TECHNICAL PUBLICATION

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TDF® LOW NO_x BURNER AND WINDBOX MODIFICATIONS FOR EMISSIONS CONTROL ON A TURBO® FURNACE

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ABSTRACT

J.P. Madgett Station is located in Alma, Wisconsin. The boiler is a TURBO® fired unit, manufactured by Riley Power Inc., a Babcock Power Inc. company (formerly Riley Stoker). The unit is designed to operate at a maximum continuous rating (MCR) of 2,700,000 pph of superheated steam at an outlet pressure of 1,900 psig and a temperature of 955 °F. The reheater is designed for 2,425,000 pph of steam flow with an outlet pressure of 462 psig and outlet temperature of 955 °F. This boiler was originally equipped with twenty-four (24) directional flame burners and four (4) Riley Ball Tube Mill pulverizers. The unit was designed to fire sub-bituminous coal. The burners were producing sustained NO_x emissions of 0.66 lb/MBTU with average CO emissions of 52 ppm. NO_x emissions needed to be reduced substantially to meet regulation requirements.

Dairyland Power Cooperative contracted Riley Power Inc. to retrofit the unit with twenty-four (24) Tilting Directional Flame (TDF)® Burners and Windbox modifications to improve NO_x emissions control. The aim was to achieve post-retrofit NO_x emission levels of = 0.331lb/MBtu over the range of loads, while maintaining CO emissions below 100 ppm and unburned carbon (UBC) levels below 1% by weight. The modifications to the combustion system associated with the TDF low NO_x burner installation combined with mill system tuning/optimization to improve coal flow distribution between burner lines resulted in a final NO_x emission of 0.271 lb/MBtu, an overall reduction of more than 18%. And, this level of NO_x reduction was achieved without the use of an overfire air system. Furthermore, the CO emissions and UBC levels were below the specified requirements with CO at 69 ppm (at 3% O_2) and UBC less than 1% by weight. This paper will describe the TDF burner design, modifications made to the windboxes, adjustments made to the existing mill system, start-up issues, and final results.

INTRODUCTION

Since 2004, Riley Power Inc. (RPI) has retrofitted several utility boilers having Riley Turbo® Furnace designs with low NO_x combustion system technology. The Dairyland Madgett Station Unit No. 6 was designed to produce 2,700,000 lb/hr of steam at an operating pressure of 1,900 psig and an outlet temperature of 955 ^oF while firing a PRB coal. This unit was originally equipped with twenty-four directional flame burners configured in two rows of twelve, one row on the front wall and one on the rear wall mounted at a 25 degree downward firing angle. The pulverized PRB coal is supplied by three Ball Tube Mills with model 80 classifiers. Figure 1 shows the side elevation of the unit with the basic layout of the boiler internals.

The scope of the low NO_x combustion system modification equipment supplied for this installation was based on the level of NO_x reduction necessary to meet the new limits for Madgett Unit No.6. This installation included new TDF burners including all hardware from the existing burner boot to the secondary air duct. The design includes the patented TDF coal nozzle as well as a new divided secondary air damper for controlling the airflow above and below each burner. RPI also utilized the existing under fire air system to improve the lower furnace reducing atmosphere.

In addition to the modifications associated with the combustion system, RPI and Dairyland Power worked in partnership to modify the existing mill system to improve the coal fineness and distribution to the burners. The Madgett Unit No. 6 classifiers were retrofitted with a prototype inlet distribution device, designed to improve the distribution of particles into the classifier. The improved distribution works to maximize the fineness and improve the outlet distribution to the coal pipes.

