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AN ECONOMICAL SOLUTION FOR REDUCING NO_x EMISSIONS FROM CELL BURNER BOILERS FIRING PULVERIZED COAL

by

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ABSTRACT

Over 12% (26,000 MWe) of the U.S. generating capacity is produced from utility boilers equipped with pre-New Source Performance Standard (NSPS) cell burners. These burners, manufactured in the 1950's and 60 s, rapidly mix the pulverized coal and combustion air resulting in highly turbulent and efficient combustion. Unfortunately, NO, emissions produced by this firing configuration are extremely high, typically averaging 1.0 to 1.81bs/10^6 Btu.

This paper presents the results of retrofitting a 600 MWe supercritical cell burner boiler at American Electric Power's Muskingum River Unit 5 with Riley low NO, Controlled Combustion Venturi. (CCV ®) burners. This project successfully demonstrated the ability to reduce NO, emissions greater than 50% without the requirement for overfire air (OFA), off-stoichiometric firing, burner respacing, mill system or coal piping changes, or pressure part modifications.

Emissions and boiler performance results are presented together with the typical costs for this type retrofit.

INTRODUCTION

American Electric Power (AEP), based in Columbus, Ohio, has over 24,000 MWe of installed electrical generating capacity. More than 5600 MWe of this electrical capacity comes from six coal-fired boilers equipped with pre-NSPS cell burners. The units range in size from 600-1300 MWe generating capacity, making AEP one of the largest owners of this type of boiler.

AEP implemented a program in 1993 to find a viable solution for reducing NO_X emissions from cell burner boilers. Specific objectives were:

- reduction of NOx emissions by at least 50%.
- reduction of NOx emissions using low-NOx burners that did not require air staging via overfire air (OFA) or off- stoichiometric firing.
- development of a technical and economical low NOx technology for application to all of AEP's cell burner boilers.
- reduction of NOx emissions without degrading boiler performance.

A review of available technology in the industry indicated that NOx reduction was possible by (1) installing modified cell burners that replace the upper nozzle with an OFA port, or (2) respacing and installing low NO,; burners to resemble a more conventional wall fired installation. These options were abandoned because of concerns for lower furnace corrosion, the long term effects of deep staging on overall boiler operation, and the significant cost associated with pressure part modifications to rearrange the burners.

The technical approach AEP wanted was to install low NOx burners without OFA as a direct replacement for all the cell burners. AEP selected Rile)' Stoker Corporation to *carry* out this approach. The significant factors influencing this decision were:

- The Riley Controlled Combustion Venturi (CCV®) burners did not require overfire air or air staging for reducing NOx by 50%, thus minimizing the potential for lower furnace waterwall corrosion due to reducing atmospheres.
- No costly pressure part changes were needed, since the CCV® burners were simply a " plug in" replacement for the pre-NSPS cell burners.
- No changes to the existing milling system or coal piping configuration were required by the CCV® burners.
- Despite the high furnace heat release rates typical of this type of boiler, the CCV® ers would not require burner respacing.

UNIT DESCRIPTION

AEP and its subsidiary, Ohio Power, selected Muskingum River Unit 5 (MRS) as the demonstration site for the Riley burner technology. The plant, located in Beverly, Ohio, is shown in Figure 1. The unit was originally designed and manufactured by Babcock and Wilcox (B&W) in the early 1960's. It is a supercritical design producing superheated steam at a rate of 4,035,000 lbs/hr, 3800 psig operating pressure and 1000°F operating temperature. The electrical generating capacity is a nominal 600 MWe.

As shown in Figure 2, pulverized coal was originally burned using twenty B&W two-nozzle cell burners and ten standard circular burners arranged in an opposed fired configuration. Figure 3 shows a schematic of the original two-nozzle cell burner. The unit has five B&W MPS Size 89 Pulverizers that feed ten coal nozzles each. The furnace dimensions are approximately 63 feet wide x 39 feet deep.

Muskingum River Unit 5 burns a high volatile bituminous coal from Ohio. Typically, uncontrolled NOx levels from cell burner boilers average from 1.0 to 1.8 $lbs/10^6$ Btu. The uncontrolled NOx level measured at MR5 was 1.2 $lbs/10^6$ Btu. The objective of this project was to reduce NOx emissions to below 0.6 $lbs/10^6$ Btu with minimal impact on boiler performance and flyash unburned carbon (UBC) levels.

