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ABSTRACT

This paper documents the installation of plug-in low NO_x burners on a utility boiler with cell burners. The original rapid mix burners and typical close burner centerline spacing produced a very hot furnace environment resulting in extremely high NO_x emissions, in this case as high as 1.0 lbs/MMBtu.

The unit was a #6 oil-fired, 560 MWe supercritical pressure, three-cell burner boiler at Commonwealth Electric's Canal Station, Unit #1. This paper presents the results including emissions and boiler performance of the retrofit of DB Riley low NOx STS® (Swirl Tertiary Stage) burners. Low NO_x burners were used in conjunction with close-coupled overfire air using existing burner openings. The project reduced NO_x emissions greater than 70% while firing #6 oil, and this was accomplished with less than 10% flue gas recirculation.

INTRODUCTION

Over 39,000 MW of the United States' generating capacity is produced by heavy oil (No. 6 oil) fired steam generators. Operations of most of these utilities are governed by stringent

NO_X emission regulations. Typical low NO_X systems reduce NO_X emissions by careful control of combustion stoichiometry and by reducing combustion flame temperature. Low excess air operation, burner out-of-service (BOOS) operation, replacement low NO_X burners, overfire air systems, and flue gas recirculation through the burners are widely used techniques to reduce the production of NO_X. Low NO_X systems should be designed to maintain CO emission and flue gas opacity levels within allowable limits.

This paper describes a low NO_X retrofit on Commonwealth Electric's Canal Electric Company, Unit #1 boiler. Unit #1 is a Babcock & Wilcox supercritical pressure (UP-38), No. 6 oil-fired boiler. DB Riley, Inc. used a system approach to reduce NO_X emissions on this boiler. The heart of DB Riley's solution to this NO_X reduction application is the STS® burner. The axial staged burners were installed together with an overfire air system and burner flue gas recirculation system. These modifications involved minimum boiler pressure part modifications. NO_X emission reduction of over 70% was achieved. Low NO_X levels were achieved accompanied by very low CO emission and opacity levels. Low NO_X system description, pre-retrofit and post-retrofit field emission and boiler performance test results, as well as field observations are discussed here.

UNIT DESCRIPTION

The Canal Electric Company, Unit #1 boiler, is located in Sandwich, Massachusetts. Unit #1 is a once through, supercritical, double reheat boiler with a pressurized furnace. See Figure 1. Superheated steam temperature control is by firing rate and spray water attemperation. Reheat steam temperature control is by flue gas recirculation through the furnace hopper and spray water attemperation. The unit is equipped with two forced draft (FD) fans

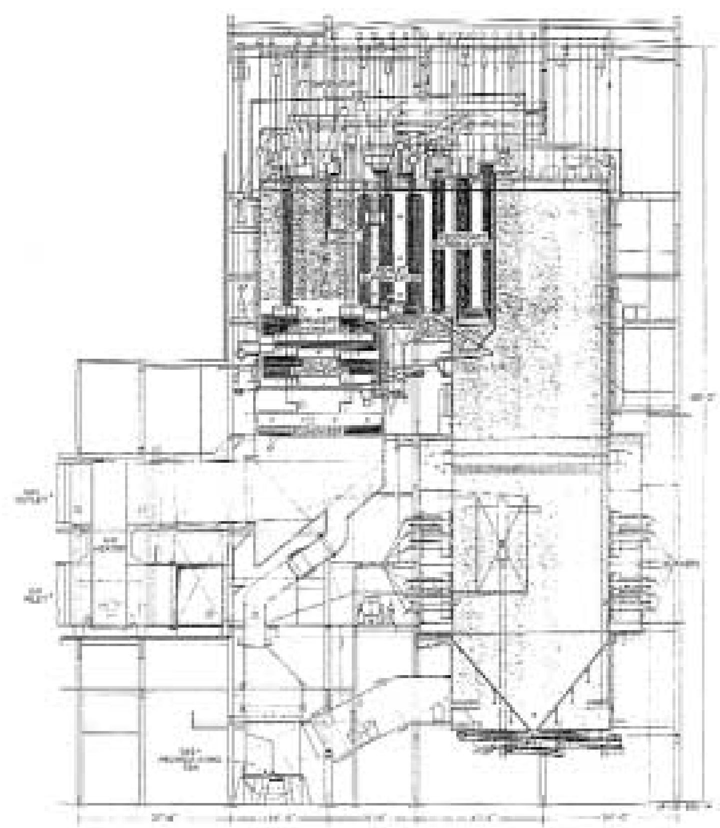

Figure 1 Canal Electric Company, Unit #1

and two gas recirculation (GR) fans. The original gas recirculation fans recirculated flue gas from the economizer outlet to the furnace hopper.

