Evaluation of Gas Reburning and Low-NO_x Burners on a Wall-Fired Boiler

Project completed

Participant

Energy and Environmental Research Corporation

Additional Team Members

Public Service Company of Colorado—cofunder and host

Gas Research Institute—cofunder

Colorado Interstate Gas Company—cofunder

Electric Power Research Institute—cofunder

Foster Wheeler Energy Corp.—technology supplier

Location

Denver, Adams County, CO (Public Service Company of Colorado's Cherokee Station, Unit No. 3)

Technology

Energy and Environmental Research Corporation's gas reburning (GR) system and Foster Wheeler Energy Corp.'s low-NO_x burners (LNB)

Plant Capacity/Production

172 MWe (gross), 158 MWe (net)

Coal

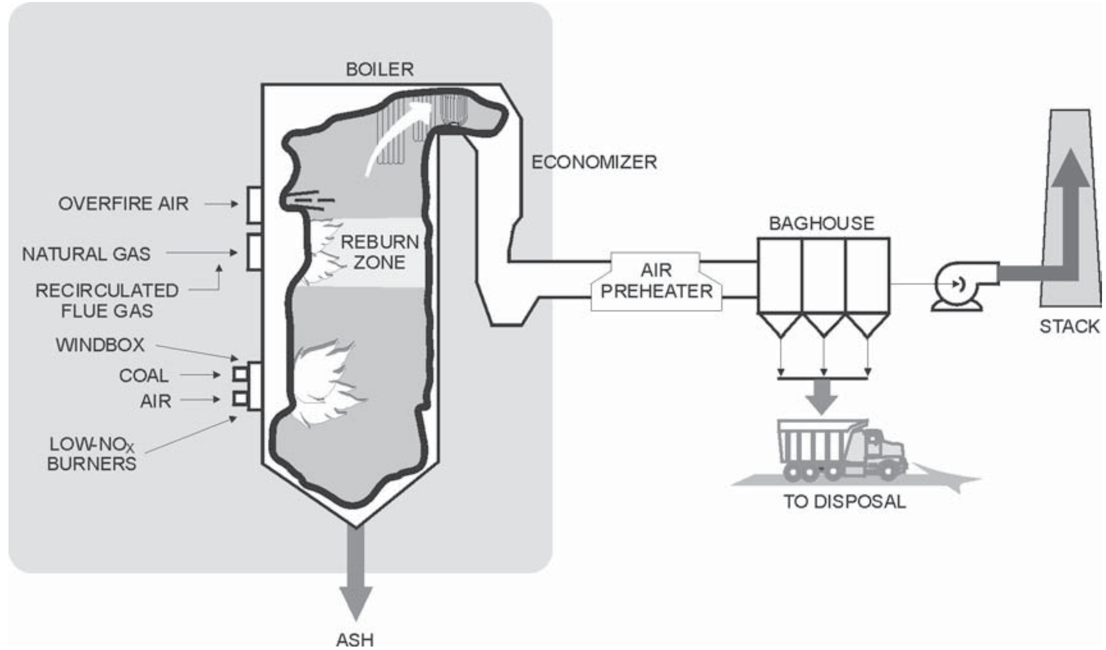
Colorado bituminous, 0.40% sulfur, 10% ash, 1.51% nitrogen

