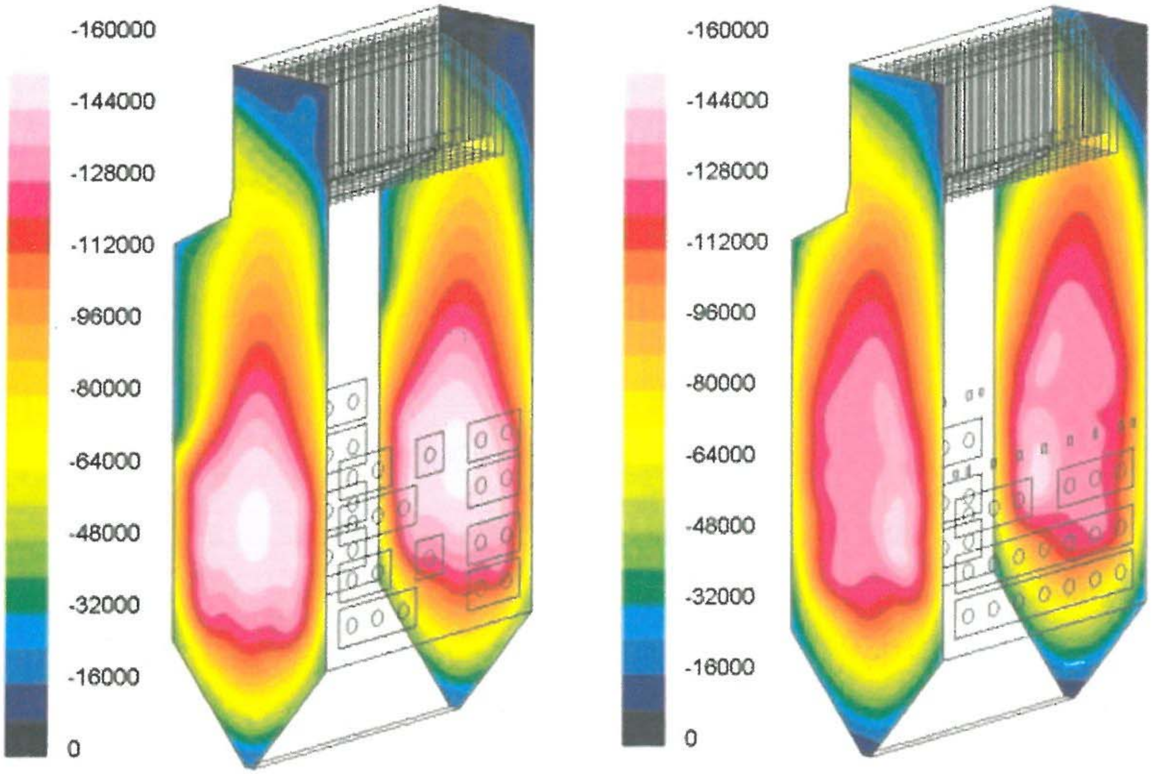

Figure 9 Sidewall Heat Flux [Btu/hr ft²] for a) Pre-Retrofit and b) Post-Retrofit Furnaces

