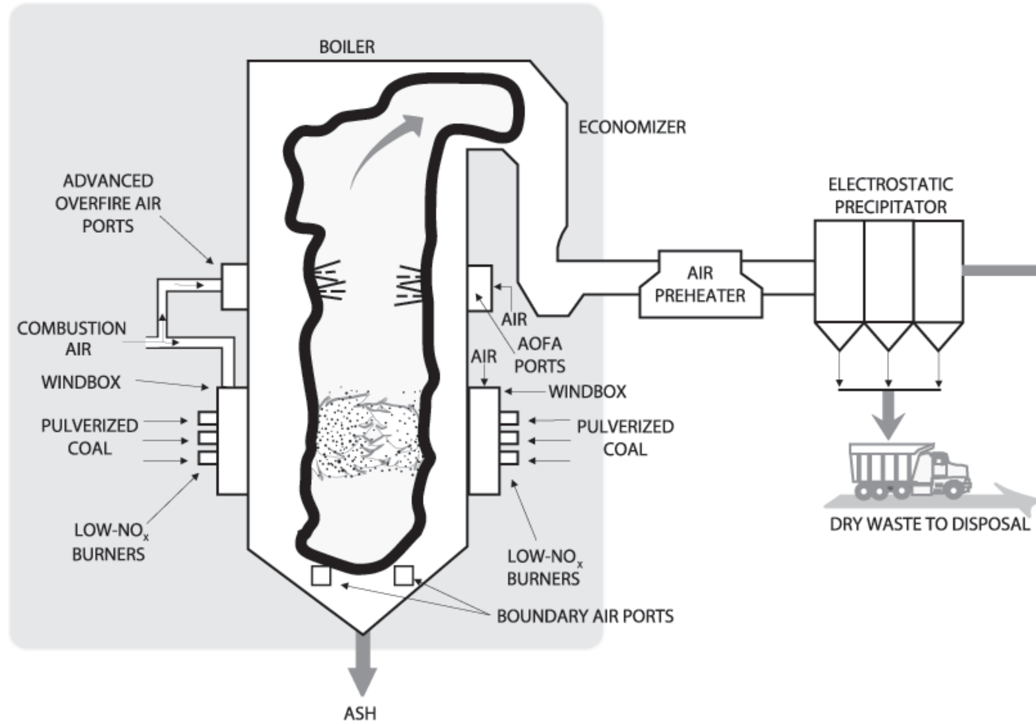
Demonstration of Advanced Combustion Techniques for a Wall-Fired Boiler



Project completed

Participant

Southern Company Services, Inc. (SCS)

Additional Team Members

Southern Company—cofunder

Electric Power Research Institute (EPRI)—cofunder

Foster Wheeler Energy Corporation (Foster Wheeler)—technology supplier

Georgia Power Company—host

PowerGen—cofunder

U.K. Department of Trade and Industry—cofunder

EnTEC—technology supplier

Radian—technology supplier

Tennessee Technological University—technology supplier

Location

Coosa, Floyd County, GA (Georgia Power Company's Plant Hammond, Unit No. 4)

Technology

Foster Wheeler's low-NO_x burner (LNB) with advanced overfire air (AOFA) and EPRI's Generic NO_x Control Intelligent System (GNOCIS) computer software.