Project Funding

Total	$17,807,258	100%
DOE	8,895,790	50
Participant	8,911,468	50

Project Objective

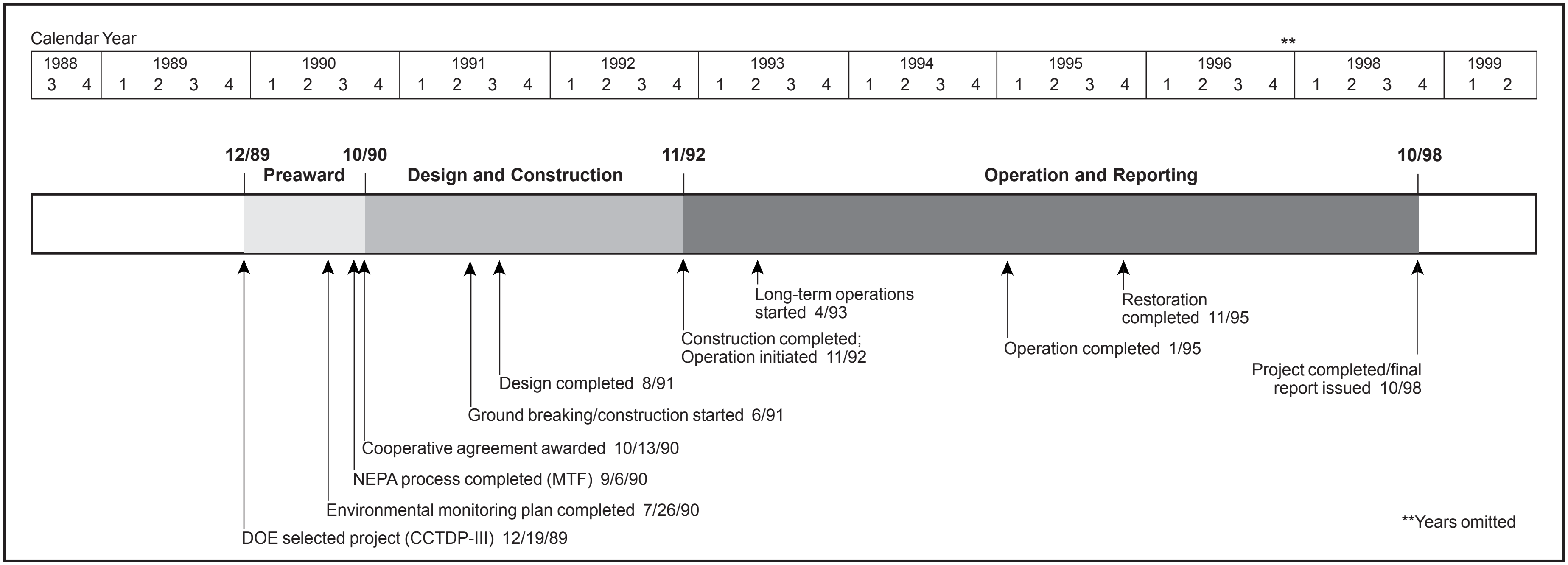
To attain up to a 70% decrease in NO_x emissions from an existing wall-fired utility boiler, firing low-sulfur coal using both gas reburning and low-NO_x burners (GR-LNB); and to assess the impact of GR-LNB on boiler performance.



Technology/Project Description

Gas reburning involves injecting natural gas (up to 25% of total heat input) above the primary combustion zone in a boiler. This upper-level injection and partial combustion by limiting available oxygen creates a fuel-rich zone. NO_x moving upward from coal combustion in the lower furnace is stripped of oxygen as the reburn fuel is partially combusted in the reburn zone and converted to molecular nitrogen. Overfire air ports above the reburn zone provide for complete combustion in a relatively cool region of the boiler. Reburning allows the low-NO_x burners to operate at excess air levels far below that needed for complete combustion, thus enhancing their effectiveness. The synergistic effect of adding a reburning stage to wall-fired boilers equipped with low-NO_x burners was intended to lower NO_x emissions by up to 70%. Gas reburning was demonstrated with and without the use of flue gas recirculation (FGR).

A series of parametric tests was performed on the gas reburning system, varying operational control parameters and assessing the effect on boiler emissions, completeness of combustion (carbon-in-ash or loss-on-ignition), thermal efficiency, and heat rate. A one-year long-term testing program was performed in order to judge the consistency of system outputs, assess the impact of long-term operation on the boiler equipment, gain experience in operating GR-LNB in a normal load-following environment, and develop a database for use in subsequent GR-LNB applications. Both first- (with FGR) and second-generation (without FGR) gas reburning tests were performed.



