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ALTERNATIVE SOLUTIONS FOR REDUCING NO_X EMISSIONS FROM CELL BURNER BOILERS

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ABSTRACT

An economical solution for reducing NO, emissions from coal fired utility boilers equipped with pre-New Source Performance Standard (pre-NSPS) cell burners is being developed. Since over 12% of the U.S. generating capacity is produced from cell burner boilers, this development is very' significant for the utility industry.

Cell burners manufactured in the 1950's and 1960's rapidly mix the pulverized coal and combustion air, resulting in highly turbulent and efficient combustion. Typical NO, emissions from cell burner boilers average 1.0 to 1.8lb/10^5 Btu.

*This paper presents the results of retrofitting American Electric Power's Muskingum River Unit 5, a 600 MWe supercritical cell burner boiler, with **DB** Riley low NO, CCV ' burners. Initial results demonstrated the ability to reduce NO_B emissions greater than 50% without the requirement for over-fire air, off-stoichiometric firing, burner respacing, mill system and coal piping changes or pressure part modifications. Long term operation, which recently included switching coals, has resulted in some deterioration in NO, performance. Results of the initial optimization testing are presented along with plans for reoptimizing unit operation to restore the low NO_X levels.*

Plans for developing DB Riley's "next generation " low NOx pulverized coal burner (CCV® II) will also be presented. There is potential use for this advanced design on other cell burner units in American Electric Power's system for improved NO, reduction performance.

INTRODUCTION

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

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

- reduce NOx emissions by at least 50%
- reduce NOx emissions using low NOx burners that would not require air staging via overfire air (OFA) or off-stoichiometric firing
- develop a technical and economical low NOx technology for application to all of AEP's cell burner boilers
- reduce NOx emissions without degradation in 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-NOx 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 desired by AEP was to install low NOx burners without OFA as a direct replacement for all the cell burners. DB Riley was selected by AEP to implement this approach. The significant factors influencing this decision were:

- With the DB Riley Controlled Combustion Venturi (CCV®) burners we did not anticipate any requirement for overfire air or air staging for reducing NOx by 50%, thus minimizing lower furnace waterwall corrosion due to reducing atmospheres.

  The CCV® burners were simply a "plug in" replacement for the pre-NSPS cell burners and would not require costly pressure part changes.

- The CCV® burners would not require any changes to the existing miffing system and coal piping configuration.

  The CCV® burners would not require respacing the burners despite the high furnace heat release rates typical of these types of boilers.

UNIT DESCRIPTION

AEP and its subsidiary, Ohio Power, chose Muskingum River Unit 5 (MR5), shown in Figure 1, as the demonstration site for the DB Riley burner technology. This unit, originally designed and manufactured by Babcock and Wilcox (B&W) in the early 1960's, is located in Beverly, Ohio. The boiler is a supercritical design producing superheated steam at a rate of 4,035,000 lb/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 previously 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 which feed ten coal nozzles each. The furnace dimensions are approximately 63 feet wide by 39 feet deep. MR5 burned a high volatile bituminous coal from Central Ohio. Typically, uncontrolled NOx levels from cell burner boilers average from 1.0 to 1.8 lb/10^6 Btu. The uncontrolled NOx level measured at Muskingum River Unit 5 was 1.2 lb/10^6 Btu. The objective of this project was to reduce NOx emissions to below 0.6 lb/10^6 Btu with minimal impact on boiler performance and particularly on fly-ash unburned carbon (UBC) levels.