Plant Capacity/Production

500 MWe

Coal

Eastern bituminous coals, 1.7% sulfur

Project Funding

Total	$15,853,900	100%
DOE	6,553,526	41
Participant	9,300,374	59

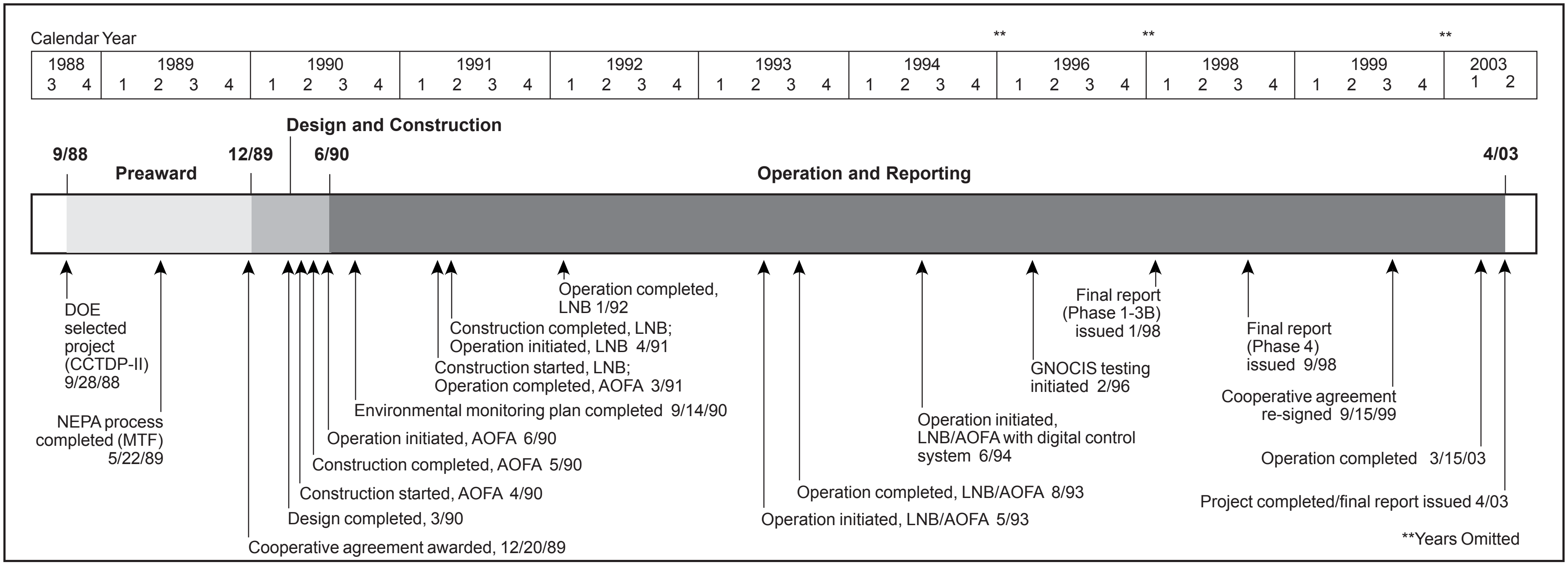
Project Objective

To achieve 50% NO_x reduction with the LNB/AOFA system; to determine the contributions of AOFA and LNB to NO_x reduction and the parameters for optimal LNB/AOFA performance; and to assess the long-term effects of LNB, AOFA, combined LNB/AOFA, and the GNOCIS advanced digital controls on NO_x reduction, boiler performance, and peripheral equipment performance. The project has been reopened and extended to demonstrate an overall unit optimization system.

Technology/Project Description

AOFA involves: (1) improving OFA mixing to enable operation of the burners below the air/fuel ratio theoretically required to complete combustion (substoichiometric), without increasing combustible losses; and (2) introducing "boundary air" at the boiler walls to prevent corrosion caused by the reducing atmosphere.

In the Foster Wheeler Controlled Flow/Split Flame (CFSF) LNB, fuel and air mixing is staged by regulating the primary air/fuel mixture, velocities, and turbulence to create a fuel-rich core with sufficient air to sustain combustion at a severely sub-stoichiometric air/fuel ratio. The burner also controls the rate at which additional air, necessary to complete combustion, is mixed with the flame solids and gases so as to maintain a deficiency of oxygen until the remaining combustibles fall below the peak NO_x-producing temperature (around 2,800 °F). The final excess air then can be allowed to mix with the unburned products so that combustion is completed at a relatively low temperature. The CFSF LNB splits the coal/air mixture into four streams, which minimizes coal and air mixing and combustion staging.