Results Summary

Environmental

- LNB alone reduced NO_x emissions from a pre-construction baseline of 0.73 lb/10^6 Btu to 0.46 lb/10^6 Btu (at 3.5% O_2), a 37% NO_x reduction.
- First-generation GR, which incorporated FGR in combination with LNB, reduced NO_x emissions to an average 0.25 lb/10^6 Btu (at 3.25% O_2), a 66% NO_x reduction at an 18% gas heat input rate.
- Second-generation GR, without FGR and in combination with LNB, reduced NO_x emissions to an average 0.26 lb/10^6 Btu, a 64% NO_x reduction with only 12.5% gas heat input.
- Both first- and second-generation GR with LNB were capable of reducing NO_x emissions by up to 70% for short periods of time, but only with higher than acceptable reburn gas heat inputs.
- The average NO_x emission reduction achieved in a dispatch mode over the longer term was approximately 64% for both first- and second-generation GR.
- After modifying the overfire air system to enhance penetration and turbulence (as part of second-generation GR), CO emissions were controlled to acceptable levels at low gas heat input rates.
- SO_2 emissions and particulate loadings were reduced by the percentage heat input supplied by GR.

Operational

- Boiler efficiency decreased by 1%.
- There was no measurable boiler tube wear and only a small amount of slagging.
- Carbon-in-ash and CO levels were acceptable for first- and second-generation GR with LNB, but not with LNB alone.

Economic

- Capital cost for a GR-LNB retrofit of a 300-MWe plant is $26.01/kW (1996$) plus the gas pipeline cost, if not already existing ($12.14/kW for GR only and $13.87/kW for LNB only).
- Operating costs were related to the gas/coal cost differential and the value of SO_2 emission allowances because GR reduces SO_2 emissions when displacing coal.

Project Summary

The demonstration established that GR-LNB offers a cost-effective option for deep NO_x reductions on wall-fired boilers. GR-LNB NO_x control performance approached that of selective catalytic reduction (SCR), but at significantly lower cost. The importance of cost-effective technology for deep NO_x reductions is that it meets the need for NO_x reduction in ozone nonattainment areas beyond what is currently projected in Title IV of the CAAA. Title I of the CAAA deals with ozone nonattainment and is currently the driving force for deep NO_x reduction in many regions of the country. Even for the more stringent levels required under Title I, GR-LNB can be used to reduce the size and cost of downstream treatment.

The GR-LNB was installed and evaluated on a 172-MWe (gross) wall-fired boiler—a Babcock & Wilcox balanced-draft pulverized coal-fired unit. The GR system, including an overfire air system, was designed and installed by Energy and Environmental Research Corporation. The LNBs were designed and installed by Foster Wheeler Energy Corp.

A worker inspects the support ring for the Foster Wheeler low-NO_x burner installed in the boiler wall.

Parametric testing began in October 1992 and was completed in April 1993. The parametric tests examined the effect of process variables (such as zone stoichiometric ratio, percent gas heat input, percent overfire air, and load) on NO_x reduction, SO_2 reduction, CO emissions, carbon-in-ash, and heat rates. The baseline performance of the LNB was also established.

Environmental Performance

At a constant load (150 MWe) and a constant oxygen level at the boiler exit, NO_x emissions were reduced with increasing gas heat input. At gas heat inputs greater than 10%, NO_x emissions were reduced marginally as gas heat input increased. Natural gas also reduced SO_2 emissions in proportion to the gas heat input. At the Cherokee Station, low-sulfur (0.40%) coal is used, and typical SO_2 emissions are 0.65 lb/10^6 Btu. With a gas heat input of 20%, SO_2 emissions decreased by 20% to 0.52 lb/10^6 Btu. The CO_2 emissions were also reduced as a result of using natural gas because it has a lower carbon-to-hydrogen ratio than coal. At a gas heat input of 20%, the CO_2 emissions were reduced by 8%.

