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Coal Reburning for Cyclone
Boiler NO_x Control Demonstration

Quarterly Report No. 11
October, November, and December, 1992

DOE Agreement No.: DE-FC22-90PC89659

B&W CRD Agreement No.: CRD-1229

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J.W. [Signature] 6/4/93 Date
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Prepared by:

Babcock & Wilcox
a McDermott Company

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1.0 EXECUTIVE SUMMARY

The Coal Reburning for Cyclone Boiler NO_x Control Demonstration project (DOE Agreement No. DE-FC22-90PC89659) progress for October, November, and December, 1992 is identified in this eleventh quarterly report and pertains to the on-going activities of Phase III - Operation and Disposition. The project involves retrofitting/testing the reburning technology at Wisconsin Power & Light's 100 MWe Nelson Dewey Unit #2 in Cassville, Wisconsin to determine the commercial applicability of this technology to reduce NO_x emission levels.

Phase III - Operation and Disposition activities emphasized completion of long-term testing. The final set of performance tests on Lamar coal were carried out from September 27 through October 9, 1992. Hazardous air pollutant (HAP) testing was performed on Lamar coal from November 2 through November 9, 1992. Also, parametric optimization testing on western sub-bituminous coal was performed from November 16 through December 11, 1992. Both the HAP and western fuel testing were additions to the original project testing scope of Phase III. As of the end of this quarterly report period, project Phase III testing is complete.

Preliminary results with western sub-bituminous coal indicate NO_x reductions in excess of 50% down to the 50% load range. In general, similar reductions are experienced but at a less aggressive stoichiometry in the reburn zone. Accordingly, an additional few percent of NO_x reduction at the same stoichiometry are noted with the western fuel compared to Lamar results.

Data evaluation continued in an effort to support preparation of the final report.

2.0 INTRODUCTION

As per the Cooperative Agreement No. DE-FC22-90PC89659 dated April 2, 1990, the following quarterly report has been prepared for the Coal Reburning for Cyclone Boiler NO_x Control Demonstration Project. The period covered by this quarterly report is October through December 1992. This report represents the eleventh three-month period of the project.

The subject of this report identifies progress during the quarter for Phase III - Operation and Disposition.

Under Phase III - Operation and Disposition, long-term performance testing was completed. Additional testing scope in the form of Hazardous Air Pollutant (HAP) testing as well as parametric optimization on a second fuel, sub-bituminous western coal, were carried out to better understand the impacts of the technology. These are discussed in this quarterly report.

3.0 PROJECT DESCRIPTION

3.1 PROJECT OVERVIEW

The current energy policy of the United States includes the expanded use of coal in utility and industrial applications. However, the increased use of coal must not conflict with environmental goals and thus requires development of cost-effective technology to control the pollutants resulting from coal combustion. Of major concern is the problem of oxides of nitrogen in the Northeastern United States and portions of Canada.

The reduction of NO_x and SO_2 emissions from fossil fired boilers has been a major objective of the DOE, the EPA, and all of the major boiler and burner manufacturers for many years. This is demonstrated by a number of concurrent efforts that have been and are being conducted to develop lower NO_x burners for pulverized coal applications. Reduction of NO_x emissions via combustion modifications presents many options for most coal-fired utility boilers, but not for the 26,000 MWe of cyclone boiler generating capacity. The operating characteristics of a cyclone boiler do not lend themselves to delayed mixing or staged combustion which are the two major low- NO_x alternatives for coal-fired boilers. The reburning process is the best known technically and economically feasible low- NO_x alternative via combustion modification for cyclone boilers. Back-end NO_x removal systems, such as Selective Catalytic Reduction (SCR) technology offers promise of NO_x control for cyclones but at high capital and operating costs.

B&W engineering studies followed by pilot-scale testing has developed/confirmed the potential of utilizing gas, oil or coal reburning as a viable NO_x reduction technology. To date, two U.S. sponsored programs promote natural gas/oil as a reburning fuel because it was believed that gas/oil will provide significantly higher combustion efficiency than using coal at the reburn zone. Although B&W has shown that gas/oil reburning will play a role in reducing NO_x emissions from cyclone boilers, B&W coal reburning research has also shown that coal as a reburning fuel performs nearly as well as gas/oil without deleterious effects on combustion efficiency. This means that boilers using reburning for NO_x control can maintain 100% coal usage instead of switching to 20% gas/oil for reburning. As a result of the B&W performed coal reburning research, the technology has advanced to the point which it is now ready for demonstration on a commercial scale.