Results Summary

Environmental

- Using LNB alone, long-term NO_x emissions were 0.65 lb/10^6 Btu, representing a 48% reduction from baseline conditions (1.24 lb/10^6 Btu).
- Using AOFA only, long-term NO_x emissions were 0.94 lb/10^6 Btu, representing a 24% reduction from baseline conditions.
- Using LNB/AOFA, long-term NO_x emissions were 0.40 lb/10^6 Btu, representing a 68% reduction from baseline conditions.
- Chemical emissions testing showed no evidence of organic compound emissions resulting from the combustion modifications installed for NO_x control. Trace element control, except for mercury and selenium, proved to be a function of electrostatic precipitator (ESP) performance.

Operational

- AOFA accounted for an incremental NO_x reduction beyond the use of LNB of approximately 17%, with additional reductions resulting from other operational changes.
- GNOCIS achieved a boiler efficiency gain of 0.5 percentage points, a reduction in fly ash loss-on-ignition (LOI) levels of 1–3 percentage points, and a reduction in NO_x emissions of 10–15% at full load.
- Fly ash LOI increased from a baseline of 7% (corrected to representative excess oxygen conditions) to 10% with AOFA and 8% with LNB and LNB/AOFA, despite significant improvements in coal fineness.

Economic

- Capital cost for a 500-MWe wall-fired unit is \$8.8/kW for AOFA alone, \$10.0/kW for LNB alone, \$18.8/kW for LNB/AOFA, and \$0.5/kW for GNOCIS.
- Estimated cost of NO_x removal is \$79/ton using LNB/AOFA in a baseload dispatch scenario as experienced at Plant Hammond.

Project Summary

SCS conducted baseline characterization of the unit in an “as-found” condition from August 1989 to April 1990. The AOFA system was tested from August 1990 to March 1991. Following installation of the LNBs in the second quarter of 1991, the LNBs were tested from July 1991 to January 1992, excluding a three-month delay when the plant ran at reduced capacity. Post-LNB increases in fly ash LOI, along with increases in combustion air requirements and fly ash loading to the electrostatic precipitator (ESP), adversely affected the unit’s stack particulate emissions. The LNB/AOFA testing was conducted from January 1992 to August 1993, excluding downtime for a scheduled outage and for portions of the test period due to excessive particulate emissions. However, an ammonia flue gas conditioning system was added to improve ESP performance, which enabled the unit to operate at full load, and allowed testing to continue.

Operational Performance

LOI increased for the AOFA, LNB, and LNB/AOFA phases, as shown in Exhibit 3-20, despite improved mill performance due to the replacement of the mills. Increased LOI was a concern not only because of the associated efficiency loss, but also due to a potential loss of fly ash sales. The increased carbon in the fly ash renders the material unsuitable for use in making concrete.

During October 1992, SCS conducted parametric testing to determine the relationship between NO_x and LOI emissions. The parameters tested were: excess oxygen, mill coal flow bias, burner sliding tip position, burner outer register position, and burner inner register position. Nitrogen oxide emissions and LOI levels varied from 0.44–0.57 lb/10^6 Btu and 3–10%, respectively. As expected, excess oxygen levels had considerable effect on both NO_x and LOI. The results showed that there is some flexibility in selecting the optimum operating point and making trade-offs between NO_x emissions and fly ash LOI; however, much of the variation was the result of changes in excess oxygen. This can be more clearly seen in Exhibit 3-21 in which all sensitivities are plotted. This exhibit shows that, for excess oxygen, mill bias, inner register, and sliding tip, any adjustments to reduce NO_x emissions are at the expense of increased fly ash LOI. In contrast, the slope of the outer register adjustment suggests that improvement in both NO_x emissions and LOI can be achieved by adjustment of this damper. However, due to the relatively small impact of the outer register adjustment on both NO_x and LOI, it is likely the positive NO_x/LOI slope is an artifact of process noise.

