Technical Publication

Dual Fuel Firing - The New Future for the Aging U.S. Based Coal-Fired Boilers

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ABSTRACT

As the emissions regulations for power plants are becoming ever more restrictive and operating the equipment and cost for coal-firing power is increasing, the industry is turning to natural gas firing. This presents a concern for the existing U.S. power generation base of coal-fired boilers. Many owners are conducting investigative test firing of natural gas to determine the long-term feasibility of either conversion or dual fuel firing to meet the demands for electric power. Other utilities are having exhaustive feasibility studies performed to evaluate the impact of converting a boiler from solid or liquid fuel to natural gas. Recently, Riley Power Inc. (RPI) in conjunction with a major Southeast utility conducted a week-long program to test the boiler's ability to fire full load natural gas in an existing RPI low NOx coal-fired burner. The goal was to determine the ability of the equipment to meet steam load requirements and emissions requirements. The result of this investigation is that the unit can achieve the original steam flow capacity and meet the current emissions regulations. However, substantial control changes will be necessary to ensure the unit can operate automatically on load control. This paper will detail the findings of the testing, the future work that will need to be completed and the challenges to make dual fuel firing a working reality for an existing coal-fired boiler.

INTRODUCTION

In the United States, the fleet of coal-fired boilers is developing plans for producing electric power while utilizing advanced low NOx combustion systems in conjunction with a coal supply that comes from an open or spot market with varying compositions. In addition, these coal-fired facilities are now competing with the natural gas firing facilities because of lower natural gas prices. This trend has created a need for coal-fired utilities to evaluate the potential of switching from conventional coal-firing to natural gas firing. This evaluation can include potential solutions such as;

1. Complete conversion from coal-firing to natural gas firing [1]
2. Utilizing full load gas firing capabilities integrated into the existing coal-fired system (co-firing) [2]
3. Decommissioning of the coal-fired facility
4. Natural gas for preheated coal combustion [2]
5. Natural gas reburn for reduced NOx emissions [2]

The combination of older coal-fired boiler designs along with retrofitted low NOx burners and post-combustion emissions regulating systems make fuel switching a process that requires additional study. As an OEM, Riley Power Inc. (RPI), a Babcock Power company has conducted several feasibility studies of boiler and firing equipment for utilities interested in either 100% conversion of the coal-fired boiler to natural gas firing or adding the capability to fire either natural gas or coal. In the early 1990's RPI successfully designed a Turbo® furnace to burn either natural gas or coal depending on the market pricing for fuel in order to remain competitive when producing electric power in today's U.S. energy market. This paper presents the experiences with two (2) different style coal/gas fired utility boilers. The first is a RPI Turbo® furnace located in the southwest United States and the second is a Foster Wheeler opposed fired furnace in the southeast United States. Both furnaces are designed to fire either natural gas or coal for full steam load capacity.

CASE 1 – IMPLEMENTATION ON A TURBO® FURNACE

Riley Power Inc., has performed several studies on coal-fired utility boilers to determine the feasibility of burning alternative fuels on the potential impact to boiler design and performance. In 1993, RPI implemented the use of natural gas firing on an existing coal fired boiler that is a Turbo® style boiler. Figure 1 shows the arrangement of the combination coal and gas burners installed on this boiler.

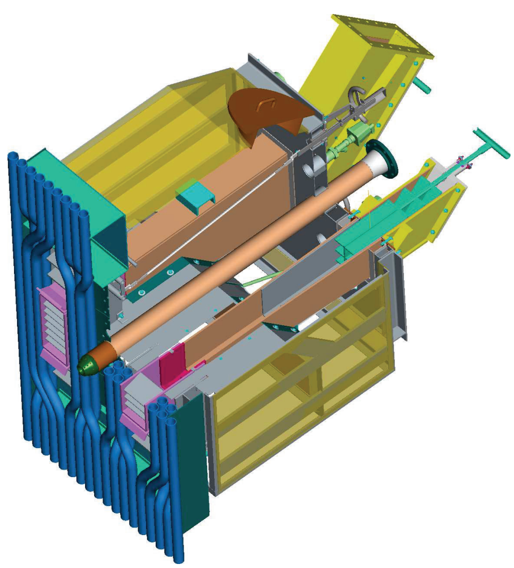

Figure 1 – RPI Turbo® Furnace Directional Flame Burner for Coal and Gas Firing

The boiler is equipped with twelve (12) directional flame burners that receive pulverized coal from three (3) ball tube mills. The burner arrangement is six (6) burners on the front wall and six (6) burners on the rear wall. The boiler was designed to operate at a maximum continuous rating (MCR) of 1,355,000 lbs/hr of superheater outlet pressure of 2,620 psig and a temperature of 1,005°F. Pressure part modifications were not required to accommodate the gas firing. However, as originally designed in the 1970's, flue gas recirculation introduced through the side wall of the furnace in the lower furnace hopper is used to control steam temperature at reduced boiler loads.

