GAS REBURNING AND INTEGRATED NO_x AND SO_2 CONTROL: READY FOR COMMERCIAL INSTALLATIONS

B.A. Folsom, R. Payne, and R. Lyon
Energy and Environmental Research Corporation (EER)
Irvine, California 92718

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INTRODUCTION

Gas Reburning (GR) is a retrofit NO_x control technology for boilers and furnaces. This paper presents recent field test results from demonstrations of GR and integrated NO_x and SO_2 control technologies on three coal fired utility boilers: tangential, wall and cyclone fired. GR was integrated with Sorbent Injection for enhanced SO_2 on two units and with Low NO_x Burners for enhanced NO_x control on one unit. Recent test results are presented from all three sites. An economic analysis compares costs for GR and integrated technologies with competing conventional technologies.

GAS REBURNING AND INTEGRATED TECHNOLOGIES

GR is a NO_x control technology where NO_x emissions are reduced by reactions with hydrocarbon fragments produced from natural gas (1). Figure 1 shows the application of GR to a front wall fired boiler.

In contrast to conventional firing systems which have a single combustion stage, GR is a three zone process. In the primary zone, the normal boiler fuel (coal, oil, or gas) is fired through conventional (or low NO_x) burners under low excess air conditions. The firing rate is reduced by 15-20% to accommodate the natural gas. This reduces combustion intensity and NO_x emissions.

In the reburning zone, natural gas is injected to produce a slightly fuel rich zone (nominally 90 percent theoretical air). The natural gas, principally methane (CH_4), breaks down to produce hydrocarbon fragments (CH and CH_2). The hydrocarbon fragments react with the NO_x produced in the primary combustion zone to reduce it to atmospheric nitrogen (N_2).

The gases exiting the Reburning Zone contain considerable carbon monoxide (CO) as well as unburned hydrocarbons. These are consumed in the burnout zone by injection of additional combustion air (overfire air), completing the heat release.

Since GR does not require modifications to the main firing system, it is compatible with all types of firing systems. Demonstrations are currently being conducted on tangential, wall and cyclone fired systems. Applications on stokers are also feasible.

By itself, GR can achieve NO_x control of 60-70% and SO_2 control proportional to the gas firing (typically 15-20%). NO_x and SO_2 control can be increased by integrating GR with other control technologies. Examples include:

- <u>Low NO_x Burners (LNB)</u> NO_x control increases to about 75%. GR-LNB is being demonstrated on a wall fired unit (2).

- <u>Selective Non-Catalytic Reduction (SNCR)</u> The integration of SNCR with GR is termed Advanced Gas Reburning (AGR). The GR system is tuned to optimize the conditions for SNCR improving agent utilization, increasing NO_x control to about 85%, and eliminating NH_3 slip. AGR has been tested at pilot scale (3).

- <u>Methanol Injection</u> A small amount of methanol injected into the back pass of the boiler converts NO to NO_2 which can be removed in a wet scrubber. The integration of Methanol Injection with AGR, CombiNO_x, increases NO_x control to the 90-95% range. CombiNO_x has been tested at pilot scale (3).

- <u>Sorbent Injection (SI)</u> A calcium based sorbent can be injected in several ways to boost SO_2 control. GR integrated with furnace sorbent injection (GR-SI) can increase SO_2 control to about 50% with conventional sorbents and to over 80% with advanced sorbents, such as

PromiSORB. GR-SI is being demonstrated on tangential and cyclone fired units (4).

- SO_2 Scrubber Since the GR modifications affect only the boiler, GR is fully compatible with all types of post combustion emission controls such as SO_2 Scrubbers.

Figure 2 shows the ranges of NO_x and SO_2 control achievable with these integrated technologies in comparison to conventional technologies without GR (Low NO_x Burners, SNCR, SCR and SO_2 Scrubber).

DATA FROM THREE FULL SCALE DEMONSTRATIONS

EER is demonstrating GR and integrated technologies on three utility boilers in two DOE Clean Coal Technology Projects as shown in Table 1. The host sites are all utility boilers and include the three major firing configurations: tangential, wall and cyclone fired. They cover a capacity range from 33 to 158 MW, a factor of nearly 5/1. As part of the design process, EER projected (and published) performance goals. NO_x control of over 60% was projected for each of the units.

At all three units the emission control equipment has been installed and tested extensively. The NO_x control goals have been achieved. Testing has been completed at the Hennepin tangentially fired unit and Illinois Power, the host utility, has elected to retain the equipment. Testing is still in progress at the other three units.