A subsidiary goal of the project was to evaluate advanced instrumentation and controls (I&C) as applied to combustion control. The need for more sophisticated I&C equipment is illustrated in Exhibit 3-22. There are trade-offs in boiler operation, *e.g.*, as excess air increases, NO_x increases, LOI decreases, and boiler losses increase. The goal is to find and maintain an optimal operating condition. The instrumentation and control (I&C) systems tested included GNOCIS and carbon-in-ash analyzers.

The GNOCIS software applies an optimizing procedure to identify the best set points for the plant, which are implemented automatically without operator intervention (closed-loop), or conveyed to the plant operators for implementation (open-loop). The major elements of GNOCIS are shown in Exhibit 3-23. The GNOCIS system provided advice that reduced NO_x emissions by 10–15% at full load, while improving the heat rate or reducing fly ash LOI by 1–3 percentage points.

Exhibit 3-21

NO_x vs. LOI Tests—All Sensitivities

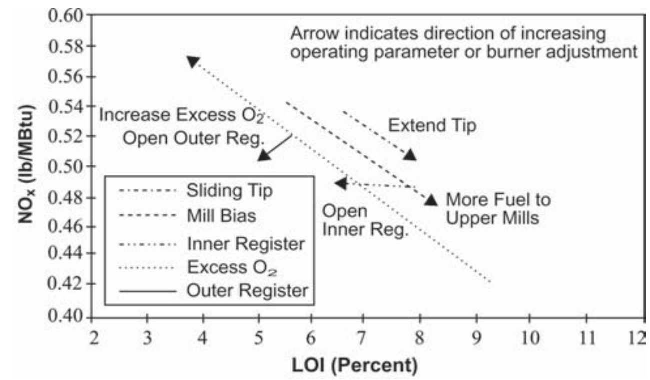


Exhibit 3-20

LOI Performance Test Results

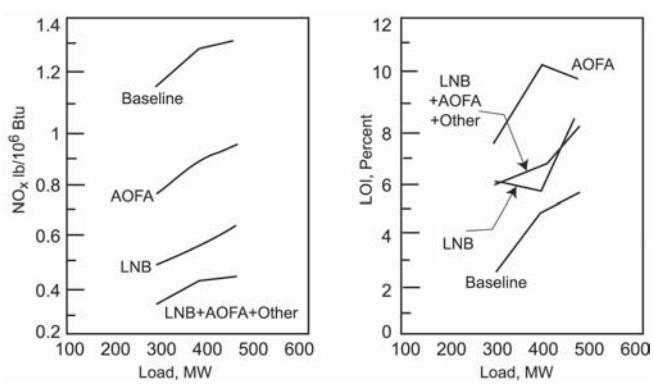


Exhibit 3-22

Typical Trade-Offs in Boiler Optimization

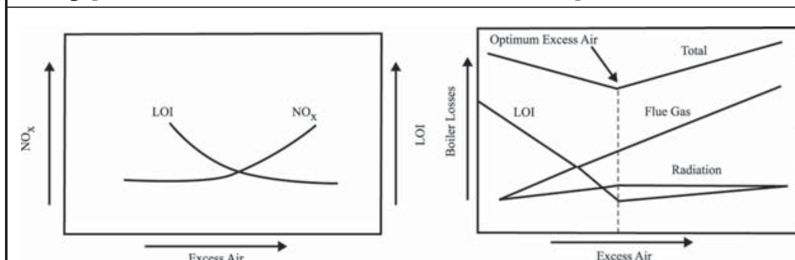
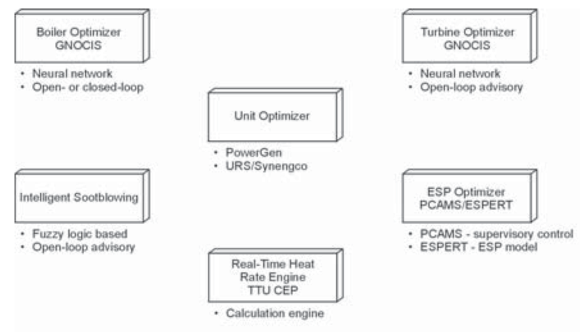