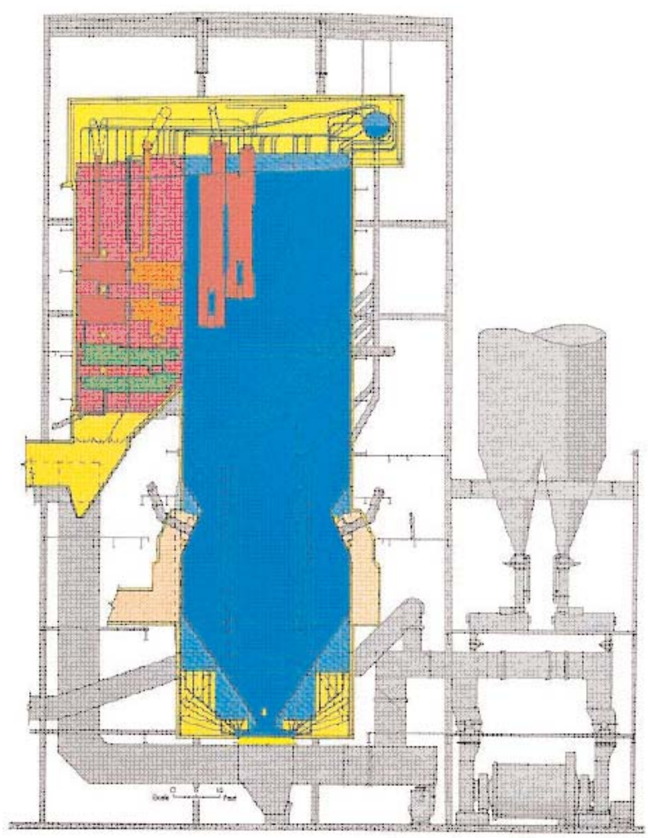

Figure 1. Side Elevation of J.P. Madgett Unit No. 6

Combustion System Design

The modifications RPI made to the firing system at J.P. Madgett Station Unit No. 6 to increase the controllability of furnace combustion and reduce NO_x emissions are as follows and shown in Figure 2:

* New Windbox assemblies including air chambers with directional vanes.

* New Tilting Directions Flame (TDF) coal nozzles.

* New burner secondary air (SA) control dampers with independent control for the air to the upper and lower burner.

* New coal head with inlet turning vanes to improve coal distribution.

These modifications promote more controlled mixing of the coal and air streams, better flame attachment, and controllable stochiometric conditions, which allow for the reduction of NO_x formation.

