TECHNICAL PUBLICATION

The Effects of Coal Quality and Fuel Switching on Low NO_x Burner Performance

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ABSTRACT

One of the greatest challenges facing the advanced Low NO_x coal-fired burner is the requirement for utilizing a wide range of fuels. Utility boilers are benefiting from the cost savings associated with burning coals that were not available in the past. Many original boiler designs were based upon very narrow fuel specifications for coals available from the immediate area. With today's more global market a wide variety of coals are available for most utility boilers and the existing burner equipment must be designed for fuel flexibility and operating longevity. Today's state of the art low NO_x burners are designed with the knowledge that the utility will most likely be firing this wide range of fuels. However, older existing burner technology was not designed to address this type of fuel switching. It is vital that the utility understand the impacts to the performance of the burner and boiler when deciding to change the coal supply. Site-specific studies are key to understanding the unique problems associated with each individual utilities equipment. In general, changing air/fuel ratio's, excess air requirements, primary air temperature and coal fineness deviations as a result of changing coals will impact the burner equipment and operating performance.

INTRODUCTION

In the United States the current fleet of coal-fired boilers is going through an evolution from a fixed or long-term coal supply to an open or spot market, providing coals with varying compositions. This increasing trend has created a need for utilities to evaluate the effect of changing coal supplies on the performance of the existing boiler and firing system components. In the early 1990's the fleet of coal-fired boilers underwent the first of many changes to regulate the NO_x emissions emitted from the boiler. The first major undertaking was to install low NO_x burners. In the early 2000's the second round of changes began with the installation of backend NO_x reduction equipment such as Selective Catalytic Reactors (SCR's).

The combination of the older coal-fired boiler design along with retrofitted low NO_x burners and post combustion emissions regulating systems make fuel switching a process that requires additional study. As an OEM, Riley Power Inc., a Babcock Power Company, has conducted several feasibility studies to the boiler and firing equipment for utilities interested in changing their coal supply from a traditional eastern bituminous coal to a western sub-bituminous coal or lower rank bituminous coal. The following details the key parameters that are affected by fuel switching along with several case studies indicating the kind of changes that may be necessary to permit fuel switching.

APPROACH

The process by which a utility boiler evaluates fuel switching will depend somewhat on the coal the boiler was originally designed for compared to the coal(s) that is being evaluated for the future. The utility must first understand the potential range of the coal composition to be selected for future firing. If the range varies greatly then the utility should consider obtaining multiple samples of coals spanning the range of coal properties. A basic Ultimate analysis will not be sufficient to completely evaluate the impact of fuel switching on the boiler.[1] Each coal should have a minimum of an Ultimate, Proximate and Ash Mineral Analysis completed to initiate the evaluation. If slagging/fouling is a concern for a particular boiler, the utility should consider additional analysis of the coals for the ash softening and ash fusion temperatures. Free Swelling Index (FSI) is also an important parameter to know about a coal in regard to the coal's tendency to stick to hot surfaces prior to combustion, such as burner components.

After information on the future coals is collected, the owner must be prepared to review the entire boiler system to assess the impact on all equipment involved with the coal transport, combustion and steam production.[2] The capacity of the current pulverizer system to grind and transport the future coal is key to determining the performance of the overall system. Next the performance of the Low NO_x Burner equipment will be dependent on the changes to the pulverizer outlet conditions and several key fuel properties. Finally, the boiler steam performance including slagging and fouling can be greatly impacted by the future coals to be burned.

Initially the original design basis of the boiler will be reviewed to determine how the existing low NO_x burner equipment should be performing based on the original design. Current operating data may be collected to determine if the system has undergone any changes/modifications that have already affected the original design performance. The current data will also highlight any current boiler performance and low NO_x burner performance issues that may not have been part of the original design of the boiler.

Using a series of programs developed for evaluating the pulverizer, burner and boiler performance, an OEM selected by the Owner can complete a series of comparative studies for original design coal, current coal and all future coals selected for the boiler being evaluated. These comparisons may require the owner to collect additional site information during the evaluation but this information should not be difficult to obtain. This paper will focus on the evaluation of a low NO_x burner system and the impact of fuel switching on the mechanical and dynamic design of the burner.