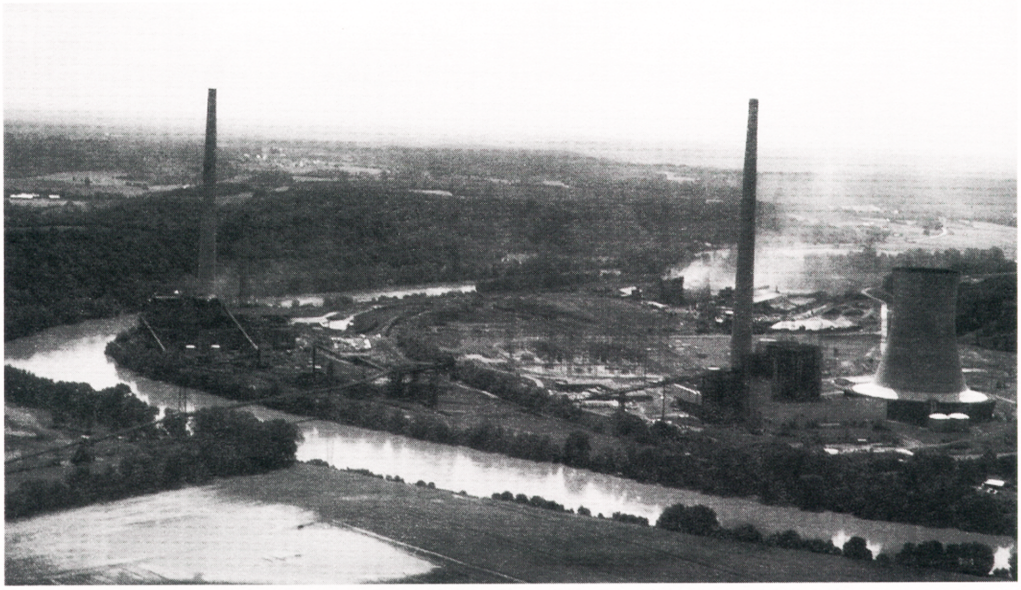

Figure 1 Muskingum River Unit 5 (on right)