In regards to emissions performance, this boiler achieves NOx emissions of 0.39 lb/mmBtu when firing western bituminous coal while CO remains less than 50 ppm. The coal firing system utilizes a separated Overfire Air (OFA) system that reduces the NOx emissions while maintaining boiler performance.[4] RPI testing of the natural gas firing using the OFA system and optimized burner and boiler settings achieved NOx emissions of 0.18 lb/mmBtu with CO emissions of 5 ppm. Adjustments to the operational O_2 curve and airside balancing helped to achieve these emissions levels while maintaining boiler thermal performance.

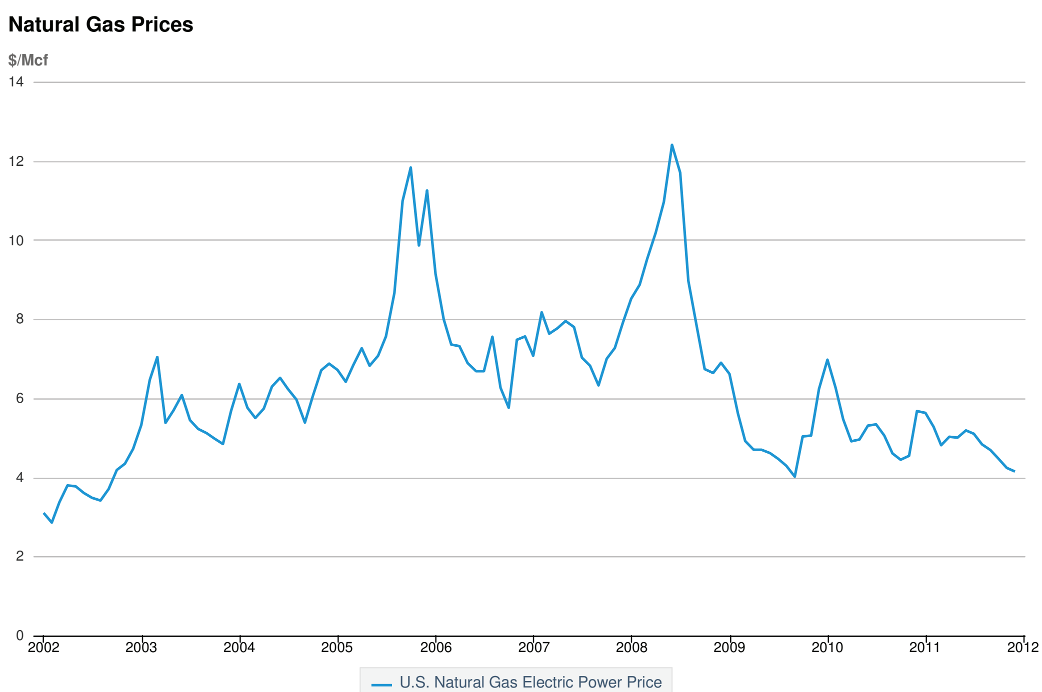

Figure 2 - Natural Gas Prices 2002 To Present [3]

The ability to fire natural gas instead of coal when market prices for natural gas are low (see Figure 2) provides the utility with the flexibility to select the best fuel for producing energy at the lowest overall cost. Producing low cost energy is important to utilities for producing more power over a given operating time. The variability in the price of natural gas is evident in Figure 2, which spans a 10-year period. From our experience, when the price of natural gas exceeds about $6/Mcf, a complete gas conversion project is not economically feasible. Thus, the approach of adding gas firing capability to an existing coal boiler provides the utility with more flexibility to adjust to these price fluctuations.

CASE 2 – IMPLEMENTATION ON A WALL-FIRED FURNACE

The second case study that this paper will discuss is a dual fuel capabilities for an existing coal-fired steam-electric generating facility located in the Southeast United States. This boiler is an opposed-wall fired unit originally manufactured by Foster Wheeler. It is a single-stage reheat, natural circulation steam generator that currently has twenty-four (24) RPI CCV® DAZ Low NOx Burners firing bituminous coal. These burners included the capability to fire full load gas on each burner, see Figure 3.

