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Southern Company Services, Inc.

180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of NO_x Emissions

Project Performance Summary
Clean Coal Technology Demonstration Program

June 1999

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Environmental Control Devices

Advanced Tangentially Fired Combustion Techniques for NO_X Reduction

Overview

The Southern Company Services, Inc., demonstration of low-NO_x burners on tangentially fired boilers:

- **Pioneered the technology's introduction into the United States,**
- **Provided real time input to regulation development, and**
- **Carried out the tests necessary to identify key control parameters and understand the effects on the plant as well as environmental and economic performance.**

The technology was retained at Gulf Power and adopted by eight other utilities shortly after the demonstration. Some four years later, LNCFS™ and its derivative technology TFS 2000™ had been applied to 116 boilers, representing over 25,000 MWe.

Southern Company Services, Inc., demonstrated a range of low-NO_x burners on the 180-MWe tangentially fired Unit No. 2 at Gulf Power Company's Plant Lansing Smith. At the time of the demonstration, specific nitrogen oxide (NO_x) emission regulations were being formulated under the Clean Air Act Amendments of 1990 (CAAA). The data developed over the course of this project provided needed real-time input to regulation development.

The project is part of the U.S. Department of Energy's Clean Coal Technology Demonstration Program (CCTDP) established to address energy and environmental concerns related to coal use. Cost-shared partnerships with industry were sought through five nationally competed solicitations to accelerate commercialization of the most advanced coal-based power generation and pollution control technologies. The CCTDP, valued at nearly $6 billion, has leveraged federal funding twofold through the resultant partnerships encompassing utilities, technology developers, state governments, and research organizations. This project was one of 16 selected in May 1988 from 55 proposals submitted in response to the Program's second solicitation.

Tests were conducted on three configurations of ABB Combustion Engineering's (ABB CE) Low-NO_x Concentric Firing System , designated LNCFS™ I, II, and III. The objective was to determine NO_x emission reductions and the impact on boiler performance over the long-term under normal dispatch and operating conditions. By using the same boiler, the demonstration provided direct comparative performance analysis of the three low-NO_x burner configurations. Short-term parametric testing enabled extrapolation of results to other tangentially fired units by evaluating the relationship between NO_x emissions and key operating parameters.

The LNCFS™ systems tested achieved NO_x reductions of 37 to 45 percent. A range of capital cost estimates were made for each LNCFS™ system based on the demonstration and subsequent retrofits in constant 1993 dollars. The range for LNCFS™ I was $5–15/kW and for LNCFS™ II and III it was $15–25/kW. Cost effectiveness for LNCFS™ I, II, and III was estimated to be $103, $444 and $400 per ton of NO_x removed respectively.

Gulf Power has retained the LNCFS™ at its Plant Lansing Smith. Shortly after the demonstration, the technology was adopted by eight other utilities. As of September 1998, LNCFS™ and its derivative technology TFS 2000™ had been applied to 116 pulverized coal, tangentially fired boilers, representing over 25,000 MWe.

The Project

At the time of the demonstration, NO_x emission regulations were being formulated under the CAAA. Although introduced commercially in Western Europe, low-NO_x burner technology had yet to be evaluated in the United States where plant design, generating conditions, and coals are quite different. The project objectives were to (1) evaluate ABB CE's low-NO_x burner configurations over the long-term in an actual utility dispatch mode, examining not only NO_x emissions but effects on unit performance, and (2) understand the relationship of key parameters to NO_x emissions so that the results could be translated to other units. These objectives were realized, and the data generated provided needed real-time input to regulation development.

In addition to determining NO_x emission reductions and boiler performance impact for ABB CE's LNCFS™ configurations under normal dispatch operating conditions, air toxics testing was conducted to assess the impact of low-NO_x firing on trace element, volatile and semi-volatile organic compounds, and acid gas emissions.

