# 180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of $NO_x$ Emissions from Coal-Fired Boilers

***Project completed***

### Participant

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 Company's Plant Lansing Smith, Unit No. 2)

### Technology

ABB Combustion Engineering's Low-$NO_x$ Concentric Firing System (LNCFS™) with advanced overfire air (AOFA), clustered coal nozzles, and offset air

### Plant Capacity/Production

180 MWe

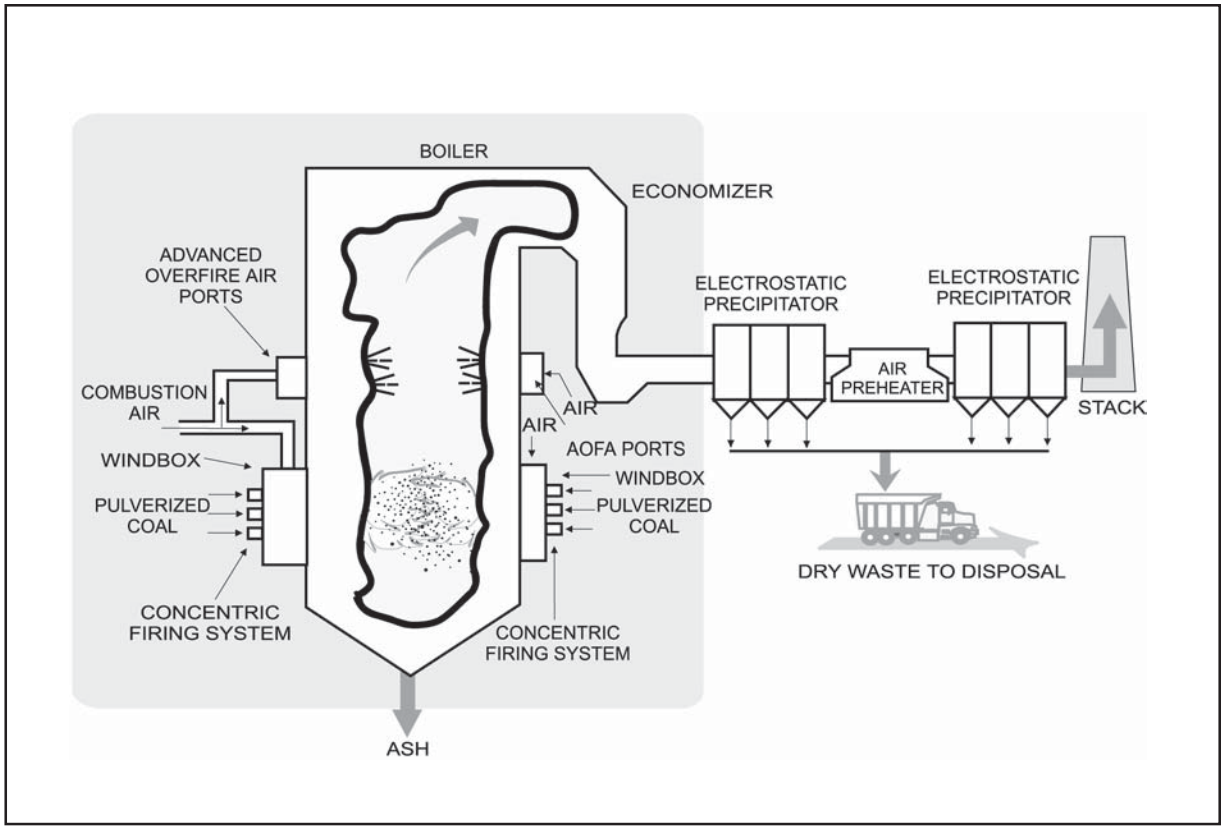
### Coal

Eastern bituminous, high reactivity

### Project Funding

| | | |
|---|---|---|
| Total | $8,553,665 | 100% |
| DOE | 4,149,382 | 49 |
| Participant | 4,404,283 | 51 |

LNCFS is a trademark of ABB Combustion Engineering, Inc.