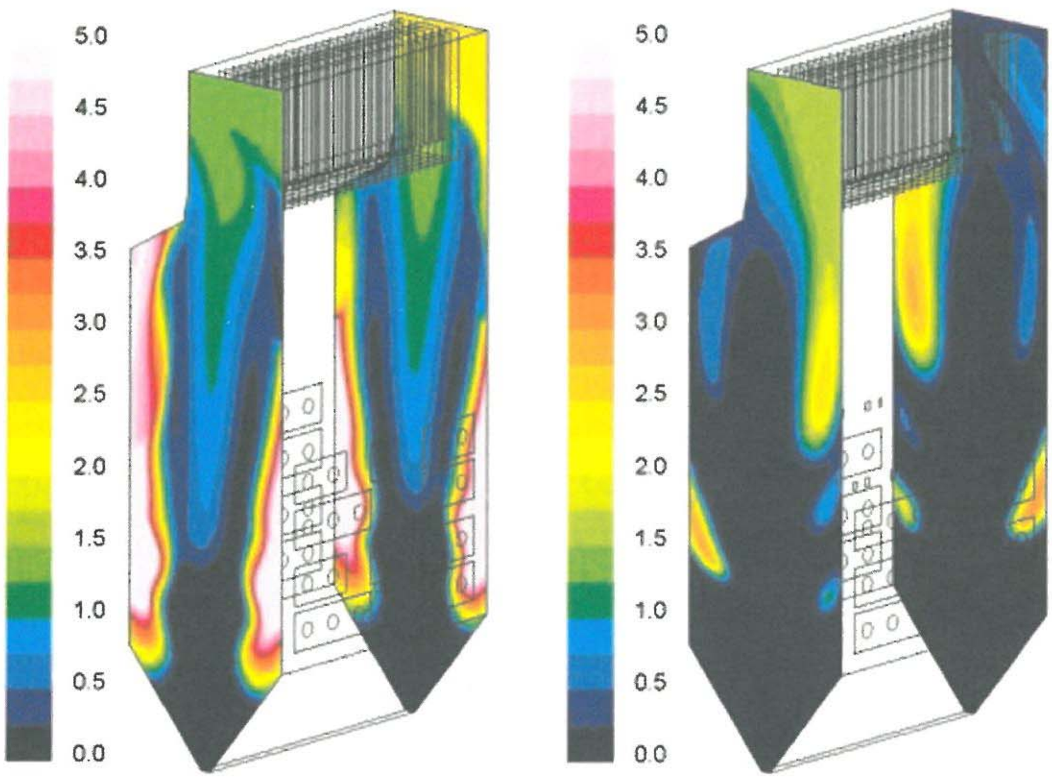

Figure 10 Computed Sidewall Oxygen [%] for a) Pre-Retrofit and b) Post-Retrofit Furnaces

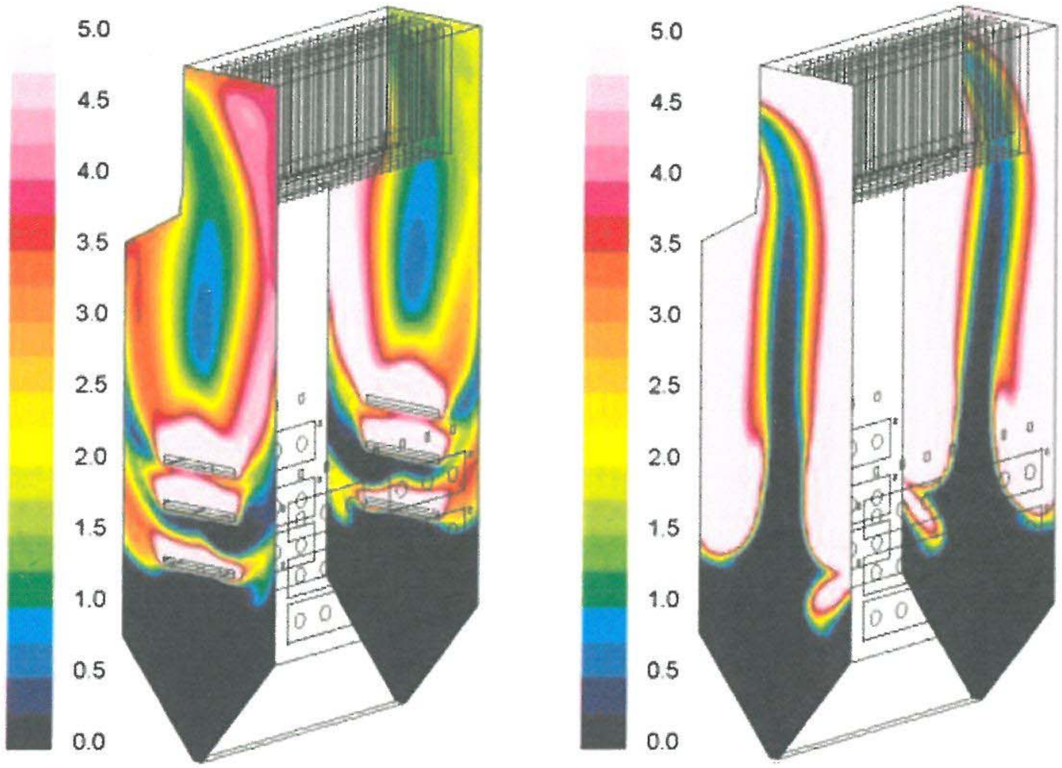

Figure 11 Post-Retrofit Sidewall O_2 for a) Slot and b) Multi-Port Boundary Air Systems

