

TECHNICAL PUBLICATION

CCV® Components and Overfire Air Improve Existing First Generation Low NO_x Burner Emissions

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ABSTRACT

In 2003, Alabama Power began to implement their next increment of NO_x reduction strategy on Unit 2 of the Greene County Steam Plant. This was the second major NO_x retrofit on the unit. In 1997, the unit was modified to perform at NO_x levels of 0.45 lb/MBtu with B&W XCL Low NO_x burners. The new performance goal for this most recent phase was to lower NO_x emissions to less than 0.320 lb/MBtu over the load range with sustained CO levels less than 150 ppm.

Riley Power Inc., a Babcock Power Inc. company, was contacted by Alabama Power with a request for new burners and the addition of an overfire air system. In addition, Alabama Power requested proposals to include any additional innovative approaches, which would meet their performance goals when evaluated on life cycle costs. As such, RPI proposed a more economic solution involving fewer hardware modifications and easier installation. The solution was to modify the B&W XCL Low NO_x burners with Riley Power Inc.'s low NO_x CCV[®] burner components and to add a separated overfire air (OFA) system.

These combustion system modifications achieved NO_x emissions of 0.288 lb/MBtu at full load and below 0.320 lb/MBtu over the load range of the unit. In addition, CO levels obtained during testing were less than 150 ppm. Testing demonstrated that burner modifications alone (operating with OFA closed) resulted in a NO_x reduction exceeding 12% without any optimization. The overall approach of a components retrofit with OFA achieved a NO_x reduction of 30% at a significantly lower total cost than complete burner replacement.

INTRODUCTION

Alabama Power, a Southern Company, owns and operates the Greene County generating facility, located in Demopolis, Alabama. Unit 2 was designed by Riley Power Inc. in 1967 to generate 1,800,000 lb/hr of steam at an operating pressure of 1650 psig and temperature of 1005 °F (See Figure 1). It has a generating capacity of 270 MWg. This unit was designed to burn an eastern bituminous coal using 18 flare type pulverized coal burners. In the original configuration, three Riley Ball Tube mills supplied the pulverized coal to 18 Riley Flare Burners®. The ball tube mills were later replaced with B&W MPS 75 roller mills.

In 1997, in order to meet Clean Air Act Amendment of 1990, Alabama Power chose to install a new low NO_x combustion system. During this installation, the Flare Burners were replaced with B&W XCL Low NO_x Burners. With this initial modification, unit NO_x emissions decreased to below 0.45 lb/MBtu from an uncontrolled level of 1.2 lb/MBtu. However, the decrease in NO_x emissions resulted in higher than desired CO emissions and poor flame attachment. The unit also experienced an increase in superheat and reheat attemperator spray flows required for full load operation.

In 2003, Riley Power Inc. (RPI) was contacted by Alabama Power with a request for new burners and the addition of an overfire air system to achieve even lower NO_x emissions. RPI proposed an innovative option to achieve low NO_x emissions at lower cost. RPI developed four potential solutions for the Greene County Unit #2.

1. The first solution included installing a separated Overfire Air (OFA) system only.
2. The second possibility was replacement of the existing burners with new low NO_x CCV® Dual Air Zone burners.
3. The third option offered the best NO_x reduction. It included a complete replacement of the existing B&W XCL burners with the RPI CCV® Dual Air Zone burners and adding a separated OFA system.
4. The final option developed by RPI offered a more economic solution involving fewer hardware modifications and much easier installation. This solution involved replacing critical components within the existing B&W XCL burner with RPI CCV® burner technology and adding a separated OFA system.

Alabama Power determined that the fourth option would meet the requirements for NO_x emissions and significantly reduce the capital cost in addition to greatly simplifying the installation of the project. In April of 2003, RPI supplied new CCV® coal nozzles as well as new secondary and tertiary air diverters for retrofit to the B&W XCL low NO_x burners. In addition, a complete separated OFA system was supplied incorporating the proven RPI segmented OFA duct design with 1/3rd and 2/3rd air splits for better control over the entire load range.

