TECHNICAL PUBLICATION

T-Fired Low NOx Retrofit and Superheater Replacement on Xcel Energy Comanche Unit 1

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ABSTRACT

Xcel Energy contracted with Riley Power Inc. (RPI), a Babcock Power, Inc company, to furnish and install a new low NO_X retrofit combustion system and replacement superheater front pendant assembly on Comanche Unit 1. Comanche Unit 1 is a tangentially fired 365 MWg, subcritical utility boiler designed to burn Power River Basin (PRB) sub-bituminous coal. The NO_X reduction system included a partial windbox retip, a single level of separated OFA and the addition of yaw capability on the existing close coupled OFA system. New coal tips featuring Conforma Clad® infiltration brazed tungsten carbide cladding were installed to extend coal tip wear life. The new superheater was designed to increase outlet steam temperature and featured stainless steel construction as well as alternate tube spacing and configuration to mitigate excessive fouling.

Following the equipment installation in the fall of 2008, NO_X emissions were initially reduced from a pre-retrofit baseline level of 0.38 lb/MMBtu to 0.128 lb/MMBtu (a reduction of > 65%) when operating at maximum continuous rating (MCR) with all mills in service. Concurrently, boiler efficiency and flyash unburned carbon levels were improved from baseline levels, while CO emissions were maintained at the pre-retrofit level. Target performance was also met for the replacement superheater. Subsequent tuning of the combustion system several weeks later resulted in NO_X emissions at 0.124 lb/MMBtu with CO below baseline levels and NO_X levels as low at 0.115 lb/MMBtu. This paper describes the retrofit hardware furnished as well as the impact on emissions and boiler performance.

INTRODUCTION

Xcel Energy's Comanche station located in Pueblo, Colorado is currently the largest electric generating station in the state of Colorado with a total gross output of 1568 MWg. Key design and operating parameters for the units at the Comanche station are summarized in Table 1.

Table 1

Key Design / Operating Parameters for the Comanche Station Units

Unit	OEM / type	MWg	Initial In-Service Date
Unit 1	CE / 4-corner T-fired	365	November 1973
Unit 2	B&W / opposed wall	375	December 1975
Unit 3	Alstom / 4-corner T-fired	828	May 2010

Comanche Unit 1 shown in Figure 1, is a tangentially fired, sub-critical boiler designed for a maximum continuous main steam flow of 2,534,000 lb/hr at 2,500 psig and 1005 °F and reheat steam flow of 2,155,000 lb/hr at 577 psig and 1005 °F (Figure 1). The unit burns sub-bituminous Power River Basin (PRB) coal (Table 2) and natural gas. Coal is pulverized by five (5) CE 803 RS mills, which feed five elevations of coal nozzles. Natural gas is introduced through gas spuds in the four (4) intermediate auxiliary air compartments. The original corner windbox assemblies also featured two (2) levels of Close-Coupled Overfire Air (CCOFA) with manual tilt capability.

OEM modifications to Comanche Unit 1 in 2000, included the following:

* Complete windbox retip with natural gas addition
* Stationary coal nozzles
* Nozzle tilt upgrade
* New windbox damper modules
* Coal piping supports

The construction permit for Unit 3 was issued contingent upon reducing the NO_X emissions for both Units 1 and 2. The new limits include a 30-day rolling average of 0.20 lb/MMBtu on a per unit basis and a combined 365-day rolling, BTU weighted average of 0.15 lb/MMBtu for Units 1 & 2 averaged together. Xcel Energy established NO_X target emission limits of 0.134 and 0.154 lb/MMBtu respectively for Units 1 & 2 to provide a small level of margin to meet the 0.15 lb/MMBtu average for both units. Riley Power Inc. was the only bidder willing to accept the established NO_X limits as well as the contract terms and conditions on both units. Riley Power was awarded the contract for Unit 2 in September 2006 with subsequent installation of RPI CCV — DAZ low NO_X burners and new OFA ports in the fall of 2007. The Comanche 2 retrofit design evaluation, scope and post-retrofit results are summarized in previous literature [1, 2]. In August 2007, Riley Power, Inc. was awarded the low NO_X retrofit and boiler performance improvement contract for Comanche 1. RPI and Xcel jointly conducted pre-retrofit baseline testing in September 2007. This paper provides a summary of the emissions and performance modifications implemented on Comanche Unit 1 together with the results and subsequent steps proposed by Xcel Energy to maintain long-term environmental compliance.