The unit was originally equipped with forty-eight cell burners; twenty-four front and twenty-four rear, assembled in sixteen cells of three burners each. The cells are in two levels with four cells across. The main fuel oil in the original system was mechanically atomized. The original burner configuration is shown in Figure 2.

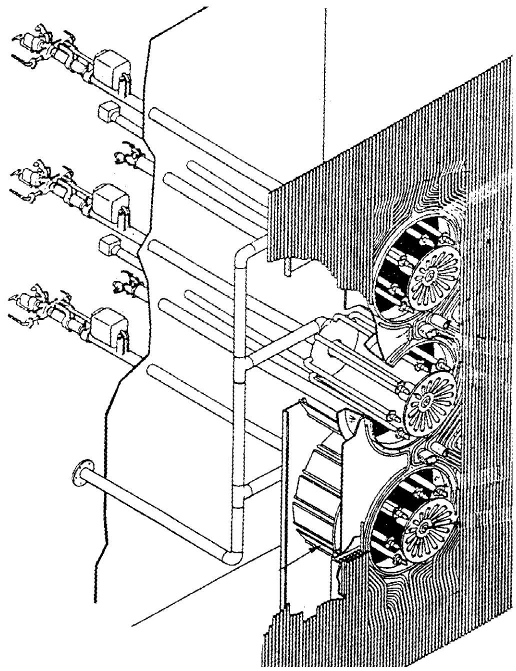

Figure 2 Original Cell Burner

The unit is designed for a superheat steam flow of 3,720,000 lbs/hr at 1007°F and 3,825 psig. Reheat I steam flow, as originally designed, is 3,152,000 lbs/hr at 1007°F and 1,074 psig. Reheat II steam flow is 2,896,000 lbs/hr at 1000°F and 330 psig. Feedwater temperature to the economizer is 561°F. The unit is designed for a gross generation of 560MW.

LOW NO_X COMBUSTION RETROFIT

Commonwealth Electric contracted with DB Riley, Inc. in July, 1994 for the design, fabrication and installation of a low NO_X system for Unit #1 at Canal Station. The original forty-eight oil burners (opposed fired; twenty four per firing wall) were replaced with forty DB Riley STS® burners. Each heavy oil burner was rated for 130 MMBtu/hr heat input at full load conditions. A schematic showing the burner design is shown in Figure 3. The burner supplied for this project was a modified version of the standard STS burner, as shown in Figure 4. Design changes were necessary due to the very close centerline spacing of the burner openings (3' 10") for the three cell high arrangement. The standard arrangement of the axial staged STS® burner includes an adjustable register for the secondary air only. Shrouds are used for primary and secondary air passages for taking the burner out of service. The shrouds are also used to bias primary/secondary air ratios as well as to effect burner to burner air/fuel ratio biasing.

The modified STS® burner supplied for this project used the same axial staging principles and flow splits of the standard design, but used the curved blade register as a means to