WALL-FIRED BOILER WITH SECOND GENERATION LOW NO_x BURNERS

Riley Power has completed several studies to analyze the future performance of the firing and boiler equipment due to potential fuel changes. A current case study will focus on the details of an older utility boiler designed to burn a bituminous coal when originally commissioned in 1968 but currently evaluating, due to the trends and costs of coals, converting the unit to fire sub-bituminous PRB coal. The utility boiler was designed to produce 615,000 pph of steam for electric power generation with a superheated steam outlet at 1,625 psig and 1,005F. The unit was designed to burn a bituminous coal with a higher heating value of 11,500 Btu/lb and a composition of 42% Fixed Carbon, 39% Volatile matter, 8% moisture and 11% Ash. The unit was modified in 2003 with second generation Riley Power CCV® DAZ low NO_x coal burners. Figure 1 is the general arrangement of the boiler, which has eight (8) burners and utilizes four (4) 556S Atrita pulverizers. Figure 2 shows a schematic of the burner design.

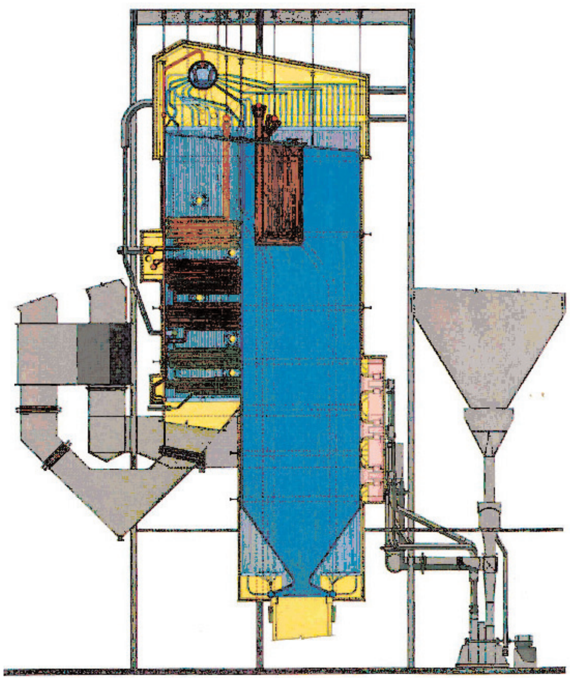

Figure 1. General Arrangement of Steam Generator being converted from Bituminous to PRB Coal

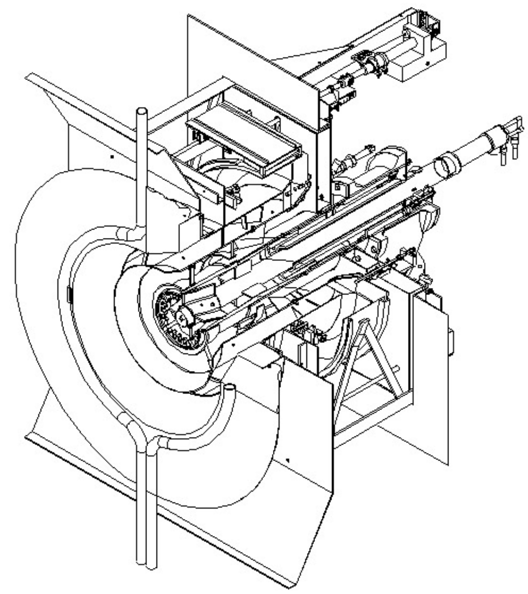

Figure 2. CCV® DAZ Low NO_x burner installation

The owner engaged Riley Power in the fall of 2010 to evaluate the impact of switching to 100% PRB firing utilizing the existing pulverizers and low NO_x burners. The customer supplied data on the current operation of the unit at the design MCR and a lower potential load condition of 400,000 pph of main steam flow. This lower load condition was suggested as the potential boiler steam load when firing the new "Flex Fuel" coal. Riley Power then evaluated this load and theoriginal design load to determine the expected boiler, burner and mill performance with the new design "flex" coal. Tables 1 shows the basic properties for the original design and flex coals.

Table 1

Fuel Analysis

		Bituminous Design	West Elk	Elk Creek	Proposed Flex Fuel
HHV	Btu/lb	11,500	12,120	12,200	9,020
Fixed Carbon	%	42.0	47.4	49.0	37.7
Moisture	%	8.0	7.5	8.0	26.6
Ash	%	11.0	9.5	7.5	4.4
Volatile Matter	%	39.0	35.6	35.4	31.3

Riley Power Engineering conducted a detailed review of the current CCV® DAZ Low NO_x Burner sizing and basic design for the new boiler load conditions specified for this study. Table 2 shows the basic design information utilized during the evaluation.