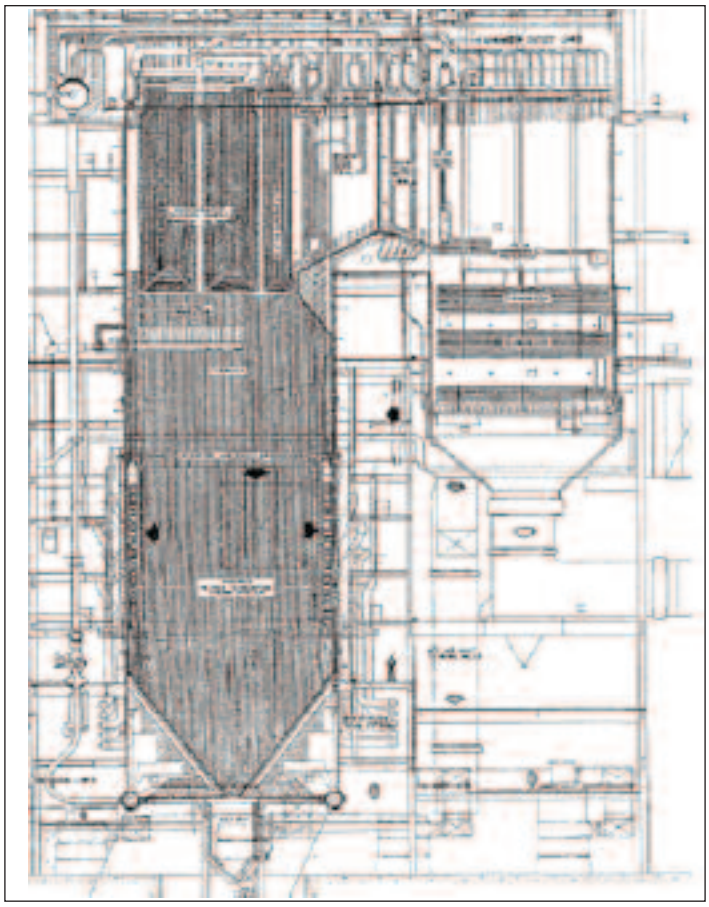

Figure 1. Comanche Unit 1 Schematic

Table 2

Belle Ayr PRB Coal Properties (As-Received Bases)

Proximate Analysis (wt%)		Ultimate Analysis (wt%)	
Fixed Carbon	36.11	Carbon	51.35
Volatile Matter	31.70	Hydrogen	3.59
Moisture	26.20	Nitrogen	0.78
Ash	5.26	Sulfur	0.24
HHV (Btu/lb)	8,800	Oxygen	12.08

LOW NO_X RETROFIT SYSTEM

RPI's experience with low NO_X retrofits on tangentially fired boilers dates back to as early as 1993 and is presented in previous literature [3,4]. RPI's low NO_X retrofit system for Comanche 1 consisted of a single elevation of separated OFA with automatic tilt capability, a partial windbox retip, and modifications to the close coupled OFA compartments to add yaw capability in addition to the pre-existing manual tilt capability. A comparison of the pre-retrofit and modified windbox arrangement is depicted in Figure 2. A photo of the separated OFA windbox assembly is shown in Figure 3. RPI's scope also included new, pneumatic drives for both the main windbox tilts and compartment dampers.