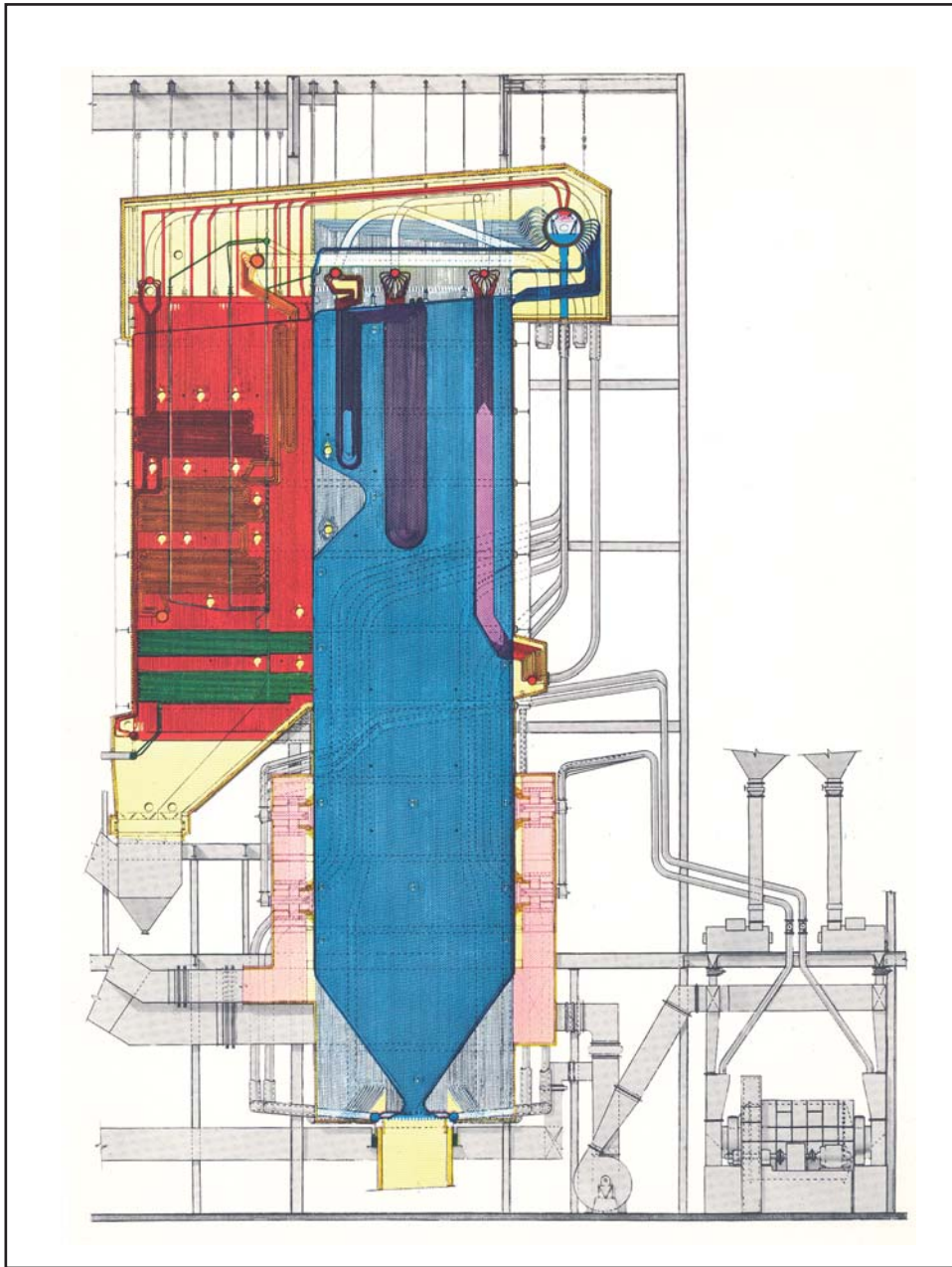


Figure 1. Greene County Unit 2

COMBUSTION SYSTEM DESIGN

RPI determined that Greene County Unit 2 was a good candidate for installing a separated overfire air system to further decrease the existing NO_x levels beyond that achievable with burner component modifications only. RPI utilizes a comprehensive set of engineering tools, design standards and experience based calculations to determine the amount and design of an OFA system (ref. 1). Among the design objectives of the new modifications to the combustion system were operability over a wide load range and optimization of the furnace conditions while reducing emissions. The design of the system for this unit incorporates one OFA port located above each burner column and four wing OFA ports located between the sidewalls and the outer most burner column. The ports are designed in a $1/3^{\text{rd}}$ and $2/3^{\text{rd}}$ air split configuration as shown in Figure 2. This configuration allows for varying amounts of OFA to be fed into the furnace depending on the unit load and the required staging levels for NO_x control. The use of different size OFA port openings allows the OFA system to maintain excellent penetration velocities that exceed the furnace exit gas velocities (Reference 1) over a wide load range.