Long-term test data were collected and analyzed with the baseline configuration of the boiler and three LNCFS™ configurations. (An additional configuration was tested, but the results were inconclusive and are not addressed here.) The technologies were retrofitted on Plant Lansing Smith Unit No. 2, a tangentially fired boiler commissioned in 1967. The unit burns eastern bituminous coal with a higher than normal reactivity, which favorably affects the amount of unburned combustibles (loss-on-ignition). The unit is rated at 180-MWe but is capable of producing 200-MWe. The test sequence was as follows:

1. Installation of a continuous emissions monitor and data acquisition system, followed by baseline testing
2. LNCFS II™ retrofit and testing
3. Conversion of LNCFS™ II to LNCFS™ III by exchanging the top coal nozzle with the air nozzle below it and installing two close-coupled overfire air (CCOFA) nozzles
4. LNCFS™ III testing
5. Testing of "simulated" LNCFS™ I by closing the separated overfire air (SOFA) ports of the LNCFS™ III

Project Sponsor
Southern Company Services, Inc.

Additional Team Members
Gulf Power Company—cofunder and host
Electric Power Research Institute—cofunder
ABB Combustion Engineering, Inc.—cofunder and technology supplier

Location
Lynn Haven, Bay County, FL
(Gulf Power's Plant Lansing Smith, Unit No. 2)

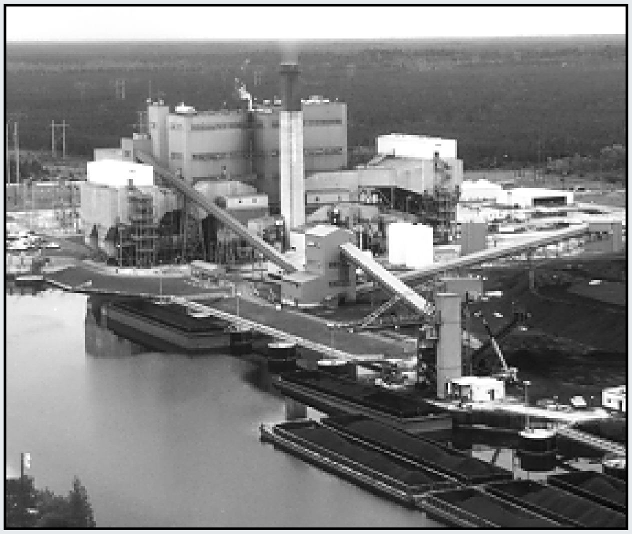
Technology
ABB Combustion Engineering's Low-NO_x Concentric Firing System (LNCFS™) with advanced overfire air

Plant Capacity
180-MWe

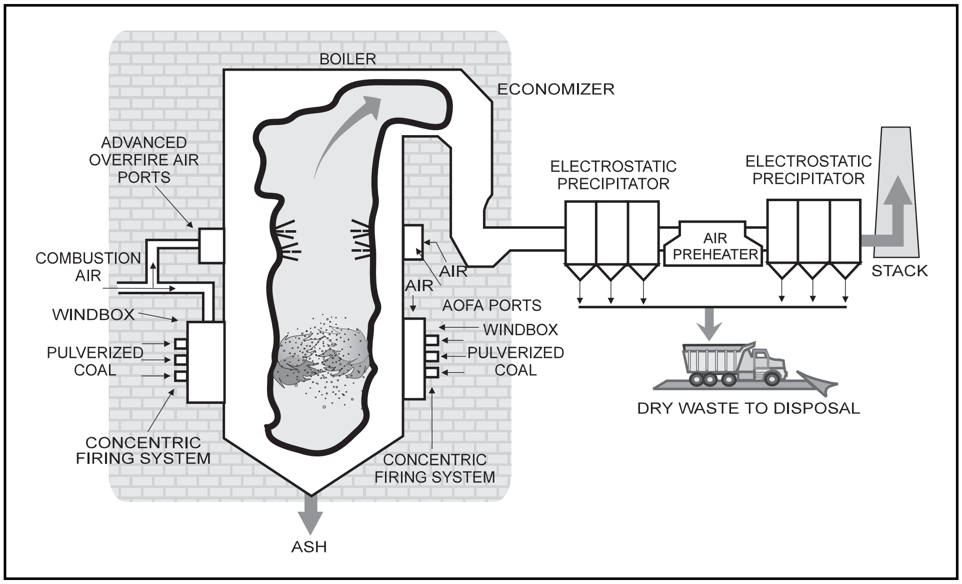
Demonstration Duration
May 1991–December 1992
Continuous operation

