

Demonstration of Coal Reburning for Cyclone Boiler NO_x Control

Project completed

Participant

The Babcock & Wilcox Company

Additional Team Members

Wisconsin Power and Light Company—cofunder and host

Sargent and Lundy—engineer for coal handling

Electric Power Research Institute—cofunder

State of Illinois, Department of Energy and Natural Resources—cofunder

Utility companies (14 cyclone boiler operators)—cofundors

Location

Cassville, Grant County, WI (Wisconsin Power and Light Company's Nelson Dewey Station, Unit No. 2)

Technology

The Babcock & Wilcox Company's Coal Reburning System (Coal Reburning)

Plant Capacity/Production

100 MWe

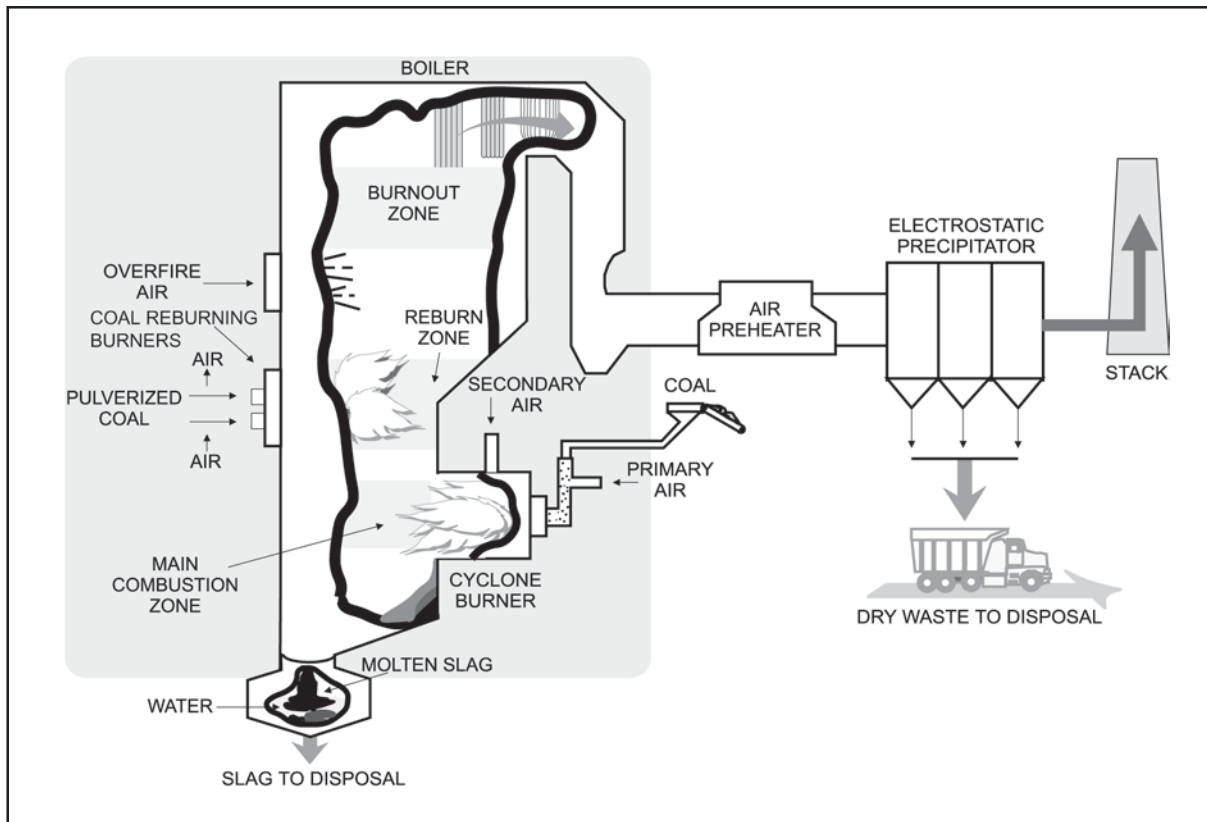
Coal

Illinois Basin bituminous (Lamar), 1.15% sulfur, 1.24% nitrogen

Powder River Basin (PRB) subbituminous, 0.27% sulfur, 0.55% nitrogen

Project Funding

Total	\$13,646,609	100%
DOE	6,340,788	46
Participant	7,305,821	54



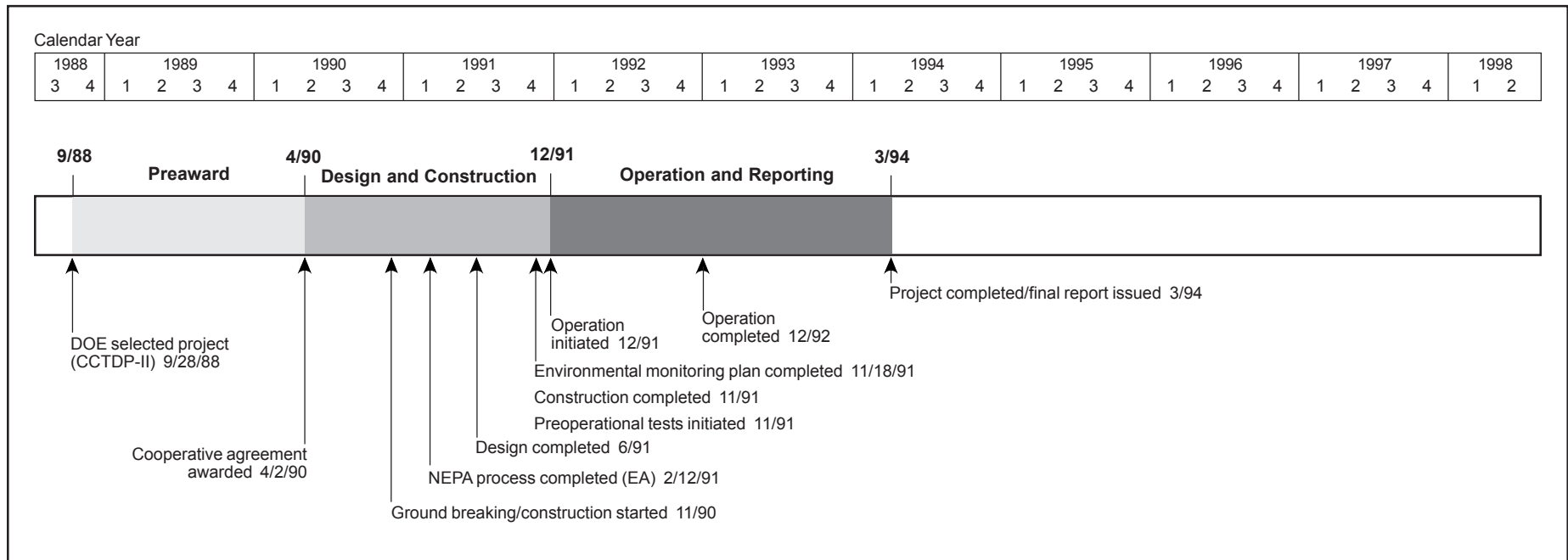
Project Objective

To demonstrate the technical and economic feasibility of Coal Reburning to achieve greater than 50% reduction in NO_x emissions with no serious impact on cyclone combustor operation, boiler performance, or other emission streams.

Technology/Project Description

