Technical Publication

DB Riley Successfully Retrofits 4500 MW of Utility Coal Fired Generating Capacity with Low NO_x CCV® Burner Technology in 1998

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ABSTRACT

Since the promulgation of the Phase I Clean Air Act Amendment (CAAA) in 1990, DB Riley, Inc. has sold over 1500 Controlled Combustion Venturi (CCV®) burners for reducing NO_x emissions on pulverized coal fired utility boilers. Using a combination of various combustion control technologies, NO_x reductions of 50 - 70% from uncontrolled levels have been demonstrated for most utility boilers ranging in size from 50 to 1300 MWn in electrical generating capacity. DB Riley's recent experience shows that NO_x reductions of this magnitude can be achieved with burners only, in furnaces with different firing configurations.

In 1998 alone, DB Riley retrofitted seven utility boilers with a total of 356 low NO_x CCV® burners. These units burn a variety of different coals and range in size from 165 to 1300 MWn. The larger utility boilers are equipped with cell fired burners while the smaller units utilize more traditional single circular coal burners. The low NO_x CCV® burner technology installed consisted of a variety of different designs including CCV® single register, CCV® cell and CCV® dual air zone burners.

All burners were designed and supplied to be a "plug into the existing waterwall openings" type and without an overfire air (OFA) system to preclude pressure part modifications. The utilities specified that all burner systems must achieve low NO_x emissions without the use of any OFA or other combustion related NO_x control system. The absence of OFA minimizes the potential for lower furnace corrosion particularly on supercritical units, some of which are discussed in this paper.

Pre-retrofit baseline NO_x levels on these seven utility boilers ranged from 1.0 to 1.6 lb / MMBtu while post-retrofit NO_x emission levels ranged from 0.40 to 0.70 lb / MMBtu. This represents a 50 – 65% reduction in NOx from uncontrolled levels using the "burners only" technology. This paper describes the results of these seven low NO_x burner retrofit projects.

INTRODUCTION

DB Riley has been using Controlled Combustion Venturi (CCV®) burners for reducing NO_x emissions from pulverized coal fired utility boilers for many years, and since 1990, over 1500 CCV® burners have been sold. The CCV® technology has developed into a "family" of low NO_x burners such as CCV® single register, CCV® dual air zone and CCV® cell burner designs. This wide range of designs allows the flexibility and the opportunity to customize the selection that best meets the requirements, preference and overall objectives of a particular project.

As a part of a continuing effort to comply with the Clean Air Act, DB Riley retrofitted, in 1998 alone, a total of seven coal fired utility boilers with low NO_x CCV® burner technology. These utility boilers burn a variety of different coals and produce from 165 – 1300 MWn of electrical generating capacity. A total of 356 low NO_x burners were designed, installed and commissioned within a one-year period. Various CCV® burner designs were utilized in these low NO_x retrofit projects including single register, cell and dual air zone burner configurations.

The heart of the CCV® burner technology, common to all of these burners, consists of a patented venturi coal nozzle and low swirl coal spreader (Patent No. 4,479,442) developed, tested and marketed by DB Riley in the early 1980's.[1] DB Riley has used this technology in all of its low NO_x burner retrofit projects since that time. This technology has also been applied to non-DB Riley burners to improve overall performance and reduce NO_x emissions.

DB Riley's low NO_x CCV® burner technology is unique to the industry. DB Riley is the only manufacturer in the world to offer a low NO_x single register burner (SRB), with a proven track record in the industry, in various firing configurations. A few years ago, DB Riley expanded its CCV® burner technology to include a dual air zone burner to provide additional control flexibility for reducing NO_x emissions.[2] Two of the utility units converted in 1998 were retrofitted with the CCV® dual air zone burners. These first two commercial installations, have once again validated the performance of the CCV® technology.

REVIEW OF CCV® BURNER TECHNOLOGY

Figure 1 shows schematic drawings of the three low NO_x coal burner designs used by DB Riley in the "family" of CCV® burners. The patented venturi coal nozzle, low swirl coal spreader and secondary air diverter in all of these designs produces a fuel rich flame core, the fundamental condition necessary for minimizing the formation of both fuel and thermal NO_x.[1]

For single register and cell burner applications, the main combustion air side of the CCV® burner is similar. Secondary air initially passes through the air register, which imparts swirl, and then through the burner barrel and over the secondary air diverter. Secondary air is diverted away from the primary combustion zone, which reinforces the fuel rich flame core produced by the venturi nozzle for further control of NO_x emissions.

Secondary air flow is controlled by a movable shroud surrounding the air register independent of the spin vane control. Secondary air flow is accurately measured using individual burner air flow measurement (IBAM™) probes supplied by Air Monitor Corporation.[3]

The CCV® dual air zone burner also utilizes the low NO_x venturi coal nozzle, burner air shrouds and IBAM™ probes. However, the main combustion air side of the burner is further divided into secondary and tertiary air passages, each containing swirl vanes for spin control and burner shrouds and dampers for independent control of the air flow to each passage. The divided burner throat provides greater control of the stoichiometry at the burner

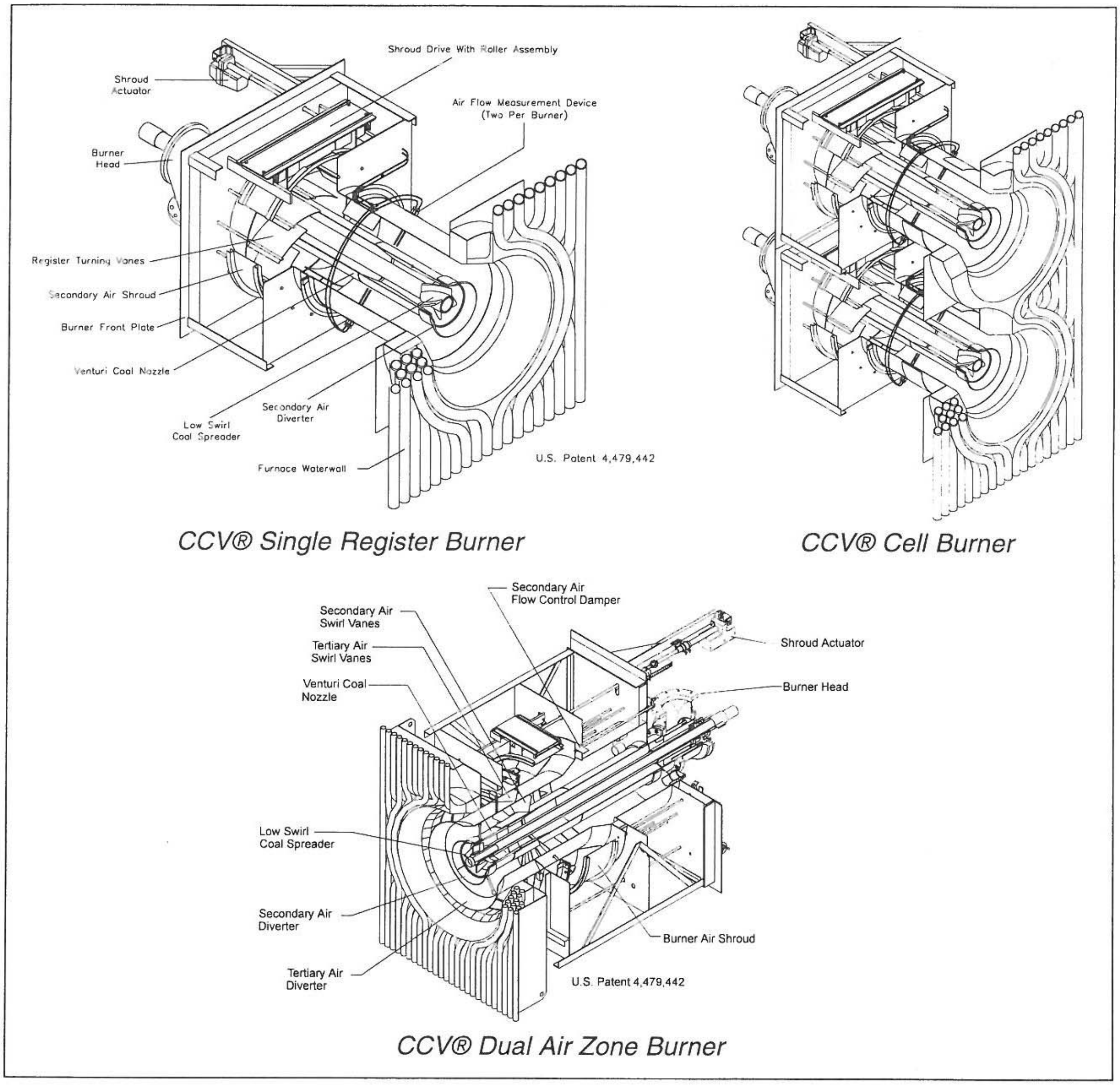


Figure 1 DB Riley Low-NO_X CCV® Burners

discharge for additional flexibility in the control of NO_X emissions, if needed. The following sections discuss the results of using all three low NO_X burner designs in retrofit applications.