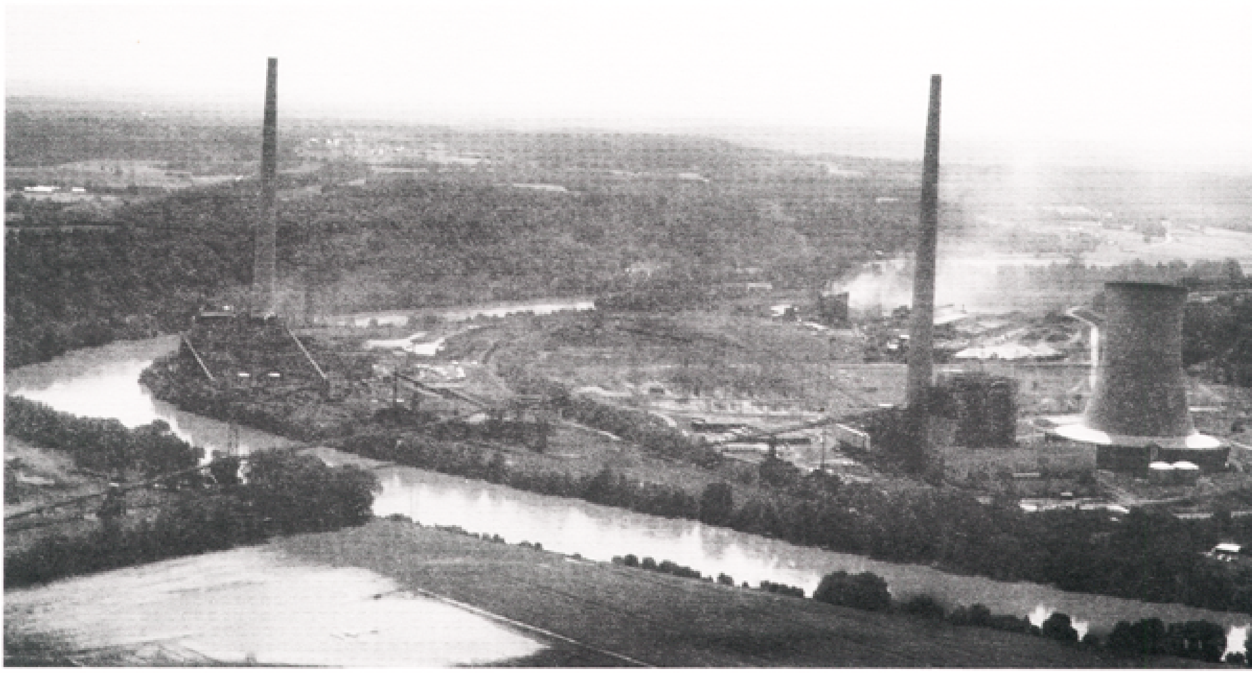

Figure 1 Muskingum River Unit 5 (on right)