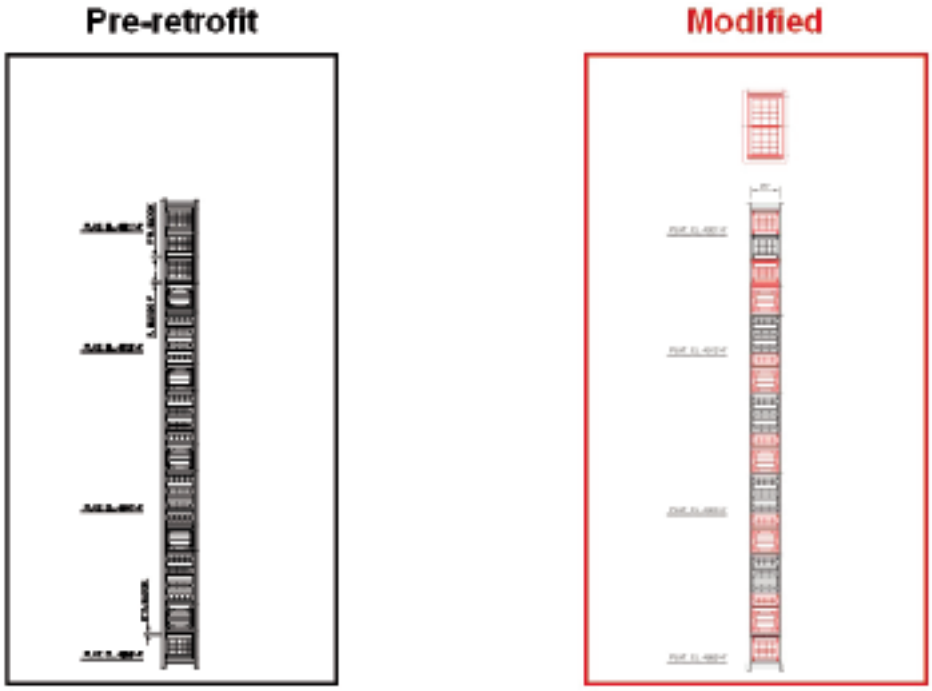

Figure 2. Comparison of Pre-retrofit and Modified Windbox Arrangements

Figure 3. Comanche 1 Separated OFA Windbox Assembly

EXTENDED WEAR COAL TIPS

Xcel Energy, like many utility boiler owners, continuously searches for options to reduce the frequency and associated costs of scheduled maintenance outages in order to maximize station profitability. As a major wall fired burner manufacturer, RPI has been continuously evaluating various options for materials of construction, the application of weld overlay and wear resistant coatings in order to maximize burner component wear life and minimize required maintenance. Through both laboratory and field experience RPI has found Conforma Clad© tungsten carbide cladding by Kennametal Inc. to be a superior product for extending the operating life of burner wear parts[5]. RPI has been offering this material as an option on wall fired burner applications since 2004. Conforma Clad© is a tungsten carbide material in the form of a cloth delivery system that can be applied to burner components exposed to pulverized coal through an infiltration brazing process that forms a metallurgical bond with the base material (> 70,000 psi) when heated in a vacuum furnace.

Although not required for the low NO_X retrofit system, Xcel Energy exercised an option to purchase replacement adjustable coal tips with Conforma Clad© tungsten carbide cladding for Comanche 1 with a target wear life of > three (3) years with no significant deterioration. Coal tip life on Comanche 1 prior to this retrofit typically ranged from three (3) to five (5) years with deterioration depending on the location. This application represents RPI's first use of Conforma Clad© on adjustable coal tips for tilting tangential firing systems. Conforma Clad© has been used successfully to substantially reduce adjustable coal tip wear on units firing highly erosive Indian coals, which exhibit ash contents of nearly 50% and are typically four (4) to five (5) times and eight (8) to ten (10) times more abrasive than typical US bituminous and sub-bituminous PRB coals, respectively. Figure 4 shows a comparison of adjustable coal tip wear performance for non-cladded and Conforma Cladded tips following one (1) year of service firing highly abrasive Indian coal. Note that the non-cladded coal tip exhibits sever splitter plate erosion with the upper splitter plate completely eroded away.

