Full-Scale Demonstration of Low-NO_x Cell Burner Retrofit

Project completed

Participant

The Babcock & Wilcox Company

Additional Team Members

The Dayton Power and Light Company—cofunder and host

Electric Power Research Institute—cofunder

Ohio Coal Development Office—cofunder

Tennessee Valley Authority—cofunder

New England Power Company—cofunder

Duke Power Company—cofunder

Allegheny Power System—cofunder

Centerior Energy Corporation—cofunder

Cincinnati Gas & Electric Company—cofunder

Columbus and Southern Power Company—cofunder

Location

Aberdeen, Adams County, OH (Dayton Power and Light Company's J.M. Stuart Plant, Unit No. 4)

Technology

The Babcock & Wilcox Company's low-NO_x cell-burner (LNCB®) system

Plant Capacity/Production

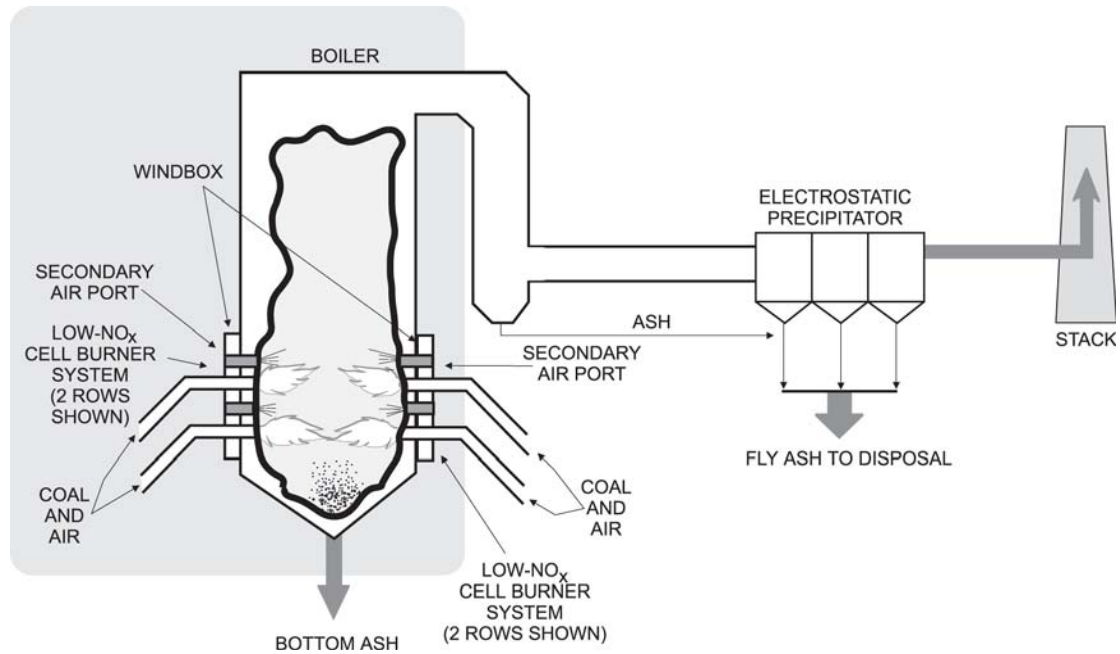
605 MWe

Coal

Bituminous, 1.2% sulfur

Project Funding

Total	$11,233,392	100%
DOE	5,442,800	48
Participant	5,790,592	52



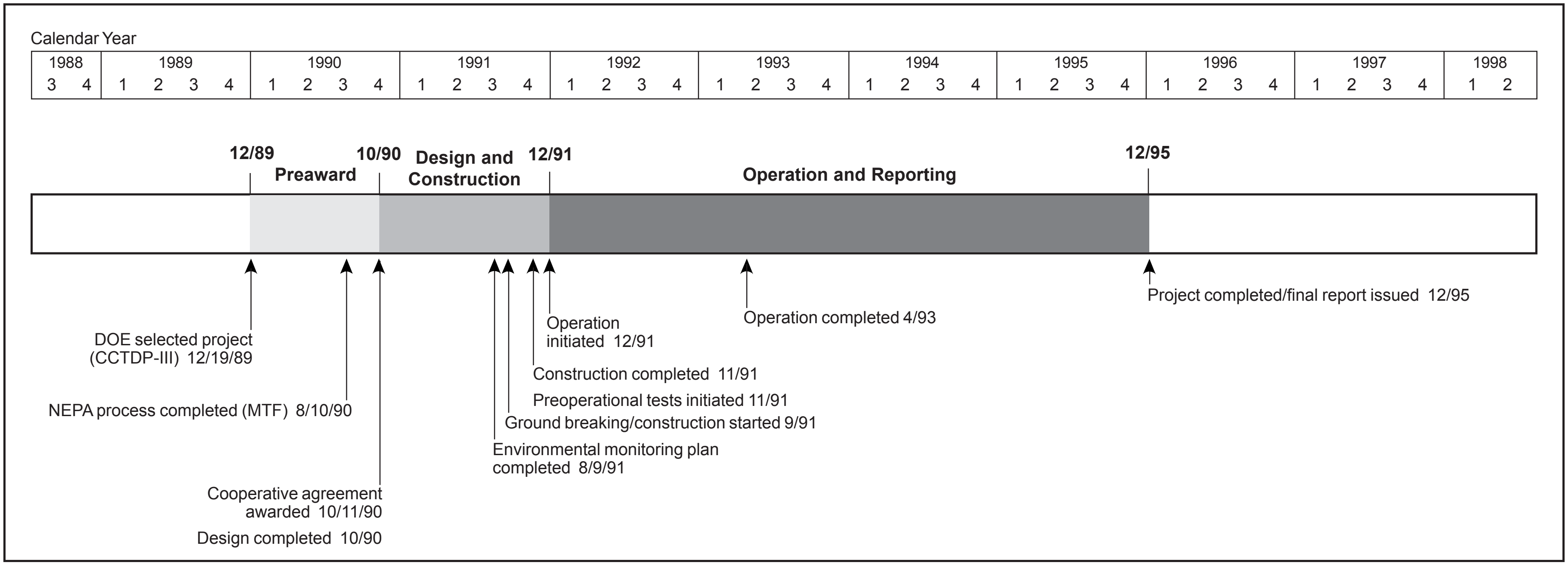
Project Objective

To demonstrate, through the first commercial-scale full burner retrofit, the cost-effective reduction of NO_x from a large, baseload coal-fired utility boiler with LNCB® technology and to achieve at least a 50% NO_x reduction without degradation of boiler performance at less cost than that of conventional low-NO_x burners.

Technology/Project Description

The LNCB® technology replaces the upper coal nozzle of the standard two-nozzle cell burner with a secondary air port. The lower burner coal nozzle is enlarged to the same fuel input capacity as the two standard coal nozzles. The LNCB® operates on the principle of staged combustion to reduce NO_x emissions. Combustion is staged by providing only about 58% of the air theoretically required for complete combustion through the lower burner and the balance of the air through the secondary air port (NO_x port).