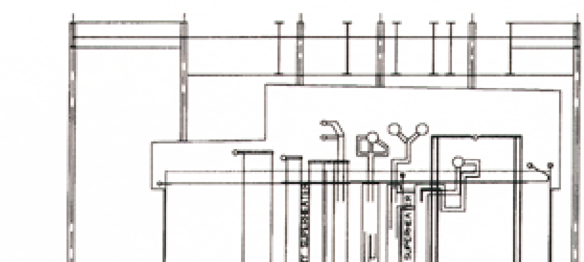

Figure 2 Muskingum River Unit 5

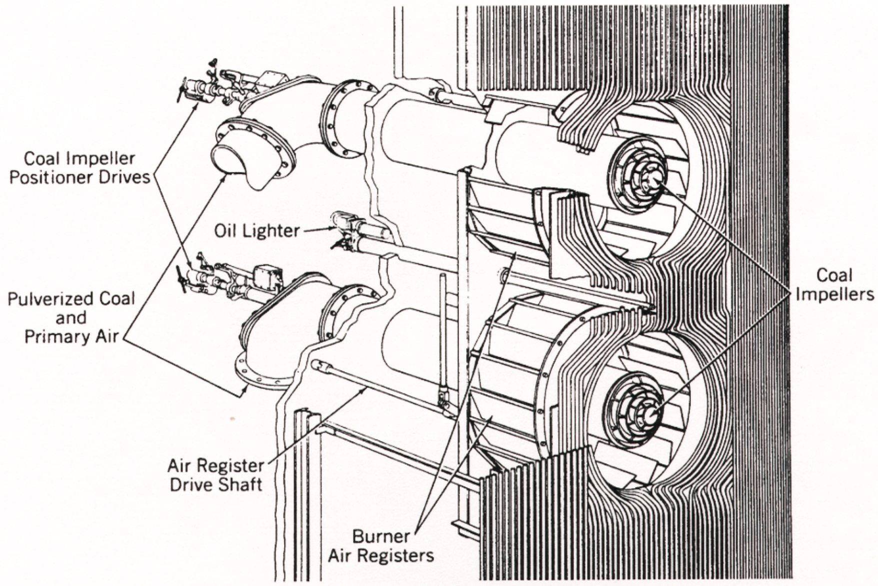

Figure 3 Original Two-Nozzle Cell Burner

LOW NO_X COMBUSTION RETROFIT

In the spring of 1993, AEP contracted with DB 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. The key element of the burner design is the patented (U.S. Patent No. 4,479,442) venturi coal nozzle and low swirl coal spreader located in the center of the burner[1]. 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, producing very gradual mixing of the coal and secondary air. Secondary air is introduced to the furnace through the air register, supported off the burner front plate, and subsequently 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 reduced by the gradual mixing, thus suppressing the 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 original B&W cell burners. The CCV® burner 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]. As discussed below, detached coal flames on the upper row of standard circular burners may be limiting the full NO_X reduction potential of this retrofit.

The furnace depth of 39 feet is sufficient to accommodate the longer low-NO_X coal flames without concern for waterwall flame impingement. Due to the very close burner spacing (4'-2") between the two nozzles in a cell burner (Figure 5), our most significant concern was that the coal flames would interact with each other. This would cause more turbulent combustion than desired, and minimal reduction in NO_X emissions.