Project Funding

Total project cost	$9,153,383	100%
DOE	4,440,184	49%
Participants	4,713,199	51%



THE TECHNOLOGY



The basic approach to NO_x control is to stage combustion beginning with a fuel-rich, oxygen deficient flame core to mitigate oxidation of nitrogen to NO_x. Additional air is introduced at a controlled rate to avoid intense combustion and hot spots conducive to thermal NO_x formation. Only upon leaving the furnace is sufficient oxygen provided, through overfire air ports above the combustion zone, to ensure complete combustion. Temperatures are somewhat lower in the overfire air region, which limits thermal NO_x formation.

Three different low-NO_x combustion technologies for tangentially fired boilers were demonstrated. The concept of overfire air was demonstrated in all of these systems. *Figure 1* shows the baseline and the LNCFS™ I, II, and III configurations. In LNCFS™ I, a close-coupled overfire air (CCOFA) system is integrated directly into the windbox of the boiler. LNCFS™ I is arranged by exchanging the highest coal nozzle with an air nozzle immediately below it. This configuration provides the NO_x-reducing advantage of an overfire air system.

In LNCFS™ II, a separated overfire air (SOFA) system is installed in the four corners of the furnace. The air supply duct work for the SOFA is taken off the secondary air duct and routed to the corners of the furnace above the existing windbox. LNCFS™ III utilizes both CCOFA and SOFA.

In addition to overfire air, the LNCFS™ incorporates other NO_x-reducing techniques into the combustion process. Using offset air, two concentric circular combustion regions are formed, as shown in *Figure 2*. The majority of the coal is contained in the fuel-rich inner region. This region is surrounded by a fuel-lean zone containing combustion air. The size of this outer annulus of combustion air can be varied using adjustable offset air nozzles. Separation of air and coal at the burner level further reduces the production of NO_x.

Demonstration Results

- At full load (180 MWe), the NO_x emissions using LNCFS™ I, II, and III were 0.39, 0.39, and 0.34 lb/10^6 Btu, respectively, which represent reductions of 37, 37, and 45 percent from baseline emissions. (These emissions are within the annual average emission limit of 0.45 lb/10^6 Btu set for tangentially fired boilers in accordance with Phase I of the CAAA. However, Phase II of the CAAA requires an annual average emission limit of 0.38 lb/10^6 Btu.)

- The emissions were not particularly sensitive to power outputs between 100- and 200-MWe. But, below 100-MWe, the NO_x emissions, while using the LNCFS™ technologies, increase significantly, reaching pre-retrofit baseline levels at 70-MWe. This result is important when the unit is operated at intermediate and peaking load conditions. In fact, the technologies' ability to meet the Phase I average annual emission limit in a peaking scenario is marginal. Only LNCFS™ III meets Phase II requirements, but not under peaking load conditions.

- Short-term testing showed that low-load NO_x emissions could be reduced by using lower excess oxygen (O_2) and burner tilt, but with adverse impacts on unit performance. These impacts include lower steam outlet temperature, higher carbon monoxide (CO) emissions, and an increase in unburned combustibles referred to as loss-on-ignition (LOI).

- The following observations were made on unit performance during long-term testing:
  - Average CO emissions increased at full load.
  - LOI was not sensitive to the LNCFS™ retrofits but was very sensitive to coal fineness.
  - Furnace slagging was reduced, but back-pass fouling was increased for LNCFS™ II and III.
  - Boiler efficiency and unit net heat rate were impacted minimally.
  - Unit operation was not significantly affected, but the operating flexibility of the unit was reduced at low loads with LNCFS™ II and III.

- The capital cost estimate for LNCFS™ I is \$5–15/kW and for LNCFS™ II and III, \$15–25/kW. The cost effectiveness of LNCFS I was \$103/ton of NO_x removed; LNCFS™ II, \$444/ton; and LNCFS™ III, \$400/ton. (All costs in 1993 constant dollars).