Exhibit 3-23

Major Elements of Optimization System



Environmental Performance

Long-term testing showed that the AOFA, LNBs, and LNB/AOFA provide full-load NO_x reductions of 24, 48, and 68%, respectively. Although the long-term LNB/AOFA NO_x level represents a 68% reduction from baseline levels, a substantial portion of the incremental change in NO_x emissions between the LNB and the LNB/AOFA configurations is the result of operational changes and is not the result of adding AOFA.

During the LNB/AOFA test phase a total of 63 days of valid long-term NO_x emissions data was collected. Based on this data set, the full-load, long-term NO_x emissions were 0.40 lb/10^6 Btu, which was consistent with earlier short-term test data. Earlier long-term testing had resulted in NO_x emissions of 0.94 lb/10^6 Btu for AOFA only and 0.65 lb/10^6 Btu for LNB only.

Chemical emissions testing showed no evidence of organic compound emissions resulting from the combustion modifications installed for NO_x control. Trace element control, except for mercury and selenium, proved to be a function of electrostatic precipitator (ESP) performance. Only a small portion of the mercury and selenium, which adopt a vapor phase, and none of the vapor-phase chlorine (as hydrochloric acid) and fluorine (as hydrofluoric acid) were captured.

Economic Performance

Estimated capital costs for a commercial 500-MWe wall-fired installation are: AOFA—$8.8/kW, LNB—$10.0/kW, LNB/AOFA—$18.8/kW, and GNOCIS—$0.5/kW. Annual O&M costs and NO_x reductions depend on the assumed load profile. Based on the actual load profile observed in the testing, the estimated annual O&M cost increase for LNB/AOFA is $333,351. Efficiency is decreased by 1.3 percent, and the NO_x reduction is 68 percent of baseline, or 11,615 tons/year at full load. The capital cost is $8,300,000 and the calculated cost of NO_x removed is $79/ton for the Hammond baseload dispatch scenario.

The addition of GNOCIS to the LNB/AOFA, using the actual load profile observed in the testing, results in a range of costs depending on whether the unit is operated to maximize NO_x removal efficiency, or LOI. For the maximum NO_x removal case, the efficiency is improved by 0.6 percent, the annual O&M cost is decreased by $228,058, the incremental NO_x reduction is 11 percent (696 tons/year), and the capital cost is $250,000. The calculated cost per ton of NO_x removed is -$299 (net gain due to increased efficiency).

Project Extension

On September 15, 1999, the cooperative agreement was extended and work began on the design and installation of an overall unit optimization system. The work has been carried out as part of Phase 4 of the project. The overall goal of Phase 4 is to demonstrate on-line optimization techniques, including use of a real-time heat rate monitor, for power plant processes and for the unit as a whole. The major tasks include unit optimization, boiler optimization, automated sootblowing, and precipitator modeling/optimization.

Commercial Applications

The technology is applicable to the 411 existing pre-NSPS dry-bottom wall-fired boilers in the United States, which burn a variety of coals. The GNOCIS technology is applicable to all fossil fuel-fired boilers, including units fired with natural gas and units cofiring coal and natural gas. The host has retained the technologies for commercial use.

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References

500-MW Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers. Phase 4—Digital Control System and Optimization. Southern Company Services, Inc. September 1998.

500-MW Demonstration of Advanced Wall-Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers. Phases 1-3B, Final Report. Southern Company Services, Inc. January 1998.