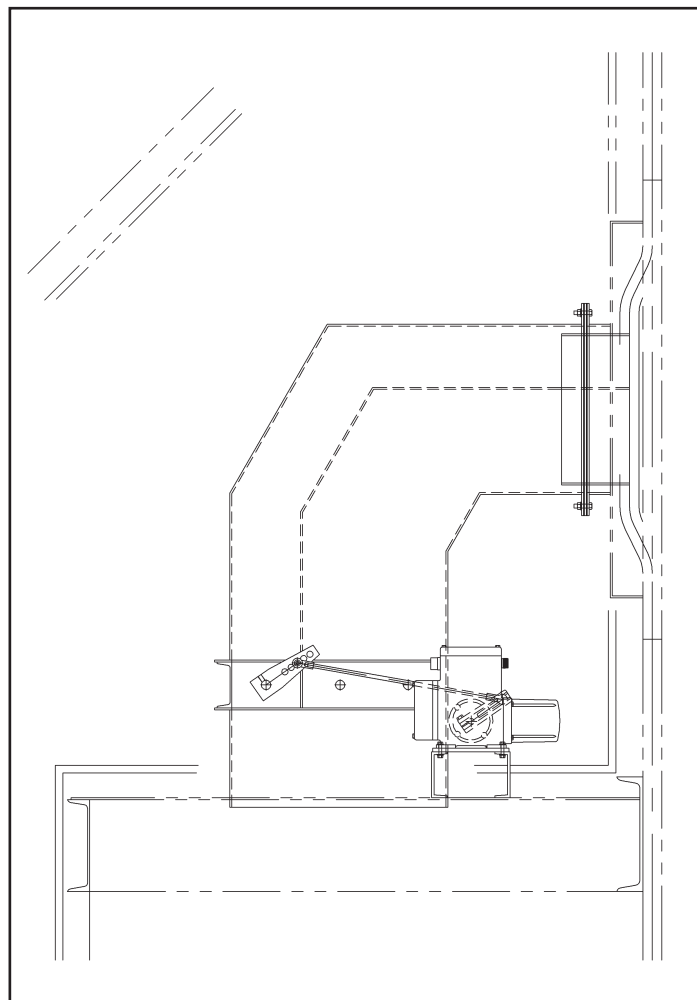


Figure 2. OFA Port & Duct Arrangement

The OFA arrangement, shown in Figure 3, allows for control of the system for various mill firing configurations. The Greene County unit was designed for a maximum OFA staging of 20%. This design reduces burner zone stoichiometry to slightly below 1.0. Dampers controlling OFA flows are ganged into sets of three with a single damper set used in the center of the unit. This is especially important in the center of the unit where the center port is located above only a single burner.