The coal reburning equipment is to be installed in the furnace of the boiler, downstream of the cyclone burners. The equipment consists of coal reburning burners and overfire air ports and associated control systems. Outside of the boiler, a coal pulverizer will be installed as well as coal piping to the reburn burners. The reburn system will inject 20% to 30% of the coal feed

directly into the boiler, bypassing the cyclones and reducing cyclone load to 80% to 70% of normal. An increase in ash particulate, which is substantially removed in the cyclones will occur within the boiler, increasing ash collection requirements at the precipitator. The majority of plant's precipitators should be capable of handling the increased ash loading.

The coal reburning for cyclone boiler NO_x control system consists of commercially available equipment, such as a pulverizer, burners, a pneumatic coal transfer system, overfire air ports and a control system, all of which are well proven, reliable equipment that can be readily installed. Extensive power plant modification is not required to implement the reburn technology which will increase the potential for commercialization.

The coal reburning technology will be a desirable alternative for cyclone boiler NO_x control by offering:

- A technically and economically feasible low-NO_x alternative for cyclone boilers to achieve a 50% to 60% NO_x reduction where one currently does not exist.
- Significant reductions in emission-levels of oxides of nitrogen achieved at a low capital cost and very low operating costs (compared to the SCR technology).
- No need for a supplemental fuel. Reburn will be carried out using the present boiler fuel which is coal.
- A system that will maintain boiler reliability, operability, and steam production performance after retrofit.

The coal reburning for cyclone boiler NO_x control demonstration project will be carried out at the Nelson Dewey Station Unit No. 2 of Wisconsin Power and Light in Cassville, Wisconsin. Unit No. 2 is small enough (100 MWe) to limit project costs, but large enough to assure that the reburning technology can be successfully applied to the cyclone-fired utility boiler population. As part of the project, B&W's 6 million Btu/hr SBS pilot facility will be utilized to duplicate the operating practices of WP&L's Nelson Dewey Unit #2. The coal which is fired at Nelson Dewey will be fired in the SBS cyclone and will also be utilized as the reburn fuel. During the field test phase at Nelson Dewey Station, emission and performance data will be acquired and analyzed before and after the coal reburn conversion to determine the NO_x reduction and impact on boiler performance. Combining these combustion test results with physical and numerical flow modeling of the technology as applied to Dewey Unit #2, will provide a comprehensive test program not only for successful application of WP&L's Unit, but for the cyclone population as a whole.

3.2 OBJECTIVES

It is the objective of the Coal Reburning for Cyclone Boiler NO_x Control Project to fully establish that the coal reburning clean coal technology offers cost-effective alternatives to cyclone operating electric utilities for overall oxides of nitrogen control. The project will evaluate the applicability of the reburning technology for reducing NO_x emissions in full scale cyclone-fired boilers which use coal as a primary fuel. The performance goals while burning coal are:

- Greater than 50 percent reduction in NO_x emissions, as referenced to the uncontrolled (baseline) conditions at full load.
- No serious impact on cyclone combustor operation, boiler efficiency or boiler fireside performance (corrosion and deposition), or boiler ash removal system performance.

3.3 BACKGROUND

Boilers equipped with cyclone furnaces have many important advantages over conventional pulverized-coal-fired boilers, such as the capability to burn a range of low-grade fuels and simpler, more economical coal preparation and feeding system. However, cyclone units utilize extremely fast mixing between the coal and combustion air and, therefore, inherently promote well mixed combustion and elevated NO_x emissions. It is estimated that 21% of the total NO_x emissions from coal fired power stations in the U.S. come from cyclone fired boilers. The majority of the existing 26,000 MW of cyclone boiler generating capacity will probably continue to operate for the next 20 years. Thus, cyclone boilers are prime candidates for mandated reduction in the emissions of oxides of nitrogen. Currently there is no proven retrofit low NO_x combustion control technology for cyclone boilers. The previous attempts to apply staged combustion have not been successful due to operational problems (cyclone corrosion).

The use of Selected Catalytic Reduction (SCR) technology offers promise of controlling NO_x from these units, but at high capital and operating cost. Reburning is therefore a promising alternative NO_x reduction approach for cyclone equipped units at a more reasonable operating cost.