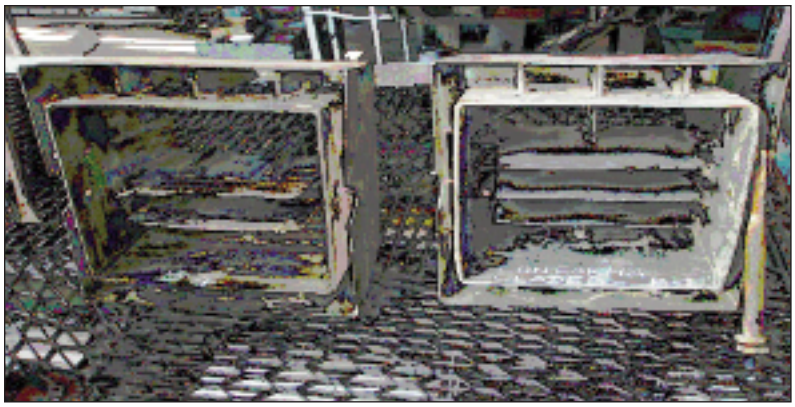

Figure 4. Comparison of Wear Performance for Non-cladded (left) vs. Conforma Cladded (right) Adjustable Coal Tips — Indian Coal Application (photo courtesy of Conforma Clad Inc. / Kennametal Inc.)

REPLACEMENT SUPERHEATER

RPI was also awarded a separate contract to replace the existing superheater front pendant assembly in order to improve main steam outlet temperature and to mitigate historical problems with excessive fouling on the lower portion of front pendant assembly, which is located in the convective pass tunnel.

The new front pendant design featured increased surface area for additional heat recovery, 347H stainless steel construction to facilitate improved slag shedding, and alternating length elements to maximize tube spacing and minimize the potential for bridging along the lower portion of the pendant assembly. The replacement front pendant assembly is shown in Figure 5.

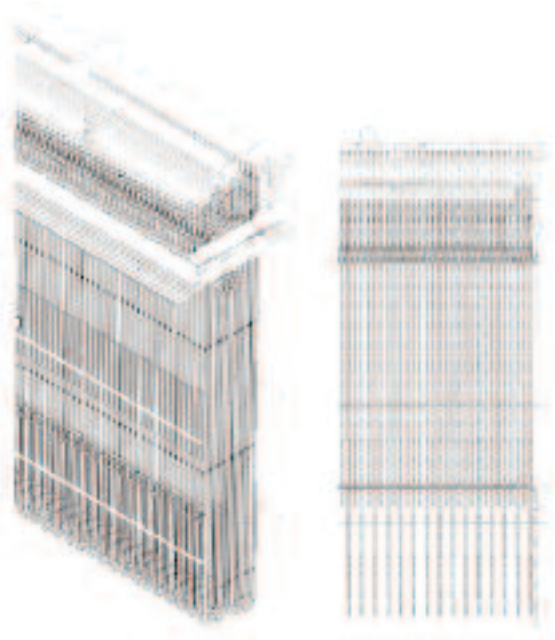

Figure 5. Replacement Superheater Front Pendant Assembly (partial isometric and front views)

XCEL ENERGY SCOPE

Other major equipment provided by Xcel Energy or its sub-vendors on Comanche 1 included the following:

* Burner management system upgrade to current NFPA code
* New ignitor gas flame scanners
* New coal main flame scanners with fiber optic extensions
* Dry flue gas desulphurization system

Comanche Unit 1 underwent a nine (9) week outage for the equipment installation, which began in September 2008.

POST RETROFIT DATA AND RESULTS

Comanche Unit 1 restarted on schedule in early November 2008. A joint optimization test program was conducted by RPI and Xcel and included two (2) weeks of testing in December and one (1) week in January 2009. Full load NO_x compliance was demonstrated almost immediately, while the majority of optimization tests were conducted to reduce CO emissions to near baseline levels with optimum thermal performance as well as to evaluate part load operation. Acceptance tests were conducted over a five-day period at five (5) different operating conditions and were successfully completed in mid-January 2009.