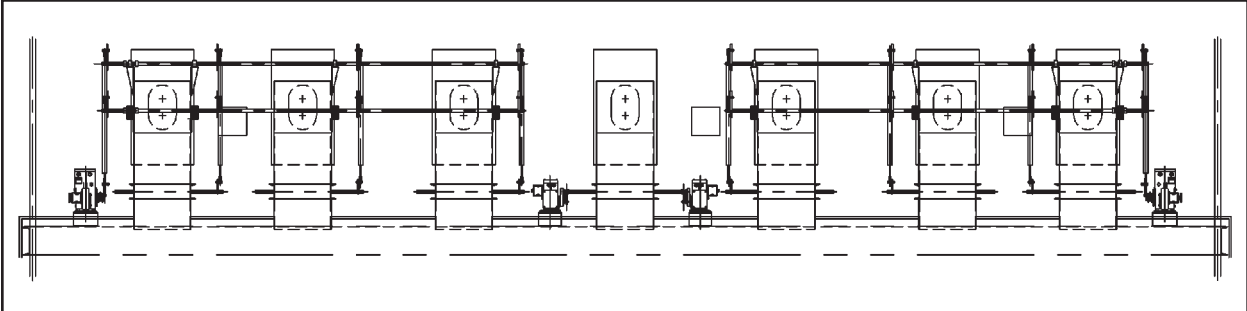


Figure 3. OFA Linkage Arrangement

Focusing now on the improvement of burner near field performance and the additional NO_x reduction required, RPI determined that retrofitting existing B&W XCL burners with CCV[®] components would significantly enhance combustion system burner performance. The replacement and additional components are highlighted in Figure 4, which shows the entire burner with only new components labeled. The patented CCV[®] (Reference 4) venturi coal nozzle, flame stabilizer ring (FSR), low swirl coal spreader, and special air diverters provide the flow improvements necessary for reducing NO_x at Greene County Unit 2. RPI has successfully applied this type of equipment retrofit on a large 1300 MWg generating facility, also with successful operational & emissions improvements (ref. 2).

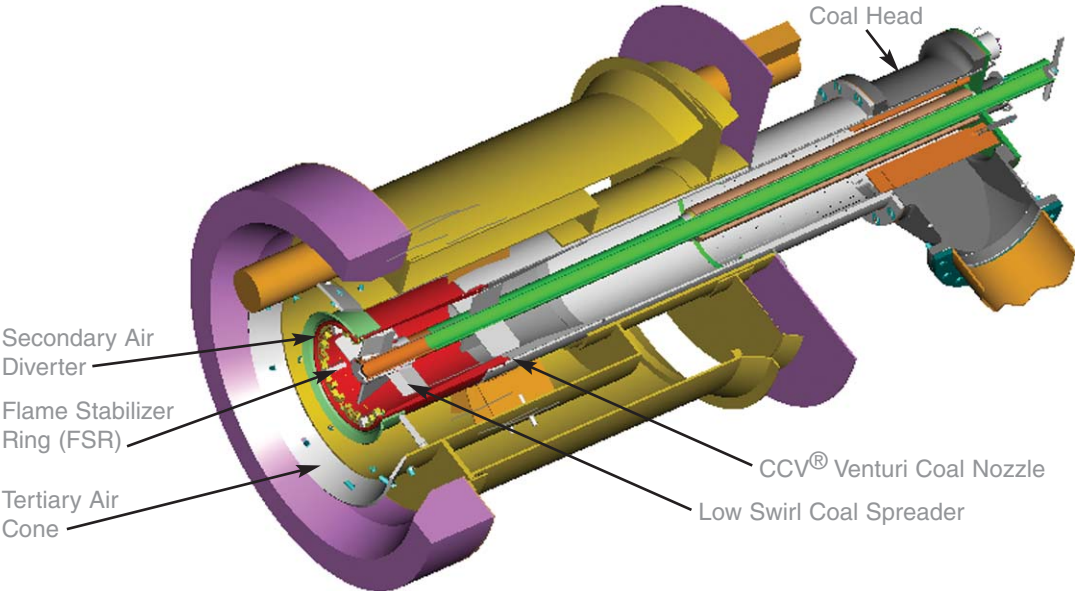
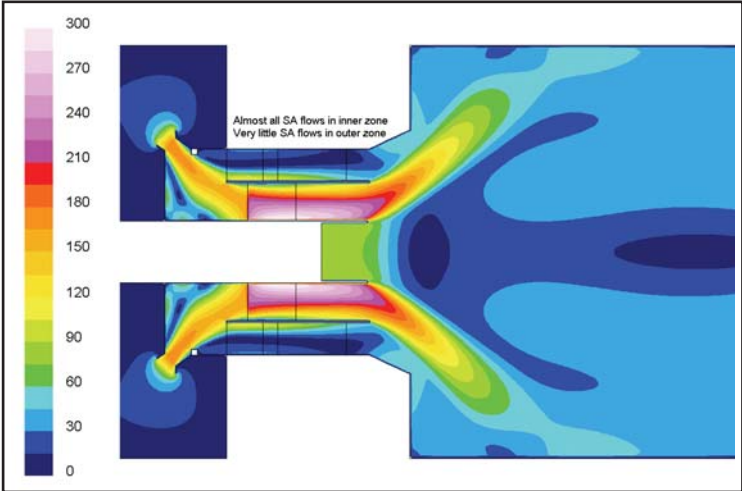
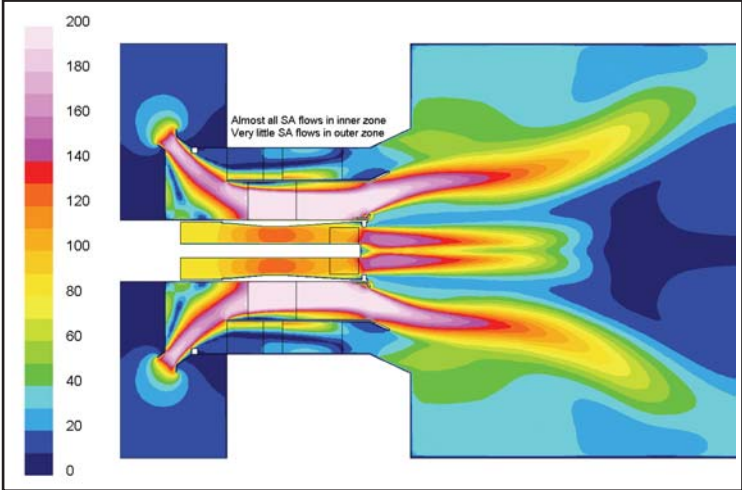