The demonstration was conducted on a Babcock & Wilcox-designed, supercritical once-through boiler equipped with an electrostatic precipitator (ESP). This unit, which is typical of cell-burner boilers, contained 24 two-nozzle cell burners arranged in an opposed-firing configuration. Twelve burners (arranged in two rows of six burners each) were mounted on each of two opposing walls of the boiler. All 24 standard cell burners were removed and 24 new LNCBs® were installed. Alternate LNCBs® on the bottom rows were inverted, with the air port then being on the bottom to ensure complete combustion in the lower furnace.



Results Summary

Environmental

- Short-term optimization testing (all mills in service) showed NO_x reductions in the range of 53.0–55.5%, 52.5–54.7%, and 46.9–47.9% at loads of 605 MWe, 460 MWe, and 350 MWe, respectively.
- Long-term testing at full load (all mills in service) showed an average NO_x reduction of 58% (over 8 months).
- Long-term testing at full load (one mill out of service) showed an average NO_x reduction of 60% (over 8 months).
- Carbon monoxide (CO) emissions averaged 28–55 ppm at full load with LNCB® in service.
- Fly ash increased, but ESP performance remained virtually unchanged.

Operational

- Unit efficiency remained essentially unchanged.
- Unburned carbon losses (UBCL) increased by approximately 28% for all tests, but boiler efficiency loss was offset by a decrease in dry gas loss due to a lower boiler economizer outlet gas temperature.
- Boiler corrosion with LNCB® was roughly equivalent to boiler corrosion rates prior to retrofit.

Economic

- Capital cost for a 600 MWe plant in the Midwest, with a 1.2 lb/10^6 Btu initial NO_x emission rate and 65% capacity factor, was $9/kW (1994$).
- Levelized cost (15-year) for the same 600 MWe plant was estimated at 0.284 mills/kWh and $96.48/ton of NO_x removed (constant 1994$).

Project Summary

Utility boilers equipped with cell burners represent 7.4% or approximately 24,000 MWe of pre-NSPS coal-fired generating capacity. Cell burners are designed for rapid mixing of fuel and air. The tight burner spacing and rapid mixing minimize flame size while maximizing the heat release rate and unit efficiency. Combustion efficiency is good, but the rapid heat release produces relatively large quantities of NO_x.