IMPLEMENTATION OF LOW NO_X RETROFIT PROJECTS

In the spring and fall of 1998, DB Riley installed a total of 356 low NO_X CCV® burners in seven utility boilers. The burners were typically installed during a six or eight week outage. In some cases, the burners were pre-assembled on the ground, hoisted to the burner decks, and then positioned into the windboxes as a "one-piece" design. This minimized the construction effort inside the windboxes. Following the burner installation, each unit was started and commissioned in a relatively short time period. Optimization testing commenced after the units could sustain full load operation. The optimization testing efforts extended from one week to three months depending on unit operation and availability.

RESULTS OF CCV® SINGLE REGISTER BURNER RETROFITS

DB Riley retrofitted American Electric Power's (AEP) Big Sandy Unit 1 with low NO_x CCV® single register burners. As shown in Figure 2, this B&W boiler is an opposed fired design with eighteen burners and produces 260 MWn of nominal generating capacity. Twelve burners were installed on the front wall and six burners were installed on the rear wall. The individual burner capacity at full load is 130 MMBtu/hr heat input. The unit is equipped with six B&W EL mills and typically operates at full load with all mills in service. Variables evaluated during the optimization testing included register vane setting, coal spreader position, number of mills in service, boiler load, excess air, and air flow balance to the burners. The coal burned was from the Kanawha Valley region.

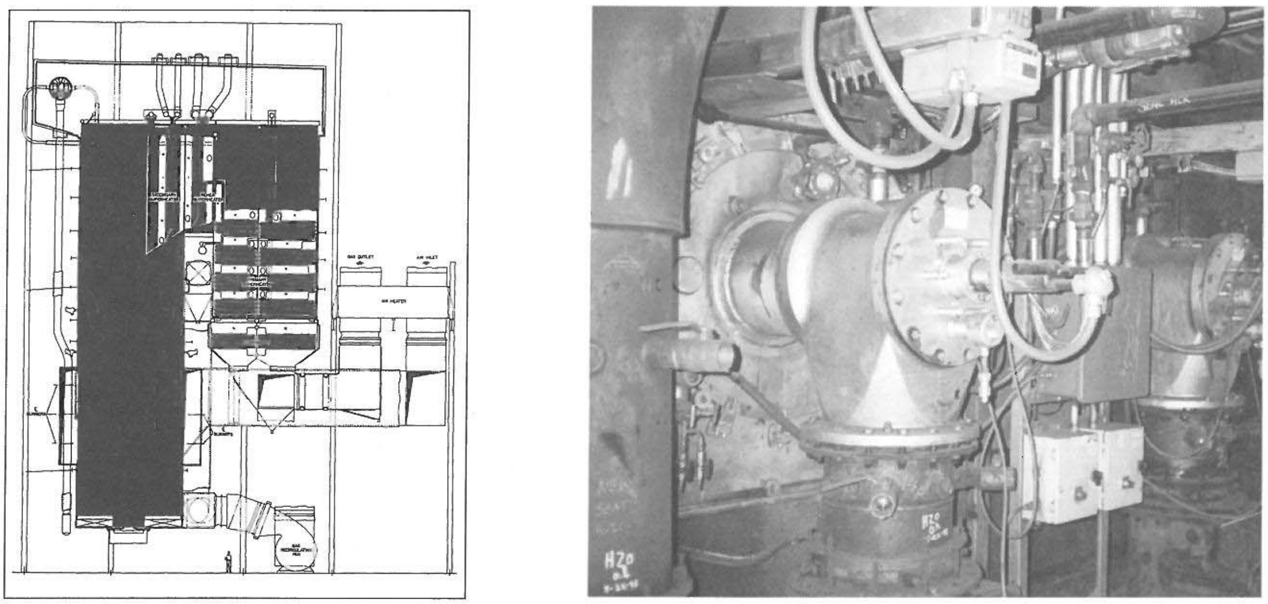


Figure 2 (Left) AEP Big Sandy Unit 1 Boiler Schematic, (Right) Burner Deck

Table I compares the results of post retrofit performance with pre-retrofit operating conditions for the final full load optimized settings. NO_x was effectively reduced by 59% from uncontrolled levels.

CO emissions were negligible and unburned carbon (UBC) in the flyash remained essentially unchanged from pre-retrofit values. No special efforts were made to optimize the mill operation.

Table I Pre- and Post-Retrofit Results for CCV® SRB Burners at AEP Big Sandy Unit 1 – Full Load

Parameter	Pre-retrofit	Post-retrofit	% NO_x reduction
NO_x, lb/MMBtu	0.98	0.42	57
UBC, %	5	5.1	
Excess air, %	20	19	
W/F dp, "wg	3	4	

Figure 3 shows NO_X emissions measured as a function of unit load for all of the optimization tests. Significant data scatter is evident at full load due to non-optimized conditions. NO_X decreases only slightly with boiler load because of increasing excess air with decreasing load.