Babcock & Wilcox Coal Reburning reduces NO_x in the furnace through the use of multiple combustion zones. The main combustion zone uses 70–80% of the total heat-equivalent fuel input to the boiler, and slightly less than normal combustion air input. The balance of the coal (20–30%), along with significantly less than the theoretically determined requirement of air, is fed to the reburning zone above the cyclones to create an oxygen-deficient condition. The NO_x formed in the cyclone burners reacts

with the resultant reducing flue gas and is converted into elemental nitrogen in this zone. Completion of the combustion process occurs in the third zone, called the burnout zone, where the balance of the combustion air is introduced.



Results Summary

Environmental

- Coal Reburning achieved greater than 50% NO_x reduction at full load with Lamar bituminous and PRB sub-bituminous coals.
- Reburning-zone stoichiometry had the greatest effect on NO_x control.
- Gas recirculation was vital to maintaining reburning-zone stoichiometry while providing necessary burner cooling, flame penetration, and mixing.
- Opacity levels and electrostatic precipitator (ESP) performance were not affected by Coal Reburning with either coal tested.
- Optimal Coal Reburning heat input was 29–30% at full load and 33–35% at half to moderate loads.

Operational

- No major boiler performance problems were experienced with Coal Reburning operations.
- Boiler turndown capability was 66%, exceeding the 50% goal.