Figure 1. Tangentially Fired Combustion System Configurations

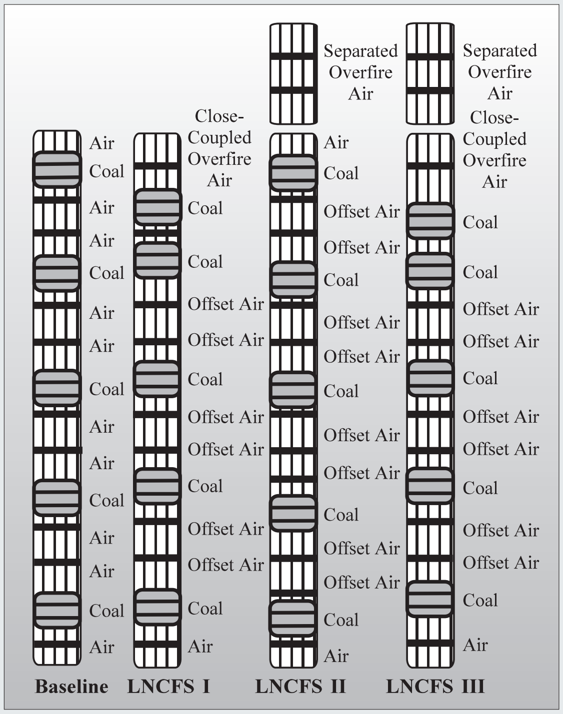
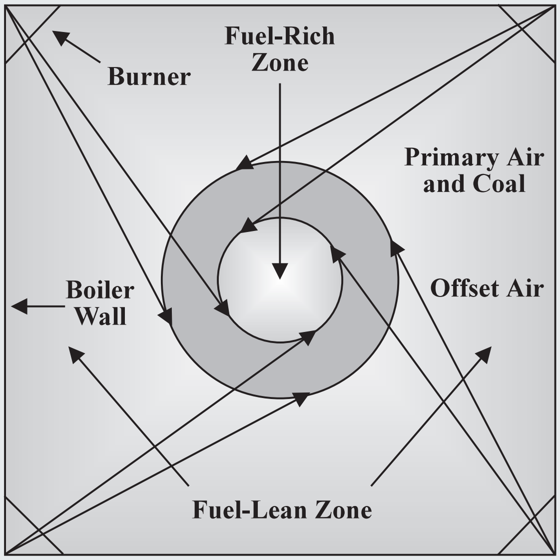


Figure 2. Concentric Firing Concept



Source: Reference 8

Operational Performance

During the demonstration, operating performance parameters assessed included CO emissions, excess O_2 requirements, LOI, steam outlet conditions, furnace slagging and back-pass fouling, operating flexibility, boiler efficiency, and unit heat rate. *Table 1* summarizes the results.

Generally, the reliability of the NO_x control equipment was favorable. However, long-term operating experience remains limited, and some reliability problems continue to be reported. These include plugging of coal/air nozzles.

Table 1. Unit Performance Impacts Based on Long-Term Testing

	Baseline	**LNCFS™ I**	**LNCFS™ II**	**LNCFS™ III**
Avg CO at full load, ppm	10	12	22	33
Avg excess O_2 at full load, %	3.7	3.2	4.5	4.3
% LOI at full load (% O_2)	4.8 (4.0)	4.6 (3.9)	4.2 (5.3)	5.9 (4.7)
Steam outlet conditions	Satisfactory at full load; low temps at low loads	Full load: 5–10 °F lower than baseline; low loads: 10–30 °F lower than baseline	Same as baseline	160–200 MWe:OK; 80 MWe: 15–35 °F lower than baseline
Furnace slagging & back-pass fouling	Medium	Medium	Reduced slagging, but increased fouling	Reduced slagging, but increased fouling
Operating flexibility	Normal	Same as baseline	More care required at low loads (watch: windbox pressure drop and flame stability)	More difficult to operate than the other systems (sensitive to operating changes)
% boiler efficiency (efficiency change)	90 (N/A)	90.2 (+0.2)	89.7 (-0.3)	89.85 (-0.15)
Turbine heat rate, Btu/kWh	9,000	9,011	9,000	9,000
Unit net heat rate, Btu/kWh (% change)	9,995 (N/A)	9,986 (-0.1)	10,031 (+0.36)	10,013 (+0.18)
Source: Reference 1				

Environmental Performance

Table 2 shows the NO_x emissions for LNCFS™ I, II, and III at full load (180 MWe).