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

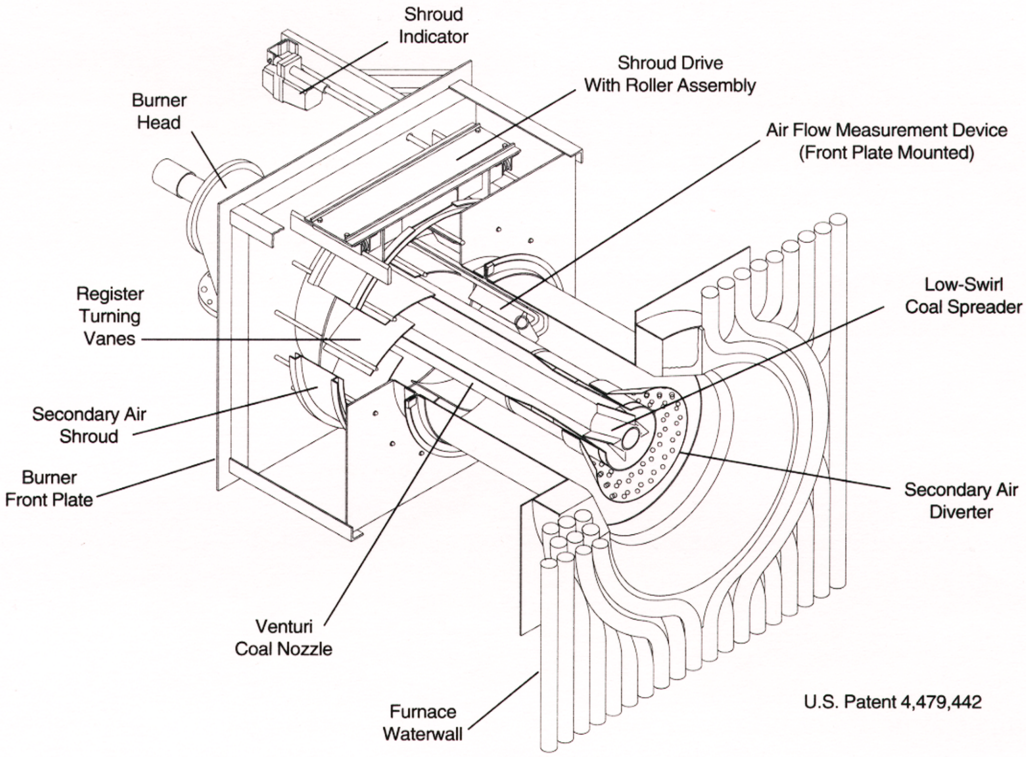

Figure 4 DB Riley Low -NO_x CCV® Burner

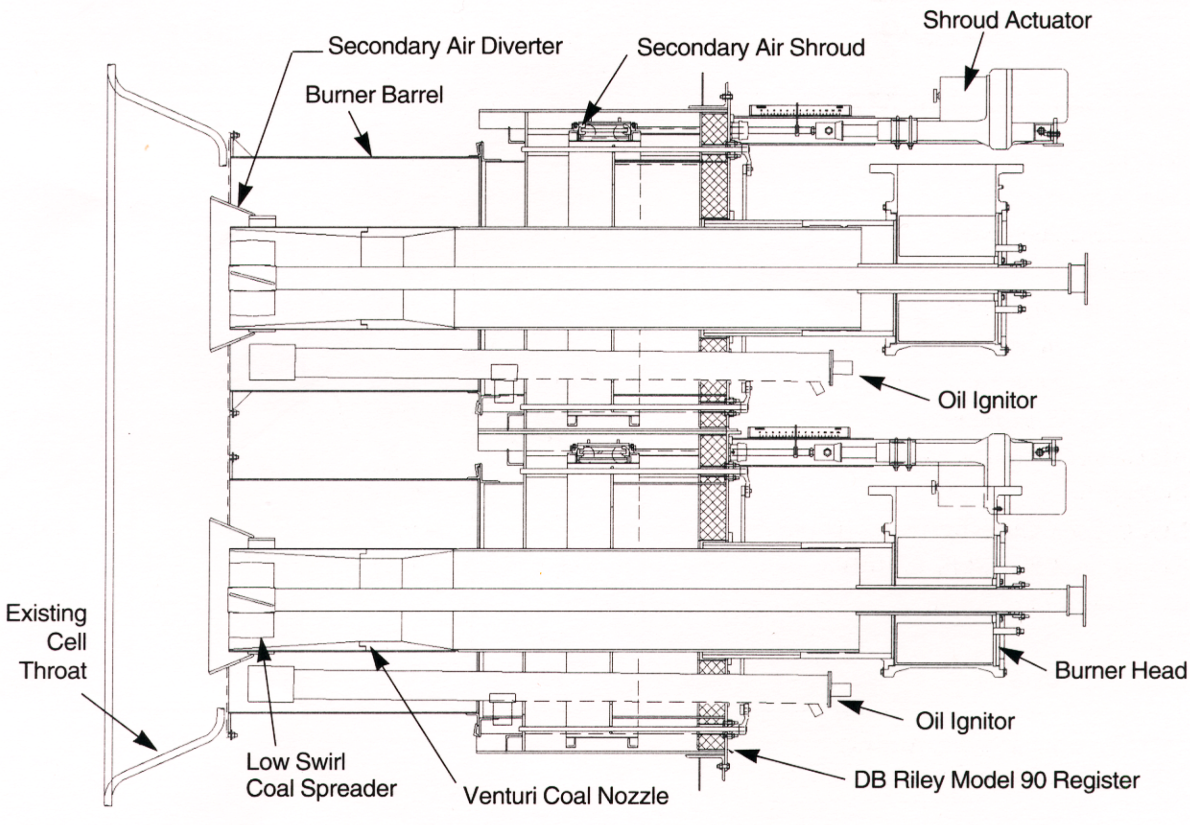

Figure 5 DB Riley Low-NO_x Cell Burner

OPTIMIZATION TEST RESULTS

Post-retrofit optimization testing was performed in early summer, 1994. Our primary concern regarding flame interaction impacting NO_x due to the close burner spacing quickly diminished after observing the CCV® cell burner flame shape. The CCV® cell burner flames were all well attached, narrow and tubular in shape. The flames were distinctly independent from each other with little or no flame interaction between adjacent flames.