Figure 4. Existing B&W XCL Burner retrofitted with RPI CCV[®] Components for Low NO_x

Central to the economic and installation advantages developed for this combustion system improvement was the modification of an existing burner. RPI utilized its in-house Computational Fluid Dynamic (CFD) 2-D axi-symmetric flow modeling experience using FLUENT® to ensure proper sizing of the FSR and to determine the initial burner spin vane and damper settings required for full load operation. Balancing improved performance with existing hardware, there were mechanical limitations internal to the Greene County’s B&W XCL burner module, which supports the coal nozzle. While design velocities usually control coal nozzle sizing, the nozzle selected for this application was restricted to be 1" smaller than the standard RPI design for this size burner and primary airflow. Using FLUENT®, a custom designed FSR was developed to accommodate the differences in velocities and velocity ratios resulting from using a smaller coal nozzle size. The results of CFD modeling indicated the desired flow field could be obtained using existing equipment with a custom FSR design. Figure 5 shows the CFD comparison between original equipment and the new retrofitted CCV® components. Notice the improved near field flow characteristics at the burner throat.



Baseline B&W XCL Burner Airflow Patterns



Modified B&W XCL Burner with CCV® Components – Burner Airflow Patterns

Figure 5. CFD Comparison of Near Field Flow Patterns

CONSTRUCTION AND INSTALLATION

The CCV[®] components were fabricated at RPI's Erie, Pennsylvania manufacturing facility. Secondary and tertiary air diverters are constructed from high quality steel alloy. The flame stabilizer ring and coal spreaders are cast from a RPI proprietary alloy, Riloy[®] 74, which offers extended wear resistance and can operate under elevated temperatures. The CCV[®] coal nozzle assembly is constructed of high quality cast Riloy[®] 36 material and fabricated steel components. This combination gives the coal nozzle extended reliable operating life.

The contract requirements for these components include a three year wear life guarantee. The materials selection and combustion system design described above ensure this guarantee will be met by RPI. High wear components such as the coal spreader and flame stabilizer ring have the added protection of Conformaclad[®] infiltration brazed tungsten carbide which extends the wear life of the components. RPI and Conformaclad[®] have extensively tested this material on several different burner components under a multitude of fuel and velocity conditions (ref. 3).

Similarly, the OFA system is designed for extended performance. The OFA port is constructed from high quality alloy steel of various grades dependent on the radiant heat exposure of the component. These materials are able to withstand elevated temperatures in this region of the furnace when the system is not in service. Along with the ports and ducting, RPI supplied Beck rotary actuators and connecting linkages for control of the 1/3rd and 2/3rd OFA dampers.

The installation of the burner components and OFA system was the responsibility of Southern Company. Component installation was accomplished as designed except for minor warpage related modifications to the tertiary air diverter. In a few cases, some cutting of the existing outer air barrels was required to repair damaged/warped material in order to mount new components supplied by RPI. The outer barrels were repaired by replacing the last 6 inches with new material prior to attaching the tertiary air cone with straps and bolts supplied by RPI. The installation of RPI's material scope (burner components and OFA system) was accomplished easily during the scheduled 4-week outage, keeping the combustion system upgrade off of the critical path for the outage.