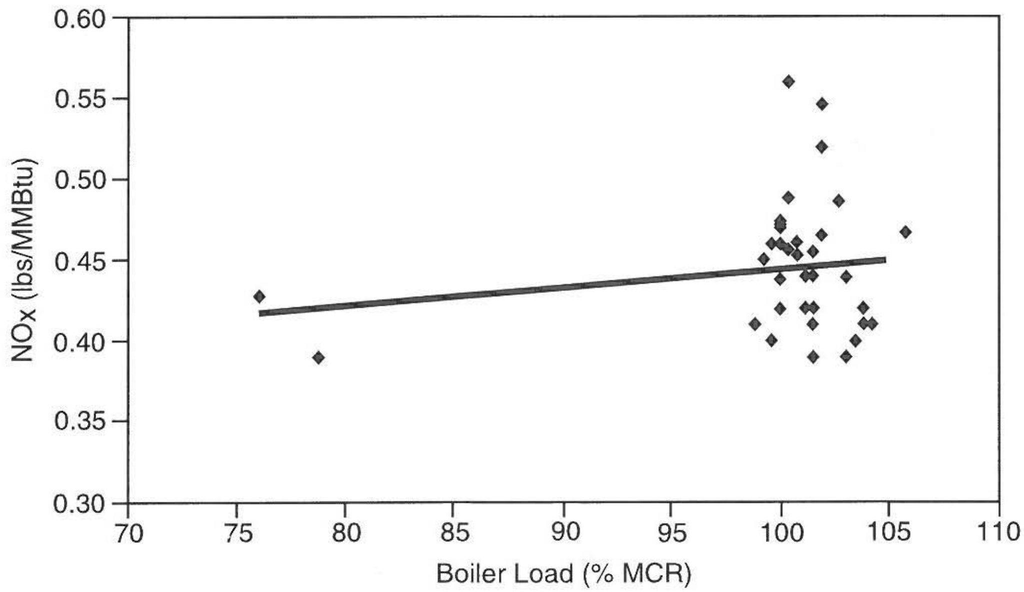


Figure 3 The Effect of Boiler Load on NO_X at AEP Big Sandy Unit 1

RESULTS OF CCV® CELL BURNER RETROFITS

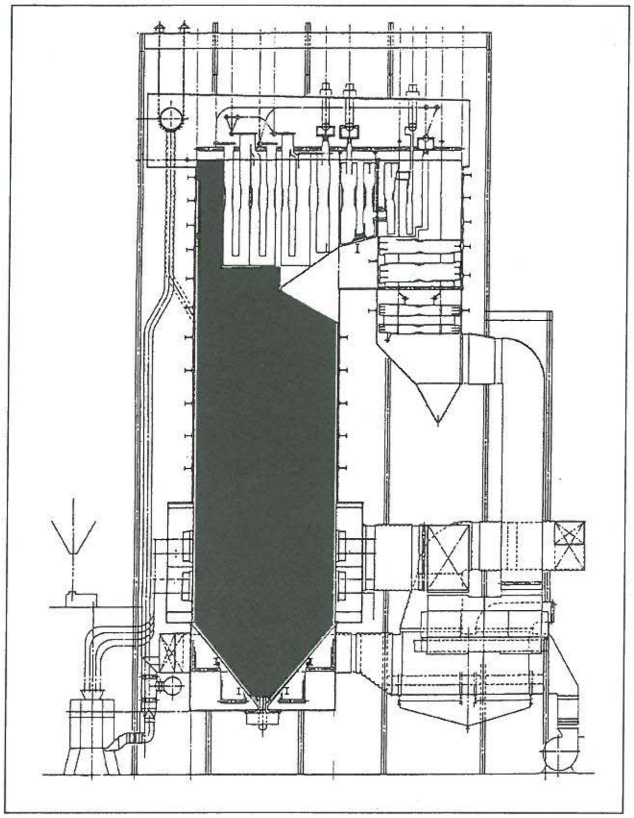
Cell fired boilers are the most challenging for reducing NO_X emissions. They typically exhibit extremely high heat release rates in the burner zone resulting in high levels of NO_X emissions. As such, the EPA has established a NO_X emission limit of 0.68 lb/MMBtu on these boiler designs considerably more than the levels targeted for traditional wall fired boilers.

In 1998, four large B&W cell fired utility boilers were retrofitted with DB Riley CCV® cell burner technology. They were Cinergy Miami Fort Unit 7, American Electric Power (AEP) Cardinal Unit 1, AEP Gavin Unit 1, and AEP Amos Unit 3. These units ranged in size from 525 to 1300 MWn.

Cinergy Miami Fort Unit 7, a 525 MWn boiler, was retrofitted with forty CCV® burners arranged in a cell configuration with twenty burners installed on each of the front and rear walls. Pulverized coal is delivered to the burners from five B&W MPS 89 mills. Figure 4 shows a schematic of this cell fired boiler design. Each burner was designed for a full load capacity of 124 MMBtu/hr.

The project required performance to be achieved over a wide range of coals, nearly 100 different sources. The optimization testing was performed on a coal supplied by the Cumberland River Coal Mine. Based on the performance demonstrated during and after the optimization testing, the specification requirement for acceptance testing on this project was waived by Cinergy.

Table II compares the results of pre and post retrofit performance measured at full load with all five mills in service. NO_X emissions were reduced by 52% while CO emissions and flyash UBC were comparable to pre-retrofit levels.



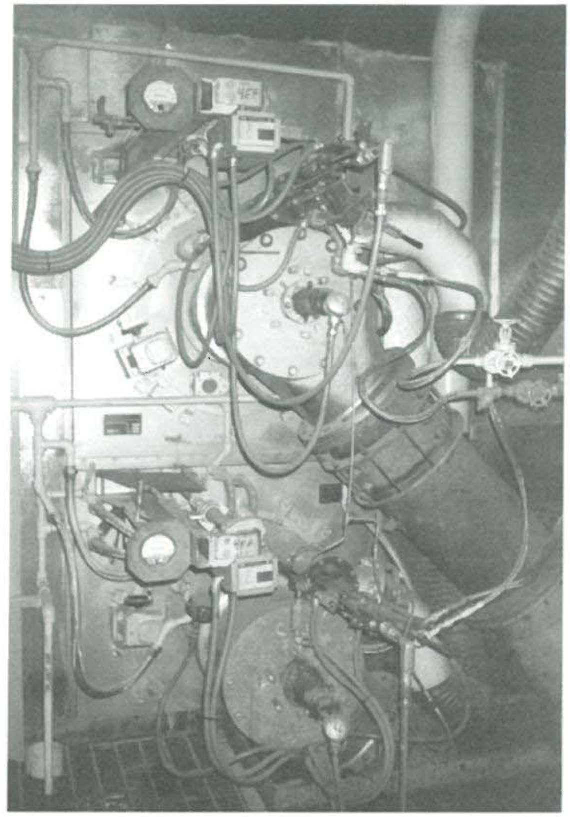


Figure 4 (Left) Cinergy Miami Fort Unit 7 Boiler Schematic (Right) Burner Deck

Table II Pre- and Post-Retrofit Results for CCV® Cell Burners at Cinergy Miami Fort Unit 7 — Full Load

Parameter	Pre-retrofit	Post-retrofit	% NO_X reduction
NO_X, lb/MMBtu	1.10	0.53	52
CO, ppm	37	< 25	
UBC, %	2 - 3	2.8	
Excess Air, %	22	22	
W/F dp, " wg	2.5	3.2	

Figure 5 shows the effect of excess air on NO_X emissions. As expected, NO_X decreases linearly with decreasing excess air. The correlation shows very little data scatter. Figure 6 shows an example of how the burner shroud positioning controls the measured secondary air flow to the upper cell burners on the rear wall. Figure 6 also shows the corresponding NO_X, O2, and CO emissions profiles measured at the economizer outlet duct. The burner shrouds were very effective for producing uniform profiles as measured across the unit, left to right.

AEP Cardinal Unit 1 was retrofitted with fifty low NO_X CCV® cell burners. This unit, rated at 600 MWn, is very similar to AEP's Muskingum River Unit 5 which was retrofitted in 1993 with DB Riley low NO_X CCV® cell burner technology.[4] Muskingum River Unit 5 was the first cell fired unit retrofitted with low NO_X burners using "plug in" low NO_X burners only, i.e., the original cell fired configuration was maintained. The demonstrated NOx performance on this unit, combined with extrapolations for the larger 1300 MWn units, was the basis for the current EPA NOx limits for cell fired boilers.

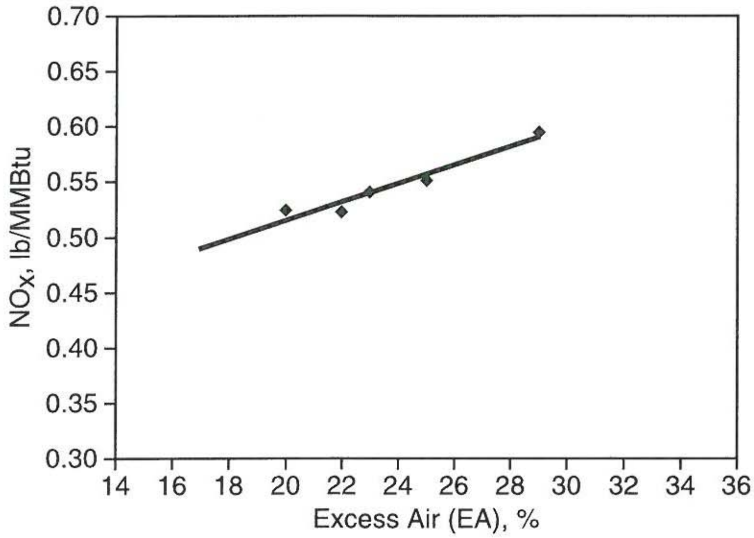


Figure 5 The Effect of Excess Air on NOx at Miami Fort Unit 7

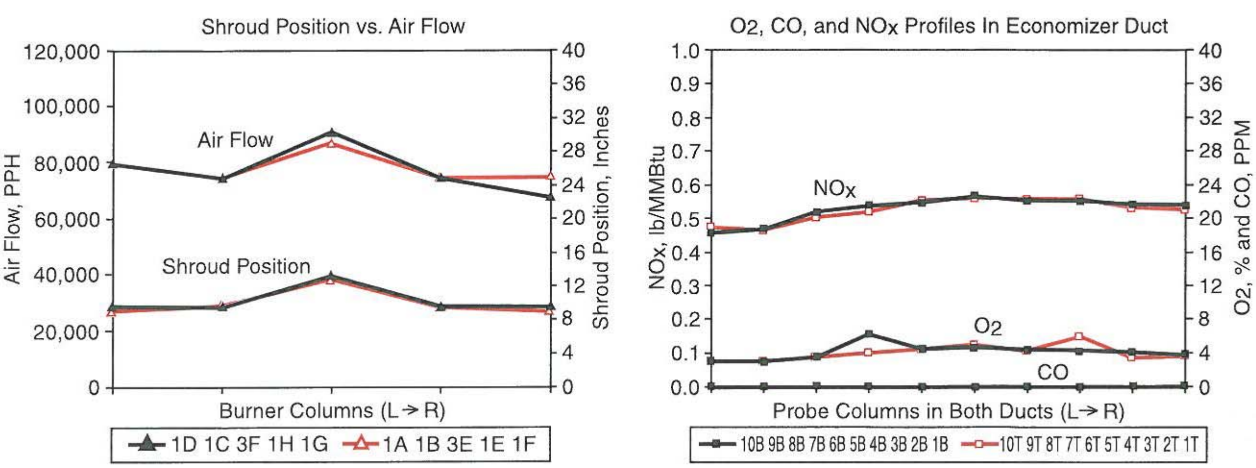


Figure 6 Burner Air Distribution and Backend NOx, O2, and CO Profiles Measured at Cinergy Miami Fort Unit 7

As shown in Figure 7, Cardinal Unit 1 is equipped with twenty cell burners in the lower portion of the furnace and ten standard circular burners installed above the cell burners. Pulverized coal is delivered to the burners from five B&W MPS 89 mills.