Figure 3 illustrates the fact that the NO_x emission profiles were relatively constant within the 100–200-MWe range.

As shown in *Figure 3*, NO_x emissions with the LNCFS™ technologies increase significantly below the 100-MWe control point, reaching baseline pre-retrofit levels at 70 MWe. The increase in NO_x emissions at low loads for LNCFS™ II and III is attributed to the following factors (there was insufficient low-load operation with LNCFS™ I):

- Higher excess O_2 requirements than the baseline
- Use of tilt (+6° for LNCFS™ III, +8° for LNCFS™ II, 0° at baseline)
- Lower SOFA flow rates at low loads required to maintain windbox pressure
- Greater fuel flow rate needed for quick unit load response

To assess the impact of unit dispatch profiles on average annual NO_x emissions and the ability of the LNCFS™ retrofitted unit to comply with NO_x regulations, three types of dispatch scenarios were developed and analyzed: baseload (Plant Lansing Smith baseload profile), intermediate load, and peaking load. The intermediate and peaking scenarios were simulated load profiles. *Table 3* presents the NO_x emission estimates obtained in the assessment of the average annual NO_x emissions for the dispatch scenarios.

Table 2. NO_x Emissions at Full Load

Technology	NO_x (lb/10^6 Btu)	% NO_x Reduction
Baseline	0.63	—
LNCFS™ I	0.39	37
LNCFS™ II	0.39	37
LNCFS™ III	0.34	45
Source: Reference 1		

Figure 3. Comparison of Long-Term NO_x Emissions—Baseline, LNCFS™ Levels I, II, and III

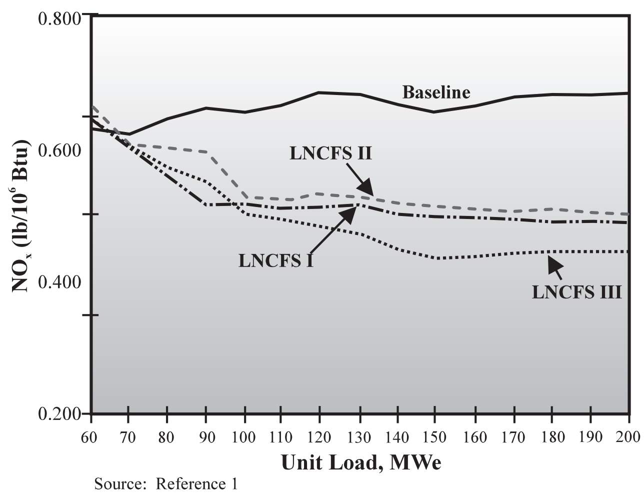


Table 3. Average Annual NO_x Emissions

Boiler Duty Cycle		Baseline	LNCFS™ I	LNCFS™ II	LNCFS™ III
Baseload (161.8 MWe avg)	Avg NO_x emissions (lb/10^6 Btu)	0.62	0.41	0.41	0.36
	Avg NO_x reduction (%)		38.7	38.7	42.2
Intermediate load (146.6 MWe avg)	Avg NO_x emissions (lb/10^6 Btu)	0.62	0.40	0.41	0.34
	Avg NO_x reduction (%)		39.2	35.9	45.3
Peaking load (101.8 MWe avg)	Avg NO_x emissions (lb/10^6 Btu)	0.59	0.45	0.47	0.43
	Avg NO_x reduction (%)		36.1	20.3	28.0
Source: Reference 1					

Under Phase I of the CAAA, the annual average NO_x emission limit for tangentially fired boilers has been set at 0.45 lb/million Btu. From the estimates contained in *Table 3*, LNCFS™ I and II barely meet the emission limit at baseload and intermediate load, and LNCFS™ II does not meet the regulated emission limit under peaking dispatch conditions. LNCFS™ III appears to meet the regulation at base and intermediate loads and marginally at peaking loads. Only LNCFS™ III meets Phase II CAAA requirements, but not under peaking load conditions. Low-NO_x burners for peaking units may require giving special attention to burner/windbox design or correcting of operational parameters.