To reduce NO_x emissions, the LNCB® has been designed to stage mixing of fuel and combustion air. A key design criterion was accomplishing delayed fuel-air mixing with no modifications to boiler walls. The plug-in LNCB® design reduces material costs and outage time required to complete the retrofit, compared to installing conventional, internally staged low-NO_x burners, thereby providing a lower cost alternative to address NO_x reduction requirements for cell burners.

Environmental Performance

The initial LNCB® configuration resulted in excessive CO and hydrogen sulfide (H_2S) emissions. Through modeling, a revised configuration was developed (inverting alternate burners on the lower rows), which addressed the problem without compromising boiler performance. The modification served to validate model capabilities.

Following parametric testing to establish optimal operating modes, a series of optimization tests were conducted on the LNCB® to assess environmental and operational performance. Two sets of measurements were taken, one by Babcock & Wilcox and the other by an independent company, to validate data accuracy. Consequently, the data provided is a range reflecting the two measurements.

The average NO_x emissions reduction achieved at full load with all mills in service ranged from 53.0–55.5%. With one mill out of service at full load, the average NO_x reduction ranged from 53.3–54.5%. Average NO_x reduction at intermediate load (about 460 MWe) ranged from 52.5–54.7%. At low loads (about 350 MWe), average NO_x reduction ranged from 46.9–47.9%. NO_x emissions were monitored over the long term at full load with all mills in service and one mill out of service. Each test spanned an 8-month period. The NO_x emission reductions realized were 58% for all mills in service and about 60% for one mill out of service.

Complications arose in assessing CO emissions relative to baseline because baseline calibration was not sufficiently refined. However, accurate measurements were made with LNCB® in service. Carbon monoxide emissions were corrected for 3.0% O_2 and measured at full, intermediate, and low loads. The range of CO emissions at full load with all mills in service was 28–55 ppm, and 20–38 ppm with one mill out of service. At intermediate loads (about 460 MWe), CO emissions were 28–45 ppm, and at low loads (about 350 MWe), 5–27 ppm.

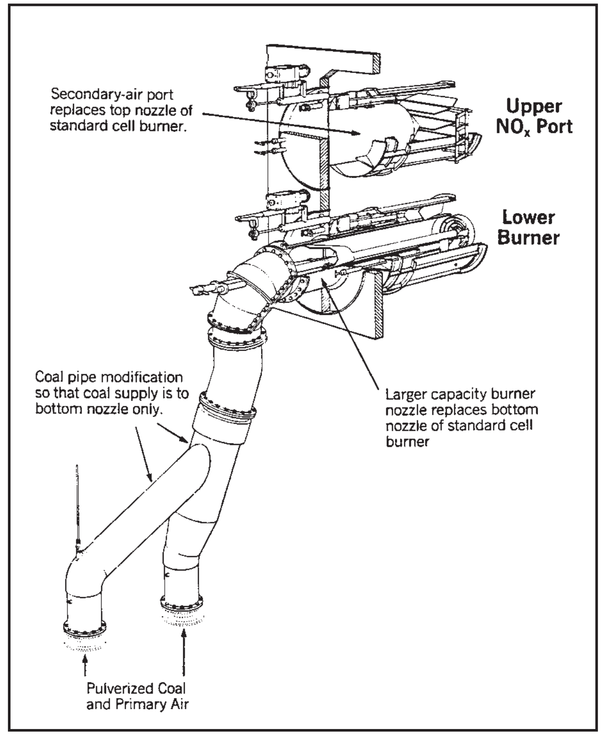
Particulate emissions were minimally impacted. The LNCB® had little effect on fly ash resistivity, largely due to SO_3 injection, and therefore ESP removal efficiency remained very high. Baseline ESP collection efficiencies for full load with all mills in service, full load with one mill in service, and intermediate load with one mill out of service were 99.50%, 99.49%, and 99.81%, respectively. For the same conditions, in the same sequence with LNCB® in operation, ESP collection efficiencies were 99.43%, 99.12%, and 99.35%, respectively.

Operational Performance

Furnace exit gas temperature initially decreased by 100 ºF, but eventually rose to within 10 ºF of baseline conditions. The UBCL increased by approximately 28% for all tests. The most significant increase from baseline data occurred for a test with one mill out of service. A 52% increase in UBCL resulted in an efficiency loss of 0.69%.

Boiler efficiency showed very little change from baseline. The average with all mills in service increased by 0.16%. The higher post-retrofit efficiency was attributed to a decrease in dry gas loss with lower economizer gas outlet temperature (and subsequent lower air heater gas outlet temperature), offsetting UBCL and CO emission losses. Also, increased coal fineness mitigated UBCL.