Table III compares the pre- and post-retrofit performance results measured at full load with all five mills in operation. The low NOx burners reduced NOx by 53% from uncontrolled levels while the CO emissions and flyash UBC were 20 ppm and < 2%, respectively.

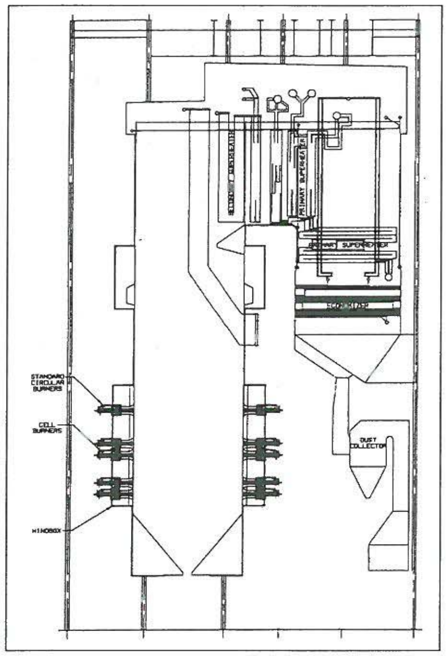


Figure 7 AEP Cardinal Unit 1 Boiler Schematic

Table III Pre- and Post-Retrofit Results for CCV® Cell Burners at AEP Cardinal Unit 1 — Full Load

Parameter	Pre-retrofit	Post-retrofit	% NO_x reduction
NO_x, lb/MMBtu	1.20	0.57	53
UBC, %	–	2	
Excess Air, %	20	22	
W/F dp, "wg	4	6	

Figure 8 shows the effect of excess air and boiler load on NO_x emissions with all burners and mills in service. The excess air at 92% load was 23-24%. The burner shrouds were used to balance the O_2 profile measured at the economizer outlet grid to be within ± 1.0%. Future testing on the next unit to be retrofitted, (Cardinal Unit 2), will concentrate on balancing this O_2 profile to be within ± .5% in an effort to produce even lower NO_x emissions and lower flyash UBC.

CCV® cell burners were also retrofitted on AEP's Gavin Unit 1 and Amos Unit 3, both 1300 MWn supercritical boiler designs. Figure 9 shows a boiler schematic of these units. Gavin Unit 1 is equipped with 112 while Amos Unit 3 is equipped with 96 CCV® Cell burners. Individual burner capacities at full load are 126 MMBtu/hr. and 135MMBtu/hr., respectively.

These 1300 MWn units are the largest coal fired boilers equipped with low NOx burners and, as indicated earlier, exhibit the highest heat release rates the industry has ever experienced. The units are 111' wide x 51' deep and both fire coal from the Ohio and Kanawha river valleys. A total of fourteen MPS 89 mills are installed on Gavin Unit 1, while Amos Unit 3 is equipped with twelve MPS 89 mills. Both units typically operate at full load (1360 MWg) with one to three mills out of service.

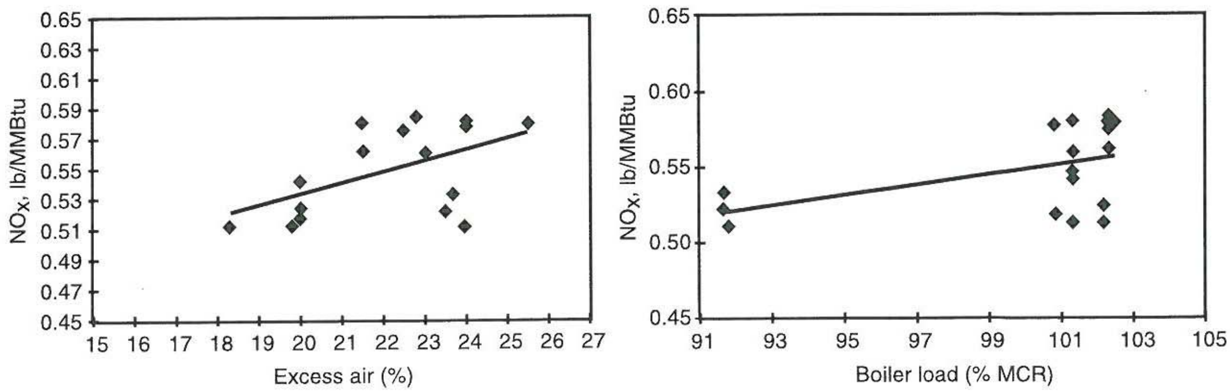


Figure 8 The Effect of Excess Air and Boiler Load on NO_X at AEP Cardinal Unit 1

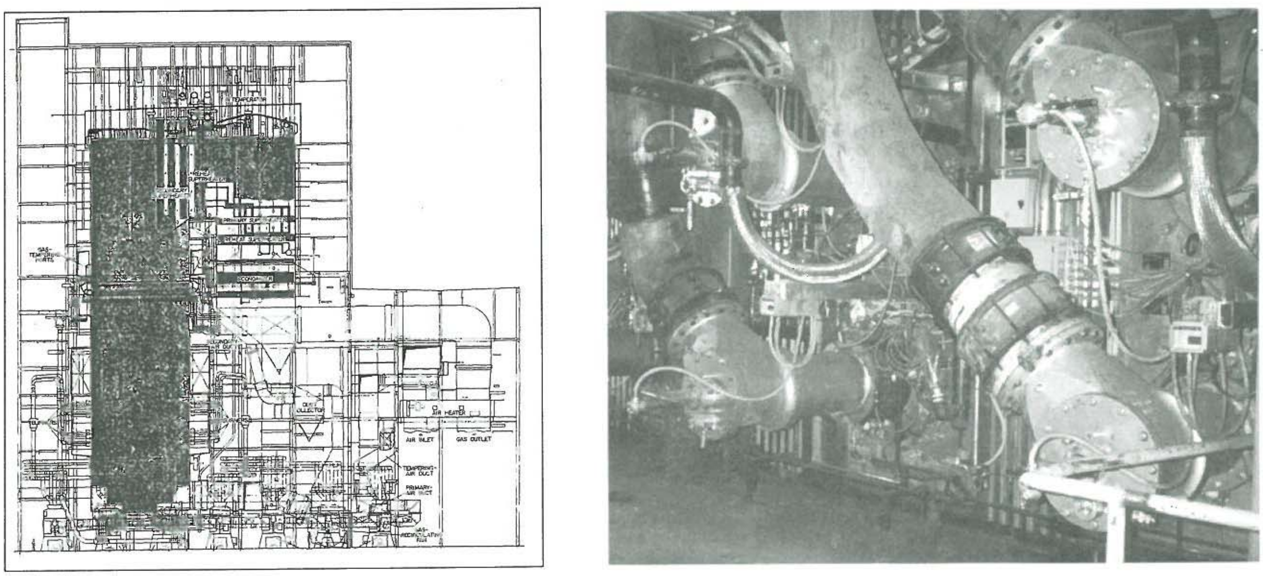


Figure 9 (Left) AEP Gavin Unit 1 and Amos Unit 3 Boiler Schematic (Right) Burner Deck

Table IV compares the results of pre- and post-retrofit performance measured at full load on Gavin Unit 1 with 11 out of 14 mills in operation. All idle or out of service burner shrouds were fully closed during this testing to minimize air leakage. The low NO_X burners reduced NO_X emissions on Gavin Unit 1 by 61% from uncontrolled levels while the CO emissions were negligible and the flyash UBC averaged 1 – 2%.