Workman Installing Coal Injection Nozzle in Corner Housing

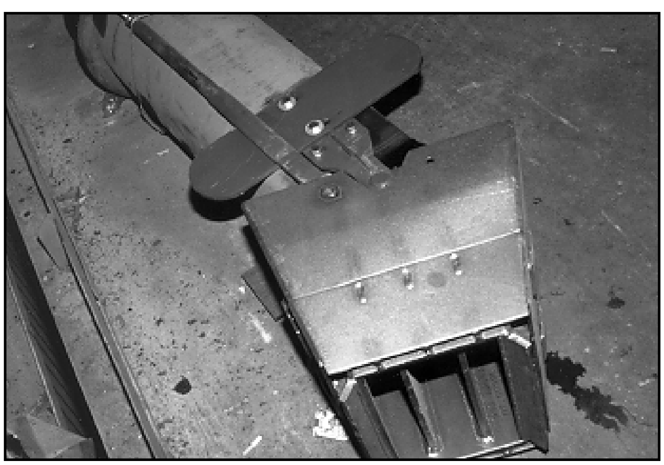
Air Toxic Testing Results—Tests were conducted to investigate the effects of low-NO_x combustion on emissions of trace elemets, volatile and semi-volatile organic compounds, and acid gases. Most of the trace elements were from the list in the CAAA. These included antimony, arsenic, beryllium, cadmium, cobalt, chromium, lead, manganese, mercury, nickel, and selenium. Four other metals were added—barium, copper, molybdenum, and vanaduim. Two arsenic species were assessed separately—its trivalent state As (III) and pentavalent state As (V) . Chromium's acutely carcinogenic form, Cr(VI), was dealt with separately. Mercury was assessed in its elemental and oxidized states. Inorganic acid gases included oxides of sulfur (SO_x), hydrogen fluoride (HF), hydrogen chloride (HCl), nitrogen bearing hydrocarbons (HCN), and ammonia (NH_3). The first three are common forms in which sulfur, flourine, and chlorine are emitted during coal combustion. The latter two gases contain nitrogen in reduced states (as opposed to the oxidized state, NO_x). Aldehydes and ketones were specifically addressed. Volatile organic compounds (VOCs) of primary interest were benezene and toluene, and polynuclear aromatic hydrocarbons (PAHs) were the focus of the semi-volatile organic compound analysis.

Low-NO_x firing was found to have no clear-cut effect on the emission of trace metals or acid gases. The data provided marginal evidence for a decreased emission of Cr (VI). The effect on aldehydes/ketones could not be assessed because baseline data was compromised. Volatile organic compounds (VOCs) appeared to be reduced and semi-volatiles increased. The increase in semi-volatiles was deemed to be consistent with increases in the amount of unburned carbon in the ash.

Effects of the hot-side electrostatic precipitator (ESP) were also assessed. With the exception of mercury and selenium, which remained largely in a vapor state, trace element emissions were reduced from 95 to 99 percent of inlet levels. The 1 to 5 percent penetration was attributed to a fraction being present as fine particulate. The ESP had no measurable effect on SO_x, HF or HCl. Surprisingly, the ESP suppressed the emission of certain organic substances (e.g., formaldehyde). This was attriuted to either chemical changes at the high ESP temperature or in the corona regions, where ozone and other high-energy reactants are present. It was surmised that destruction of semi-volatiles was aided by high temperature while adsorbed to ash particles in the hoppers.

Implications for Other Units—Each LNCFS™ level has the following implications for other units:

- *LNCFS™ I.* Long-term NO_x reductions of 25–37 percent within the 50–100 percent load range is projected for LNCFS™ I. This is more than the 25–30 percent reduction observed in other tangentially fired units (e.g., TVA's Gallatin Unit No. 4).
- *LNCFS™ II.* Long-term NO_x reduction of 30–40 percent within the 50–100 percent load range is expected from LNCFS™ II. This range is based on the Plant Lansing Smith Unit No. 2 experience, as well as results from LNCFS™ II retrofits, such as Public Service Company of Colorado's Cherokee Unit 4 and Indianapolis Power and Light's Stout Unit 5.
- *LNCFS™ III.* Long-term NO_x reduction of 40–50 percent is expected within the 50–100 percent load range with LNCFS™ III. This is based on the Plant Lansing Smith Unit No. 2 demonstration and Union Electric's Labadie Unit 4 retrofit.



