MEETING TODAY'S EMISSION STANDARDS WITH 198WS COMBUSTION TECHNOLOGY

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Presented at the Council of Industrial Boiler Owners Industrial Power Plant Improvement Conference Concord, Ohio
May 6-7, 1991
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ABSTRACT

Emissions results from testing a low NO_x combustion system installed in a 400, 000 pounds of steam per hour pulverized coal Turbo-Furnace are discussed. The advanced combustion system, installed when the boiler was originally erected in the early 1980's, consists of Riley low NO_x Tertiary Staged Venturi (TSV) burners and advanced air staging.

The boiler was recently tested to quantify NO_x and CO emission levels as well as carbon burnout efficiencies on both Oklahoma and Wyoming bituminous coals. Results clearly, demonstrated the ability of ***this 1980's burner technology to control NO emissions down to 0.31bl106 Btu with CO emissions of less than 15 ppm and with excellent carbon fumout efficiencies. Acceptable boiler performance, in regard to steam temperature, boiler efficiency, controllability and reliability was maintained throughout the boiler load range and numerous operating conditions tested***

lb/10^6 Btu. F--isting boilers will be required to

INTRODUCITON

Recent amendments to the Clean Air Act have instigated a great deal of activity by utilities to lower NO_x emissions in power boilers. Original equipment manufacturers are thus implementing or developing new combus-tion technologies to meet the much more stringent NO_x emission requirements of the 1990's. In general, new boiler installations will be required to limit NO_x emissions to 0.3

reduce their emissions to 0.5 lb/10^6 Btu when burning pulverized coal in a wall fired and

0.45 lb/10^6 Btu in a tangential fired application (1).

Riley Stoker Corporation developed a low NO_x combustion system technology in the early

1980's capable of limiting NO_x emissions to < 0.451b/10^6 Btu, a level much lower than most state and federal requirements at that time (2). The combustion system, which included low NO_X Tertiary Staged Venturi (TSV) burners, combined with an advanced air staging system was installed in a new Riley Turbo-Furnace owned and operated by a major paper manufacturer in the midwest. The boiler was successfully started in 1984 and has been operating within NO_X compliance limits, since then.

Recently, Riley Stoker conducted performance testing to evaluate the full potential of reduc-ing NO_X emissions from this boiler to levels well below 0.45 lb/10^6 Btu. No modifications have been made to the combustion system equipment since start up other than routine maintenance items. Tests were conducted while burning both an Oklahoma and Wyo-ming bituminous coal. Continuous monitoring of NO_X, CO, 02 and $C0_2$ was performed at the air heater inlet for each test while fly ash samples to evaluate % loss on ignition (LOI), were collected for selected test conditions. This paper discusses the results of the perfor-mance testing.

DESCRIPTION OF LOW-NO_X COMBUSTION SYSTEM

The advanced combustion system, developed by Riley Stoker in the early 1980's, focused not only on the low NO_X TSV burner design but integrating this burner with a unique furnace design that incorporates advanced air staging. The Riley Turbo-Furnace has been used for many years as an efficient way of burning a wide variety of coals and other fossil fuels because of its inherently longer retention time than more conventional wall fired instal-lations (3).

A conceptual drawing of the Turbo Furnace advanced air staging system integrated with the low NO_X TSV burner is shown in Figure 1. The TSV burner, shown in the right of the figure, is a circular shaped swirl stabilized burner. Pulverized coal is introduced into the furnace through a centrally located venturi shaped coal nozzle (Patent Numbers 4,479,442 and 4,517,904). The purpose of the venturi is to concentrate the coal air mixture and form a fuel rich combustion zone discharging from the center of the coal nozzle. As the rich mixture passes over the coal spreader, the blades divide the coal stream into four (4) distinct streams which enter the furnace in a gradual helical pattern. The intent is to produce more distributed, controlled and gradual mixing of the coal and air for reduced NO_X emissions.