ECONOMIC ANALYSIS

In 2002 Alabama Power considered the addition of an OFA system to the existing low NO_x burners for further NO_x reduction. They realized, however, that low NO_x combustion systems and burner technology had made advancements since the installation at this site in 1997. Therefore, Alabama Power requested options.

RPI presented Alabama Power with four unique approaches to improving NO_x emissions on Greene County Unit 2. Each option was detailed with applicable guarantees and cost. Table 1 below outlines the four options proposed and their associated guarantees for NO_x and the normalized cost associated with each option.

Table 1
Low NO_x Options for Greene County Unit 2

	BL01 Test data	Option 1	Option 2	Option 3	Option 4
Description	2002 XCL Burners	OFA System Only	New CCV DAZ Burners	OFA and CCV DAZ Burners	OFA and Burner Modify
NOx Guarantee lb/MBtu	0.411	0.340	0.380	0.300	0.320
CO Guarantee ppm	169	200	50	100	150
UBC Guarantee % wt.	8.1	19.7	10.1	18.9	19.3
Normalized Cost	- -	0.31	0.74	1.0	0.53

Alabama Power determined that option four would meet all regulatory requirements and Southern Company's environmental strategy for reducing NO_x across the system. Option four also created a cost savings of 47% over option three, a complete low NO_x burner retrofit with separated OFA. In addition to the cost of equipment and materials, there is the cost and outage schedule associated with equipment installation to consider.

The cost of installing an OFA system on this project includes pressure part replacement of waterwall panels, requiring more than 400 tube cuts and welds. In addition, OFA ducts with individual flow control dampers were installed. Each of the installed dampers required linkage and connecting linkage to the common drives.

The cost of installing a low NO_x burner system includes a much larger scope of plant site work. Typically new burner installations require:

- Removal of all existing burner equipment
- Removal of existing burner support steel
- Installation of new support steel in the windbox
- Installation of new burners
- Potential changes to the coal piping
- Installation of new igniters and flame scanners
- Potentially new burner throats or burner openings
- New electrical wiring
- New control inputs and outputs from the DCS system
- New oil and air piping for the auxiliary burner components

The burner modification approach significantly reduced the field installation scope which was now limited to coal piping support, coal head replacement, primary coal nozzle replacement, tertiary air cone replacement and installation of the secondary air diverter. None of these modifications required burner removal or windbox modifications. All modifications were completed from the furnace or burner deck.

Although the combination of OFA and new low NO_x burners had the potential to achieve the best emissions, installing OFA and modifying the existing burners yielded a significant decrease in installation and equipment costs with resulting emissions that approach those of installing a set of new burners. Alabama Power selected the modification option as the best fit to their overall system NO_x strategy.

UNIT PERFORMANCE RESULTS

After completion of the unit outage, Alabama Power, Southern Company Services and RPI began the start-up, commissioning, tuning and testing. The unit capacity was increased quickly to full load at which time RPI began the combustion tuning process. The combustion system tuning was completed in five days with nine tests. This included full load tuning, intermediate load testing and low load testing. RPI was required to meet all guarantees at three different loads while maintaining NO_x emissions below 0.320 lb/MBtu during all loads between full and low load conditions.

The CFD modeling conducted earlier in the project had determined the initial burner settings to produce the best near field flow patterns. These settings were utilized during start-up and significantly decreased the commissioning time needed before conducting acceptance testing.

Table 2 below details the baseline and full load results for Greene County Unit 2 as performed by Southern Company Services. The results for NO_x, CO and O₂ are averaged across the economizer outlet grid. Data for unburned carbon, superheat temperature, reheat temperature, boiler load and efficiency were also collected and analyzed by Southern Company Services and submitted to RPI in a final report.