- ESP efficiency improved slightly during Lamar coal testing and did not change with PRB coal.
- Coal fineness levels above the nominal 90% through 200 mesh were maintained, reducing unburned carbon losses (UBCL).
- UBCL was the only major contributor to boiler efficiency loss, which was 0.1, 0.25, and 1.5 percentage points at loads of 110, 82, and 60 MWe, respectively, when using Lamar coal. With PRB coal, the efficiency loss ranged from zero at full load to 0.3 percentage points at 60-MWe.
- Superior flame stability was realized with PRB coal, contributing to better NO_x control than with Lamar coal.
- Expanded volumetric fuel delivery with reburning burners enabled switching to PRB low-rank coal without boiler derating.

Economic

- Capital costs for 110 and 605 MWe plants were \$66/kW and \$43/kW, respectively (1990\$).

- Levelized 10- and 30-year busbar power costs for a 110-MWe plant were 2.4 and 2.3 mills/kWh, respectively (constant 1990\$).
- Levelized 10- and 30-year busbar power costs for a 605-MWe plant were 1.6 and 1.5 mills/kWh, respectively (constant 1990\$).

Project Summary

Although cyclone boilers represent only 8.5% of the pre-NSPS coal-fired generating capacity, they contribute 12% of the NO_x formed by pre-NSPS coal-fired units. This is due to the cyclone combustor's inherent turbulent, high-temperature combustion process. However, at the time of this demonstration, there was no cost-effective combustion modification available for cyclone boiler NO_x control.

Babcock & Wilcox Coal Reburning offers an economic and operationally sound response to the environmental requirements. This technology avoids cyclone combustor modification and associated performance complications, and provides an alternative to postcombustion NO_x control options, such as SCR, which have relatively high capital and/or operating costs.

The majority of the testing was performed firing Illinois Basin bituminous coal (Lamar), because it is typical of the coal used by many utilities operating cyclones. Subbituminous PRB coal tests were performed to evaluate the effect of coal switching on reburning operation. Wisconsin Power and Light's strategy to meet Wisconsin's sulfur emission limitations as of January 1, 1993, was to fire low-sulfur coal.

Environmental Performance

Three sequential tests of Coal Reburning used Lamar coal. Parametric optimization testing set up the automatic controls. Performance testing evaluated the unit in full automatic control at set load points. Long-term testing assessed performance in a load-following mode. PRB coal was used for parametric optimization and performance modes. Exhibit 3-24 shows changes in NO_x emissions and boiler efficiency using the reburning system for various load conditions and coal types.

Coal Reburning tests on both the Lamar and PRB coals indicated that variation of reburning-zone stoichiometry was the most critical factor in changing NO_x emissions levels. The reburning-zone stoichiometry can be varied by alternating the air flow quantities (oxygen availability) to the reburning burners, the percent reburning heat input, the gas recirculation flow rate, or the cyclone stoichiometry.

Hazardous air pollutant (HAP) testing was performed using Lamar test coal. HAP emissions were generally well within expected levels, and emissions with Coal Reburning were comparable to baseline operation. No major effect of reburning on trace-metals partitioning was discernible. None of the 16 targeted polynuclear aromatic semi-volatile organics (controlled under Title III of CAAA) were present in detectable concentrations, at a detection limit of 1.2 parts per billion.

Operational Performance

For Lamar coal, the full-, medium-, and low-load efficiency losses due to unburned carbon were higher than the baseline by 0.1, 0.25, and 1.5 percentage points, respectively. Full-, medium-, and low-load efficiency losses with PRB coal were 0.0, 0.2, and 0.3 percentage points, respectively. Coal Reburning burner flame stability improved with PRB coal.

During Coal Reburning operation with Lamar coal, the operators continually monitored boiler internals for increased ash deposition and the on-line perfor-



Wisconsin Power and Light Company's Nelson Dewey Station hosted the successful demonstration of Coal Reburning.

mance monitoring system for heat transfer changes. At no time throughout the system optimization or long-term operation period were any slagging or fouling problems observed. In fact, during scheduled outages, internal boiler inspections revealed that boiler cleanliness had actually improved. Extensive ultrasonic thickness measurements were taken of the furnace wall tubes. No observable decrease in wall tube thickness was measured.

Another significant finding was that Coal Reburning minimizes and possibly eliminates a 10–25% derating normally associated with switching to subbituminous coal in a cyclone unit. This derating results from using a lower Btu fuel in a cyclone combustor, which has a limited coal feed capacity. Coal Reburning transferred about 30% of the coal feed out of the cyclone to the reburning burners, bringing the cyclone feed rate down to a manageable level while maintaining full-load heat input to the unit.