The upper row of non-cell configured burners also produced a long narrow flame, but they were detached by various amounts. The detachment was felt to be the result of:

- windbox air maldistribution
- insufficient diverging throat depth for adequate burner recirculation.

Regardless, the optimization testing continued.

As summarized in Figure 6, NOx was reduced to below 0.6 lb/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% as compared to 2.7% prior to the retrofit while the actual percent of unburned carbon in the ash averaged <1%, compared to 1.5% prior to the retrofit. As shown in Figures 6 and 7, NOx decreased with reduction in load and with normal increases in excess air for maintaining steam temperature.

While the Muskingum River Unit 5 burner arrangement benefits somewhat in terms of NOx control (baseline and post-retrofit) 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

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

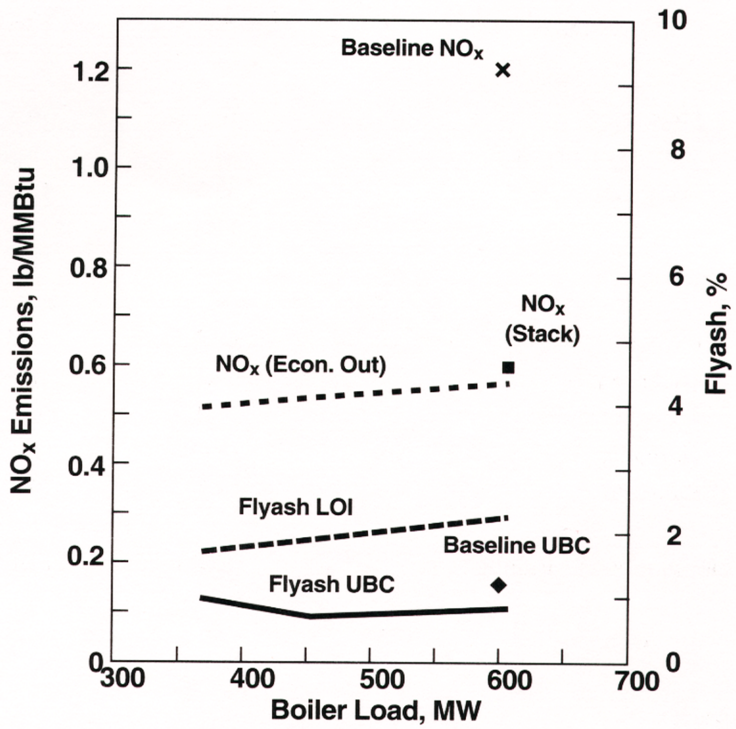

Figure 7 The Effect of Load on NO_x and LOI

tested to simulate the furnace thermal environment of AEP's cell fired 1300 MWe units. The NO_x emissions under this condition increased at full load to 0.63 lbs/10^6 Btu, less than the 0.66 lbs/10^6 Btu predicted, which supports that a nearly 50% reduction in NO_x from the existing 1300 MW units is possible with "plug in" CCV® burners.

It was 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 optimization testing along with pulverized coal fineness results.

LONG TERM OPERATING RESULTS

Long term operation following the optimization testing has resulted in a deterioration of NO_x levels. Data collected from the CEMS equipment indicated NO_x emissions had increased to an average 0.69 lb/10^6 Btu until mid December 1994. Then, a coal change to a lower sulfur East Kentucky coal occurred. NOx emissions increased further to an average 0.75 lb/10^6 Btu and also became more erratic. Figure 8 shows a comparison of the fuel analysis.