Table IV Pre- and Post-Retrofit Results for CCV® Cell Burners at AEP Gavin Unit 1 — Full Load

Parameter	Pre-retrofit	Post-retrofit	% NO_X reduction
NO_X, lb/MMBtu	1.35	0.53	61
UBC, %	< 2	1 - 2	
Excess Air, %	18	18	
W/F dp, "wg	1.75	3.0	

Figure 10 shows the effect of boiler load on NO_x at Gavin Unit 1. The first graph was produced from data collected during the optimization testing. The second graph shows the effect of load based on a 50 point rolling average over four months of operation. This type of operation includes several mills in and out of service throughout the load range. Note the similarity in NO_x performance comparing "optimized conditions" with "day to day" type of operation. As shown in Figure 11, excess air had only a minor impact on NO_x emissions at Gavin Unit 1.

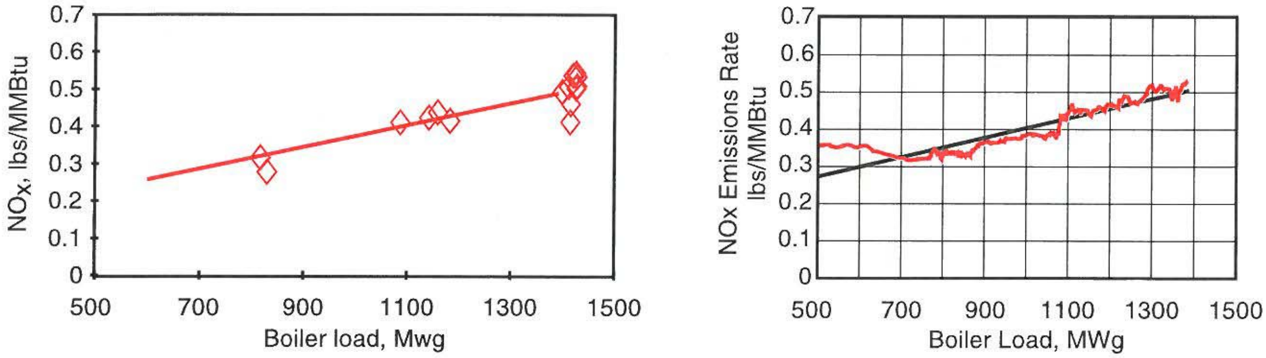


Figure 10 The Effect of Boiler Load on NO_x at AEP Gavin Unit 1

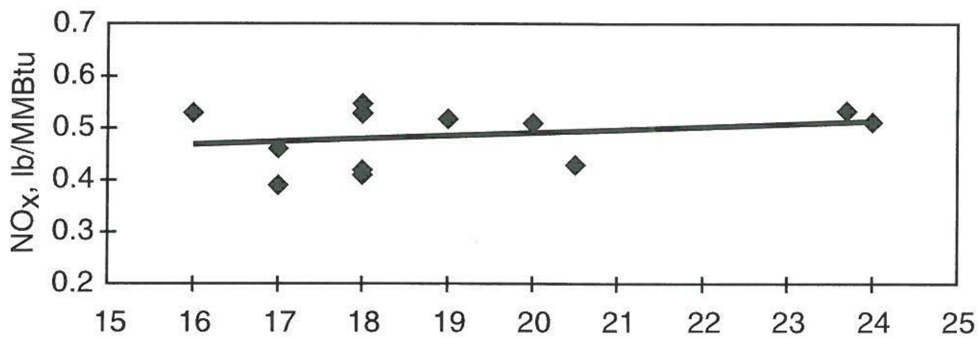


Figure 11 The Effect of Excess Air on NO_x at AEP Gavin Unit 1

Amos Unit 3 was the most challenging of all the units discussed in this paper for reducing NO_x emissions to relatively low levels. The pre-retrofit baseline NO_x levels averaged 1.6 lb/MMBtu, 20% higher than the baseline NO_x for Gavin Unit 1 which, as indicated earlier, is of the same physical size and steam flow capacity.

Optimization testing on this unit was more involved than on the previous units discussed. Numerous tests were performed by evaluating different shroud positions, register vane settings, excess air levels, number of mills in service, variations in boiler load, etc. The variable, which had the most significant impact on controlling NO_x emissions at full load, was shroud positioning.

The flue gas emissions contour plots, developed from local measurements at the economizer outlet using a test truck supplied by Fossil Energy Research Co. (FERCO), showed significantly higher O_2 and NO_x concentrations at the center of the unit than at the sides even with balanced secondary air flow to the burners. As shown in Figure 12A, the NO_x emission profile displayed a significant "hump" in the center of the unit, much more pronounced than DB Riley has ever experienced on other low NO_x CCV® burner retrofit projects.

The higher NOx levels produced in the center of the unit were felt to be caused by greater thermal NO_x conversion in this portion of the furnace due to abnormally high localized peak flame temperatures. Therefore, in an attempt to balance the NO_x profile, the secondary air flow, to the center groups of burners, was reduced by operating these burners with the shroud positions more closed than on the side burners. Individual burner adjustments failed to affect the backend gas sample measurements and profiles. Adjustments had to be made in groups of burners to affect the readings. Figure 12B shows the NO_x and O2 profiles with biased secondary air flow to the burners. The data shows that there was a slight improvement in the NO_x and O2 profiles but the center burner shrouds could have been closed more to flatten these profiles further.

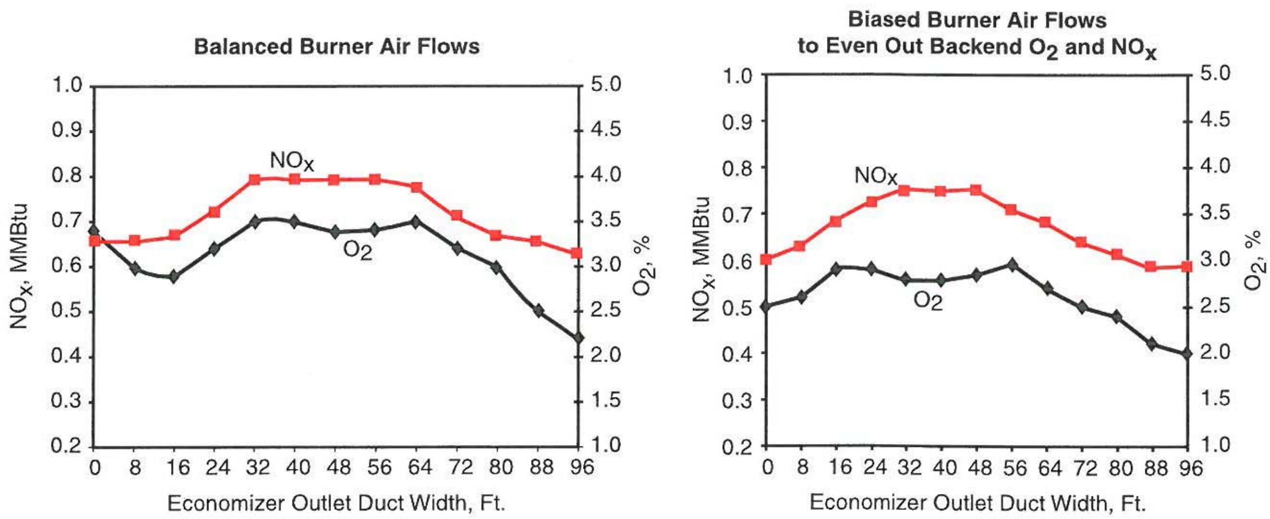


Figure 12A (Left) and 12B (Right) A Comparison of Backend NO_x and O2 Profiles Measured at AEP Amos Unit 3 for Balanced and Biased Burner Air Flows

Table V compares the results of pre and post retrofit performance with the unit set per optimized conditions with 10 out of 12 mills operating at full load. Based on this data, the low NO_x CCV® cell burners reduced NO_x on Amos Unit 3 by 56% during the optimization testing.

Figure 13 shows the effect of boiler load on NO_x emissions as measured during the optimization testing. Note the similarity in slopes between baseline and post retrofit NO_x performance.