Surrounding the primary air and coal mixture is swirling secondary air imparted by an air register for flame stability and combustion control. Tertiary air is introduced through outboard tertiary air ports surrounding the burner proper. Directional vanes within these ports can be used to direct the tertiary air into or away from the primary combustion zone as desired. The burner zone is designed to operate with only 60-75% of total combustion air.

The remainder of the air, required to complete the combustion process and to provide addi-tional staging for NO_X control, is added through furnace staging ports located above and below the burners. Staged combustion combined with low NO_X burners has been proven to be a very effective technology for controlling NO_X emissions.

DESCRIPTION OF FIELD INSTALLATION

The advanced low NO_X combustion system was subsequently integrated into the design of the 400,000 pounds steam per hour industrial boiler. Figure 2 shows a front and side eleva-tion view of the boiler #4 installation. Six (6) TSV burners rated at 85 x 10^6 Btu/hr are mounted on the furnace sidewalls with overfire air (OFA) above and underfire air (UFA) below each burner. Three (3) Riley Atrita pulverizers are used to process and convey pulverized coal to the burners. The unit produces superheated'steam at 750°F and 630 psig operating pressure. The steam is used to operate the equipment for manufacturing tissue paper.

During the testing, Taylor venturi pitot tubes were installed to measure air **flow** quantities to the secondary and tertiary sides of the burners as well as the air flow to the UFA ports. OFA **flow** was determined by subtracting the sum of these flow rates and primary air **flow** from total combustion air. From this information burner zone stoichiometry could be calculated for selected tests.

Several other industrial boilers incorporating this advanced combustion system design, ranging from 280,000 - 400,000 pounds steam per hour have been or are presently under construction for controlling NO_x emissions.

FIELD RESULTS

Testing began by measuring the same NO $_x$ emission level that the unit was operating at six (6) Y ears ago following boiler start up (0.45 lbs/10 Btu). Numerous tests were subse-quently conducted to quantify emissions and carbon burnout efficiencies for various operat-ing conditions and for two (2) different coals. Figure 3 shows the fuel analysis for the Okla-homa and Wyoming bituminous coals tested.

Figure 4 shows the effect of air staging on NO_x emissions at full load. Both the UFA and OFA ports were open with more staging air being introduced through the upper OFA ports. The NO $_x$ emissions decreased from a high of 0.51bs/10^6 Btu to a low of 0.31bs/10^6 Btu for both coals. The NO emissions were higher for the Oklahoma coax as compared to the Wyoming coal at similar burner zone stoichiometries. This was due to the higher fuel nitrogen content for the Oklahoma coal. Lowest burner zone stoichiometries corre-sponding to the lowest NO_x emissions record-ed were 0.86 and 0.925 for the Oklahoma and Wyoming coals respectively. This level of air staging is still considered to be "conventional"

as compared to "advanced" when stoichiome-tries approach 0.7.

CO emissions and carbon burnout were excel-lent throughout the range of burner stoichiom-etries tested. Figure 5 shows the impact of air staging on carbon burnout and CO emissions. Flyash % LOI results averaged < 4% while CO emissions remained < 15 ppm for both coals. Coal fineness produced by the three (3) Atrita pulverizers was a standard grind of 98% passing 50 mesh and 85% passing 200 mesh. Since the CO and LOI curves tend to increase slightly with decreasing NO_x emissions or burner zone stoichiometry it would appear that in order to achieve the same degree of excel-lent carbon burnout during extremely low NO_x operation (< 0.3 lb/10^6 Btu) on eastern bitu-minous coals with relatively high % fixed carbon/'Yo volatile matter ratios, finer coal grind will most likely be required. A product fineness of > 99% passing 50 mesh and > 85% passing 200 mesh would be recommend-ed.

As anticipated, rotating the directional air vanes in the tertiary air ports so that the tertiary air was directed into the primary combustion zone increased NO emissions by approximately 60 ppm from t9e levels pro-duced with the directional vanes pointing away. As shown in Figure 6, decreasing unit load from 100% to 75% MCR reduced NO_x emissions by approximately 25-50 ppm.