The combustion system also includes RPI's separated Overfire Air (OFA) System.[4] The burners are positioned in a 3-level configuration with four (4) burners per level, for twelve (12) burners on both the front and rear walls of the unit with a burner heat capacity of 205 mmBtu/hr. The rated steam capacity of this unit is 3,619,500 lb/hr of main steam flow at 2,486 psig and 1005°F. The total generating capacity is 500 MWg.

The full load gas firing capabilities were never commissioned when the RPI low NOx coal burner equipment was originally installed on the boiler in 2008. Now, due to the economics of coal firing versus natural gas firing, this facility is investigating what will be required to allow the boiler to operate on either natural gas or coal on a day-to-day basis driven by unit availability and economics. RPI approached this feasibility study by reviewing the combustion requirements that would need to be investigated and tested in order to ensure safe reliable operation on both natural gas and coal. The initial investigation included testing of the natural gas fired equipment under the original operating conditions engineered for this unit.

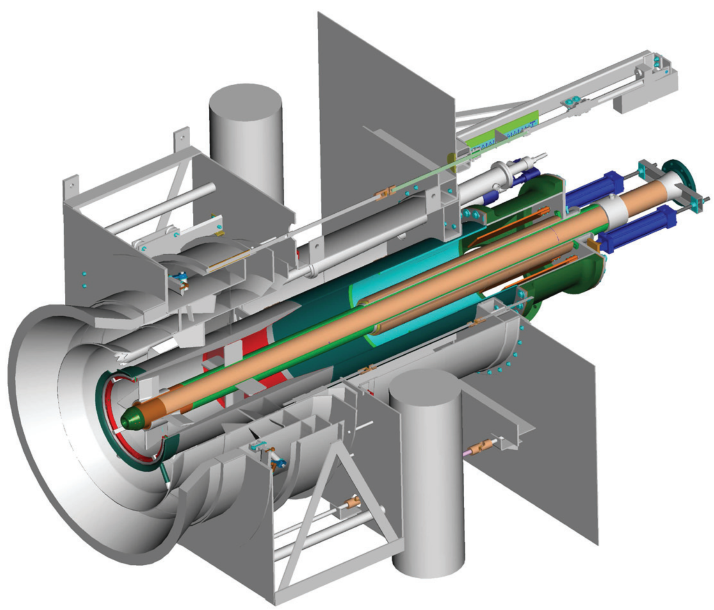

Figure 3 - CCV® DAZ Low NOx Burner With Natural Gas Firing Capability

System Test Parameters

In order to establish long-term operation for natural gas firing, the system must have the necessary control curves for the key operating parameters defined and implemented into the control system.

Table 1 – Test Protocol

Adjustments	Variable being Tested
Burner Shroud Position	% Open for optimum Windbox pressure and burner flame dynamics
Boiler Outlet %O_2	The required excess air for good combustion and boiler performance
Shroud Bias	Balancing the airflow burner-to-burner
TA Swirl Vanes	Flame shaping and NOx/CO optimization
OFA System	Staging to reduce the NOx emissions

The test program spanned a range of boiler loads including 100% MCR, Valves Wide Open (VWO) demonstration, 80% MCR, 60% MCR and 40% MCR. During testing, the FD Fan controls, main gas regulating valve and bypass valve were all controlled in manual, as the current boiler controls do not allow for automatic operation while firing gas. This test program was intended to develop key curves for future automatic operation on natural gas firing. As testing progressed thru the week, some tests were modified to better suit the boiler operation.

Boiler O_2 Curve Development

The testing conducted during the week-long program established an economizer exit O_2 versus boiler load curve for the operating range of the unit. The final data points shown in Figure 4 were determined to be the optimum set point based on boiler operation, visual inspection and economizer outlet gas sampling. Gas sampling was utilized to determine the maximum CO that was less than 100 ppm. The CO value was set by mutual agreement between the client and RPI engineering for continuous safe operation of the boiler. The curve shown in Figure 4 is based on the main steam flow but can also be related on a natural gas flow basis. Following this optimized O_2 curve, the CO emissions can be maintained below 100 ppm.