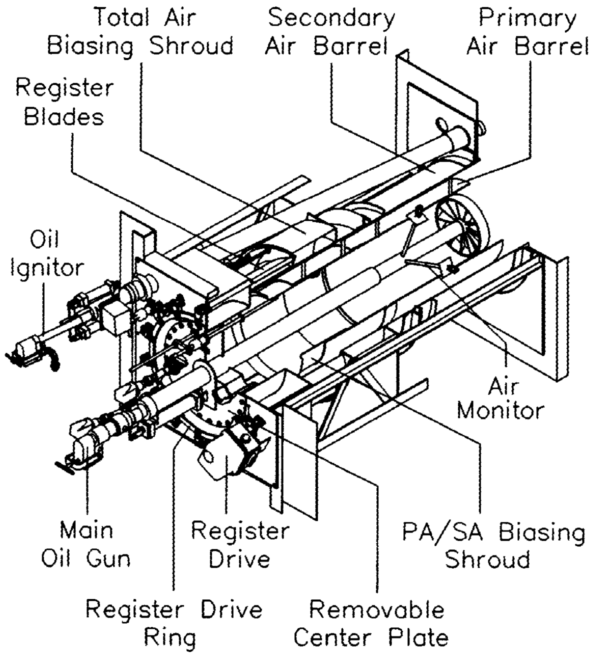

Figure 3 STS® (Swirl Tertiary Stage) Burner Adapted for Cell Fired Applications

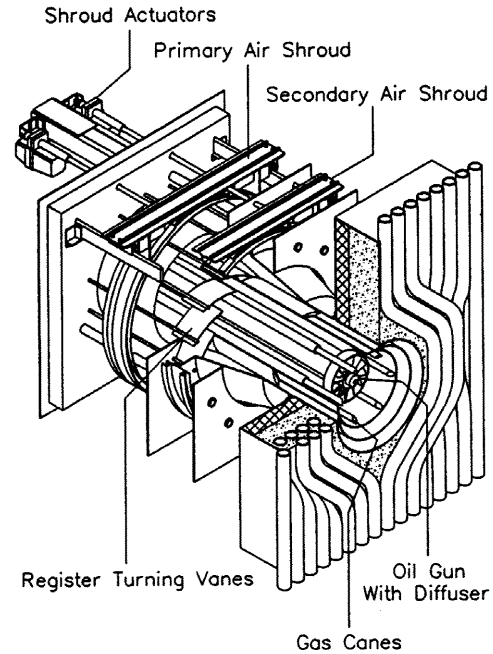

Figure 4 Standard STS® Burner

shut off the air flow to the burner when it is taken out of service. In this design, the register imparts swirl to both the primary and secondary air streams. This swirled air to the primary side of the burner resulted in some minor mechanical problems that will be discussed later. Two internal shrouds were employed; a primary/secondary air shroud for varying flow splits between the primary barrel and the outer secondary air annulus, and a total air shroud used to adjust the total air entering the burner. A curved, multi-vane swirler was provided by Combustion Components Associates (CCA). CCA also provided the oil guns and internal mix atomizers for the project.

The original mechanically atomized, return flow, #6 oil system (900 psig maximum) was upgraded to a steam atomized system utilizing maximum oil pressures at the oil gun of 190 psig. The system was designed to operate with a constant oil/steam differential pressure of 10 psig.

Further air staging was provided by using the existing top burner openings for overfire air ports. Port sizing was designed to accommodate 20% of the total combustion air flow. The close proximity of the OFA ports to the top burners was not optimum for maximum effectiveness but was considered adequate. Additionally, two wing OFA ports were added to help control carbon monoxide (CO) production. This approach is common in OFA design to mix combustion air more effectively with products of combustion that travel up the corners of the furnace.

The existing gas recirculation system was modified to enable recirculated flue gas to be introduced into the windbox as well as the lower furnace hopper. This involved replacing the original gas recirculation fans to ones with higher static pressure capability. Recirculated gas flow rates to the windbox of at least 15% of total were anticipated to achieve the mandated NO_X levels of .28 #/MMBtu. The air foils used to measure air flow in both secondary air ducts were modified to mix the flue gas with the combustion air. Slots were cut into the trailing edges of the foils and ductwork connected to the bottom of the twenty-four foot high foils. Dampers were provided to enable characterization of the gas flow to the windbox as well as furnace hopper with load.

Additionally, a “turndown” damper was provided to shut off FGR to one of the two air foils in each duct to ensure adequate mixing of the flue gas with combustion air at low recirculated flow rates.

Lastly, the mechanically atomized light oil ignitors were replaced with air atomized oil ignitors. For the upper cells consisting of two burners, one ignitor was provided. Two ignitors were used for the lower, three cell configuration.

TEST RESULTS

Baseline testing in the Fall of 1994, performed after the contract was awarded, demonstrated that the unit produced NO_X emissions with values as high as 1.0 #/MMBtu at less than 5.0% excess air at the economizer outlet. Analysis of the fuel oil being burned during the testing showed nitrogen levels of approximately .3%. NO_X emissions is heavily dependent upon the fuel nitrogen levels; the contract conditions involved meeting the NOx emission guarantee with fuel nitrogen levels of up to .5%. During post retrofit testing, the fuel nitrogen levels were in the range of .48%.

Post retrofit optimization testing was performed in the early summer of 1995. Initial balancing of burner air flows were done by using the outputs of the Air Monitor Corporation air flow measuring devices. After a brief tuning period, the unit was shown to be in compliance and deemed acceptable by the customer. Before and after emission and boiler thermal performance is shown in Figure 5. A graph showing the effects of load on NO_X and carbon monoxide are shown in Figure 6.