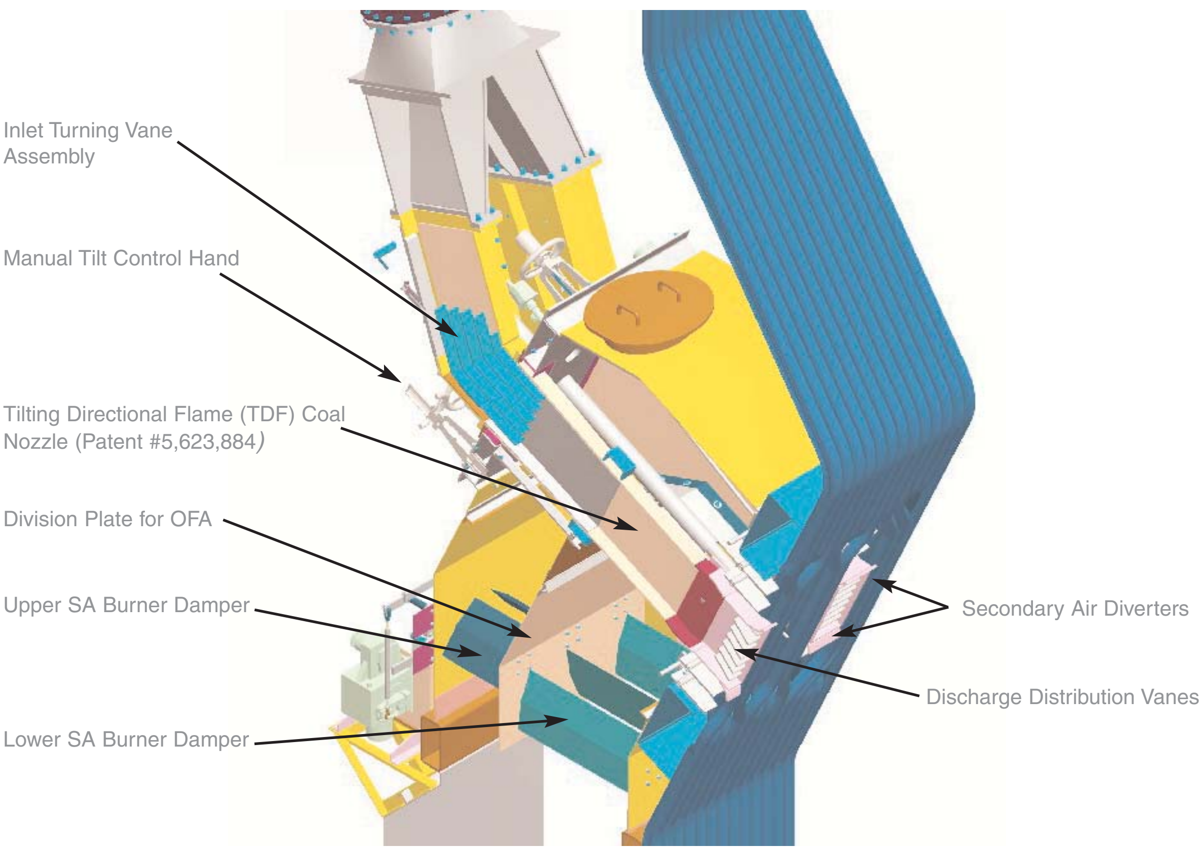

Figure 2. Dairyland Power J.P. Madgett Unit No. 6 TDF Burner

Tilting Directional Flame Coal Nozzle

The Riley Power Inc (RPI) Tilting Directional Flame (TDF) burner coal nozzle was developed four (4) years ago under patent # 5,623,884 to reduce NO_x in RPI TURBO® furnaces. While the TDF nozzle was originally designed to manipulate the position of the combustion zone, it also allows better positioning of the pulverized coal for reduction of NO_x emissions. NO_x emissions can be reduced up to 15% with the TDF over the previous stationary directional flame (DF) coal nozzles. The tilting range of the new coal nozzle is a positive (+) upwards tilt of 10º and a negative (-) downward tilt of 10º. The discharge end of the coal nozzle also includes distribution vanes at a fixed downward angle of 20º. This additional downward tilt increases the downward direction of the coal particles, which increases the residence time allowing for longer burnout. A longer residence time enables the unit to run at cooler peak load flame temperatures and reduced oxygen temperatures, which reduces the amount of NO_x produced during combustion. The upward tilt option was developed for increasing outlet steam temperature if desired. However, this decreases the residence time and increases NO_x emissions.

Inlet Turning Vanes

The inlet turning vane assembly is designed to redistribute coal entering the coal nozzle more evenly for better mixing in the furnace. In order to lower the particle distribution location in the coal head the assembly must be adjusted in. Conversely, retracting the assembly out will elevate the distribution of particles higher into the coal nozzle.

Secondary Air Diverter

The secondary air diverters are mounted on the exterior of the TDF coal nozzle. These diverters will direct the secondary air stream immediately adjacent to the coal nozzle away from the primary air/coal stream so that the near field flow of the burner will form. This field promotes better flame attachment and is required for lower NO_x performance. The secondary airside diverters work to rapidly devolatization the coal in a reducing environment to control the NO_x levels.

Burner Secondary Air Control Dampers

These dampers will function to control the airflow balance from burner to burner as well as the amount of air split above and below the coal nozzles. It is important that the airflow to each burner be balanced so that the stoichiometric conditions at the burners are nearly equivalent.