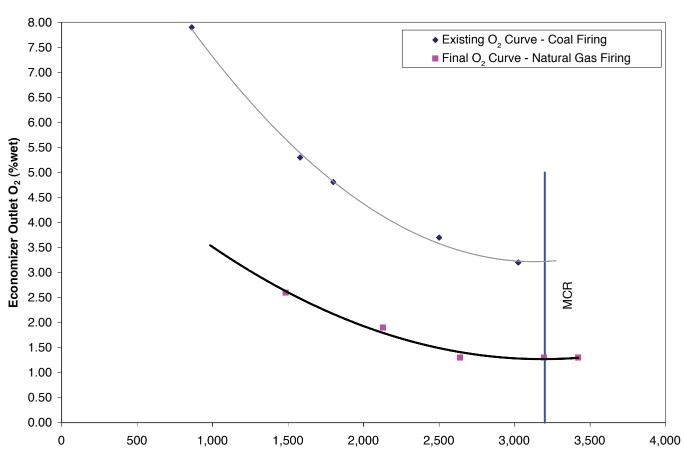

Figure 4 - Final O_2 Curve For Natural Gas Firing

Burner Light-off and Operational Parameters

In order for the boiler to control the combustion with automatic controls, the combustion requirements have to be determined for light-off and normal operation with varying windbox and gas pressures. Figure 5 below is a typical curve showing the burner shroud position versus load for the boiler load range. During testing the light-off position was determined to be optimal at 30% open. In addition to the burner shroud position, a windbox-to-furnace differential pressure curve (Figure 6) was required for automatic control of the unit using the existing equipment and control logic. The RPI low NOx burner will modulate the burner shroud on this pressure curve as the boiler load varies. Establishing these operational curves is essential to controlling the unit for long-term automatic operation.

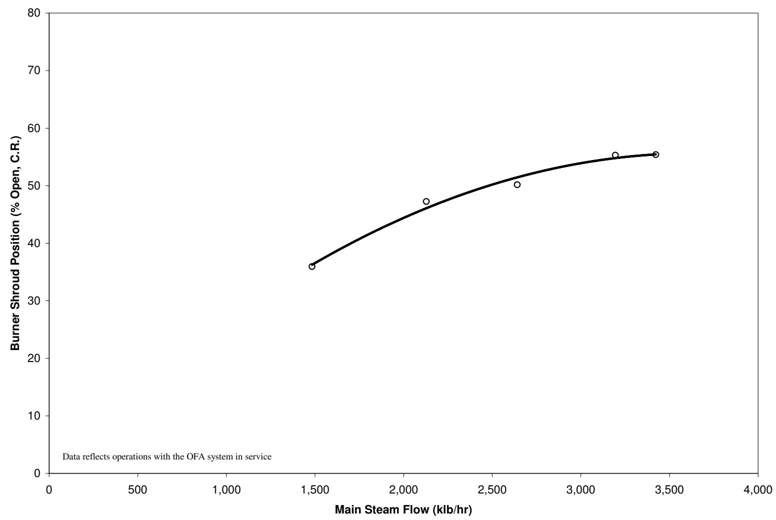

Figure 5 - Burner Shroud Position Versus Boiler Main Steam Flow

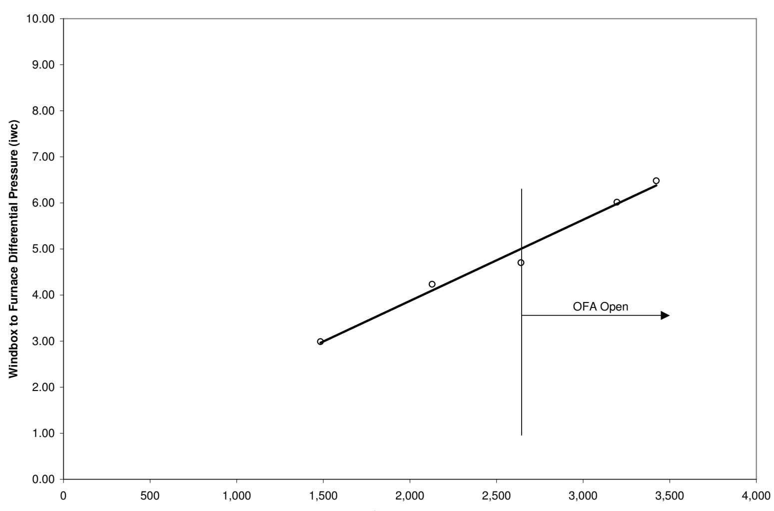

Figure 6 - Windbox To Furnace Dp Vs Main Steam Flow

NOx Emissions Evaluation

Like any new technology or upgrades to an existing system, the emissions performance is always a critical parameter. RPI's evaluation included some preliminary predictions of the NOx emissions prior to the testing. The final test results shown below in Figure 7 indicate that the unit can operate below the current permit requirements established for the unit while firing coal. However, one of the recommendations from the engineering evaluation and testing is a modification to the existing standard gas gun to promote lower NOx emissions.