Reburning is a process by which NO_x produced in the cyclone is reduced (decomposed to molecular nitrogen) in the main furnace by injection of a secondary fuel. The secondary (or reburning) fuel creates an oxygen deficient (reducing) region which accomplishes decomposition of the NO_x. Since reburning can be applied while the cyclone operates under its normal oxidizing condition, it effects

on cyclone performance can be minimized. Sometime ago, B&W performed a feasibility analysis for applying reburn technology to utility cyclone-fired boilers, and the results were very encouraging. Based on the results of the feasibility analysis, pilot scale evaluation of cyclone reburn was undertaken. B&W's 6 million Btu/hr Small Boiler Simulator (SBS) was utilized to perform the pilot-scale cyclone reburning tests. Three different reburning fuels, natural gas, #6 oil, and pulverized coal were utilized. The results indicate that 50 to 80% NO_x reduction from baseline conditions can be achieved while utilizing 15 to 25% reburning fuel. Additionally, the tests revealed that the potential side effects of the technology (e.g., changes in combustion efficiency, deposition, and corrosion) would not adversely affect boiler performance.

3.4 HOST SITE BOILER

The host site is Wisconsin Power and Light's Nelson Dewey Unit No. 2. The following is a summary of pertinent information.

- UTILITY: Wisconsin Power & Light
- UNIT ID: Nelson Dewey Unit No. 2
- LOCATION: County Trunk VV, Cassville, Grant County, Wisconsin
53806
- NAME PLATE RATE: 100 MWe
- TYPE: Steam Turbine
- PRIMARY FUEL: Bituminous Coal
- OPERATION DATE: October 1962 - Unit No. 2
- BOILER ID: B&W RB-369
- BOILER CAPACITY: Nominal 110 MWe
- BOILER GENERAL CONDITION: Good
- BOILER MANUFACTURER: Babcock & Wilcox
- BOILER TYPE: Cyclone Fired RB Boiler
- REBURNING DEMONSTRATION FUEL: Indiana (Lamar) Bituminous
Coal, Medium Sulfur (1.87%)
- BURNERS: Three B&W Vortex-Type Burners, Single-wall fired
- PARTICULATE CONTROL: Research Cottrell ESP
- BOILER AVAILABILITY: 90% Availability

3.5 PROJECT TEAM

The Coal Reburning Project organization consists of the U.S. Department of Energy, The Babcock & Wilcox Company, Wisconsin Power & Light and the Electric Power Research Institute (EPRI). Team members from B&W represent the Research and Development Division (R&DD), the Fossil Power Division (FPD), The Energy Service Division (ESD) and the Contract Research Division (CRD).

Major subcontractors are Acurex and Sargent & Lundy. Acurex has been designated to perform continuous emissions monitoring activities as well as various analytical requirements during the testing program. Sargent & Lundy will perform those activities pertaining to the coal handling system supplying coal to the coal pulverizer in addition to various structural steel and electrical design specification activities.

A summary of the overall project organization is as follows:

Project Organization

- Department of Energy - 50% funding co-sponsor
- Babcock & Wilcox - Prime contractor and project manager
- Wisconsin Power & Light - Host site utility and funding co-sponsor
- EPRI - Technical advisor and funding co-sponsor
- State of Illinois - funding co-sponsor
- Utility funding co-sponsors
- Acurex Corporation - testing subcontractor
- Sargent & Lundy - architect engineer subcontractor

3.6 PROJECT PHASES

The coal reburn project, which is a \$10.65 million project, consists of four separate phases which are planned to occur over a 43 month period. These are:

- Phase I - Design and Permitting

During this phase, collection of baseline emissions and performance data, along with performance of general boiler system assessment, will be completed at WP&L's Nelson Dewey Unit #2 prior to the coal reburning retrofit. The coal reburn

system will be designed based upon B&W's pilot-scale combustion tests, physical and numerical flow modeling tests, and experience/knowledge of full-scale burner/OFA port/control system retrofits.

- Phase IIA - Long Lead-Time Item Procurement

In order to meet the construction schedule, long lead-time equipment will be ordered during the design and permitting phase. To facilitate the funding of this procurement activity, Phase II is divided into two parts, Phase IIA and Phase IIB.

- Phase IIB - Construction and Start-up

The coal reburn system will be fabricated and installed at Nelson Dewey No. 2 and started up to provide a fully operational system prior to testing.