Construction

Modularized design components assist with reducing the required outage time for installation of the new TDF low NO_x burners. New perforated plate and air chamber assemblies shown in Figure 3 are installed on the existing burner boot opening and welded into place. The new secondary air control dampers for the burner are mounted on the existing windbox duct and buck-stay (see Figure 4). Once these items are in place, the modular windbox/front plate assembly (Figure 5) is hoisted into position and mounted to the burner boot then attached to the secondary air dampers shown. Finally the coal heads and turning vane assemblies (Figure 6) are installed to connect the coal nozzles and coal pipe.

This process is repeated for each burner until the entire row is installed on both the front and the rear of the unit. Due to the modularization of the burner components, pre-outage planning, and installation of a monorail system for moving the burner components into position, the outage for the burner replacement took 36 days to complete. The burner components range in weight from 400 lbs to 3,600 lbs. Sequence planning and pre-staging are critical to achieving a smooth burner installation on a Turbo® unit retrofit.

Figure 3. Perforated Plate and Air Chamber

Figure 4. Secondary Air Burner Damper

Figure 5. Windbox Assembly

Figure 6. Coal Head with Turning Vanes

Performance Results

Low NO_x Burner Retrofit

RPI and Dairyland Power Cooperative began the start-up, optimization testing, and commissioning process for Unit No. 6. The series of tests that determined the optimal settings took six (6) days and ten (10) tests. The system settings include the coal nozzle tilt angles, directional vane angles, and secondary air damper positions. Table 1 shows the results of the initial optimization process and settings.

Table 1

Low NO_x Burner Retrofit Performance Summary

Test		Guarantee	Baseline	Optimization
Date			12/3/2006	11/3/2007
Time			12:45-13:45	10:42-11:07
Gross Load	MWg	-	388	380
Main Steam Flow	KPPH	-	2695	2,547
SH Spray Flow	KPPH	-	63	86.3
RH Spray Flow	KPPH	-	0	64.35
SH Outlet Steam Temp	^oF	-	956	956
RH Outlet Temp	^oF	-	955	957
Avg. CR O_2	% Vol. Wet	-	NA	2.35
Avg. Local O_2 @ Economizer Outlet	% Vol. Dry	-	2.54	2.53
Local Grid NO_x	Lb/MBTU	85% Baseline	0.39	0.268
CEMS CO	ppm wet	Baseline + 50	NA	42
Local Grid CO	ppm @ 3%O_2dry	Baseline + 50	49.4	34
Unburned Carbon (UBC) see discussion	% wt	< 1%	0.55	1.0
Excess Air	%	-	12.02	14.65

Initially, the optimization settings exceeded all guarantees except the UBC guarantee. The NO_x emissions level decreased by 31% from the baseline value of 0.39 lb/MBtu to 0.268 lb/MBtu. The CO emissions also decreased by 31% from the baseline value of 49.4 ppm to 34 ppm. However, the UBC content (by weight) was 98% greater than the guarantee due to the Unit's combustion conditions, mill fineness and potential burner tuning parameters. The fineness testing in the coal pipes found that there was less than 97% through 50-mesh and less than 70% through 200-mesh, both before and after burner modifications.

Due to the high levels of UBC content J.P. Madgett and RPI decided to further tune the burners. Recommendations were also made to further balance the fuel/air flow with the coal pipes to improve the UBC in the flyash. In addition to these changes the excess air was increased to 18% versus the 14.65% during optimization testing.

The result of these changes had little effect on the NO_x increasing it from 0.268 lb/MBtu at initial optimization to 0.271 lb/MBtu at final optimization, which remains well below the guarantee. Also, the CO increased from the baseline value of 49.4 ppm to 69 ppm, which is still under the guarantee value of 100 ppm at 3% O_2 dry. However, these adjustments have the greatest impact on the UBC, decreasing the optimization value from the initial 1.98% to a final value of approximately 1.0%. This indicates that the efforts to reduce the UBC with further burner adjustments successfully reduced it to within the guarantee conditions.