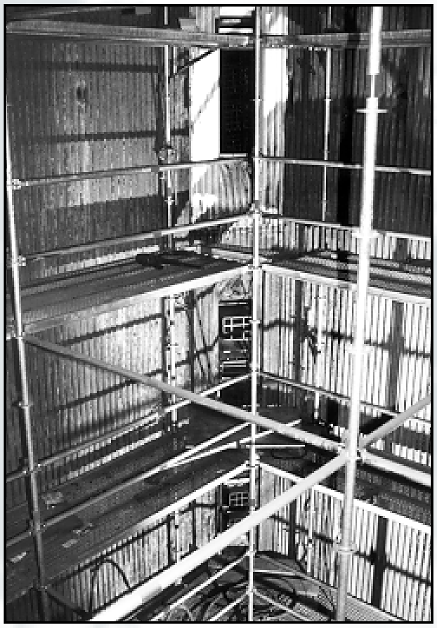
Coal Injection Nozzle

Economic Performance

Capital Costs—LNCFS™ II was the only complete retrofit (LNCFS™ I and III were modifications of LNCFS™ II), and therefore capital cost estimates were based on the Plant Lansing Smith Unit No. 2 retrofit as well as other tangentially fired LNCFS™ retrofits. The capital cost ranges in 1993 constant dollars follow:

- LNCFS™ I—$5–15/kW
- LNCFS™ II—$15–25/kW
- LNCFS™ III—$15–25/kW

Site-specific considerations have a significant effect on capital costs; however, the above ranges reflect recent experience and are planning estimates. The actual capital cost for LNCFS™ II at Plant Lansing Smith Unit No. 2 was $3 million, or $17/ kW, which falls within the projected range.



Opening Created for Separated Overfire Air

Air Injection Nozzles Top and Bottom (With Oil Guns in Two of Them) and Coal Injection Nozzle in Middle

Operating and Maintenance Costs—As shown in *Table 1*, the LNCFS™ retrofits have an impact on boiler efficiency and heat rate. Thus, fuel requirements are impacted and consequently have operating and maintenance (O&M) cost implications. Considering the heat rates shown in *Table 1*, a 65 percent capacity factor, and a $\$2/10^6$ Btu coal cost, the following annual O&M changes are estimated for LNCFS™ technologies in 1993 constant dollars:

- LNCFS™ I—$18,450/yr reduction
- LNCFS™ II—$73,800/yr increase
- LNCFS™ III—$36,900/yr increase

Cost Effectiveness—The cost effectiveness of the LNCFS™ technologies is based on the capital and O&M costs and the NO_x removal efficiency of the technologies. The cost effectiveness of the LNCFS™ technologies in 1993 constant dollars is listed below (based on a levelization factor of 0.144):

- LNCFS™ I—$103/ton of NO_x removed
- LNCFS™ II—$444/ton of NO_x removed
- LNCFS™ III—$400/ton of NO_x removed

Commercial Applications

Technical Implications for Other Units

The following characteristics of the Plant Lansing Smith Unit No. 2 boiler design and coal are important in considering the application of LNCFS™ technology to other tangentially fired units:

- Plant Lansing Smith Unit No. 2 furnace size is larger than average relative to other pre-New Source Performance Standards (NSPS) units. The net heat input per plan area is 1.65 million Btu/hr-ft^2 as compared to 1.6–2.2 million Btu/hr-ft^2 for most pre-NSPS ABB CE boilers.
- The existing windbox is taller than average and thus allowed the installation of a 20 percent larger CCOFA system.
- There was adequate distance (40 ft 4 in) between the top coal burner and the furnace outlet to fit the SOFA system.