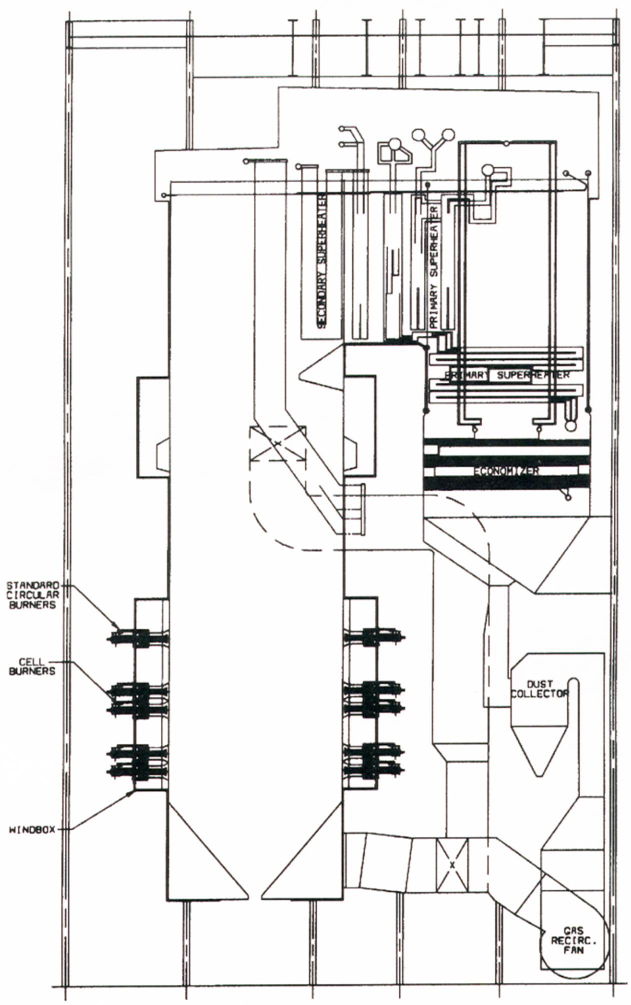

Figure 2   Muskingum River Unit 5

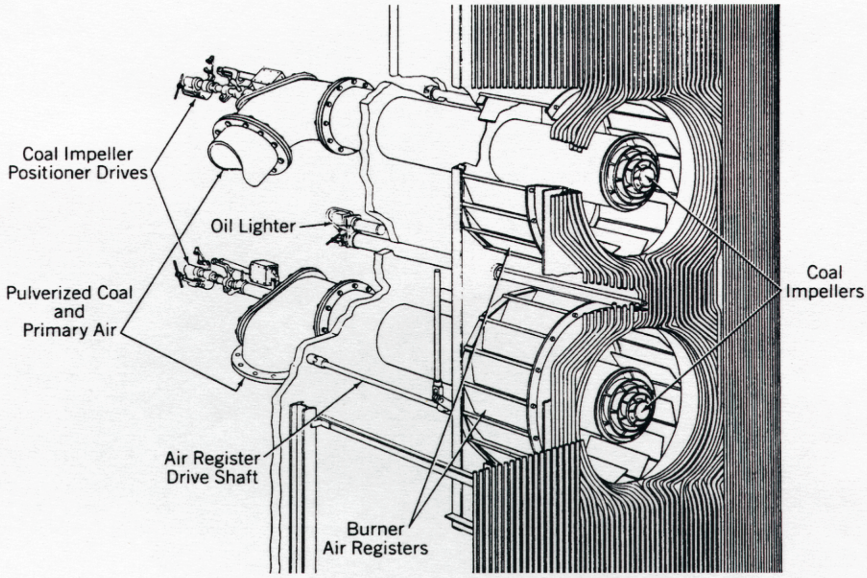

Figure 3 Original Two-Nozzle Cell Burner

LOW NO_x COMBUSTION RETROFIT

In the spring of 1993, AEP contracted with Riley for the design, fabrication and installation of fifty low-NO_x CCV® burners for Ohio Power's Muskingum River Unit 5. Each burner was rated for 107 MMBtu/hr heat input at MCR conditions. The basic CCV® burner design is shown in Figure 4.