While it is important to analyze Unit performance as new equipment is installed and optimized, it is also important to look at the long-term emissions trend produced by the modifications. Figure depicts the NO_x emissions values comparing the pre-retrofit and post-retrofit data during the same time period. The TDF burner retrofit decreased the NO_x emission approximately 26% from the baseline pre-retrofit emissions, which is consistently above the guarantee of 15% reduction in NO_x.

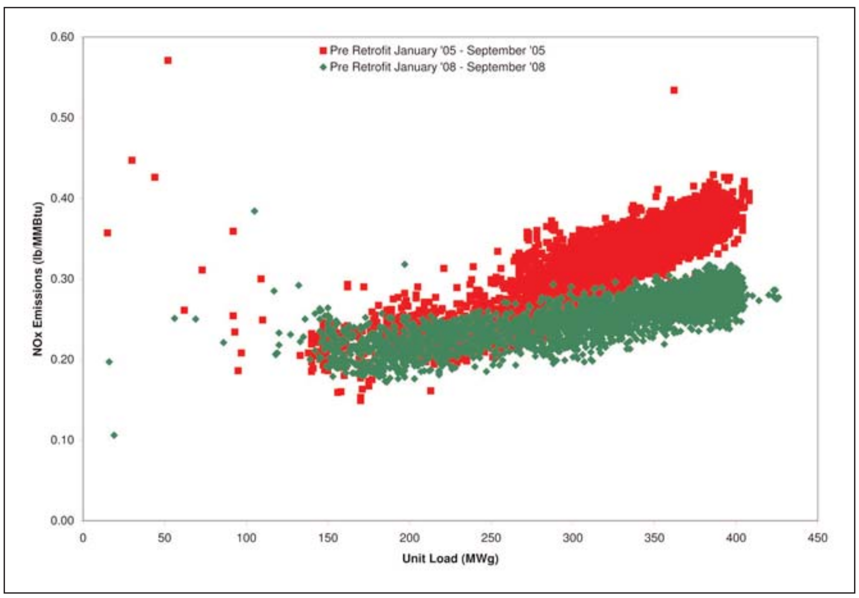

Figure 7. Pre-Retrofit and Post-Retrofit vs. Load NO_x Data

Ball Tube Mill Classifier Modifications

After the completion of the Low NO_x Combustion System Modifications, Dairyland Power and RPI began a test program on the existing Ball Tube Mills to work toward achieving better fineness passing 50 mesh and better pipe-to-pipe coal distribution. A condition of most low NO_x retrofit performance guarantees is that the mill fineness must meet the industry standard of 98% passing 50 Mesh and 70% passing 200 mesh. In addition, the pipe-to-pipe distribution of coal was to be +/- 15% with the primary airflow distribution to be +/-10%.

During the initial optimization of the low NO_x burners, the mills were checked and the fineness was determined to be less than the required standard and the coal pipe-to-pipe distribution exceeded the allowable deviation. Through careful tuning of the burner airflow distribution and balance the reported performance compliance was achieved for the low NO_x combustion system modification project. However, RPI and Dairyland Power wanted to improve the ball tube mill performance for long-term reliability.

In November of 2007, RPI, working with Dairyland Power, extensively tested the existing Ball Tube mill and classifier arrangement to determine precise performance and data that could be utilized in a CFD model of the classifier to design a better inlet distribution device. RPI utilized its extensive in-house CFD modeling capabilities to analyze the current classifier performance and determine what area of the inlet needed to be modified in order to improve the coal distribution entering the classifier. The CFD modeling included several different designs, which eventually lead to the device shown in Figure 8.

