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ARB ICAT Grant #02-01 DEMONSTRATION OF AN ULTRALOW NO_x BURNER ON A FIRETUBE BOILER

PROJECT OBJECTIVE:

The objective of this joint project between S.T. Johnson Co (STJ) and Altex Technologies Inc (Altex) was to demonstrate the feasibility of applying laboratory proven combustion technology to commercially available gas burners for the purpose of reducing NO_x emissions below the current BACT of 9 ppm at a lower cost per lb of NO_x removed. Current technology requires massive amounts of FGR, operating very close to the limits of flammability, or large amounts of excess air, to reduce NO_x emissions below the 9 ppm level currently enforced in many systems in California. Operation with NO_x emissions below the 5 ppm level has heretofore required the use of post-combustion treatment.

Massive FGR, especially in conjunction with operation close to the limits of flammability, requires the use of active control systems to prevent unstable operation and has resulted in systems unable to follow load demand and in some installations has resulted in equipment failure and severe property damage. These systems have a cost as high as \$3676/ton of NO_x removed.¹ Post-combustion treatment (low temperature oxidation) results in a very high cost per ton of NO_x removed, has higher energy costs, and requires the handling of a sodium nitrate waste stream. The cost of LTO systems can be as high as \$ 24,500/ton of NO_x removed.³ For the business climate to be viable for California industry a much lower cost to achieve even lower levels of emissions has to be developed.

TECHNOLOGY:

Burner development in the past decade has reduced NO_x emissions from around 90 ppm to less than 30 ppm without the use of FGR by developing different fuel/air mixing techniques to reduce thermal NO_x. The addition of FGR or high levels of excess air has further reduced these levels to less than 9 ppm but at a high cost to industry. In order for a stable combustion system to produce NO_x levels less than 9 ppm at a reasonable cost the formation of prompt NO_x in the initial combustion process must be addressed. Unlike thermal NO_x, prompt NO_x is not greatly influenced by flame temperature. Combustion techniques originally developed and patented by Altex Technologies reduces the formation of prompt NO_x and thermal NO_x by combusting a portion of the fuel in a reducing environment in a fuel rich reactor for a specific residence time. This technique results in combustion products comprising partially oxidized fuel (CO & soot) as well as nitrogenous species including amine species (NH₃) that act as NO_x reductants within the final burnout zone. The remainder of the fuel is combusted in four highly oxidizing zones and then mixed in a controlled fashion with the partially oxidized fuel and reductants in a final burn-out zone. This technique results in a total NO_x production of 15 – 18 ppm @3% O₂ without the use of efficiency robbing excess air. The majority of these emissions is thermal NO_x which can be further reduced to around 5 ppm with the use of a moderate degree of FGR.

PROJECT OVERVIEW:

A low cost burner system (Series RX) using conventional materials was designed and fabricated by S.T. Johnson Co to demonstrate the feasibility of California industry meeting even more stringent emission regulations at an affordable cost. A low cost microprocessor based combustion control system was incorporated to provide a flexible means of controlling fuel, air and FGR flow rates. The following Fig 1 is a cross-sectional sketch depicts the general concept of the burner design with an integral axial-flow combustion air fan, central reducing atmosphere reactor in the center, and (4) lean fuel/air mixers around the perimeter. The reactor is designed to provide a specific residence time for the rich fuel/air mixture.

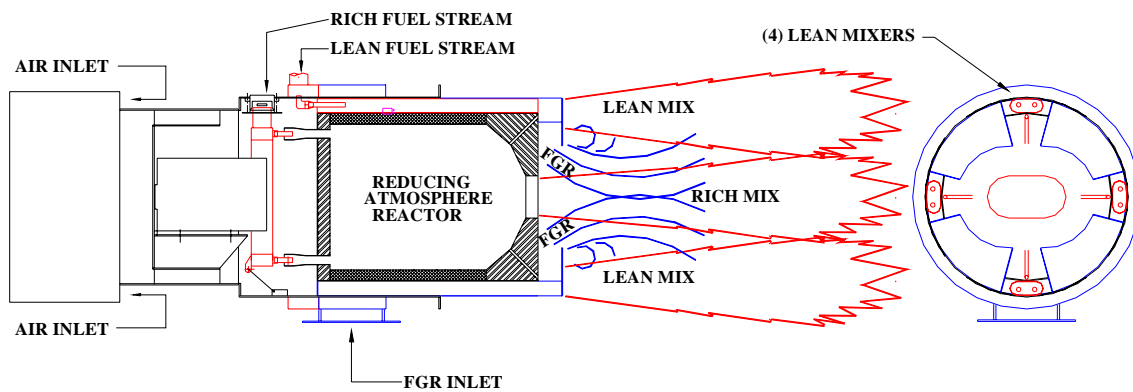


FIG 1

California Dairies Inc (CDI) agreed to host the test site at their Tipton CA plant on one of their three 500HP boilers currently permitted @ 30 ppm NO_x utilizing induced FGR. The plant also has two 750HP boilers permitted @ 9 ppm utilizing high excess-air porous matrix burners. STJ'S new burner system, RX, was initially commissioned March 18, 2003. After several days of operation several design changes were made to better suit the furnace dimensions, eliminate some material degradation which became apparent early in the testing, and change the method of introducing the FGR. Upon installing the redesigned equipment a procedure for proper commissioning and operation was established and the system was released for normal operation on May 28, 2003.

During the next 6 months the emissions were constantly monitored using EPA compliant analyzers as listed in Table 1, and numerous tests were conducted to determine optimal fuel flow fractions, FGR flow rates, and optimal levels of excess air. The calibration of the analyzers was checked before and after each data collection point.