- Phase III - Operation and Disposition

Parametric/optimization and performance tests will assess the potential of the technology from both the resulting emission reductions and boiler performance capability aspects. Both full load and reduced load operations will be evaluated for the cyclone reburn technology. Finally, readiness for commercialization will be determined from both a technical and economic viewpoint.

4.0 PROJECT STATUS

The time period covered by this Quarterly Report No. 11 is October, November, and December, 1992. Progress will be discussed on a task basis for Phase III activities.

4.1 PHASE I - DESIGN AND PERMITTING

All major activities in Phase I are complete.

4.2 PHASE IIA - LONG LEAD-TIME ITEM PROCUREMENT

The long lead-time item procurement process is complete.

4.3 PHASE IIB - FABRICATION, INSTALLATION, START-UP AND SHAKEDOWN

All major activities of Phase IIB are complete.

4.4 PHASE III: OPERATION AND DISPOSITION

Activities in Phase III include Management and Reporting Parametric Optimization Testing, Long-Term Performance Testing, Performance, Economic and Application Studies, the Final Report and Disposition. A description of activities expected in each task is provided followed by reported activity.

4.4.1 Task 1 - Project Management and Report

The purpose of this task is to account for the management and reporting activities and cost monitoring that apply to all tasks collectively in Phase III.

This task provides for overall project coordination, reporting, and supervision for Phase III of the Coal Reburning project. Additionally, this task includes a single point contact within B&W for DOE on the Coal Reburning project for reporting and resolution of technical and cost issues.

Monthly reports for the period of October, November, and December, 1992 were completed and issued to DOE/PETC.

The Status of the coal reburning project was presented at the International Joint Power Generation Conference in Atlanta, Georgia in October, 1992.

DOE supports environmental monitoring as an important aspect of the development and commercialization of each Clean Coal Technology Project. EPRI is also developing a more complete data base for the

emissions of hazardous air pollutants from utility boilers as part of its Power Plant Integrated Systems: Chemical Emissions Study (PISCES) project. To address these issues, B&W committed to perform hazardous air pollutant testing. Also, the opportunity to test a second fuel, sub-bituminous western coal was presented and all parties agreed on the value of the information. Accordingly, B&W submitted to DOE an Addition to Scope of Work/Funding request during the quarter to receive approval to proceed.

4.4.2 Task 2 - Parametric Optimization Tests of the Reburn System

Parametric optimization testing is complete. A summary of preliminary results was reported in Quarterly Report No. 9 for April, May, and June, 1992.

4.4.3 Task 3 - Long Term Performance Testing

During this task the boiler is being operated in a load demand following mode with reburn in operation as would be the normal practice at Nelson Dewey. The reburn system is set up based on the optimized parameters determined in Task 2 and under automatic control. The objectives of this task are to determine long-term reburn system operability and impact on boiler operation in a load varying mode.

This activity continued from May 21, 1992 through October 9, 1992 with Lamar coal as the fuel. Wisconsin Power & Light operated the system in the full automatic mode in a load following manner. The Acurex Continuous Emissions Monitoring System provided emissions data during long-term operation. Reductions in NO_x emissions continued at the 50%+ level at full load with no apparent significant adverse impacts to boiler operation.

The final performance tests were completed on October 9, 1992 to evaluate reburn operation after a significant period of load following operation. This effort consisted of a series of nine tests, three different loads in triplicate. In addition, more baseline testing was performed at conditions where cyclone operation was held constant (same input as during reburn operation and boiler load reduced by the previous reburn contribution to heat input) to clarify impact of reburn operation on unburned carbon. Preliminary results indicate that a 1.5% efficiency loss due to unburned carbon is experienced at low load (50%) operation. However, the unburned carbon problem is really due to very low load operation of two cyclones. If the same load is carried by one cyclone at nearly full load, unburned carbon drops to the level observed at full load with three cyclones operating at high load.

As an extension of long-term testing, it was planned to evaluate the performance of the reburn technology on a western sub-

bituminous coal. Sub-bituminous coal operation was investigated from November 16 through December 11, 1992. Tests were performed to vary the reburn zone stoichiometry from 1.07 for baseline, no reburning to 0.85 as the most aggressive reburn condition. Preliminary results indicate an average baseline NO_x value on the western fuel of 560 ppm. A 50% NO_x reduction was achieved for full load operation at a stoichiometry 0.91, not as deeply reducing as with Lamar coal (stoichiometry of 0.89 for 50% reduction). At a stoichiometry of 0.85, western fuel achieved a NO_x level of 208 ppm, a reduction of 62.9%. NO_x reductions in excess of 50% were achieved down to 60 MW boiler load with the western fuel.