Overall boiler performance in regard to steam temperature, boiler efficiency, unit controllabil-ity and reliability were not adversely affected during the low NO_x operation.

CONCLUSION

Riley Stoker will continue to utilize the latest combustion control technology available for reducing NO_x emissions to meet the require-ments of the recently amended Clean Air Act.

Though the low NO_x combustion system discussed in this paper was developed in the early 1980's, it currently meets the NO_X emis-sion requirements of the early 1990's for both new and retrofit installations. The combustion system is readily adaptable to Turbo Furnace installations as well as down fired and arch fired boiler installations. Advanced concepts utilizing multiple levels of OFA ports are being considered, as conceptually shown in Figure 7, in an effort to further reduce N03 emissions to levels approaching 0.2 lbs/10" Btu.

For more conventional wall feed boilers, Riley Stoker utilizes low NO_x Controlled Combus-tion Venturi (CCV) burners with or without an OFA system. Figure 8 shows a schematic drawing of the CCV burner. This low NO_x system formed the basis for initial development of the low NO_x TSV burner system.

REFERENCES

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R. Lisauskas, "Design and Operation of Coal Fired Turbo Furnaces for NO_x Control," Presented to AEIC Committee on Power Generation, April 19, 1979.

TSV Burner

~- Four (4) Tertiary Air Ports with Directional Vanes

Advanced TURBO Furnace Staging System

TSV Burner

Figure 1. Riley Low NO_X TSV Burner and Turbo Furnace Staging System

Figure 2. Cross Section of Industrial Turbo- Furnace

Steam Capacity - 400,000 pph

	OKLAHOMA	WYOMING
Proximate (as reed)		
Moisture, %	15.2	12.3
Volatile Matter, %	36.6	35.6
Fixed Carbon, %	43.3	38.7
Ash, %	4.9	13.4
Ultimate (dry,		
Carbon, %	73.5	66.0
Hydrogen, %	5.3	4.9
Nitrogen, %	1.68	1.47
Oxygen, %	13.14	11.69
Sulfur, %	0.60	0.61
Ash, %	5.8	15.3
HHV, Btu/Ib (dry)	12,965	11,555
Ash Fusion Temp. (H = 1/2 w)	2,250	2,220

Figure 3. Fuel Analysis Comparison

N O M fl c. a.
x 0 z
400
300 -I
200 -
100 0.14
0.8 0.9 1.0 1.1 12
0.56

0 0
Oklahoma
•ming
O s

0.42
.L7
0.28 x
0 z
m er 0

Burner Zone Stoichiometry

Figure 4. The Effect of Air Staging on Nnx Emissions

0 a
a. C U
40
30
20

Wyoming
Oklahoma
° °
0 a
0 -y
O
0
0.8 *0.9* *1.0* *t1* *1.2*

Burner Zone Stoichiometry

0 *v*
E 0 U *s v*
0
0
0 ° Wyoming
Oklahoma

0.8 *09* *1.0* *t1*

t2 Burner Zone Stoichiometry

Figure 5. The Effect of Air Staging on CO Emissions and Carbon Burnout

N O M
E a
0 z
400
300

Oklahoma Coal

200

SANTA Damper osition
o30/45
100 70/70

70 80 90 100 11c

Boiler Load, % MCR

N O
E a a
x 0 z

400
300
200
100

o Wyoming Coal

SANTA Damper
o 3O/45 osition
m70/70

70 80 90 100 11i

Boiler Load, % MCR

Figure 6. The Effect of Boiler Load on NO_X Emissions at Comparable Burner Settings

Burner L
-i Staging Port

Figure 7. Multiple Levels of Air Staging Ports in a Turbo Furnace

Low Swirl Coal Spreader

Shroud Drive With Roller Assembly
U.S. Patent 4,479,442

Figure 8. Riley Controlled Combustion Venturi (CCV) Burner for Wall Fired Boilers