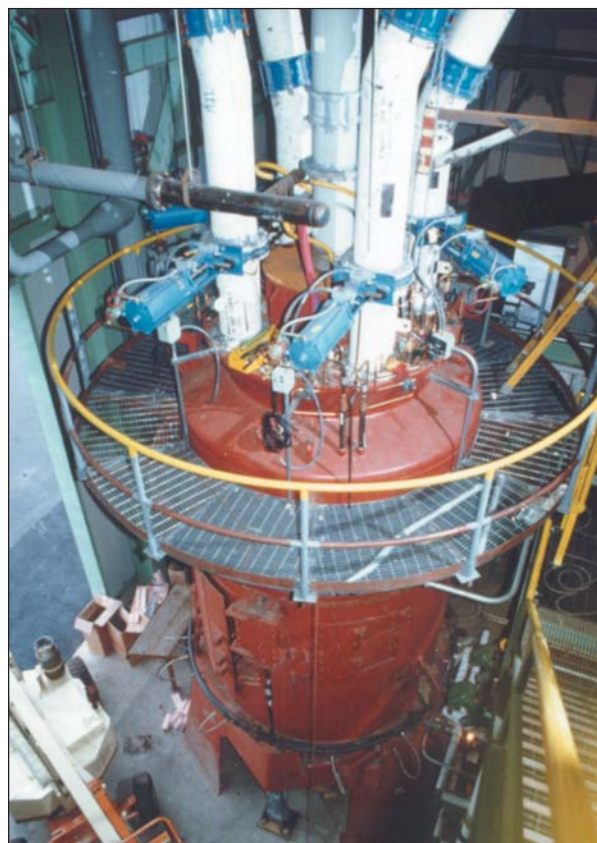
Economic Performance

An economic analysis of total capital and levelized revenue requirements was conducted using the "Electric Power Research Institute Economic Premises" for retrofit of 110- and 605-MWe plants. In addition, annualized costs per ton of NO_x removed were developed for 110- and 605-MWe plants over both 10 and 30 years. The results of these analyses are shown in Exhibit 3-25. These values assumed typical retrofit conditions and did not

Exhibit 3-24
Coal Reburning Test Results

	Boiler Load		
	110 MWe	82 MWe	60 MWe
Lamar coal			
NO _x (lb/10 ⁶ Btu/% reduction)	0.39/52	0.36/50	0.44/36
Boiler efficiency losses due to unburned carbon (%)	0.1	0.25	1.5
Powder River Basin coal			
NO _x (lb/10 ⁶ Btu/% reduction)	0.34/55	0.31/52	0.30/53
Boiler efficiency losses due to unburned carbon (%)	0.0	0.2	0.3

take into account any fuel savings from use of low-rank coal. The pulverizers and associated coal handling were taken into account. Site-specific parameters that can significantly impact these retrofit costs included the state of the existing control system, availability of flue gas recirculation, space for coal pulverizers, space for reburning burners and overfire air ports within the boiler, scope of coal-handling modification, sootblowing capacity, ESP capacity, steam temperature control capacity, and boiler circulation considerations.



The coal pulverizer is part of Babcock & Wilcox coal reburning. This system has been retained by Wisconsin Power and Light for NO_x emission control at the Nelson Dewey Station.

Commercial Applications

Coal Reburning is a retrofit technology applicable to a wide range of utility and industrial cyclone boilers. The current U.S. coal reburning market is estimated to be approximately 27,000 MWe and consists of about 89 units ranging from 100–1,150 MWe with most in the 100- to 300-MWe range.

The project technology has been retained by Wisconsin Power and Light for commercial use.

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References

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Public Design Report: Coal Reburning for Cyclone Boiler NO_x Control. The Babcock & Wilcox Company. August 1991. (Available from NTIS as DE92012554.)

Comprehensive Report to Congress on the Clean Coal Program: Demonstration of Coal Reburning for Cyclone Boiler NO_x Control. Report No. DOE/FE-0157. U.S. Department of Energy. February 1990. (Available from NTIS as DE90008111.)

Exhibit 3-25 Coal Reburning Economics (1990 Constant Dollars)

Costs	Plant Size	
	110 MWe	605 MWe
Total capital cost (\$/kW)	66	43
Levelized busbar power cost (mills/kWh)		
10-year life	2.4	1.6
30-year life	2.3	1.5
Annualized cost (\$/ton of NO _x removed)		
10-year life	1,075	408
30-year life	692	263