Table 2

Burner System Design Parameters

		Current Mill System No Modifications to the Mill System	Alternate A/C Ratios with Modifications to the Mill System
Excess Air	%	15.51	
Main Steam Flow	Lbs / hr	400,000	
Fuel Flow	Lbs / hr	66,882	
Total Combustion Airflow	Lbs / hr	522,741	
HHV	Btu / hr	9,020	
Primary Air / Coal	--	1.67	2.0
Secondary Air Temperature	°F	525	460
Mill Exit Temperature	°F	130	
Raw Coal Moisture	% Wt	26.6	
% Moisture Evaporated	%	45	
Burners in Service	#	8	

**620 °F is the Mill Primary Air Temperature. Windbox Temperature is lower.*

Current Mill System Configuration

The reduction in boiler load from the design full load of 615,000 lb/hr of main steam flow while firing bituminous coal to 400,000 lb/hr while firing the proposed Flex Fuel supplied for this study, results in a coal nozzle velocity that is the same as for bituminous coal at the original MCR. However, the low excess air levels combined with the lower total combustion airflows leads to lower than desired secondary and tertiary air burner velocities. The low velocities can produce poor burner aerodynamic flow patterns and poor burner performance. Evaluation of the burner flow patterns need to be further studied using Computational Fluid Dynamic (CFD) Modeling and understood before proceeding with using the current burner configuration while firing the proposed Flex Fuel.

The study also evaluated potential modifications to the burner secondary and tertiary air barrels to determine if the velocities could be increased with modification to the burner. The results show that the secondary and tertiary air barrel diameters would need to decrease by 4” and 7” respectively to return the burner to within the design velocity and velocity ratio criteria Riley Power has established for the Low NO_x CCV® DAZ burner.

Alternate A/C Ratios and Duct Burner Configuration

The increase in A/C ratio to 2.0 effects the current CCV® DAZ burner by increasing the primary air velocity above the allowable velocity. This change would require increasing the coal nozzle diameter along with resizing the secondary and tertiary air barrels to be within the design ranges for the CCV® DAZ Burner.

This is also the case for the potential use of a duct burner discussed for improving the mill capacity. All three zones of the burner would need modification to return the burner velocities to the acceptable design range.

TURBO® FIRED BOILER WITH LOW NO_x BURNER AND OFA

The TURBO® fired furnaces studied for fuel switching were manufactured by Riley Power, Inc (formerly Riley Stoker). The boiler is a single pass drum type, dry bottom balanced draft unit with a single reheat. The Units are designed to operate at a maximum continuous rating (MCR) of 1,355,000 pounds of main steam flow per hour at a design outlet temperature and pressure of 1,005°F and 2,620 psig, respectively. The reheater has a design steam flow of 1,166,000 pounds per hour at an outlet temperature and pressure of 1,005°F and 526 psig. Design feed water temperature is 477°F.

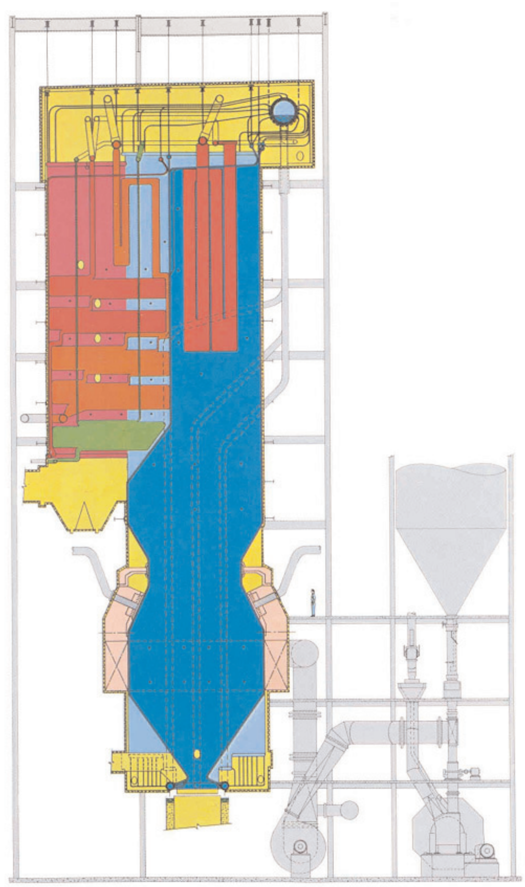

Figure 3. General Arrangement of Steam Generator being converted from Bituminous to PRB Coal