Figure 3 shows how NO_x decreases as the gas injection rate increases for all three units. It should be noted that the wall fired unit is equipped with low NO_x burners and the zero gas point corresponds to emissions from the low NO_x burners. At the Hennepin tangentially fired unit, additional tests were conducted with the unit operating on 100% gas and utilizing the GR system. As shown in figure 3, NO_x emissions were reduced to 0.05 $lb/10^6$ Btu. All three demonstrations include long term testing where the emission control systems are operated by plant personnel. The tests have been completed at Hennepin; NO_x averaged 0.245 $lb/10^6$ Btu, a 67.3% reduction.

ECONOMICS

The capital cost of GR is highly site specific. For a typical installation on a large unit (300-500 MW), the capital cost is typically in the range of 15-30 $/KW for a easy and difficult retrofits, respectively.

The operating cost for gas reburning is almost entirely related to the differential cost between the gas and the base fuel. No additional operators are required and maintenance is minimal. For coal fired units, gas generally costs more than coal and the differential cost is the largest cost component. For gas fired the fuel cost impact is zero and operating costs are near zero.

In evaluating GR operating costs it is important to account for several benefits of GR other than NO_x control. These include:

1. SO_2 Reduction in proportion to the fraction of gas fired. The value of the SO_2 reduction will depend on the utility's alternatives for SO_2 control and the SO_2 allowance market price.

2. Reduced Ash Disposal in proportion to the gas firing percentage.

3. Reduced Maintenance and Improved Availability Reducing the amount of coal and ash passing through the power plant components reduces coal and ash related maintenance. Availability via gas use to replace coal during mill outages.

The total cost of emission control can be calculated by adding the capital and operating cost components via the Electric Power Research Institute (EPRI) Technology Assessment Guide (TAG) procedure. An EPRI TAG analysis was conducted for GR and integrated technologies along with conventional emission control technologies including low NO_x burners, SNCR and SCR. Figures 4 and 5 show the results for coal and gas fired units, respectively. The coal fired analysis was based on a baseline NO_x level of 1.0 lb/10^6 Btu and a gas to coal cost differential of 1.00 \$/10^6 Btu. SO_2 credits were evaluated at 300 \$/ton for coals with 1.2 and 6.0 lb/10^6 Btu SO_2 emission potential. As shown in figure 4, the cost effectiveness of the GR technologies is comparable to low NO_x burners and SNCR but GR achieves substantially higher NO_x control. For high levels of NO_x control, where SCR is the only commercially available competing technology, GR-LNB and AGR are much more cost effective.

The gas fired analysis utilized baseline NO_x levels of 0.3 and 0.5 lb/10^6 Btu. The results shown in figure 5 are generally similar to the coal fired case except that: (1) the overall costs are higher due to the lower initial NO_x level and no SO_2 credit, and (2) the GR costs have dropped relative to the LNB and SNCR costs since there is no cost differential associated with the gas injected into the reburning zone.

CONCLUSIONS

EER has designed, installed and tested GR systems on three utility boilers covering a 5/1 capacity range and involving all three major firing configurations (tangential, wall and cyclone). In all cases the NO_x control goals were achieved or exceeded with no operational problems. GR can be installed as a stand alone technology to achieve NO_x control in the range of 60%. Higher levels of NO_x and/or SO_2 control can be achieved by integrating other synergistic controls. Costs for GR technologies are generally competitive with other technologies which can achieve comparable levels of NO_x control.

EER has been working on GR technologies for over 12 years. The results from these three Clean Coal Technology demonstrations have provided EER with the design and performance data base necessary to apply GR in the commercial market place. Accordingly, EER is now offering GR and integrated technologies with commercial guarantees for industrial and utility Clean Air Act compliance applications.

ACKNOWLEDGEMENT

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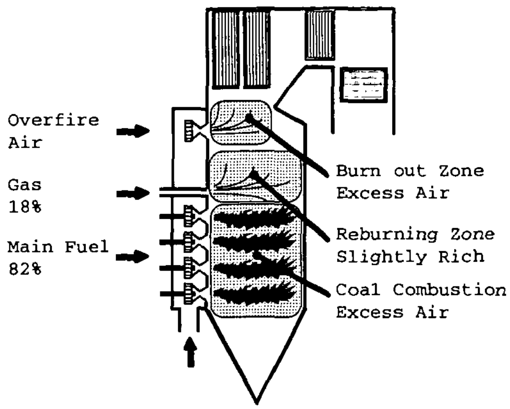