Table V Pre- and Post-Retrofit Results for CCV® Cell Burners at AEP Amos Unit 3 — Full Load

Parameter	Pre-retrofit	Post-retrofit	% NO_x reduction
NO_x, lb/MMBtu	1.60	0.70	56
UBC, %	7	6.7	
Excess Air, %	17	17	
W/F dp, "wg	3	4 - 5	

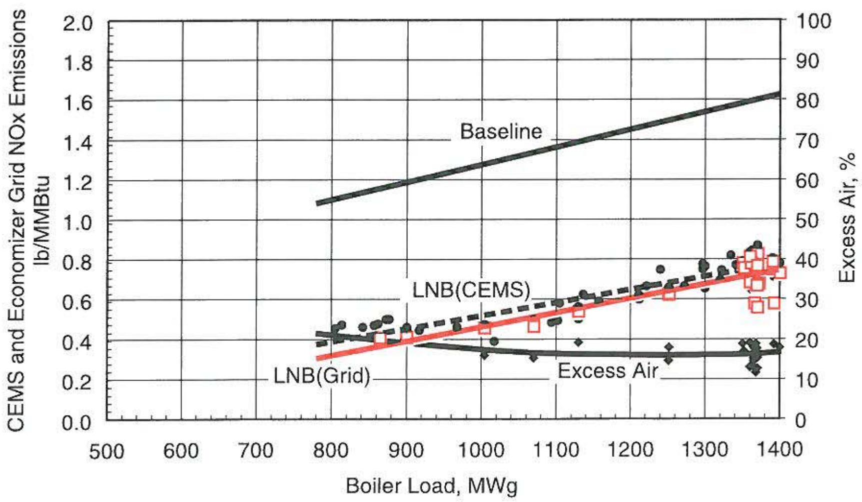


Figure 13 The Effect of Boiler Load on NOx at AEP Amos Unit 3

During the day to day operation, however, the NOx emissions at full load are quite often higher than the optimized NOx levels listed in Table V. Post retrofit NOx emissions at times exceeds 1.0 lb/mmBtu. Further data analysis and testing is planned for Amos Unit 3 in an effort to consistently maintain NOx levels of <0.7 lb/mmBtu. This will include a more detailed coal characterization and a comparison to Gavin Unit 1 operation.

RESULTS OF CCV® DUAL AIR ZONE BURNER RETROFITS

DB Riley retrofitted two wall fired utility boilers with DB Riley CCV® Dual Air Zone low NOx burners. These utility boilers, originally built in the late 1960's and early 1970's by DB Riley, ranged in size from 165 to 300 MWn.

Santee Cooper Winyah Unit 1, a 280 MWn, 2,100,000 lb/hr, 1005°F, 2400 psig boiler, was retrofitted with twenty-four CCV® dual air zone burners of the "plug in" design. As shown in Figure 14, the burners are all located on the rear wall in four rows of six burners per row.

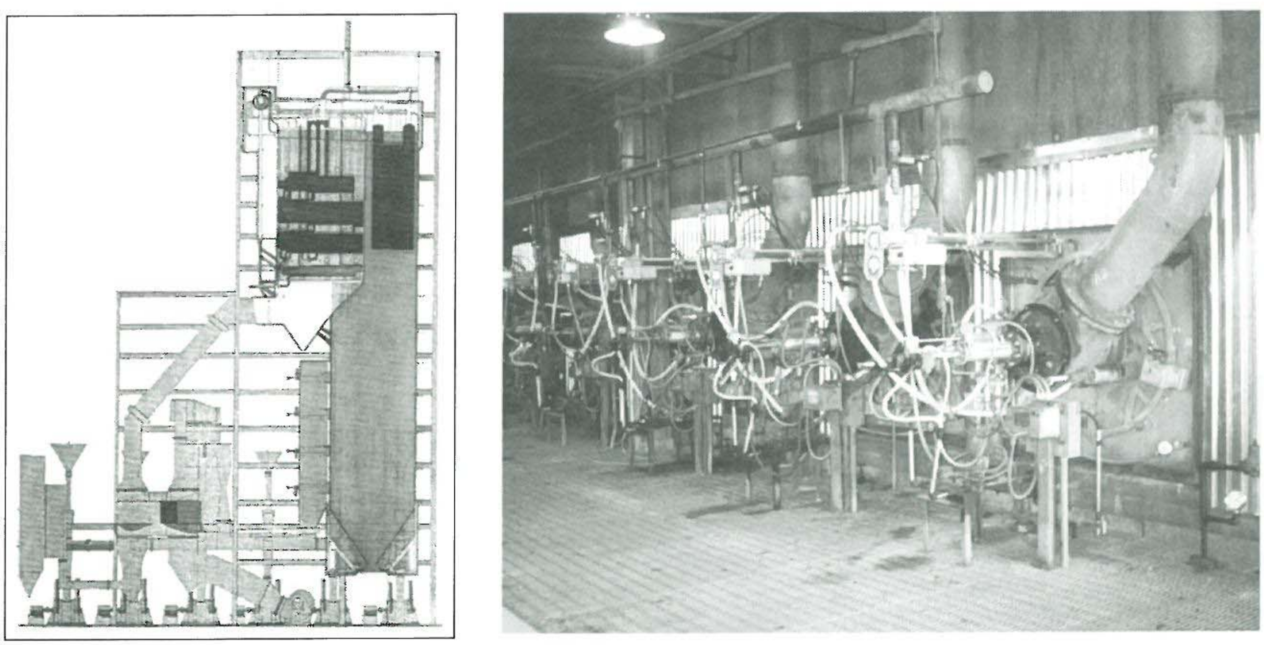


Figure 14 (Left) Santee Cooper Winyah Unit 1 Boiler Schematic, and (Right) Burner Deck

The burners were designed to attain a full load capacity of 137 MMBtu/hr with biasing capability up to 158 MMBtu/hr. The unit is equipped with six DB Riley 556D ATRITA® pulverizers but typically operates at full load with only five mills in operation. Winyah Unit 1 burns coal from various sources.

Following the initial coal spreader replacements to minimize the potential concern for waterwall flame impingement, the unit was optimized by evaluating all the typical variables mentioned earlier in addition to evaluating splits between secondary and tertiary air flow in this dual air zone burner design.

Table VI compares the pre- and post-retrofit performance measured with five out of six mills in operation. The burner shrouds were fully closed on the out of service or idle burners. The low NO_X CCV® dual air zone burners reduced NO_X on Winyah Unit 1 by 63% without a significant increase in CO emissions or flyash UBC.

Table VI Pre- and Post-Retrofit Results for CCV® Dual Air Zone Burners at Santee Cooper Winyah Unit 1 — Full Load

Parameter	Pre-retrofit	Post-retrofit	% NO_X reduction
NO_X, lb/MMBtu	1.10	0.41	63
CO, ppm	82	30	
UBC, %	8 -10	9.8	
Excess Air, %	17.6	20	
W/F dp, "wg	–	3.8	

Figure 15 shows the effect of excess air on NO_X and CO emissions while Figure 16 shows the effect of boiler load on NO_X. Additional testing and tuning will continue at Winyah Unit 1 in an effort to maximize superheat and reheat steam temperatures without affecting the combustion performance since the data indicates that this unit is marginal on steam temperature.