Long-term testing was initiated in April 1993 and completed in January 1995. The objectives of the test were to obtain operating data over an extended period when the unit was in routine commercial service, determine the effect of GR-LNB operation on the unit, and obtain incremental maintenance and operating costs with GR. During long-term testing, it was determined that flue gas recirculation had minimal effect on NO_x emissions.

A second series of tests was added to the demonstration to evaluate a modified or second-generation system. Modifications included the following:

- The FGR system, originally designed to provide momentum to the natural gas, was removed. (This change significantly reduced capital costs.)
- Natural gas injection was optimized at 10% gas heat input compared to the initial design value of 18%.
- Removal of the flue gas recirculation system required installation of high-velocity injectors, which made greater use of available natural gas pressure. (This modification reduced natural gas usage and thus operating costs.)
- Overfire air ports were modified to provide higher jet momentum, particularly at low total flows.

Over 4,000 hours of operation were achieved, with the results shown in Exhibit 3-26. Although the 37% NO_x reduction performance of LNB was less than the expected 45%, the overall objectives of the demonstration were met. Boiler efficiency decreased by only 1% during gas reburning due to increased moisture in the fuel resulting from natural gas use. Further, there was no measurable tube wear, and only small amounts of slagging occurred during the GR-LNB demonstration. However, with LNB alone, carbon-in-ash and CO could not be maintained at acceptable levels.

Economic Performance

GR-LNB is a retrofit technology in which the economic benefits are dependent on the following site-specific factors:

- Gas availability at the site,
- Gas/coal cost differential,
- Boiler efficiency,

Exhibit 3-26

NO_x Data from Cherokee Station, Unit No. 3

	GR Generation	
	First	Second
Baseline (lb/10^6 Btu)	0.73	0.73
Avg NO_x reduction (%)		
LNB	37	44
GR-LNB	66	64
Avg gas heat input (%)	18	12.5

- SO_2 removal requirements, and
- Value of SO_2 emission credits.

Based on the demonstration, GR-LNB is expected to achieve at least a 64% NO_x reduction with a gas heat input of 12.5%. The capital cost estimate for a 300-MWe wall-fired installation is $26.01/kW (1996$), plus gas pipeline costs, if required. This cost includes both equipment and installation costs and a 15% contingency. The GR and LNB system capital costs can be easily separated from one another because they are independent systems. The capital cost for the GR system only is estimated at $12.14/kW. The LNB system capital cost is $13.87/kW.

Operating costs are almost entirely related to the differential cost of natural gas and coal and reduced by the value of the SO_2 emission credits received due to absence of sulfur in the gas. A fuel differential of $1.00/$10^6$ Btu was used because gas costs more than coal on a heating value basis. Boiler efficiency was estimated to decline by 0.80%; the cost of this decline was calculated using a composite fuel cost of $1.67/$10^6$ Btu. Overfire air booster and cooling fan auxiliary loads will be partially offset by lower loads on the pulverizers. No additional operating labor is required, but there is an increase in maintenance costs. Allowances also were made for overhead, taxes, and insurance. Based on these assumptions and assuming an SO_2 credit allowance of $95/ton (Feb. 1996$), the net operating cost is $2.14 million per year and the NO_x removal cost is $786/ton (constant 1996$).

Commercial Applications

The technology can be used in retrofit, repowering, or greenfield installations of wall-fired boilers. There is no known limit to the size or scope of the application of this technology combination. GR-LNB is expected to be less capital intensive, or less costly, than selective catalytic reduction. GR-LNB functions equally well with any kind of coal.

Public Service Company of Colorado, the host utility, decided to retain the low-NO_x burners and the gas-reburning system for immediate use; however, a restoration was required to remove the flue gas recirculation system.

This demonstration project was one of two that received the Air and Waste Management Association's 1997 J. Deane Sensenbaugh Award.

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