Hazardous Air Pollutant (HAP) testing, another testing scope addition to Phase III activities was performed from November 2 through 9, 1992. The test plan explored no reburn operation and reburn operation at full load in triplicate, while burning the Lamar bituminous coal. Acurex performed the sample gathering and is currently working on sample analysis.

The following streams were sampled:

- a) Coal Feed
- b) Slag
- c) ESP Inlet
- d) ESP outlet
- e) ESP ash

Table 2.1 presents the trace elements to be analyzed in each of the streams and Table 2.2 summarizes all tests required for the streams sampled.

Nelson Dewey Unit No. 2 experienced a planned fall outage from October 9 through 25, 1992. During the outage, another series a ultrasonic thickness data was taken in the boiler furnace.

4.4.4 Task 4 - Performance, Economic, and Application Studies

As part of the economic analysis, EPRI has provided an updated version of its Technical Assessment Guide for use in evaluation of the reburn technology. Plans are to develop information on capital costs (dollars/installed KW) and levelized cost for NO_x removal (dollars/ton of NO_x removed). This is being done for the 100 MW size as well as a hypothetical 600 MW size.

4.4.5 Task 5 - Final Report

Data analysis and reduction continues as information for the report is assembled.

4.4.6 Tas 6 - Disposition

No activity is scheduled to occur as yet.

5.0 PLANNED ACTIVITIES

Planned activities for the next quarter, January, February, and March, 1993 will focus on completion of a draft of the final report. The draft will be provided to DOE/PETC for review and comment. In addition, the Phase III review will be held next quarter.

6.0 SUMMARY

The coal reburning for cyclone boiler NO_x control demonstration project's eleventh Quarterly Report covering the time period of October, November, and December, 1992 involves the work performed in Phase III -Operation and Disposition.

Phase III activities consisted of completion of long-term testing on Lamar coal with WP&L operating the reburn system on automatic control in a load following manner. A second set of performance tests were carried out to determine if any performance impacts as a result of long-term operation have occurred. Preliminary results indicate no significant problems as a result of reburn operation.

As additions to the testing scope of Phase III, both hazardous air pollutant (HAP) testing and reburn testing using a western sub-bituminous coal were performed during the quarter. Acurex collected samples of the streams into and out of the boiler at full load reburn and no reburn conditions on Lamar bituminous coal in triplicate. Analysis of the samples is under way.

Reburn performance on sub-bituminous coal was better than that observed on Lamar bituminous coal. A NO_x reduction of 50% was achieved at a reburn zone stoichiometry of 0.91 with sub-bituminous coal, a less aggressive reducing atmosphere than experienced with Lamar (0.89 for 50% NO_x reductions). Also, reductions in excess of 50% were noted at loads down to 60 MW with western fuel due to the ability to maintain a stable flame at low stoichiometry at low loads.

Evaluation of data continued in an effort to develop the final report for the project.

7.0 REPORT DISTRIBUTION LIST

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Table 2.1

Trace Elements

Arsenic	Lead
Beryllium	Nickel
Cadmium	Manganese
Mercury	Selenium

Acid Gases

Chloride/HCl
Fluoride/HF

Organics

Formaldehyde
Benzene
Toluene
Polycyclic Organics (especially benzol(a) pyrene)

TABLE 2.2

TESTING TO BE PERFORMED AT EACH STREAM					
Test Analysis Required	(a) Coal Feed	(b) Slag	(c) ESP Inlet	(d) ESP Outlet	(e) ESP Ash
HHV	✓				
Proximate	✓				
Ultimate	✓				
UBC					
Trace Elements ¹ Total	✓	✓	✓	✓	✓
Particulate Loading			✓	✓	
Volatile Organics ²				✓	
Semi-Vol. Organics ³				✓	
Formaldehyde				✓	
Acid Gases				✓	
✓ - Required					
¹ See Table 2.1 ² Benzene/Toluene ³ Polycyclic organics especially benzo(a)pyrene					

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