Parameter		Pre-Retrofit			Post-Retrofit		
Gross MW	MW	342	454	579	350	483	581
Excess Air	%	11	6	4.5	13	8	7
% Gas Recirculated (hopper)	%	22	14	7	15	14	10
% Gas Recirculated (burner)	%	–	–	–	8	8	10
Gas Temperature Leaving Unit	°F	314	327	316	316	332	314
Boiler Efficiency	%	88.6	88.4	88.8	88.7	88.5	88.8
Fuel Nitrogen	%	–	–	.3	.48	.48	.48
Emissions:							
NO_X	lbs/MMBtu	0.51	0.62	0.96	0.22	0.26	0.26
CO at 3% 0_2	ppm	11	107	78	1	31	60
Particulates	lbs/MMBtu	–	–	–	–	–	0.06

Figure 5 Boiler Performance /Emissions

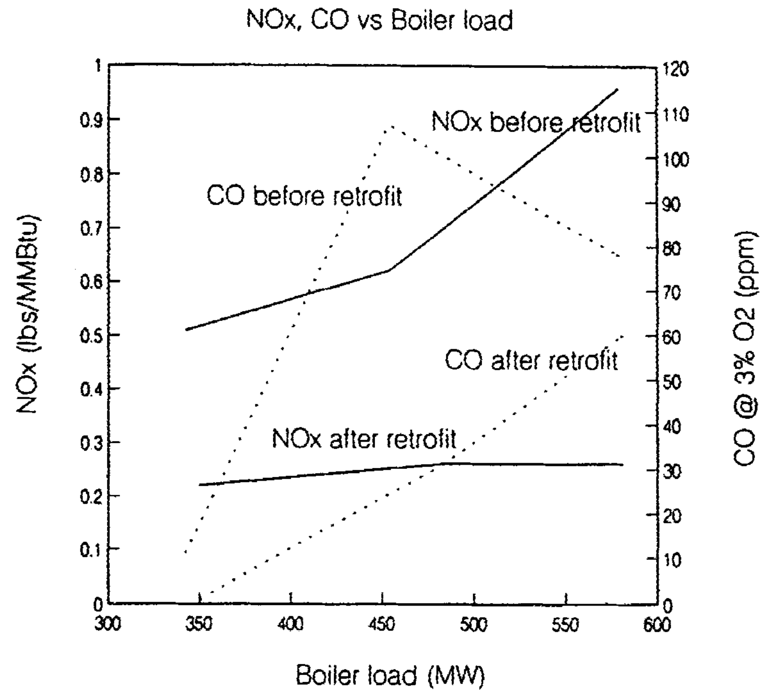

Figure 6 NO_X and CO vs. Load

FIELD OBSERVATIONS

An outage after two months of operation revealed two mechanical problems related to overheating. Some of the swirlers and ends of the oil gun guide tubes showed signs of "erosion." The preliminary conclusion was that on the burners used for start-up, the air register setting was closed more, which in turn caused more spin of the combustion air. This caused the recirculation zone in front of the swirler to move back towards the burner. While no flame was visible in or through the swirler, furnace gases were apparently being drawn through the swirlers in question. The balance of the burners and firing equipment was unaffected.

Overheating was also evident at the ends of the overfire air port ducts. The original selected grade of stainless steel was inadequate for the close proximity to the top burners and the high heat release of the cell fired configuration. Upgrading the materials to higher grade stainless steel, and Inconel corrected the problem.

The ultimate success of a project with stringent emissions requirements relies on balancing of air fuel ratios and modifying the combustion process to reduce peak flame temperatures. It is critical that the firing system is maintained carefully to keep performance at the required levels. Other factors, such as oil strainer cleanliness, atomizer condition, burner settings, and furnace cleanliness must be monitored regularly to ensure compliance over the long run.

SUMMARY

Commonwealth Electric Company successfully retrofitted the Canal Electric Company, Unit # 1, 560 MWe, triple cell burner, supercritical unit using DB Riley's low NO_X burner/system. The project was implemented without requiring burner respacing. Pressure part modifications were limited to adding four "wing" OFA ports.

The low NO_X system has reduced NO_X to <.28 #/MMBtu (>70% reduction) without significantly changing boiler thermal performance, particulate loading to the precipitator, or CO emissions.

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