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**COAL-WATER SLURRY FUEL COMBUSTION
TESTING IN AN OIL-FIRED INDUSTRIAL BOILER**

Semiannual Technical Progress Report
for the Period 02/15/1996 to 08/15/1996

By

**Bruce G. Miller, Co-Principal Investigator
Alan W. Scaroni, Project Manager**

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June 3, 1997

Work Performed Under Cooperative Agreement No. DE-FC22-89PC88697

For
U.S. Department of Energy
Federal Energy Technology Center
P.O. Box 10940
Pittsburgh, Pennsylvania 15236

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Coal Utilization Center
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EXECUTIVE SUMMARY

The Pennsylvania State University is conducting a coal-water slurry fuel (CWSF) program with the United States Department of Energy (DOE) and the Commonwealth of Pennsylvania to determine the viability of firing CWSF in an industrial boiler designed for heavy fuel oil. Penn State and DOE have entered into a cooperative agreement to determine if CWSFs prepared from cleaned coal (containing approximately 3.5 wt.% ash and 0.9 wt.% sulfur) can be burned effectively in a heavy fuel oil-designed industrial boiler without adverse impact on boiler rating, maintainability, reliability, and availability. Information will also be generated to help in the design of new systems specifically configured to fire these clean coal-based fuels.

The project consists of four phases: (1) design, permitting, and test planning, (2) construction and start up, (3) demonstration and evaluation (1,000-hour demonstration), and (4) expanded demonstration and evaluation (installing a CWSF preparation circuit, performing baseline tests firing No. 6 fuel oil, and conducting additional CWSF testing). The boiler testing and evaluation will determine if the CWSF combustion characteristics, heat release rate, fouling and slagging behavior, corrosion and erosion tendencies, and fuel transport, storage, and handling characteristics can be accommodated in a boiler system designed to fire heavy fuel oil. In addition, the proof-of-concept demonstration will generate data to determine how the properties of a CWSF and its parent coal affect boiler performance. The economic factors associated with retrofitting boilers will also be evaluated.

The first three phases (i.e., the first 1,000-hour demonstration) have been completed and the combustion performance of the burner that was provided with the boiler did not meet performance goals. A maximum coal combustion efficiency of 95% (compared to a target of 98%) was achieved and natural gas cofiring (15% of the total thermal input) was necessary to maintain a stable flame. Consequently, the first demonstration was terminated after 500 hours. The second CWSF demonstration (Phase IV) was conducted with a proven coal-designed burner.

Prior to starting the second demonstration, a CWSF preparation circuit was constructed to provide flexibility in CWSF production. The circuit initially installed involved single-stage grinding. A regrind circuit was recently installed and was evaluated.

A burner was installed from ABB Combustion Engineering (ABB/CE) and was used to generate baseline data firing No. 6 fuel oil and fire CWSF. A temporary storage system for No. 6 fuel oil was installed and modifications to the existing CWSF handling and preheating system were made to accommodate No. 6 oil.

1.0 INTRODUCTION

The Pennsylvania State University is conducting a coal-water slurry fuel (CWSF) program with the United States Department of Energy (DOE) and the Commonwealth of Pennsylvania with the objective of determining the viability of firing CWSF in an industrial boiler designed for heavy fuel oil. Penn State and DOE have entered into a cooperative agreement to determine if CWSFs prepared from cleaned coal (containing approximately 3.5 wt.% ash and 0.9 wt.% sulfur) can be burned effectively in a heavy fuel oil-designed industrial boiler without adverse impact on boiler rating, maintainability, reliability, and availability. The project will also provide information to help in the design of new systems specifically configured to fire these clean coal-based fuels.

The project consists of four phases: (1) design, permitting, and test planning, (2) construction and start up, (3) demonstration and evaluation (1,000-hour demonstration), and (4) expanded demonstration and evaluation. The boiler testing and evaluation will determine if the CWSF combustion characteristics, heat release rate, fouling and slagging behavior, corrosion and erosion tendencies, and fuel transport, storage, and handling characteristics can be accommodated in a boiler system designed to fire heavy fuel oil. In addition, the proof-of-concept demonstration will generate data to determine how the properties of a CWSF and its parent coal affect boiler performance. The economic factors associated with retrofitting boilers will also be evaluated.