**Table 2
Full Load Performance at Greene County Unit 2**

		Full Load		
		Pre-Retrofit	Guarantee *	Post-retrofit
Test Number		BL01	–	G05
Test Date		9/12/2002	–	
Load	MWg	270	270	270
SH Spray Flow	pph	43,321	–	3,490
SH Outlet Temp	°F	997	997±10	1,000
RH Spray Flow	pph	26,568	–	25,970
RH Outlet Temp	°F	1,006	1,006±10	1,003
O ₂	% Vol. dry	4.60	–	4.65
NO _x	lb/MBtu	0.411	0.320	0.288
CO	ppm	169	150	112
UBC	%	8.1	19.3	9.5
WB to Furn dP	iwc	2.8	4.0	2.96

* - RPI Guarantees Proposed for Greene County 2 with Components and OFA

Figure 6 presents the NO_x emission levels measured for the three load points, which either met or exceeded the 0.310 to 0.320 lb/MBtu requirements depending on unit load. The levels shown indicate recorded emissions while operating with the OFA system in service. An additional data point was collected at full load with the OFA system not in operation (ports closed). This data illustrates the benefits achieved with CCV[®] components only. NO_x was reduced from 0.411 lb/MBtu to 0.360 lb/MBtu or slightly over 12% with the CCV[®] component modifications only. However, this operating condition was not optimized to achieve the minimum NO_x levels possible.

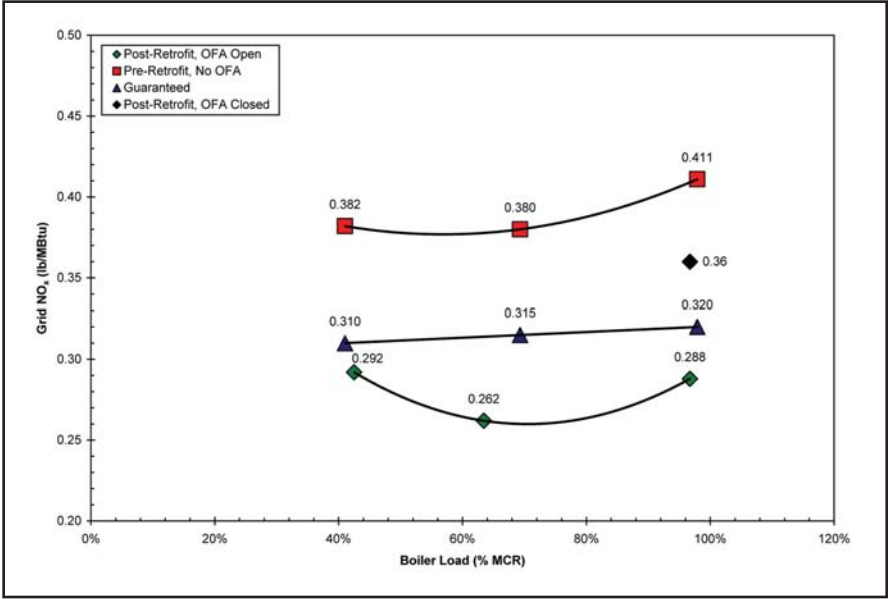


Figure 6. NO_x Emissions versus Unit Load

Figure 7 shows the CO levels achieved during testing. Post-retrofit CO levels decreased significantly, exceeding the contract requirement of 150 ppm. Achieving low CO emissions in conjunction with a separated OFA system indicates that the OFA system design has good balance and penetration across the furnace width and depth. Any CO generated in the lower furnace from staging is oxidized by the OFA.

Table 2 also summarizes the changes in superheat and reheat attemperators spray flow rates experienced during the post-retrofit testing on Unit 2. SH spray flow decreased over 90% while RH spray flow decreased about 2% from pre-retrofit conditions. This resulted from having better attached coal flames and better control of the overall combustion process. These changes indicate an improvement in the heat absorption which is more consistent with the original unit design parameters.