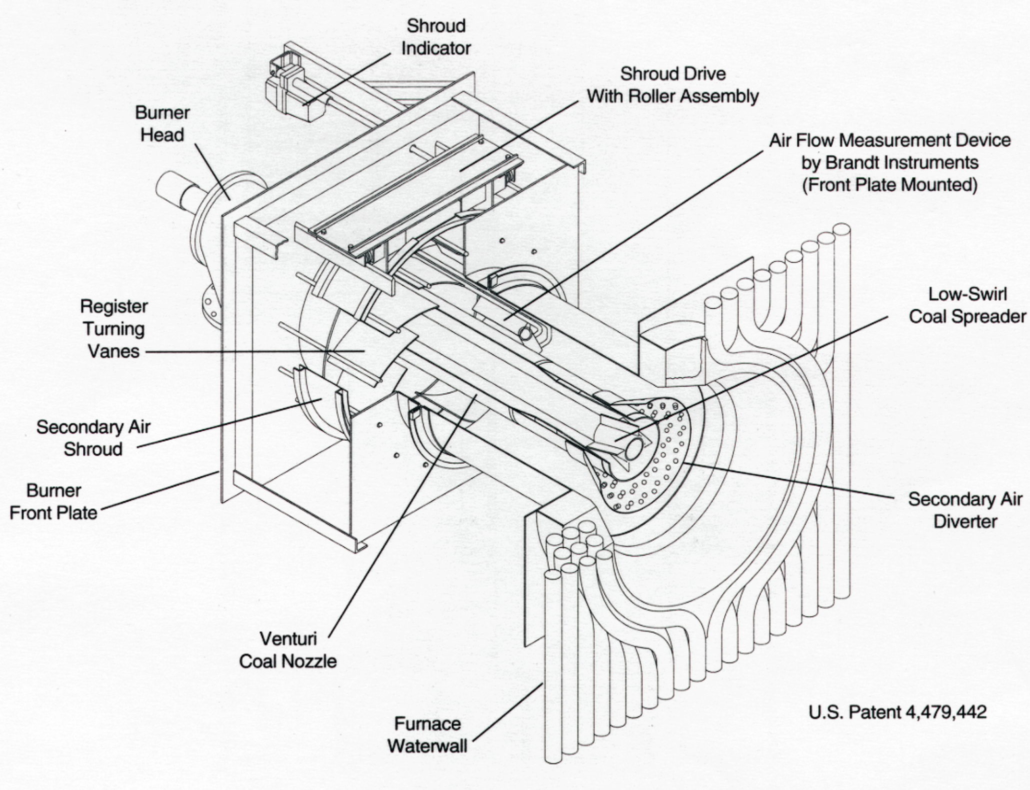

Figure 4 Riley Low -NO_x CCV® Burner

NO_x control is achieved with the patented (U.S. Patent No. 4,479,442) venturi coal nozzle (1,2), 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 very fuel-rich mixture. As this mixture passes over the coal spreader, the blades divide the coal stream into four distinct streams which then enter the furnace in a gradual helical pattern, resulting in gradual mixing of the coal and secondary air. Secondary air is introduced to the furnace through the air register, supported by the burner front plate, and then through the burner barrel and over the secondary air diverter. Devolatilization of the coal in the fuel-rich mixture occurs at the burner exit in an oxygen-lean primary combustion zone, resulting in lower fuel NO_x conversion. Peak flame temperature is also reduced, thus suppressing thermal NO_x formation.

The resulting coal flame produced by the CCV® burner is longer, narrower, and more tubular in shape than the flames produced by the highly turbulent B&W cell burners installed originally. The CCV® flame is also typically well attached to the coal nozzle tip, resulting from recirculation eddies formed on the backside of the secondary air diverter. For good NO_x control, it is very important to have a well-attached coal flame (3). The furnace depth of 39 feet was sufficient to accommodate the longer low NOx coal flames without concern for waterwall flame impingement. Our most significant concern was that because of the very close spacing between the two nozzles in the cell burner (4´-2´´), the coal flames would interact and cause more turbulent combustion than wanted, minimizing reduction in NO_x emissions. Figure 5 shows the arrangement of the Riley CCV® cell burner.