The project consists of four phases as previously mentioned. Following is an outline of the project tasks that comprise the four phases:

Phase I: Design, Permitting, and Test Planning

Task 1. Design

Task 2. Permitting

Task 3. Test Planning

Phase II: Construction and Start Up

Task 1. Host Site Readiness/Boiler Retrofit

Task 2. CWSF Preparation

Task 3. Boiler Performance Prediction

Task 4. Shakedown Testing

Phase III: Demonstration and Evaluation

Task 1. Test Burn

Subtask 1.a. CWSF combustion performance

Subtask 1.b. Slagging/fouling propensity; corrosion characteristics

Subtask 1.c. Erosion characteristics

Subtask 1.d. Fuel transport, storage, and handling characteristics

Task 2. Evaluation of Retrofit Economics

Task 3. Project Report

Phase IV: Advanced System Tests

- Task 1. Install Burner
- Task 2. Construct CWSF Preparation Facility
- Task 3. Generate Baseline Data Firing No. 6 Fuel Oil
- Task 4. CWSF Testing
- Task 5. Final Report

Penn State began a coal-water slurry fuel (CWSF) research and development program in 1984 with the ultimate goal of facilitating the replacement of petroleum-based fuels with coal-based fuels in fuel oil-fired (designed) boilers. The Pennsylvania legislature appropriated funds in 1984 for the construction of a demonstration CWSF boiler with a capacity of approximately 15,000 lb steam/h at 300 psig on the University Park campus of Penn State. The project goal was to conduct a demonstration of the use of CWSF derived from Pennsylvania coal. The boiler performance was required to be environmentally acceptable and the testing was to evaluate the effect on boiler performance of long-term firing with CWSF. From a commercialization viewpoint, it was considered necessary to demonstrate at the industrial scale the technical feasibility of retrofitting existing fuel oil-fired units to burn CWSF, particularly in the commercial and light-industrial sectors. State funding was also provided for the installation of a 1,000 lb steam/h (nominally rated) Cleaver-Brooks A-frame watertube research boiler (Kinneman et al., 1988) to investigate: the effect of boiler operating parameters on combustion performance (Miller et al., 1988); automation of the firing of CWSF, particularly with respect to start up and shutdown procedures but also for optimizing boiler performance (Wincek et al., 1989); testing candidate CWSFs (Miller et al., 1991); and providing the necessary research support and operator training prior to start up of the demonstration unit. The CWSF demonstration program is being conducted on the 15,000 lb steam/h demonstration boiler.

The approach used in the program was as follows:

1. Install a natural gas/fuel oil-designed package boiler and generate baseline data firing natural gas.
2. Shake down the system with CWSF and begin the first 1,000 hours of testing using the burner/atomizer system provided with the boiler. The first 1,000-hour demonstration was to consist of boiler optimization testing and combustion performance evaluation using CWSF preheat, a range of atomizing air pressures (up to 200 psig as compared to the 100 psig boiler manufacturer design pressure), and using steam as the atomizing medium.
3. If the combustion performance was not acceptable based on the combustion efficiency obtained and the level of gas cofire necessary to obtain flame stabilization, then low-

Figure 1. PHASE IV MILESTONE SCHEDULE

JLE (Second Demonstration)

cost modifications were to be implemented, such as installing a quarl and testing alternative atomizers.

4. If acceptable combustion performance was not obtained with the low-cost modifications, then the first demonstration was to be terminated and the burner system replaced with one designed specifically for CWSF.
5. Perform testing firing CWSF and No. 6 fuel oil with the newly installed, multifuel burner.

The first three steps (i.e., the first demonstration) have been completed and the combustion performance of the burner that was provided with the boiler did not meet the targeted performance goals. Consequently, the first demonstration (Phases I-III) was terminated at 500 hours and the results have been presented elsewhere (Miller et al., 1994). Phase IV work, which included modifications to the CWSF Preparation Facility, baseline testing firing No. 6 oil, and evaluating a second burner when firing CWSF, were completed.

The status of Phases I through III and a summary of Phase IV are presented in Sections 2.0 through 5.0, respectively. Activities planned for the next semiannual period are given in Section 6.0. References are contained in Section 7.0 and acknowledgments are given in Section 8.0.