The reactivity of the coal burned is higher than most eastern bituminous coals and, as such, would be expected to have much less impact on LOI than other, less reactive eastern bituminous coals. The reactivity of the coal burned at Plant Lansing Smith as measured by fixed carbon/volatile matter (FC/VM) is 1.30 (lower FC/VM means higher reactivity), which is below values listed for highly volatile eastern bituminous coals (FC/VM 1.4–1.7) and more typical of subbituminous coals (FC/VM 1.1–1.4).

Five pulverizer mills (RPS 623) provided coal with fineness ranging from 55–65 percent through 200 mesh. Investigation of the impact of coal fineness on LOI during LNCFS™ III testing indicated a strong relationship. For example, LOI was approximately 10 percent with coal fineness at 52 percent through 200 mesh but was reduced to 4 percent with coal fineness at 62 percent through 200 mesh.

A 4–6-week outage is needed for LNCFS™ I retrofits and a 6–8-week outage for LNCFS™ II and III retrofits. In addition, 2–3 weeks should be planned for LNCFS™ optimization. Reoptimization should be scheduled 3–6 months after original optimization.

Market Applications

The environmental and operational performance of LNCFS™ technology has been demonstrated in a number of retrofit projects, such as those listed in *Table 4*. Further, potential commercial applications of this technology include over 400 U.S. pulverized coal, tangentially fired utility units. These units range in size from 25 to 950 MWe and fire a wide range of coals, from low-volatile bituminous through lignite.

As of September 1998, LNCFS™ and its derivative technology TFS 2000™ had been installed on 116 pulverized coal, tangentially fired boilers, representing over 25,000 MWe.

Table 4. Selected LNCFS™ Retrofit Projects

Technology	Utility	Unit	Size (MWe)
LNCFS™ I	TVA	Gallatin 4	288
	Illinois Power	Joppa 3	150
LNCFS™ II	Public Service Company of Colorado	Cherokee 4	370
		Valmont 5	165
	Indianapolis P&L	Stout 5	100
	Cincinnati Gas and Electric	East Lake 2	175
	Virginia Power	Yorktown 2	175
LNCFS™ III[1]	Union Electric	Labadie[2]	600

[1] In addition, New York State Gas and Electric's Milliken Station, Units 1 and 2, 300 MWe total, have been retrofitted with LNCFS™ III.

[2] Labadie Unit 4 was retrofitted with LNCFS™ III.

Source: Reference 1

Contacts

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References

1. *180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers: Final Report and Key Project Findings*. Report No. DOE/PC/89653-T14. Southern Company Services, Inc. February 1994. (Available from NTIS as DE94011174.)

2. *180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers—Plant Lansing Smith—Phase III and Final Environmental Monitoring Program Report.* Report No. DOE/PC/89653-T9. Radian Corporation for Southern Company Services. August 1993. (Available from NTIS as DE94002339.)

3. *180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers—Topical Report LNCFS™ Levels I and III Tests Results.* Southern Company Services, Inc., and Energy Technology Consultants. October 1993.

4. *Measurement of Chemical Emissions under the Influence of Low-NO_x Combustion Modifications*. Report No. DOE/PC/89653-T12. Southern Company Services, Inc. October 1993. (Available from NTIS as DE94005038.)

5. *180-MW Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers: Final Public Design Report.* Southern Company Services, Inc. September 1993. Report No. DOE/PC/89652-T13. (Available from NTIS as DE94000218.)

6. *Advanced Tangentially Fired Low-NO_x Combustion Demonstration—Phase II LNCFS™ Level II Tests.* Southern Company Services, Inc., and Energy Technology Consultants. September 1993.

7. *180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers—Topical Report—Phase I: Baseline Tests.* Southern Company Services, Inc., and Energy Technology Consultants. March 1992.

8. *Comprehensive Report to Congress on the Clean Coal Technology Program: 180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of Nitrogen Oxide (NO_x) Emissions from Coal-Fired Boilers.* (Southern Company Services, Inc.) Report No. DOE/FE-0191P. U.S. Department of Energy. July 1990. (Available from NTIS as DE9000-1359.)

U.S. Department of Energy

Assistant Secretary for Fossil Energy

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