Figure 1. Gas Reburning on a Wall Fired Boiler

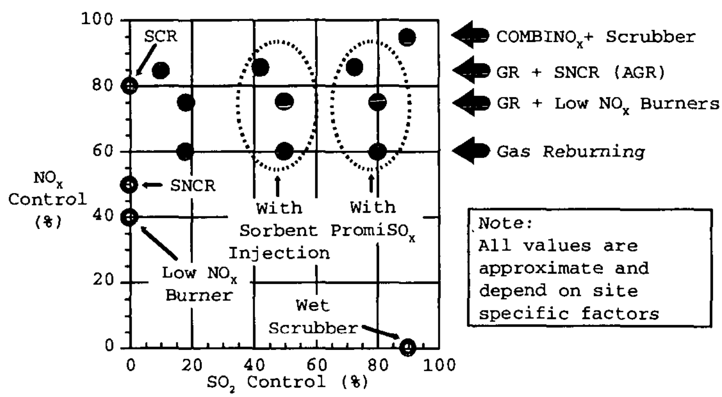

Figure 2. NO_x and SO_2 Control Comparison

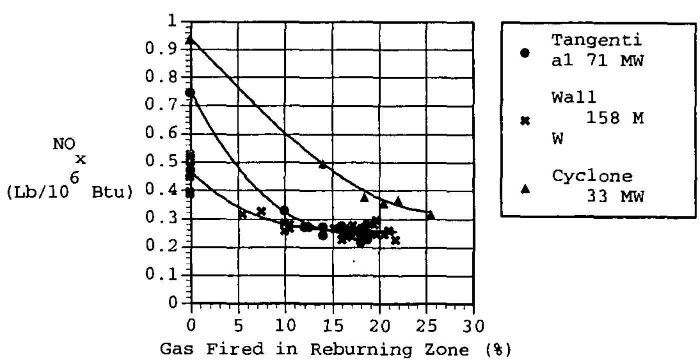

Figure 3. Gas Reburning Data from Three Demonstrations

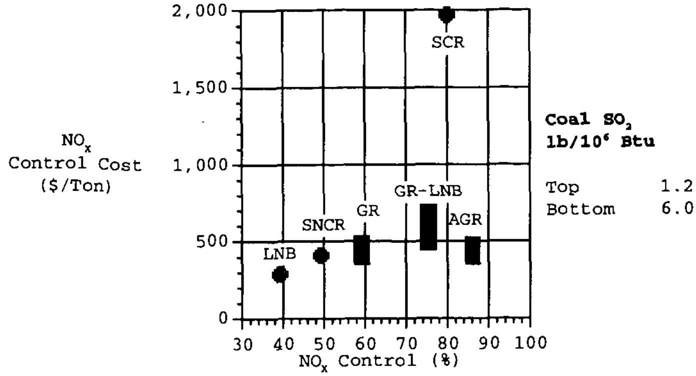

Figure 4. Gas Reburning Economics for Coal Fired Boiler

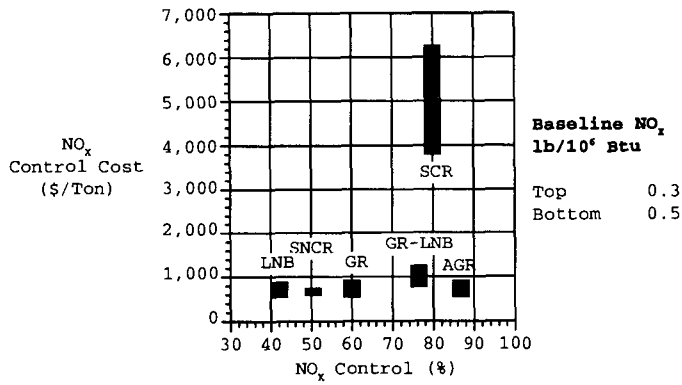

Figure 5. Gas Reburning Economics for Gas Fired Boiler

Table 1. Three Demonstrations

CCT	TECH.	UNIT	CAP MW net	FIRING CONFIG	Status	FUNDING
1	Gas Reburning	Illinois Power Hennepin 1	71	Corner	Comp. 1 Year Test	$37,000,000 DOE GRI Illinois ENR
	Sorbent Injection	CWLP Lakeside 7	33	Cyclone	1 Yr. Test in Pro	
3	Gas Reburning Low NOX Burners	P.S. Colorado Cherokee 3	158	Wall	Para. Comp. 1 Year Test in Pro	$16,000,000 DOE GRI PS Colorado CIG EPRI EER