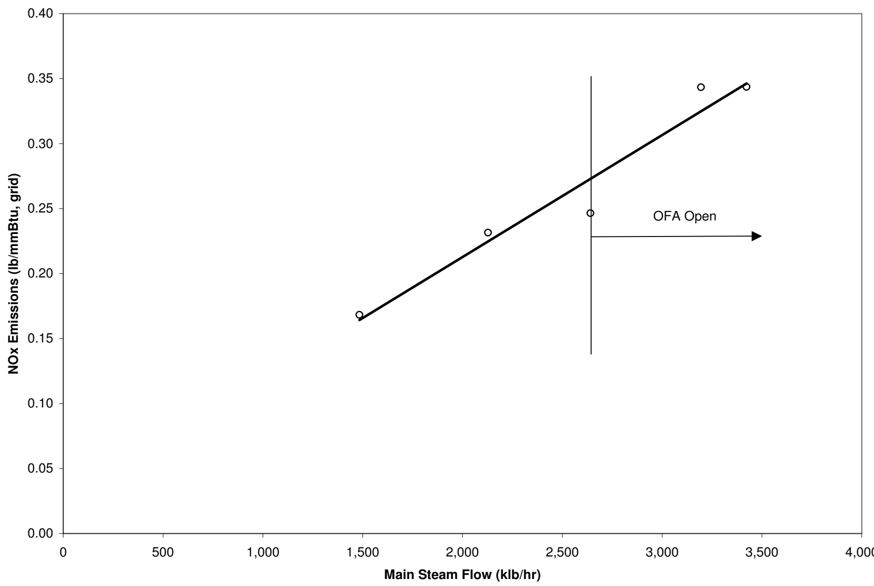

Figure 7 – Nox Emissions Vs Main Steam Flow

Boiler Thermal Performance Review

During testing data was collected on the boiler operating conditions to ensure the boiler could reach all the design conditions for Superheat (RH), Reheat (RH), throttle pressure and economizer outlet gas temperature. Table 2 shows the key boiler data collected for the full load operation and based on the original design parameters the unit is within the acceptable design limits for full load operation.

Table 2 – Boiler Performance Data Summary

		Original Design	Gas Firing Performance
Superheater Outlet Temperature	°F	1005 ±10	996
Reheat Outlet Temperature	°F	1005 ±10	1,000
Economizer Inlet Temperature	°F	485 ±10	474
Main Steam Throttle Pressure	Psig	2,400	2,400

Gas Supply Equipment Review

The final portion of the evaluation includes the natural gas supply control equipment and its functionality for continuous operation. The current system utilizes one large control valve for the main gas with a smaller by-pass valve. Since the boiler is configured with three (3) elevations of burners both front and rear this single control valve presented problems for controlling the gas pressure and flow during light-off and initial start-up. The current system is prone to fluctuations in pressure to operating burners when trying to bring other burners into service. These fluctuations make low load operation more challenging.

As a result, this boiler will require modification to the existing gas piping and control scheme in order to operate the boiler under AGC load control. The optimum design would be to have individual control valves for each burner. However, an alternate design of lower capital cost would be to use individual burner level control valves (6 valves in total). This design would install one control valve for each burner level to control the gas pressure and flow that will improve the reliability during light-off and low load operation. These improvements are a necessity for the utility to utilize natural gas firing as an on-demand fuel and be able to respond to load demands from dispatch.

SUMMARY

RPI's experience with many utilities that desire the flexibility to fire either natural gas or coal has proven that the aging coal fired U.S. fleet can be successfully retrofitted to fire both fuels. RPI has successfully retrofitted four (4) utility boilers to fire coal or gas at the original steam flow capacity requirements with acceptable emissions and acceptable boiler thermal performance. In addition, RPI has retrofitted two (2) boilers with coal and gas co-firing capability. Each site has specific challenges associated with each application to maintain boiler performance and emissions performance. Once the performance impacts have been evaluated the operation and control of the unit needs to be assessed to determine the additional equipment and controls required to allow switching between natural gas and coal automatically. The capital costs associated with these changes need to be evaluated in concert with potential emissions impacts and the current market for energy sale within the utilities region. The key factor that utilities should strongly consider is to implement dual fuel firing capability for their existing coal fired boilers instead of complete 100% natural gas conversion and decommissioning of the coal handling / firing equipment. This approach will provide the utility with the flexibility to switch back and forth between coal and natural gas depending on the price of natural gas while maintaining environmentally acceptable emissions performance.

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