The boiler has a total of twelve (12) Directional Flame Burners, six (6) burners located on each of the opposing walls of the boiler firing in a downward pattern. The burners are supplied with pulverized coal from three (3) 11 ft. diameter by 12 ft. long double-ended Riley ball tube mills. Each mill is equipped with two (2) 6 ft. Model 70 static centrifugal classifiers and two (2) No. 504 type 74 crusher dryers. Each classifier feeds two (2) burners through two (2) coal pipes of 20 inch diameter x 3/8 inch wall thickness. The original design coal has a HHV of 10,250 Btu/lb, 17.95 % moisture content, 43 Hardgrove Grindability Index (HGI), and an ash content of approximately 10.20%. These coal characteristics resulted in a design UBC of 2.08% or a reduction in boiler efficiency of 0.30 %. The original total design coal flow required for MCR was 176,979 pph (58,993 pph per mill).

Since the boiler was initially started, several modifications were made to the combustion system. In 1986, the unit was retrofitted with a new header style Overfire Air (OFA) system. This system has four supply ducts, two front and two rear, which supply common headers located in both the front and rear walls above the burners to introduce OFA into the throat section of the unit. In addition to the OFA system a separate Underfire Air (UFA) system was installed below each burner supplied from the existing windbox. The supply ducts have individual manual dampers for controlling the airflow to each port opening in the furnace.

The owner installed additional modifications to the secondary air (SA) dampers and burner windbox internals in 1998. However, in 2008, the DF burners were upgraded by Riley Power, by installing new low NO_x fixed position coal nozzles and perforated plate, see Figure 4. The existing OFA system was also modified to current Riley Power standards and design criteria to increase the amount of OFA flow and lower the burner zone stoichiometry for reduced NO_x emissions.

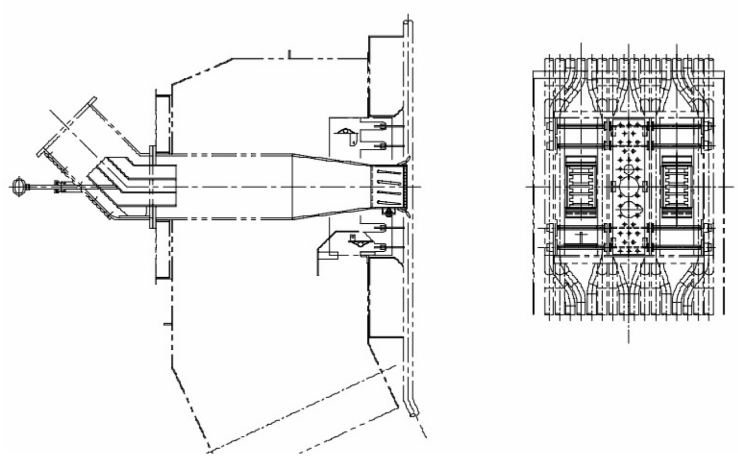

Figure 4. Upgraded Directional Flame Burner with Fixed position Low NO_x Coal Nozzles

The main combustion system analysis objective is to analyze and evaluate combustion system modifications needed for firing 100 % Jacob's Ranch PRB coal at MCR. The specific objectives accomplished so far are:

* The burner design has been evaluated to ensure that the new coal flows and airflows produce burner velocities and critical velocity ratios within the design limits for the Low NO_x Directional Flame burner.

* NO_x emissions were evaluated for 100% Signal Peak Coal, 100% Jacob's Ranch Coal and a 40/60 blend of Signal Peak /Jacob's Ranch coals.

Table 3

Comparison of Colorado-Wyoming Coal to Signal Peak and Jacob's Ranch Coals

	Colorado-Wyoming Coal, Analysis	Signal Peak Coal, Analysis	Jacobs Ranch Coal, Analysis
Proximate Analysis, Wt. %, As Rec'd.:			
Moisture	15.69	17.50	27.35
Volatile Matter	33.69	30.00	33.57
Fixed Carbon	42.9	45.70	33.19
Ash	7.82	6.77	5.49
Gross Heating Value, BTU/Lb	10,294	10,300	8,781
Ultimate Analysis, Wt. %, As Rec'd.:			
Carbon	59.94	60.00	49.86
Hydrogen	4.11	3.81	3.60
Nitrogen	1.216	0.97	0.72
Sulfur	0.46	0.55	0.40
Chlorine		0.01	0.01
Oxygen, By Difference	10.72	10.4	12.58
Ash Fusion Temp:			
Initial Deformation, Oxidizing	2350	2500	2203
Hardgrove Grindability	50	44	52

Burner Sizing and Selection

Riley Power utilized the acceptance test data collected during May of 2008 as the base comparison for the new coals and coal blends being evaluated. When operating under similar boiler conditions the primary air velocities in the coal nozzles are consistently higher than the 2008 design values and exceed the Riley Power design guidelines for the 100% Jacob's Ranch and 40/60 blend of Signal Peak and Jacob's Ranch. The case for firing 100% Signal Peak coal is slightly below the design value utilized in the recent Low NO_x retrofit.