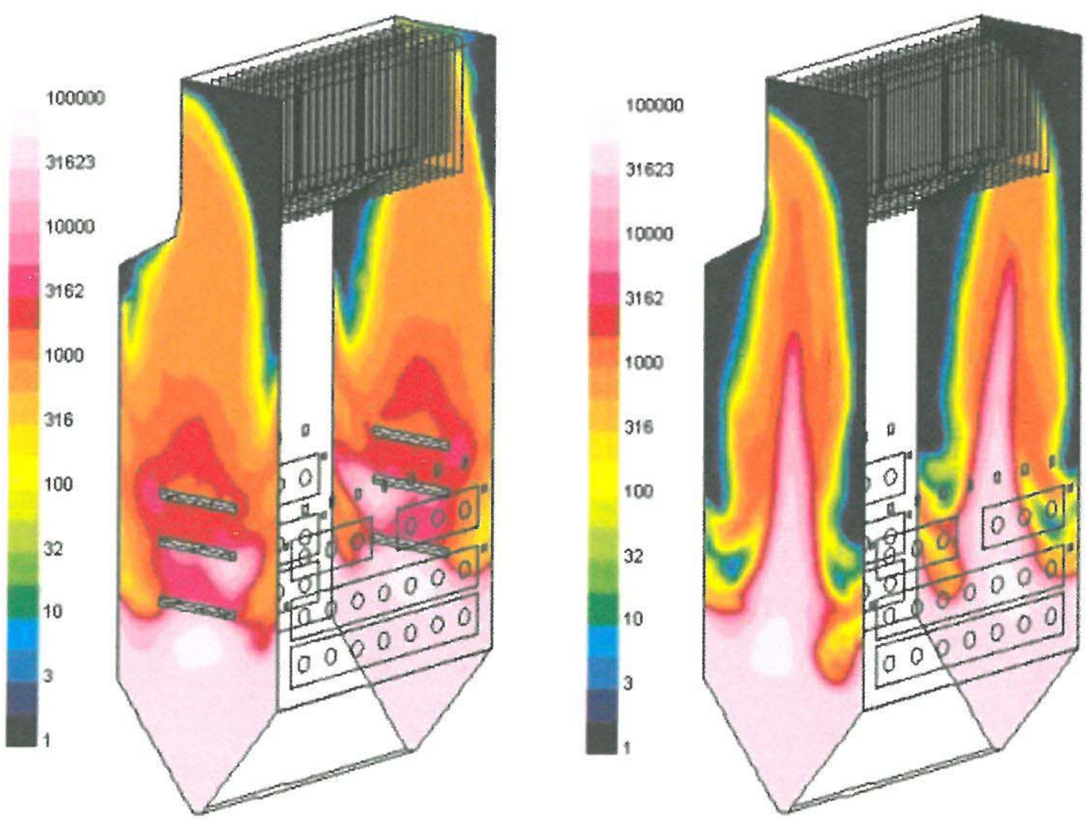

Figure 12 Post-Retrofit Sidewall CO [ppm] for a) Slot and b) Multi-Port Boundary Air Systems

wall center zone to increase oxygen or reduce CO levels. The figures suggest very strongly the slot approach can provide adequate oxygen at any and all sidewall zones of concern. This first cut at a design may be refined to give a much higher level of boundary air performance than shown in Figure 11a or possible from the multi-port approach.

Finally, CFD furnace modeling also helped control project costs. Another post-retrofit furnace model with additional "wing" OFA ports indicated this alternate OFA layout was not as effective in this unit for upper furnace oxygen mixing and distribution as originally thought. Thus the CFD modeling guided the engineering decision to discard this more complex and costly OFA layout in favor of the design in Figure 8b.

PERFORMANCE RESULTS

The low-NO_X burners and OFA were installed during a spring 2002 outage. During this period, the burners were pre-assembled on the ground and hoisted to the burner deck for installation into the windbox as a "one-piece" design, minimizing the construction effort inside the windbox. The burners were sized to fit within the existing burner throat openings, avoiding additional pressure part modifications to the boiler.

Startup and commissioning of these burners occurred in June and July 2002. Once the unit reached full load operation, coal line balancing was performed using variable orifices installed in each of the coal lines during the outage (no additional testing for coal fineness was done). Once the coal line balancing was complete, optimization testing was performed and completed over a seven day tuning period. This was facilitated by the CFD modeling, which provided starting point settings for the burner that were close to the settings finally determined at the completion of the burner tuning. Because of system load demand requirements, all post-retrofit burner optimization and performance testing was performed at 600 MWN

All performance targets were achieved with these new Dual Air Zone CCV® Burners and OFA, as shown in Table 2. This testing was performed at full load operation with seven mills in service.