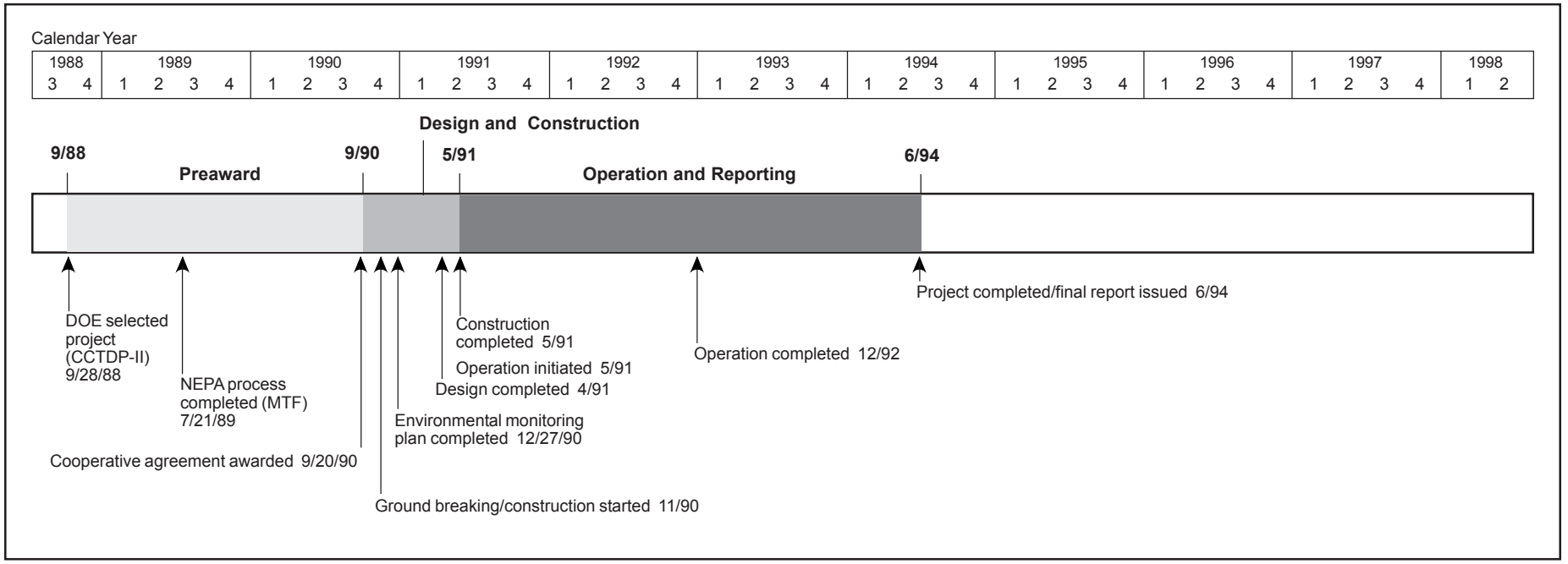

### Project Objective

To demonstrate in a stepwise fashion the short- and long-term $NO_x$ reduction capabilities of LNCFS™ levels I, II, and III on a single reference boiler.

### Technology/Project Description

Technologies demonstrated included LNCFS™ levels I, II, and III. Each level of the LNCFS™ used different combinations of overfire air and clustered coal nozzle positioning to achieve $NO_x$ reductions. With the LNCFS™, primary air and coal are surrounded by oxygen-rich secondary air that blankets the outer regions of the combustion zone. LNCFS™ I used a close-coupled overfire air (CCOFA) system integrated directly into the windbox of the boiler. A separated overfire air (SOFA) system located above the combustion zone was featured in the LNCFS™ II system. This was an advanced overfire air system that incorporates back pressuring and flow measurement capabilities. CCOFA and SOFA were both used in the LNCFS™ III tangential-firing approach.

Carefully controlled short-term tests were conducted followed by long-term testing under normal load dispatch conditions. Long-term tests, which typically lasted 2–3 months for each phase, best represent the true emissions characteristics of each technology. Results presented are based on long-term test data.




## Results Summary

### Environmental

- At full load, 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% from the baseline emissions, respectively.
- Emissions with LNCFS™ were not sensitive to power outputs between 100 MWe and 200 MWe, but emissions increased significantly below 100 MWe, reaching baseline emission levels at 70 MWe.
- Because of reduced effectiveness at low loads, LNCFS™ proved marginal as a compliance option for peaking load conditions.
- Average CO emissions increased at full load.
- Air toxics testing found LNCFS™ to have no clear-cut effect on the emissions of trace metals or acid gases. Volatile organic compounds (VOCs) appeared to be reduced and semi-volatile compounds increased.

### Operational

- Loss-on-ignition (LOI) was not sensitive to the LNCFS™ retrofits, but very sensitive to coal fineness.
- Furnace slagging was reduced, but backpass fouling was increased for LNCFS™ II and III.
- Boiler efficiency and unit heat rate were impacted minimally.
- Unit operation was not significantly affected, but operating flexibility of the unit was reduced at low loads with LNCFS™ II and III.

### Economic

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

## Project Summary

LNCFS™ technology was designed for tangentially fired boilers, which represent a large percentage of the pre-NSPS coal-fired generating capacity. The technology reduces $NO_x$ by staging combustion vertically in the boiler with separate coal and air injectors, and horizontally by creating fuel-rich and lean zones with offset air nozzles. The objective was to determine $NO_x$ emission reductions and impact on boiler performance under normal dispatch and operating conditions over the long term. By using the same boiler, the demonstration provided direct comparative performance analysis of the three 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.

At the time of the demonstration, specific $NO_x$ emission regulations were being formulated under the CAAA. The data developed over the course of this project provided needed real-time input to regulation development.

Exhibit 3-33 shows the various LNCFS™ configurations used to achieve staged combustion. In addition to overfire air, the LNCFS™ incorporates other $NO_x$-reducing techniques into the combustion process as shown in Exhibit 3-34. Using offset air, two concentric circular combustion regions are formed. The majority of the coal is contained in the fuel-rich zone. 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.