TABLE 1

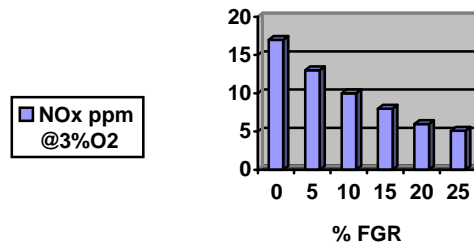
Measurement Parameter	Analyzer Manufacturer	Measurement Principle
NO, NOx	Thermo Environmental	Chemiluminescence
CO	Thermo Environmental	Gas Filter Correlation
O2	Beckman Instruments	Electrochemical Cell
CO2	Beckman Instruments	Nondispersive Infrared

NOx levels as low as 3.5 ppm were achieved at low and intermediate firing rates by increasing the FGR flow rate above the 25% level, however CO levels ranging from 400 – 450 ppm were encountered under these conditions. FGR flow rate is defined as the volume of flue gas recirculated back through the final combustion zone as a percentage of total stack flow. CO production at low fire and burner turndown ratio were found to be very interrelated. CO level can be maintained under 50 ppm with a turndown ratio of 5.5:1 but levels slightly above 100 ppm were encountered at a turndown ratio greater than 6:1. At the onset of this project the CO limitation in the San Joaquin AQMD was 50 ppm however on Sep18, 2003 this limitation was raised to 400 ppm. While a 5.5:1 turndown ratio and CO levels slightly above 100 ppm are sufficient to meet current requirements further design changes and testing is anticipated to reduce CO production at higher turndown ratios. Levels of CO were 0 ppm above 50% firing rate at all levels of FGR.

Prior to conversion to the RX burner system the source test on this boiler resulted NOx = 25.3 ppm and CO = 70.2 ppm under maximum load conditions. High fire NOx levels at varying FGR flow rates for the RX burner system are listed in Chart 1. The NOx level indicated at each level of FGR is the mean of (6) readings taken over a 30 minute period with the following means and standard deviations:

%FGR	0	5	10	15	20	25
Mean, ppm	16.8	13.3	10.0	8.1	6.0	5.1
Std Dev	.85	.56	.74	.75	.26	.21

CHART 1



During the 6 months of field testing several other distinct advantages over currently available systems were realized. Compared to fully premixed, high excess air, porous matrix burner systems in the same boiler room a significantly higher turndown ratio was realized, boiler efficiency is 82.4% compared to the 81.0%, and noise levels were significantly lower.

The 1.4% increase in efficiency relates to an approximate \$11,000 reduction in annual fuel costs, and a reduction in stack effluent of 659,000 scfm over a period of one year of continuous operation at maximum load. Also the RX burner design does not require filtered combustion air which is the case with the porous matrix burners.

At no time during this period were any combustion harmonics or flame instability problems encountered. These are common characteristics with systems utilizing an FGR rate greater than 25%. Combustion harmonics are very annoying and can reduce the service life of certain boiler components such as refractory linings. An industry standard 30-second modulating time between minimum and maximum inputs did not result in instability as can be the case with systems using massive FGR and/or operating very close to the limits of flammability. Flame instability has resulted in property damage in several instances on installations required to operate below 9 ppm NOx.

COMMERCIALIZATION:

The lower NOx emissions capability along with the above stated advantages should lead to successful commercialization of this technology especially due to the lower initial and operating costs for industry. The use of conventional burner materials along with STJ's many years of burner manufacturing experience will result in a durable product at a lower cost than systems currently available.

Market studies indicate these systems can be made available to industry at an initial equipment cost of 10 – 25% lower than massive FGR systems or porous matrix systems depending on the input capacity required. Comparative total (initial plus operating) costs for a 10-year capitalization period at a discount rate of 9% are listed in Table 2.

TABLE 2

Type of System	Retrofit \$/ton NOx	New \$/ton NOx
RX	\$ 889	\$ 258
Massive FGR ¹	\$ 4568	\$ 3676
Porous Matrix ²	\$ 4177	\$ 2787
LTO ³	\$ 24500	\$ 24500

The successful results of this project have led to a 20-year licensing agreement between Altex and STJ for the manufacturing of combustion equipment utilizing the technology and a considerable amount of interest from California industries to provide quotations for the installation of the equipment. CDI has expressed interest in converting the other two 500HP boilers and a contract to provide another 500HP system has been received for a boiler conversion in the San Diego area. A small scale demonstration system was fabricated and displayed at the International Air Conditioning, Heating, and Refrigeration Exposition in Anaheim CA on Jan 26 – 28th 2004, and an honorable mention was received at the exposition for the most innovative new product.

PROJECT PARTICIPANTS AND FUNDING:

Innovative Clean Air Technology (ICAT) grant program of the California Air Resources Board --
Matching funds

S.T. Johnson Co Inc -- ICAT Grantee

Altex Technologies Inc -- Sub Contractor - technology

Moehlman Boiler Technologies -- Sub Contractor - installation

California Dairies Inc -- Partner In Kind – host site

REFERENCES:

- 1 – S.T. Johnson market studies and conversations with burner distributors and dealers.
- 2 – Moreno, F.E., Pan, R.L. Chirolo, D.S. “Theory and Application of Ultra Low NO_x Radiant Combustion: Sub -9 ppm without SCR,” Preprints of the 1992 International Gas Research Conference, Orlando Florida, Nov 16 – 19, 1992.
- 3 – Private communication with SCAQMD on cost effectiveness aspects of NO_x control equipment on April 22, 1998.