Table 2 Comparison of Performance Targets and Test Results

	Pre-Retrofit Baseline	Performance Target	Performance Test
Unit Load (MW_N)	600	600	600
Overfire Air (%)	7	20	14
NO_x Emissions (lb/10^6 Btu)	0.30	< 0.185	0.158
CO Emissions (ppmdv)	10	< 100	40
Flyash Unburned Carbon (%)	0.06	< 2.0	0.09

Table 3 compares additional pre- and post-retrofit performance testing on the boiler at full load. Fossil Energy Research Corporation (FERCO) made flue gas emissions measurements and iso-kinetic flyash sampling at the economizer outlet ducts. Table 3 shows NO_X emissions were reduced by nearly 50% with the new Dual Air Zone CCV® Burners and OFA. These reductions were achieved from already low baseline NO_X levels because of first generation low NO_X burners.

Table 3 Summary of Boiler Operating Conditions

Operating Parameter	Pre-Retrofit	Post-Retrofit
Gross Generation (MW_N)	600	600
Feedwater Flow (lb/ hour)	4,308,500	4,066,000
Main Steam Temp (°F)	1,001	1,012
Main Steam Spray (lb/ hour)	0	162,000
Reheat Steam Temp (°F)	1,003	1,006
Reheat Steam Spray (lb/ hour)	78,000	31,000
Coal Flow (lb/ hour)	664,000	648,000
Total Air Flow (lb/ hour)	6,145,000	5,983,000
Average FEGT (°F)	2,337	2,315
Economizer O_2 (%)	3.10	3.10
NO_x Emissions (lb/10^6 Btu)	0.3	0.158
CO Emissions (ppmdv)	10	40
Carbon in Ash (%)	0.06	0.09
Opacity (%)	4.0	0.9

Carbon In Ash

Although CIA levels typically increase during low-NOx combustion conditions, the NOx emissions reduction achieved in this project was accomplished with minimal impact to CIA levels. PRB coals usually give a low CIA values, and the CIA levels on this unit were typically less than 0.1% with the pre-retrofit burners. Post-retrofit CIA levels during the optimization testing were also typically less than 0.1% with the new Dual Air Zone CCV® Burners and OFA.

Effect Of OFA Flow And Mills In Service

Figure 13 shows NOx emissions from the burner tuning as a function of % OFA. As expected, the NOx emissions decrease as the amount of OFA increases. With an OFA flow of 20%, average NOx emissions of around 0.155 lb/10^6 Btu and as low as 0.138 lb/10^6 Btu were achieved. The number of mills in operation also had an impact on NOx emissions. Seven mills rather than six of the total eight mills available produced lower NOx emissions. This was because the retrofit low NOx burners were sized for seven mill operation and six mill operation produced higher burner velocity, more turbulent mixing, and higher NOx.

Effect Of Excess Air

Figure 14 shows NOx emissions from the burner optimization testing as a function of excess air. Although there is significant scatter in this data, it is noted that there is only a small increase in the NOx emissions as the excess O2 level increases. Instead, the scatter is more likely associated with different burner settings and/or mill firing configurations.