In the spring of 2008 RPI installed new inlet distribution devices to the existing model 80 classifiers replacing the venturi section which had been installed several years prior. Additional testing was conducted and the performance of the Ball Tube Mill and Model 80 Classifier was significantly improved. Table 2 below shows the coal fineness comparison pre and post installation of coal flow inlet distribution device. For post retrofit, the coal fineness level improved by 5% passing through 50 mesh (from 92% to 97%) and 9% passing through 200 mesh (from 54.3% to 63.8%) on a weighted per mill average. This coal fineness increase results primarily from the improved rear classifier performance.

Table 2

Mill Coal Fineness Comparison

							Weighted Average		
	R1	R6	R10	F1	F6	F10	Rear	Front	Mill
Pre Retrofit with Venturi									
% passing 50 mesh	94.2	84.4	91.2	96.5	96.3	97.3	88.9	96.6	92.0
% passing 100 mesh	81.2	68.5	79.4	86.7	86.0	91.1	74.7	87.3	79.7
% passing 200 mesh	51.4	44.3	52.4	60.7	61.4	73.2	48.2	63.7	54.3
Post Retrofit with Coal Flow Distribution Device									
% passing 50 mesh	98.8	95.8	99.1	97.9	94.1	98.5	97.9	97.1	97.0
% passing 100 mesh	93.7	82.5	94.8	93.0	80.9	93.2	89.4	88.3	88.4
% passing 200 mesh	72.8	51.5	74.6	75.3	49.5	74.2	64.2	64.1	63.8

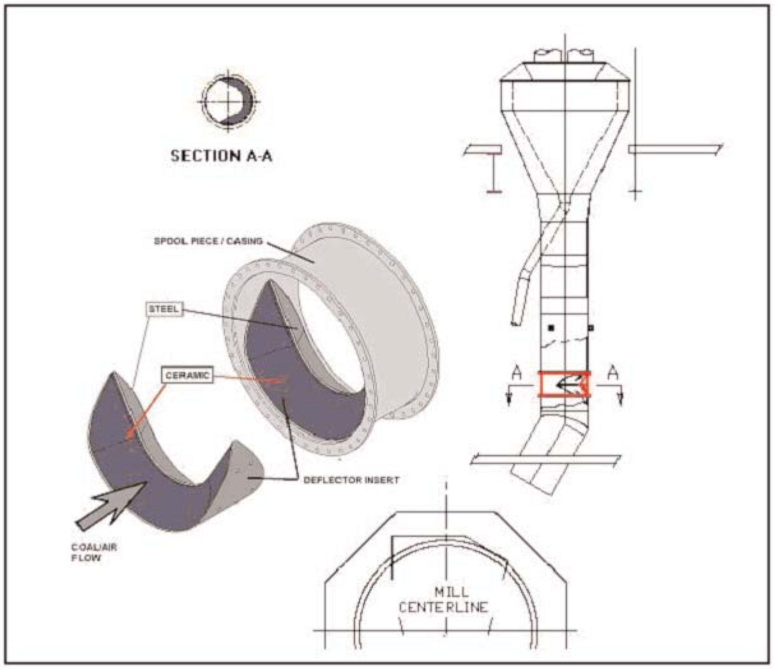

Figure 8. Coal flow distribution device at classifier inlet

ACKNOWLEDGEMENT

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SUMMARY

Reducing NO_x emissions from coal fired utility boilers including the Riley Turbo® Furnace using combustion control only continues to be a cost effective or first step approach for meeting environmental regulations. This approach for J.P Madgett Unit No. 6 improved the NO_x emissions by more than 25% while maintaining LOI levels below the values necessary to sell the flyash. The overall performance of the unit was maintained within typical operating limits with no significant changes to the everyday operation of the unit. The limited outage time for this modification improved the economic impact of the project for Dairyland Power.

The additional work completed on the Ball Tube Mill and Model 80 classifiers improved the overall fineness and distribution. These improvements are vital to achieving long term performance of the unit. Satisfied with the performance of the coal flow inlet distribution device installed at the first mill system, J.P Madgett will install this device on other mill systems.

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