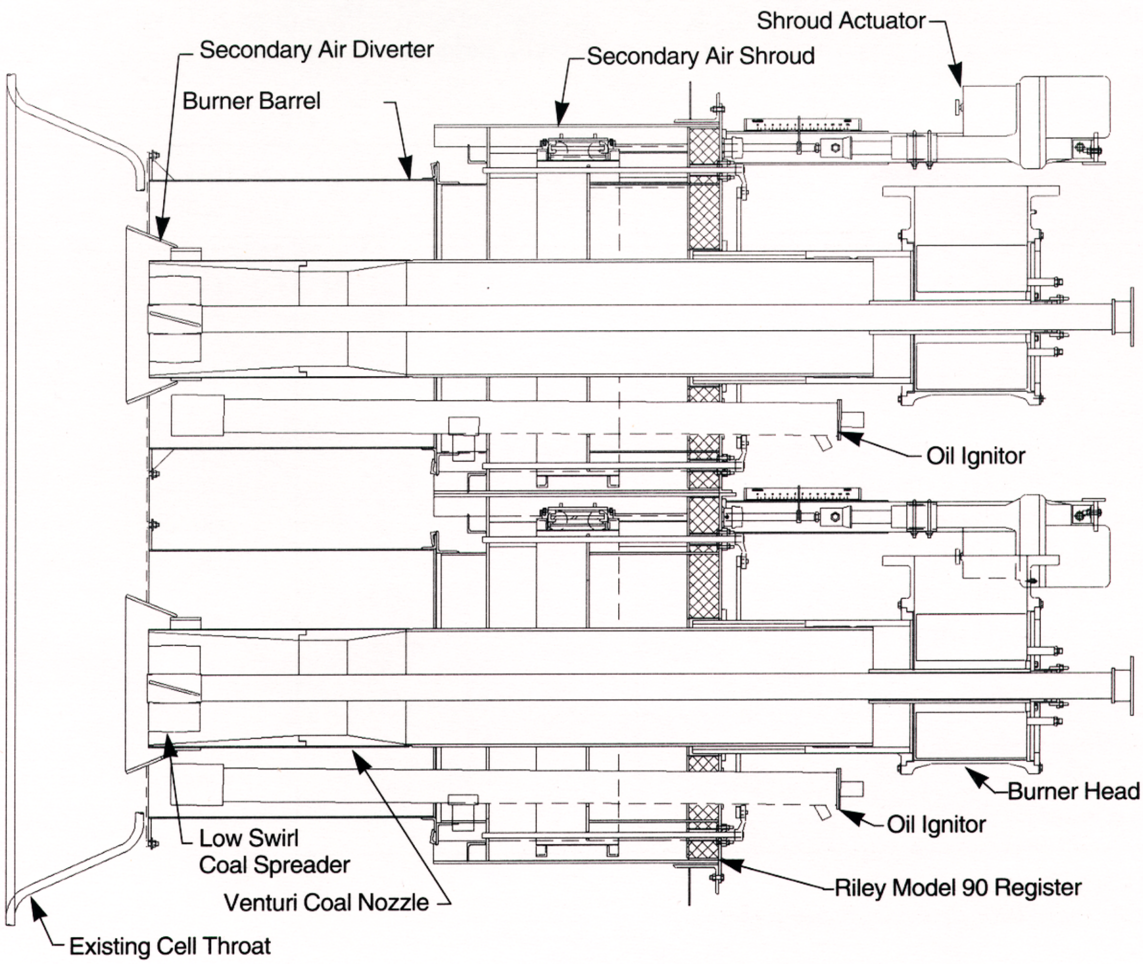

Figure 5 Riley Low -NOx CCV® Cell Burner

The new low-NO_x burners were installed in the fall of 1993 during a six-week outage. The unit was also equipped with a 33- point sampling grid at the economizer outlet for measuring gas emissions during post-retrofit performance testing. Start-up of MR5 commenced in December 1993. However, difficulties in attempting to use the original mechanically-atomized oil ignitors, which were shared between the burner nozzles within the cell, forced a delay in testing until June 1994.

TEST RESULTS

Post retrofit performance testing was performed in early summer, 1994. Within two weeks of start-up, CCV® burner operation was quickly optimized. Our primary concern of flame interaction impacting NO_x because of the close burner spacing quickly diminished after observing the CCV® cell burner flame shape. Flames were all well attached, narrow, and tubular. The flames were distinctly independent from each other with little or no interaction between adjacent flames.

The upper row of non-cell configured burners also produced long narrow flames but they were slightly detached. This detachment was felt to be the result of windbox air maldistribution and insufficient diverging throat depth for adequate burner recirculation. Despite this, test results as summarized in Figure 6 showed that all performance objectives were met. NO_x was effectively reduced to below 0.6 lbs/10^6 Btu for a 52% reduction from pre-retrofit levels. CO emissions remained extremely low and consistent with baseline operation. Flyash LOI averaged 2.23%, compared to 2.7% before the retrofit while the actual percentage of unburned carbon in the ash averaged < 1%, compared to 1.5% before the retrofit. As shown in Figures 6 and 7, NO_x decreased with reduction in load and with normal increases in excess air.

Parameter	Pre-Retrofit Baseline	Post Retrofit Optimization		
Test No.	2	9	11	10
Date	9/16/93	7/6/94	7/7/94	7/7/94
Gross Generation, MW	600	607	454	368
Excess Air, %	25	22	33	40
Superheat Outlet Temperature, °F	1000	994	996	993
Reheater 1 Outlet Temperature, °F	1023	1010	970	937
Reheater 2 Outlet Temperature, °F	1024	1003	960	917
Econ. Outlet Gas Temperature, °F	690	735	676	648
AH Outlet Gas Temperature, °F	341	353	328	325
Boiler Efficiency, % (Approx.)	87.85	87.63	-	-
NO_x @ Econ. Outlet by CLA(1), 10^6 Btu	-	0.56	0.53	0.51
NO_x @ Stack by CEMS, lb/10^6 Btu	~1.2(2)	0.59	-	-
CO @ Econ. Outlet, ppm	0	1	1	1
Flyash LOI, %	2.7	2.23	1.89	1.70
Carbon in Ash %	1.5	0.78	0.67	0.95

(1) Chemilluminescent Analysis
(2) Measured during previous boiler testing.