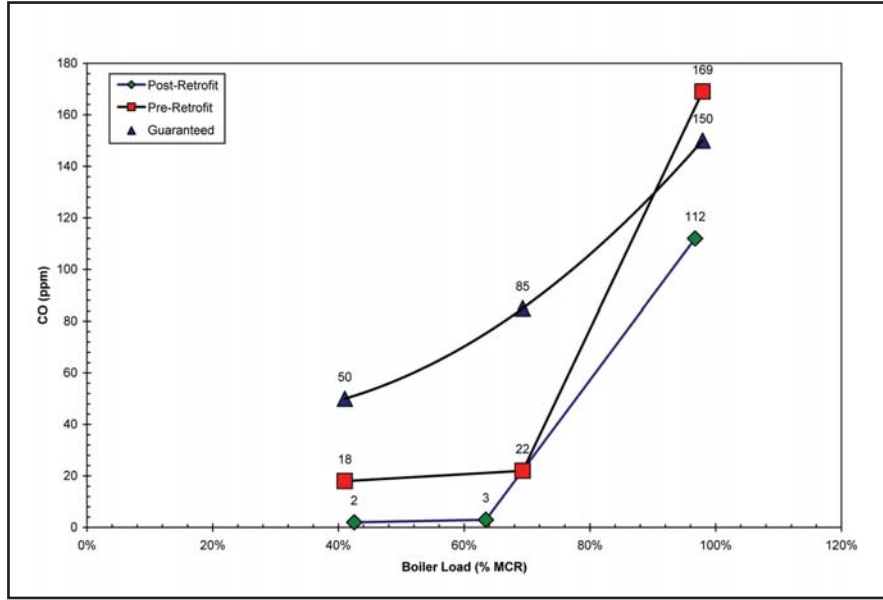


Figure 7. CO Emissions versus Unit Load

Figure 8 presents the unburned carbon results from the in-duct traverses completed by Southern Company Services during the acceptance testing on Unit 2. The samples collected represent flyash exiting the economizer. They were collected and prepared using the same isokinetic sampling approach as the baseline testing conducted on Unit 2 in May of 2002. The measured levels for all three test loads were well below the guarantee value.

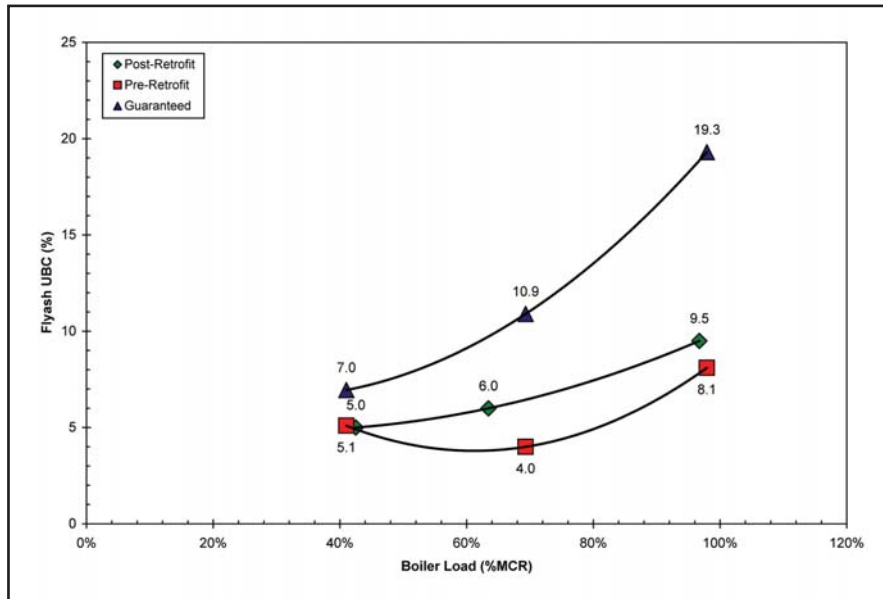


Figure 8. Unburned Carbon versus Unit Load

SUMMARY

In retrofitting Greene County unit 2, Alabama Power's emissions goals were successfully accomplished. RPI met or exceeded all contract performance guarantees. The lower cost installation of CCV® burner components to an existing B&W XCL Low NO_x burner reduced NO_x emissions over 12%. Installing the separated OFA system further decreased NO_x levels. The final unit NO_x reduction from the completed combustion system upgrades was 30% lower than pre-retrofit values at full load. In addition, the 90% reduction in superheat spray flow and the 2% reduction in reheat spray flow resulted in improved heating surface absorption.

The overriding goals for utilities operating fleets of coal fired power plants are the simultaneous achievement of reliable generation, environmental compliance, and lowest life cycle cost. In today's competitive market, it is important for utility companies and suppliers alike to seek and apply reliable, technology based solutions for achieving all of these goals at lower cost levels. Significant savings in cost and outage duration can be achieved by evaluating and applying unique combinations of technologies available from a supplier. RPI's solution combined experience, knowledge and technology to provide the best cost-effective low NO_x system for Alabama Power, Greene County Unit 2.

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