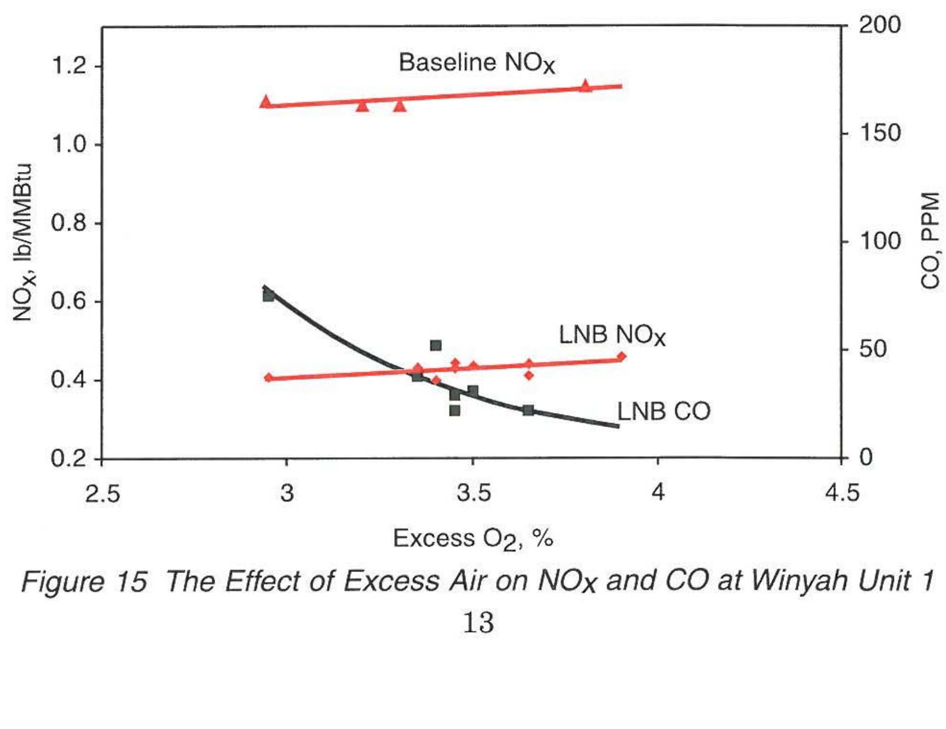


Figure 15 The Effect of Excess Air on NO_X and CO at Winyah Unit 1

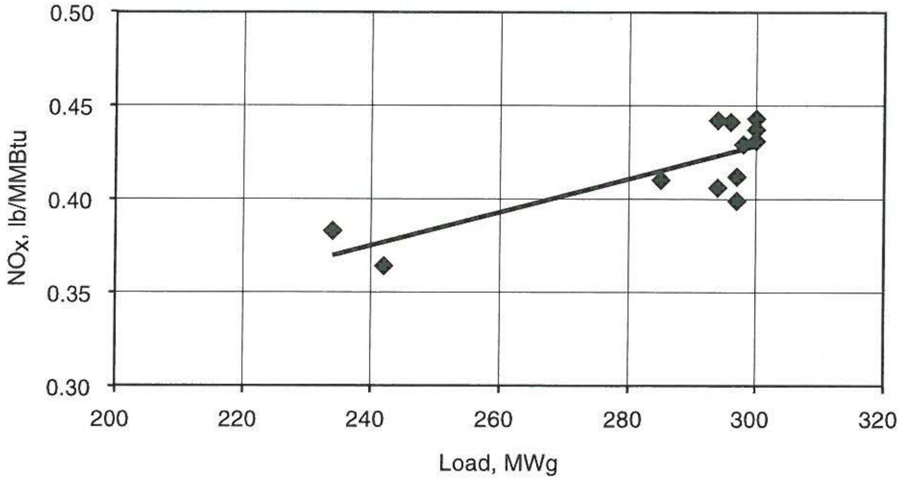
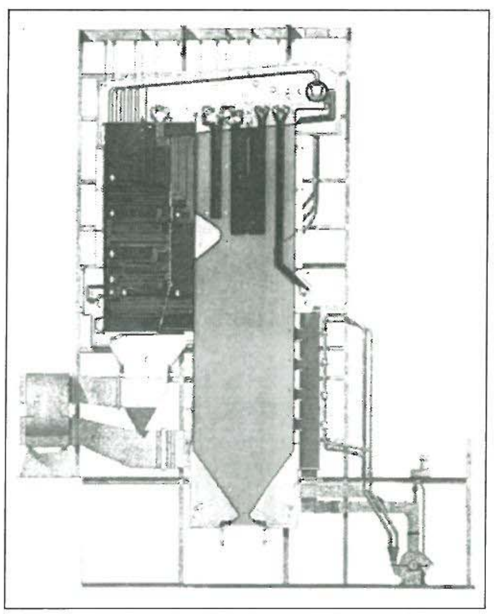


Figure 16 The Effect of Boiler Load on NO_x at Winyah Unit 1

Santee Cooper Jefferies Unit 4, a 165 MWn, 1,212,000 lb/hr, 1005°F, 2600 psig coal fired boiler was retrofitted with sixteen CCV® Dual Air Zone burners each rated at 95 MMBtu/hr with biasing capability to 105 MMBtu/hr. As shown in Figure 17, all the burners are arranged on the front wall in four rows of four burners per row. The unit is equipped with four DB Riley 554D ATRITA® Pulverizers and, like Winyah 1, burns coal from various sources.



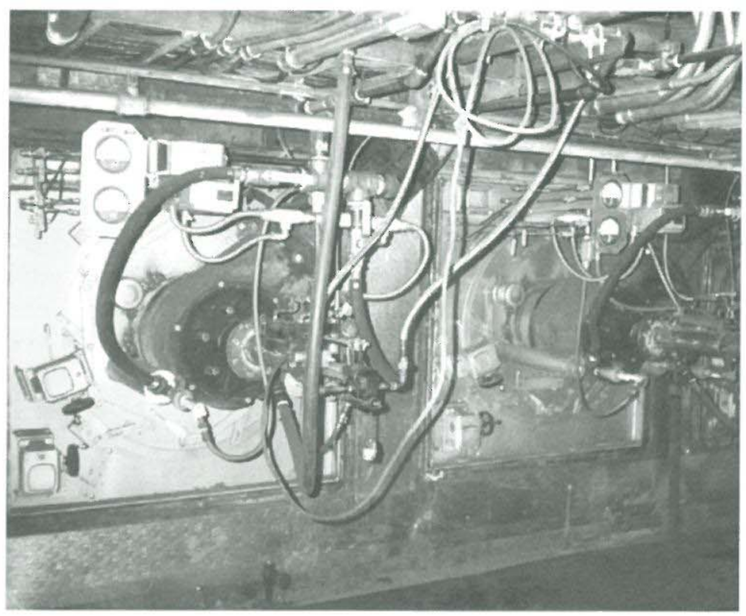


Figure 17 (Left) Santee Cooper Jefferies Unit 4 Boiler Schematic, and (Right) Burner Deck

Table VII compares the pre- and post-retrofit performance measured with the new burner equipment optimized at full load with all four mills in service.

Unlike Winyah Unit 1, excess air for Jefferies Unit 4 is expressed in terms of % O_2, as measured locally at the economizer outlet. Operating Jefferies Unit 4 at a backend O_2 slightly lower than baseline, NO_x emissions on this unit were reduced by 63% with burners only, which is comparable to the same level of reduction experienced on Winyah Unit 1. However, the % UBC in the flyash increased more significantly on Jefferies Unit 4 than experienced on Winyah Unit 1, due to the short retention time available for carbon burnout in the furnace between the upper burner level and furnace exit.

Table VII Pre- and Post-Retrofit Results for CCV® Dual Air Zone Burners at Santee Cooper Jefferies Unit 1 — Full Load

Parameter	Pre-retrofit	Post-retrofit	% NOx reduction
NO_x, lb/MMBtu	1.08	0.41	63
CO, ppm	35	69	
UBC, %	13	23	
Excess O_2, %	5.6	5.2	
W/F dp, "wg	–	3.1	

Figure 18 shows the effect of excess O2 on NO_x and CO emissions measured at full load, while Figure 19 shows the effect of boiler load on NO_x. NO_x did not decrease much with a decrease in boiler load since the excess O_2 increased as load was decreased to control steam temperature and CO emissions.

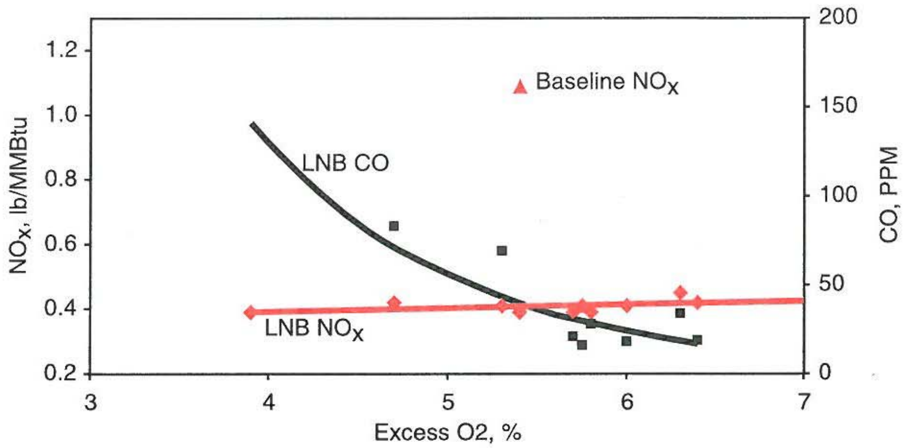


Figure 18 The Effect of Excess Air on NO_x and CO at Santee Cooper Jefferies Unit 4