NO_x emissions at full load with all five (5) mills in service were reduced more than 65% from a pre-retrofit baseline of 0.38 lb/MMBtu to 0.128 lb/MMBtu with CO at baseline levels. Figure 6 shows a comparison of the pre-retrofit and post-retrofit EPA database NO_x emissions for Comanche Unit 1 across its typical operating load range. The post-retrofit NO_x data indicates that the NO_x emission target was still being maintained approximately six (6) months after acceptance testing; the NO_x data also exhibited a substantially narrower range of variability as compared with pre-retrofit data.

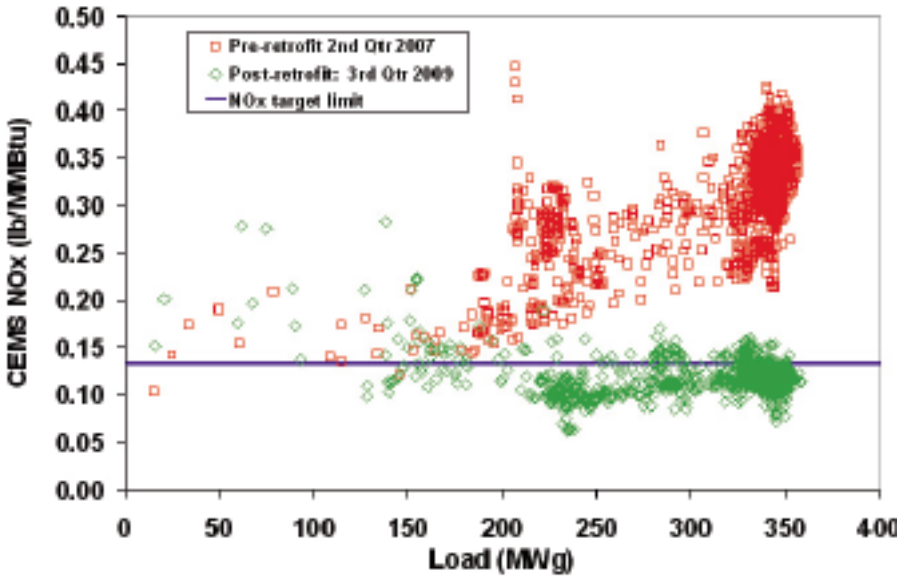

Figure 6. Comparison of Pre- and Post-retrofit NO_x Data vs. Unit Load (EPA NO_x Database)

Key boiler thermal performance parameters were also measured, and are shown in Table 3 in comparison with pre-retrofit baseline values for full load operation with five (5) mills in service.

Table 3

Comparison of Key Boiler Performance Parameters at MCR / All Mills in Service

Performance Parameters	Units	Pre-Retrofit	Post-Retrofit Actual
Generator Load	MWg	351	350
Main Steam Outlet Temperature	ºF	977	1,000
Hot Reheat Steam Outlet Temperature	ºF	953	959
Superheater Spray Flow	kpph	0	26.6
Reheater Spray Flow	kpph	0	6.2
Boiler Efficiency	%	84.61	84.77
Flyash Unburned Carbon (UBC)	Wt %	0.46	0.13
CEMS NO_x	lb/MMBtu	0.38	0.128 (> 65% redn)

Main Steam outlet and reheat steam outlet temperatures both improved from pre-retrofit levels and met the performance targets. The original main steam outlet steam temperature of 1005°F was achievable depending upon actual outlet steam temperature set point and corresponding amount of attemperating spray used. Likewise, a zero reheater spray flow could have been achieved with the spray station block valves completely closed.

Boiler efficiency was increased from pre-retrofit levels and the increase is attributed to lower carbon loss on efficiency due to > 70% reduction in flyash UBC. Additionally, there was a 50°F decrease in economizer outlet gas temperature as compared with the pre-retrofit level, which was a result of mechanical cleaning of the external convective surfaces during the retrofit outage, i.e. — after the pre-retrofit baseline performance test. Post-retrofit furnace exit gas temperature as determined through back calculation was within 3% of the pre-retrofit value.