Because sulfidation is the primary corrosion mechanism in substoichiometric combustion of sulfur-containing coal, H_2S levels were monitored in the boiler. After optimizing LNCB® operation, levels were largely at the lower detection limit. There were some higher local readings, but corrosion panel tests established that corrosion rates with LNCB® were roughly equivalent to pre-retrofit rates.



Single LNCB® retrofit.

Ash sample analyses indicated that ash deposition would not be a problem. The LNCB® ash differed little from baseline ash. Furthermore, the small variations observed in furnace exit gas temperature between baseline and LNCB® indicated little change in furnace slagging. Startup and turndown of the unit were unaffected by conversion to LNCB®.

Economic Performance

The economic analyses were performed for a 600-MWe nominal unit size and typical location in the Midwest United States. A medium-sulfur, medium-volatile bituminous coal was chosen as the typical fuel. For a baseline NO_x emission level of 1.2 lb/10^6 Btu, 65% capacity factor, and a 50% reduction target, the estimated capital cost was $9/kW (1994$). The 15-year levelized cost of electricity was estimated at 0.284 mills/kWh, or $96.48/ton of NO_x removed in constant 1994 dollars.

Commercial Applications

The market for LNCB® technology is 33, two-nozzle type cell burner boilers in the U.S. (5 cell burners are three-nozzle types) with a total generating capacity of 25,200 MWe. The LNCB® system installed at the Dayton Power & Light Company's J.M. Stuart Plant unit No. 4 has been retained for commercial service.

Commercial success to date, and likely to come, is owed largely to the establishment of the LNCB® Advisory Committee composed of most of the cell burner equipped boiler owners. The Committee participated in the demonstration, becoming familiar with the technology, supporting numerical models, providing inputs to the demonstration, and reviewing field data.

The demonstration project received *R&D* magazine's 1994 R&D Award.

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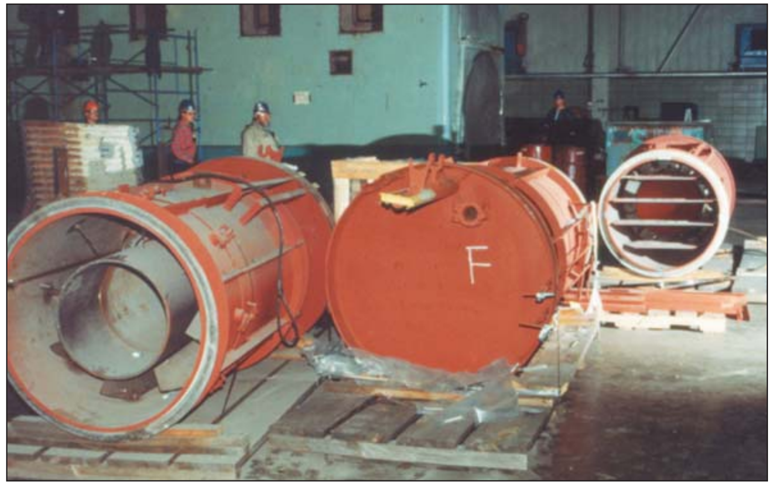
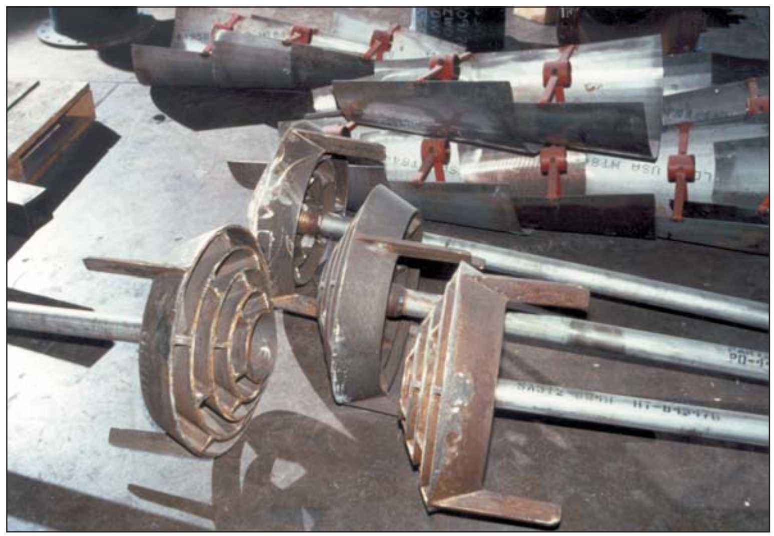


Cell burner AOFA connection with air control vanes open (right) lying next to cell burner housing showing primary air directional vanes and coal tube (left).



The S-Type burner impellers used in the LNCB® design.

References

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