The most significant factor affecting the performance is felt to be due to changes in mill operation as a result of changes in grindability, moisture content and heating value. Primary air flow quantity was reduced with the higher heating value of the new fuel, which in turn affects venturi nozzle velocities, burner mixing, and NO_x emissions. Other factors may include boiler seasoning, excess air and burner air distribution.

There are plans to reoptimize unit operation with particular emphasis on burner air distribution, proper flame attachment, and mill operation. The objective is to reduce the NO_x level back down to below 0.6 lb/10^6 Btu. Long term parametric testing is planned which will include evaluation of specific variables such as primary air flow, excess air, burner air distribution, and various burner adjustments.

Coal Source	Central Ohio	East Kentucky
Proximate		
Moisture, %	6.6	6.8
Volatile Matter, %	39.1	33.54
Fixed Carbon, %	42.5	47.82
Ash, %	11.8	11.84
Ultimate		
Carbon, %	68.3	74.0
Hydrogen, %	5.0	4.79
Oxygen, %	8.41	6.20
Nitrogen, %	0.99	1.48
Sulfur, %	4.7	0.70
Higher Heating Value, Btu/lb	11,660	12,153
Hardgrove Grindability	50	45
Coal Fineness		
% through 50 Mesh	99.5	98.4 - 99.0
% through 100 Mesh	95.5	-
% through 200 Mesh	79.1	60 +

Figure 8 Fuel Analysis and Coal Fineness Results

In parallel with this reoptimization effort, DB Riley will use mathematical modeling (Fluent analysis) to evaluate the flame detachment in the upper circular burners. Control of NO_x is difficult with detached coal flames. Potential solutions will be developed.

ADVANCED LOW NO_x COAL BURNERS

DB Riley is currently implementing a program to develop its "next generation" low NO_x coal burner design. The program will evaluate the effects of dual secondary air streams, nozzle and spreader configurations on controlling NO_x emissions. Testing is scheduled to be conducted in early summer of 1995 on prototype burners installed in the 100 MMBtu/hr coal burner test facility at DBRiley Research. All previous testing of CCV® burners has been conducted here for direct comparisons of the test results.

Included in this program will be the installation of the DB Riley SLS dynamic classifier. This will be used to study the effects of various pulverized coal particle size distributions on emissions performance and flyash unburned carbon levels. The dynamic classifier will be integrated with the existing Atrita milling system for direct coal firing. An evaluation of the feasibility of incorporating dynamic classifiers on Atrita milling systems will be made.

The program will also focus on testing three different coals of various volatile contents and reactivity. Our field experience has shown a significant impact of coal quality on combustion efficiency (unburned carbon) and to a lesser extent on NO_x. The effects of various coal qualities on burner performance will be determined during this test program.

SUMMARY

DB Riley and AEPSC have retrofitted low NO_x CCV® 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 and off stoichiometric firing using overfire air ports.

Test data demonstrated the ability to achieve 50% NO_x reduction at MR5 (< 0.6 lb/10^6 Btu) without degradation in boiler performance during post retrofit optimization testing. Long term operation has shown some deterioration in NO_x to levels exceeding 0.7 lb/10^6 Btu. Efforts to reoptimize unit operation as well as an evaluation of design upgrades are continuing.

Advanced burner designs are being tested at DB Riley's Research facilities for improved NO_x control and combustion efficiency. A total systems approach including the burner, dynamic classifier and various coals of different quality and characteristics is being evaluated to meet future requirements. The feasibility of using dynamic classifiers for improved fineness and combustion efficiency would require an economic analysis on a site specific basis. It is anticipated future requirements will include more strict air quality standards as well as special requirements for ash disposal and utilization[3].

ACKNOWLEDGEMENTS

Special thanks are extended to Ohio Power and AEPSC for their continued support throughout this low NO_x retrofit project. Also, thanks are extended to DB Riley's Service Department for their dedicated efforts during the start-up and testing of MR5.

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