POST ACCEPTANCE TESTING (January and April 2009)

Additional testing was conducted by Xcel Energy to further optimize the unit and provide the widest practical window for operating flexibility and environmental compliance. Operation at full load with all five (5) mills in service was further optimized to maintain NO_x in the range of 0.120-0.125 lb/MMBtu with CO below pre-retrofit baseline levels. NO_x levels as low as 0.115 lb/MMBtu were recorded.

Operation at full load with four (4) of five (5) mills in service was initially investigated and demonstrated NO_x emission levels as high as 0.17 lb/MMBtu depending upon the particular mill out of service — upper mills A, B, or C out of service produced the highest NO_x emissions. Through additional tuning, NO_x levels of < 0.13 lb/MMBtu were achieved with CO levels somewhat above baseline levels. The variation in NO_x emissions is shown in Figure 7 for this series of tests.

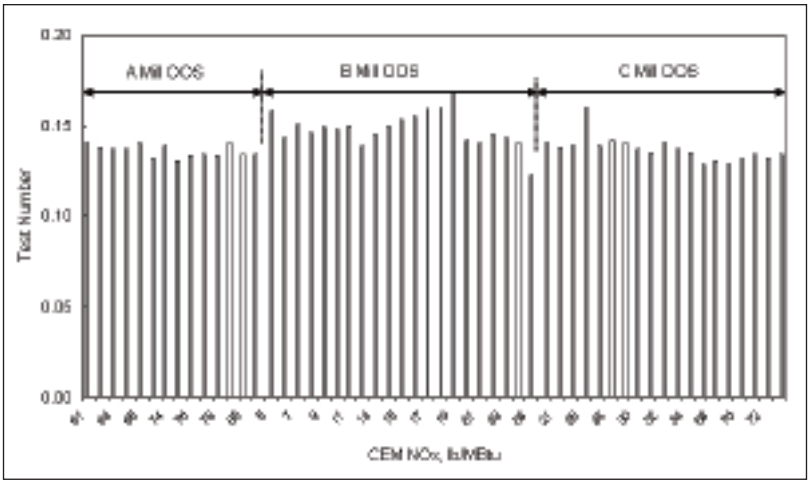

Figure 7. NO_X Variation with One Mill Out of Service

Additionally, during boiler start up conditions, NO_x emissions typically ranged from 0.16 to 0.20 lb/MMBtu NO_x for durations upwards of 36 hours due to water chemistry holds. This is particularly important because Unit 1 is subject to frequent outages and restarts. out of the mill through two outlets at the top of the mill.

STEPS FOR LONG-TERM ENVIRONMENTAL COMPLIANCE

At the conclusion of the performance test programs, Xcel Energy established additional steps to foster long-term environmental compliance including items such as:

* Operator training to fully understand the criticality of emissions compliance and mitigation of emissions fluctuations during upset conditions
* Dedicated water lance and soot blower maintenance teams to ensure proper furnace conditioning
* Mill system repairs and preventative maintenance to minimize operating time at higher NO_X producing conditions
* Plant control system tuning including turbine governor valves
* The need for additional tuning under start up conditions
* Consideration of a condensate polishing system to reduce water chemistry cycle time
* Capital expenditure projects for the 2011 outage to replace damaged pressure parts and improve overall unit availability and minimize start-ups

Figure 6 indicates that the low NO_X retrofit system and the above steps have enabled Xcel Energy to take the first step towards their long-term NO_X emissions compliance goal. Progress towards the goal for improved wear performance of the Conforma Clad lined adjustable coal tips will be evaluated during the scheduled maintenance outage in January 2011.

SUMMARY

RPI's partial windbox retip and addition of separated OFA to the existing tilting tangential firing system on Xcel Energy Comanche Unit 1 demonstrated a NO_X emission reduction in excess of 65%. Boiler performance was maintained or improved relative to pre-retrofit levels with the concurrent addition of a new superheater front pendant assembly. The successful implementation of these systems and subsequent tuning of the low NO_X system have positioned Xcel Energy to meet its long-term environmental compliance requirements for this site. The use of Conforma Clad® tungsten carbide cladding on the adjustable coal tips is expected to meet and exceed Xcel Energy's goal of extended burner wear component life.

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