Figure 6 Summary of Test Results

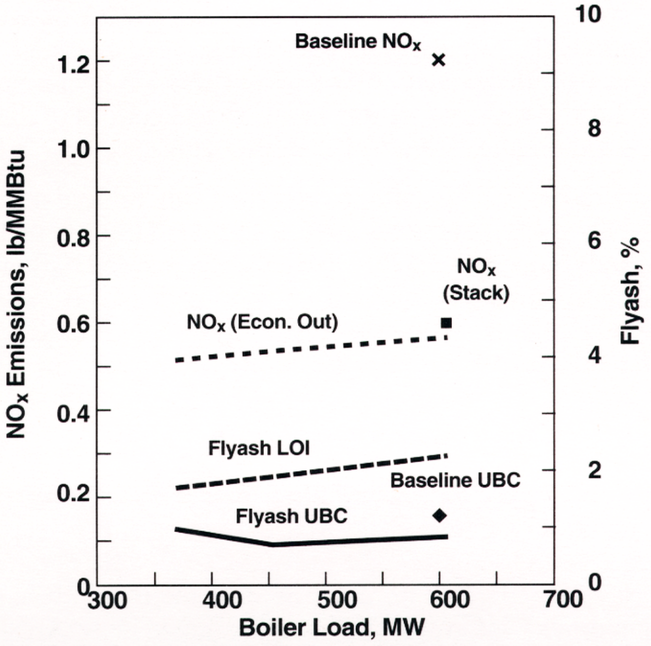

Figure 7 The Effect of Load on NO_x and LOI

While NO_x control (baseline and post-retrofit) at Muskingum River Unit 5 benefits somewhat from a row of circular burners above the two levels of cell burners (Figure 2), full load is achievable with this row of burners out of service. This firing condition was also tested to simulate the furnace thermal environment of AEP's cell-fired 1300 MWe units. NO_x emissions under this condition increased at full load to 0.63 lbs/10^6 Btu, less than the .66 lbs/10^6 Btu predicted, representing more than 50% NO_x reduction from the existing 1300 MW baseline NO_x emission values.

We also observed throughout this testing that there was no significant change in boiler thermal performance as a result of installing low NO_x burners. Figure 8 shows a typical fuel analysis of the coal burned during the testing and pulverized coal fineness results.

FUEL ANALYSIS

H_20 (%)	6.6	C (% dry)	68.3
VM (%)	39.1	H (% dry)	5.0
FC (%)	42.5	O (% dry)	8.41
Ash (%)	11.8	N (%dry)	0.99

COAL FINENESS

% through 50 mesh	99.5
% through 100 mesh	95.5
% through 200 mesh	79.1

Figure 8 Fuel Analysis and Coal Fineness Results

Long term operation has at times resulted in NO_X levels increasing above 0.6 lbs/10^6 Btu. This is due to changes in excess air levels, furnace slagging conditions (cleanliness), coal quality, burner air distribution, and mill primary air flow rates. All of these factors can cause an increase in NO_X emissions, some greater than others. Therefore, closer attention and control of these variables are required to enable the unit to operate continuously below 0.6 lbs/10^6 Btu.

On future units, consideration will be given to incorporating remote manual or automatic control of the burner shrouds for easier control of burner air distribution. The current three-position control philosophy for the burner shrouds hinders the ability to easily obtain good burner air distribution. The use of lower swirl coal spreaders for greater NO_X control margin will also be considered for the next installation. NO_X decreases with smaller coal spreader blade angles, or what Riley refers to as lower swirl coal spreaders (3). These would provide greater flexibility and margin for higher excess air operation and heavier furnace slag deposition

PROJECT COSTS

The total cost for design, supply and installation of the low NO_X burners was approximately \$10/kw. While no physical modifications to the furnace, pulverizer or coal piping were required, fifty new light oil ignitors were needed to assure light-off of the CCV® burner nozzles in the cell configuration. The ignitor upgrade required air compressor improvements, additional instrument and control work, and oil and air piping modifications. These are all included in the \$10/kw cost since this may be required for future cell burner retrofits.

SUMMARY

Riley Stoker and AEP have successfully retrofitted low NO_X burner technology on a coal fired 600 MWe cell burner supercritical unit. Of particular significance is the ability to retrofit with this "plug in" technology without pressure part modifications, burner respacing, or off-stoichiometric firing.

The new burner equipment has reduced NO_X to < 0.6 lbs/10^6 Btu (> 50% reduction) without significant degradation in boiler performance, flyash unburned carbon, and CO emissions.

The cost of the retrofit project including all new light oil ignitors is approximately \$10/kw. This cost is significantly lower than that associated with pressure part modifications, burner respacing, and an OFA system which alternative technologies may require.

Future cell burner retrofits should consider the following equipment upgrades for improved NO_X control:

- lower swirl coal spreaders
- automatic or remote control of burner air shrouds

The success of this project has demonstrated a technical and economic alternative for reducing NO_X emissions from cell burner fired boilers.

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