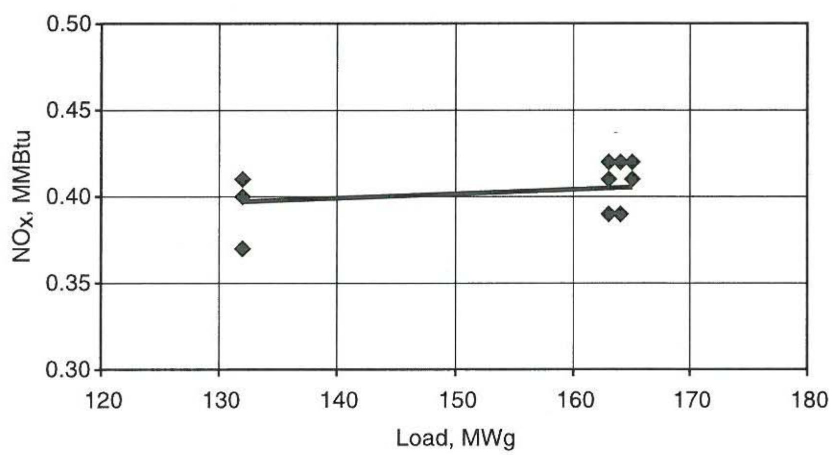


Figure 19 The Effect of Boiler Load on NO_x at Santee Cooper Jefferies Unit 4

Additional testing and tuning is also continuing at Jefferies Unit 4 in an effort to optimize the mill biasing requirement for steam temperature without adversely affecting combustion performance parameters.

COMPARISON OF COAL ANALYSES

All of the seven low NO_X burner retrofit projects discussed in this paper involved utility boilers that burn coals with a wide range of sulfur, ash fusion temperature and slagging characteristics. Table VIII summarizes the chemical properties of the coals typically burned at each of these power plants.

Table VIII Summary of Typical Coal Analyses

Utility Plant	AEP Big Sandy 1	Cinergy Miami Fort 7	AEP Cardinal 1	AEP Gavin 1	AEP Amos 3	Santee Cooper Winyah 1	Santee Cooper Jefferies 4
Proximate, as rec'd							
Moisture, %	7.14	6.5	7.25	8.01	6.22	5.09	5.77
Ash, %	10.69	11.88	10.44	11.53	10.37	7.59	6.10
Volatile, %	33.50	33.14	35.11	33.50	32.00	36.03	36.40
Fixed Carbon, %	48.67	47.74	47.19	46.90	50.81	51.29	51.70
Ultimate, dry							
Carbon, %	73.80	71.91	72.01	68.33	76.68	75.92	–
Hydrogen, %	4.89	4.69	4.97	5.08	5.03	5.19	–
Nitrogen, %	1.38	1.33	1.20	1.05	1.58	1.37	–
Oxygen, %	7.08	7.59	7.05	9.30	3.95	7.91	–
Sulfur, %	1.33	1.53	3.43	3.41	0.91	1.61	1.76
Ash, %	11.51	12.95	11.26	12.77	11.59	8.0	6.47
HHV, Btu/lb	12,103	11,890	12,204	11,372	12,479	13,135	13,339
AFT, Red. (ID)	2,680	2,700	1,990	2,020	2,545	2,100	2,100
FC/VM Ratio	1.45	1.44	1.34	1.37	1.59	1.42	1.42

Upon reviewing the various coal analyses, it is interesting to note that the coal for Amos Unit 3 contains the lowest oxygen concentration and the highest FC/VM ratio of all the coals tested. This may be relevant to the abnormally high level of NO_X emissions being experienced on Amos Unit 3. As indicated earlier, a more detailed combustion/ reactivity evaluation of the coal will be performed and compared to Gavin Unit 1 in an effort to explain the significant differences in NO_X performance between Amos Unit 3 and Gavin Unit 1.

GENERAL OBSERVATIONS AND COMMENTS

Based on DB Riley's experiences with retrofitting seven utility boilers with low NOx CCV® burner technology in 1998, the following general observations and comments can be made:

- No special pulverizer testing or optimizing was required for coal fineness and pipe to pipe coal distribution in any of these units other than standard characterization testing to determine or establish the primary air flow rate at full load for proper coal nozzle sizing and operation.

- No optimizing of the milling system was performed, such as installing variable orifices or dynamic classifiers. Fixed orifices were installed on a few units to equalize coal pipe pressure drop.
- No significant change in furnace slagging was experienced. In some cases, furnace slagging actually decreased.
- NO_x reductions of 50 - 65% from uncontrolled levels were achievable using the " burners only" technology while burning eastern bituminous type coals in seven utility boilers. Generally, eastern bituminous coals are more challenging for low NO_x applications.
- Jefferies Unit 4 was the only unit that experienced an increase in slagging at the base of the high temperature superheater but was controllable with more frequent sootblowing. This was related to the short retention time available in the furnace for proper burnout and adequate cooling of the ash particles.
- On some units, the coal analysis deviated from specification, but did not create significant performance related issues or concerns.
- No significant change in boiler thermal performance was experienced on most installations. Preliminary data indicates, however, that a small decrease in steam temperature was observed at Jefferies Unit 4. This unit was marginal on steam temperature prior to the burner replacement. The thermal performance differences between pre- and post-retrofit operation may be related to the differences in furnace slagging and lower furnace heat absorption.
- No significant change in economizer or air heater exit gas temperature was measured during these low NO_x burner projects.
- Jefferies Unit 4 was the only unit that experienced an increase in flyash UBC due to the short retention time available in the furnace for carbon burnout when compared to all other units.
- A couple of the cell fired units experienced coal nozzle fires as a result of coal or ash deposit layout. In one case, the fire was due to insufficient purge following a mill shutdown. In the other case, the fires were potentially due to flyash deposits in the coal nozzles of idle burners which became sintered when exposed to furnace radiation over a long time period. This latter cause is still being reviewed.
- Some of the cell fired units also experienced premature erosion of the coal heads and coal nozzle inlets because of relatively high primary air/coal velocities and significant coal maldistribution or roping entering the heads. Ceramic liners have been and will be installed selectively in the heads and nozzles to mitigate the erosion.
- On a few of the AEP projects, CEMS NO_x emissions observed throughout the load range during "automatic generator controls" mode, is slightly higher than "snapshot" optimization test results conducted by the OEM and utility engineers. Changes that occur during actual day-to-day operation include variations in fuel characteristics and other operating parameters such as excess air, furnace fouling and soot blowing operation, mill operation, O_2 balance, etc. These day-to-day variations significantly impact NO_x emissions as documented by the individual plants.

CONCLUSION AND FUTURE PLANS

During the last ten years, DB Riley has sold over 1500 low NO_x CCV® burners. Nearly 50% of the burners sold have or will be installed in one of the largest investor owned domestic utilities. Throughout this time period, mechanical improvements and material upgrades have been added to the CCV® burner technology to improve performance, mechanical reliability, flexibility, and component life. Through the evolution process of the CCV® burner technology, DB Riley has continued to utilize the "heart" of the CCV® burner, the patented venturi coal nozzle and low swirl coal spreader.

DB Riley offers this technology on new pulverized coal fired units that are currently being built to meet today's emissions regulations as well as on retrofit applications. A large percentage of DB Riley's CCV® burner installations (approximately 65%) are on non DB Riley boilers firing a variety of coals in various firing configurations. The database includes units ranging in capacity from only a few MWn to the largest coal fired boilers ever built (1300 MWn). NO_x reductions of 50 – 65% from uncontrolled levels have been demonstrated most recently on "burners only" applications.

In 1999, DB Riley will be retrofitting another 256 low NO_x CCV® burners on five utility boilers for a total generating capacity of 3100 MWn. One of the boilers will be equipped with low NO_x burners installed on all four furnace walls. Low NO_x CCV® burners are also being installed in a new 150 MWn coal fired utility boiler currently being built in Central America. Startup is scheduled for the fall of 1999.

The CCV® burner technology is also being used in the Low Emission Boiler System (LEBS) project, an 86 MW pulverized coal fired DOE funded contract, currently in the proof of concept stage. [5,6]

With the help and cooperation of DB Riley's largest CCV® burner user, a number of programs are currently underway testing different materials (including ceramics) to address erosion, wear, and temperature resistance in high heat release units that normally operate at full load with burners out of service.

In addition to the mechanical field testing program mentioned, and as part of DB Riley's long-term strategic planning, full scale development testing of the CCV® burner technology will continue at DB Riley's R&D facility in Worcester, Massachusetts. This effort will focus on further reducing NO_x emissions to minimize the cost of SCR systems and catalyst.

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