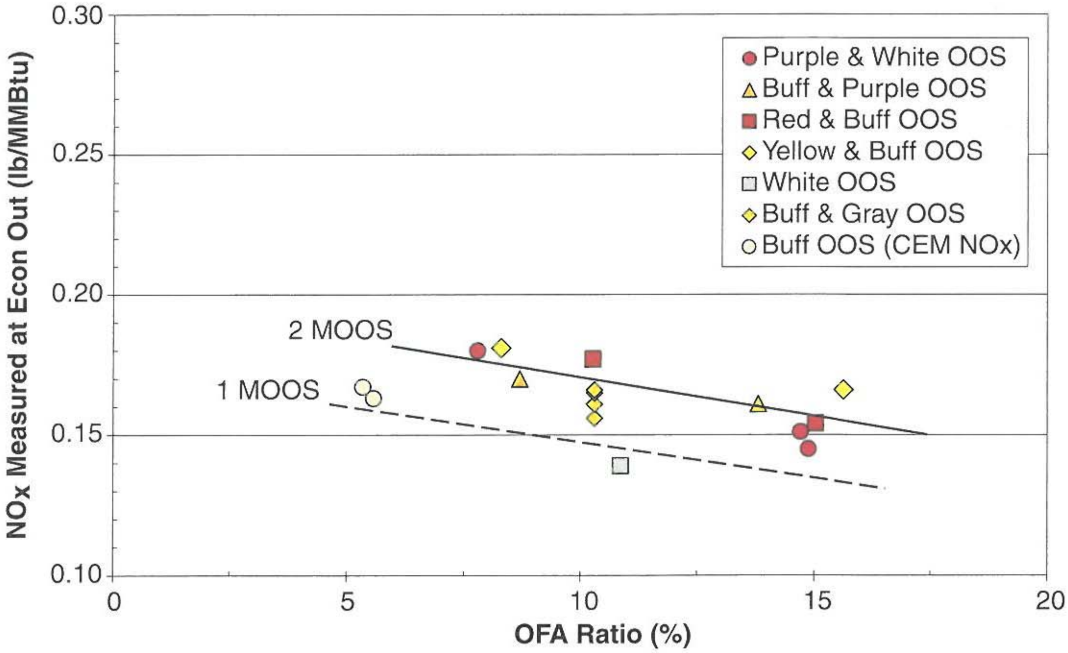

Figure 13 Effect of OFA Flow on NOx Emissions

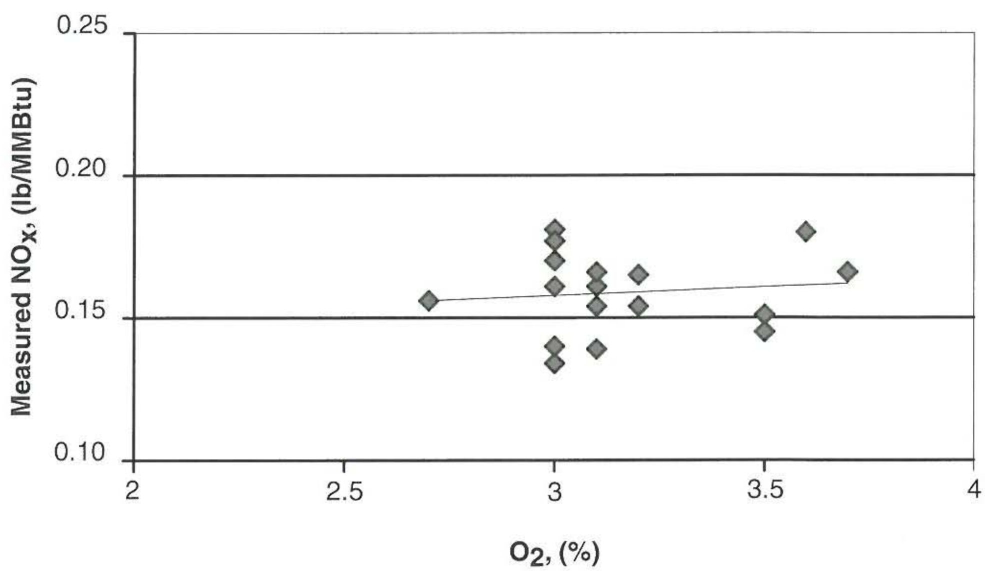

Figure 14 Effect of Excess Air on NOx Emissions

GENERAL OBSERVATIONS

Based on the experience with retrofitting this unit with new Dual Air Zone CCV® Burners and OFA, the following general observations and comments can be made:

- Balancing of primary airflow between coal lines was performed before burner optimization testing was done. This was done simply with variable orifices, which were installed in each of the coal lines during the outage. Other than this primary airflow balancing, no additional pulverizer testing, such as coal fineness, was needed.

- A slight increase in furnace exit gas temperature was noted; however, this was managed with spray attemperators and no significant change in furnace slagging between pre- and post-retrofit burner operation was experienced.
- No significant change in economizer gas temperature was measured during testing with this new low-NO_X combustion system.
- CFD modeling provided a good starting point for post-retrofit burner optimization, reducing the commissioning time of the new burners.
- These Dual Air Zone CCV® Burners even without OFA are likely to produce significant NO_X emissions reductions with a PRB sub-bituminous coal.
- The lowest NO_X emissions recorded during this testing was 0.138 lb/10^6 Btu, which are some of the lowest levels achieved in the industry using only combustion control.

CONCLUSIONS

Low-NO_X CCV® burner technology has been used for more than twenty years to reduce NO_X emissions from pulverized coal fired utility boilers. With the latest design enhancements incorporated into the low-NO_X Dual Air Zone CCV® Burner, combined with the use of an OFA system, NO_X emission levels below 0.15 lb/10^6 Btu were achieved while burning a sub-bituminous coal in an opposed-wall fired 600 MW_N utility boiler. This reduction is approximately 50% over the levels achieved with the first generation low-NO_X burners. Furthermore, these NO_X emission reductions were achieved with minimal impact to CO emissions and carbon in ash.

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