### Operational Performance

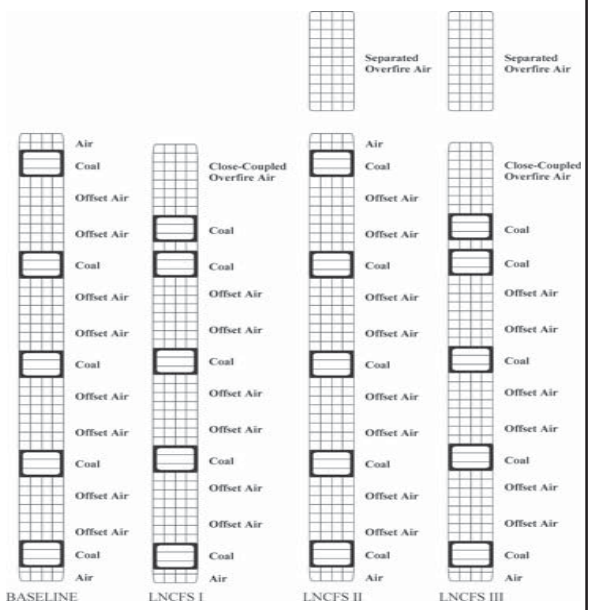
Exhibit 3-35 summarizes the impacts of LNCFS™ on unit performance.

### Environmental Performance

At full load, LNCFS™ I, II, and III reduced $NO_x$ emissions by 37, 37, and 45%, respectively. Exhibit 3-36 presents the $NO_x$ emission estimates obtained from the assessment of the average annual $NO_x$ emissions for three dispatch scenarios.

Air toxics testing found LNCFS™ 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 chromium. The effect on aldehydes/ketones could not be assessed because baseline data were compromised. VOCs appeared to be reduced and semi-volatile compounds increased. The increase in semi-volatile compounds was deemed to be consistent with increases in the amount of unburned carbon in the ash.

**Exhibit 3-33**
**LNCFS™ Configurations**



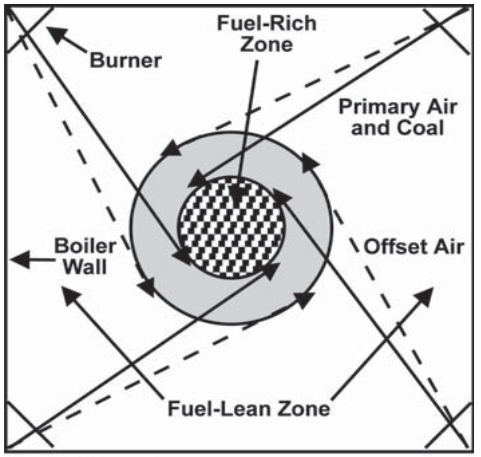

### Economic Performance

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 Lansing Smith Unit No. 2 retrofit as well as other tangentially fired LNCFS™ retrofits. The capital cost ranges in 1993 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 actual experience and are planning estimates. The actual capital cost for LNCFS™ II at Lansing Smith Unit No. 2 was $3 million, or $17/kW, which falls within the projected range.

**Exhibit 3-34**
**Concentric Firing Concept**




Source: Reference 8

The cost-effectiveness of the LNCFS™ technologies is based on the capital and operating and maintenance costs and the $NO_x$ removal efficiency of the technologies. The cost-effectiveness of the LNCFS™ technologies follows (based on a levelization factor of 0.144; 1993 constant dollars):

- 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

The LNCFS™ technology has potential commercial application to all the 423 U.S. pulverized coal, tangentially fired utility units. These units range from 25 MWe to 950 MWe in size and fire a wide range of coals, from low-volatile bituminous through lignite.

## Exhibit 3-35
## 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 (%)<br>$O_2$ (%) | 4.8<br>4.0 | 4.6<br>3.9 | 4.2<br>5.3 | 5.9<br>4.7 |
| Steam outlet conditions | Satisfactory at full load; low temperatures at low loads | Full load: 5–10 ºF lower than baseline<br>Low loads: 10–30 ºF lower than baseline | Same as baseline | 160–200 MWe: satisfactory<br>80 MWe: 15–35 ºF lower than baseline |
| Furnace slagging and backpass 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 | More difficult to operate than other systems |
| Boiler efficiency (%)<br>Efficiency change (points) | 90<br>N/A | 90.2<br>+0.2 | 89.7<br>-0.3 | 89.85<br>-0.15 |
| Turbine heat rate (Btu/kWh) | 9,000 | 9,011 | 9,000 | 9,000 |
| Unit net heat rate (Btu/kWh)<br>Change (%) | 9,995<br>N/A | 9,986<br>-0.1 | 10,031<br>+0.36 | 10,013<br>+0.18 |

## Exhibit 3-36
## Average Annual $NO_x$ Emissions and Percent Reduction

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

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### References


*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.)

*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.* Southern Company Services, Inc. December 1993.

*180-MWe Demonstration of Advanced Tangentially Fired Combustion Techniques for the Reduction of $NO_x$ Emissions—Project Performance Summary*. U.S. Department of Energy. June 1999.