An evaluation of the burner secondary airflow velocity was also completed to determine if the low NO_x design criteria would be met. The 100% Signal Peak run indicated that with the change in fuel the secondary airside of the burner would experience a small change to the average exit velocity. This change would require a small modification to the discharge end of the coal nozzle to ensure the proper design ratio between the secondary and primary sides of the burner could be maintained. Similarly, the 100% Jacob's Ranch and the 40/60 blend of Signal Peak and Jacob's Ranch has similar issues with secondary air exit velocity and the velocity ratio between the secondary and primary air. In these two cases the velocities fall outside the acceptable limits on the primary air and the secondary air velocities and fall below the design values. For both of these cases modification to both the coal nozzle, secondary air openings including the directional vanes would be required.

Riley Power's review of the burner sizing was performed on the current unit 2 design. The coal nozzle was the first component to be evaluated under the new conditions for 100% Signal Peak, 100% Jacob's Ranch and 40/60 blend of Signal Peak and Jacob's Ranch. The evaluation determined that the velocities for the 100% Jacob's Ranch and the 40/60 blend of Signal Peak and Jacob's Ranch exceeded the current design values and exceeded the Riley Power design standard limits. Comparative ratios are developed for each of the new fuels compared to the fuel fired during the May 2008 acceptance testing. These ratios are used to determine if the design velocities are acceptable or if modification is required to the burner.

The variations, as shown in table 4, illustrate the deviations from the acceptable design (1.0 is the acceptable design parameter) as the equipment performed in 2008. The values highlighted are all considered to be out of range and require some modification to the burner to return the values to the design range. The most critical of these values being the Exit PA/SA Velocity Ratio for the burner.

Table 4

Comparison of Key Burner Design Parameters

	Unit 2 - 2008	Signal Peak Coal	Jacob's Ranch Coal	40% / 60% Coal SP/JR
Coal Nozzle Velocity	1.0	0.94	1.23	1.16
Coal Nozzle Exit Velocity	1.0	0.94	1.23	1.16
Secondary Air Exit Velocity	1.0	0.76	0.74	0.72
Exit PA/SA Velocity Ratio	1.0	0.81	0.60	0.62

Red numbers indicate out of range and not acceptable for low NO_x operation as they are more than 10% outside the acceptable range.

NO_x Emissions Evaluation:

An evaluation of the potential impact of these new coals on NO_x emissions was completed by utilizing the Riley Power standard regression analysis and the data collected from the nine (9) most recent low NO_x Turbo® retrofits implemented by Riley Power. The NO_x predictions for 100% Signal Peak coal, 100% Jacob's Ranch Coal and 40/60 blend of Signal Peak and Jacob's ranch are shown in Table 9 below. The NO_x predictions are based upon utilizing the OFA flow system as designed for 20% of total combustion airflows on Unit 2.

Table 5

NO_x Predictions with a 20 % OFA System And Low NO_x Burner Modifications

Coal		100 % Signal Peak	100% Jacob's Ranch	40% Signal Peak / 60% Jacob's Ranch
NO_x Prediction	Lb/mmBtu	0.40	0.38	0.39

The NO_x emissions recorded during acceptance testing while firing the current coal was 0.39 lb/Mbtu. As noted in Table 5, the NO_x emissions are not significantly impacted by the change in coals provided the proper burner modifications are implemented to ensure the key velocity ratio criterion is maintained.

SUMMARY

The analyses completed in the two (2) cases discussed in this paper clearly show that switching coals can dramatically impact the mechanical combustion system components associated with the low NO_x burner. Regardless of the supplier of the low NO_x equipment some key design velocities will be affected with the change from bituminous to sub-bituminous coal. In some cases the variation may be small enough that the low NO_x burner design criteria are still within the acceptable range for performance, in which case modification to the low NO_x burner may be minor or not required to switch to the new coal selected by the owner.

The analysis should not be limited to only the burner design impacts. The analysis must also address the pulverizer and boiler system, as all of this equipment needs to operate properly as a complete integrated system.

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