2.0 PHASE I: DESIGN, PERMITTING, AND TEST PLANNING

Phase I was completed on February 15, 1993 and the results have been presented previously (Miller et al., 1994).

3.0 PHASE II: CONSTRUCTION AND START UP

Phase II was completed on October 10, 1992 and the results have been presented previously (Miller et al., 1994).

4.0 PHASE III: DEMONSTRATION AND EVALUATION

Phase III work was completed on June 21, 1993 and the results have been presented previously (Miller et al., 1994). Drafts of a project report covering the first three phases were submitted to DOE on June 21, 1993 and August 15, 1994.

5.0 PHASE IV: ADVANCED SYSTEM TESTS

During this reporting period, the Phase IV testing was completed. Data reduction and interpretation are currently being conducted and the final report is being prepared. The milestone schedule for Phase IV is shown in Figure 1, and Table 1 contains the milestone description for the entire project.

5.1 Task 1. Installation of a Burner

Penn State recently completed a program in which it was the host site for testing a dry, micronized coal (DMC) burner for ABB Combustion Engineering (ABB/CE; DOE Contract No. DE-AC22-91PC91660). The results were encouraging and so the burner platform was selected for

use in the CWSF testing. ABB/CE provided the burner, atomizers, and engineering support for the No. 6 fuel oil and CWSF testing.

5.2 Task 2. Construction of CWSF Preparation Facility

The installation of a regrind circuit into the CWSF Preparation Facility was completed during the last reporting period (Miller and Scaroni, 1996). The CWSF Preparation Facility was used to prepare four CWSFs for testing. Two different coal particle size distributions were obtained by processing two coals (Coalberg seam from Kentucky and Middle Kittanning from Pennsylvania) in the single and double-stage grinding circuits. The CWSF production results are being compiled and will be contained in the final report. The draft final report will be completed in October 1996.

5.3 Task 3. Generate Baseline Data Firing No. 6 Fuel Oil

The boiler being used in this program is an oil-designed boiler which is capable of firing natural gas and has been retrofitted to fire coal-based fuels. Baseline data firing natural gas were obtained during Phase II of the program. However, baseline data firing heavy fuel oil were not obtained. Since CWSF is a more likely replacement for heavy fuel oil, rather than natural gas, the boiler system was modified to accommodate heavy fuel oil. This involved installing fuel oil storage, handling, and atomizing equipment. Fuel oil testing was conducted in March and April 1996. The data are currently being reduced and the results will be contained in the final report.

The fuel oil was stored in an asphalt tanker that had steam heat capabilities. The tanker, with a capacity of 6,500 gallons, was delivered and integrated into the CWSF piping system. Steam (maximum of 75 psig) was piped to the tanker in order to preheat the fuel oil. The fuel oil passed from the tanker to the burner pump through a 15' long, 3" diameter hose by gravity flow. From the burner pump, the oil was pumped through existing piping through the CWSF (oil) preheater to the burner. The piping was modified at the burner front to circulate the oil back to the tanker through a 3/4" hose when it was not being introduced into the burner. Additional modifications included installing steam and compressed air purging capabilities to the 3 and 3/4" hoses, oil gun, burner pump, and piping from the pump to the burner.

5.4 Task 4. CWSF Testing

Two coals, one from Pennsylvania (Middle Kittanning seam) and one from Kentucky (Coalberg seam), were tested. The effect of coal particle size, atomizer type, and operating conditions on combustion and boiler performance and emissions was investigated. The data are currently being reduced and the results will be contained in the final report.

5.5 Task 5. Final Report

Work on the final report started during this reporting period.

6.0 NEXT SEMIANNUAL PERIOD ACTIVITIES

The draft final report will be completed during the next reporting period.

7.0 REFERENCES

Kinneman, W.P., R.T. Wincek, B.G. Miller, A.W. Scaroni, and R.G. Jenkins, "Conversion of a 1000 lb/h Steam Boiler to Fire Coal Water Slurry Fuel," *Thirteenth Int. Conf. on Coal and Slurry Tech.*, Denver, Colorado, p.725 (April 12-15, 1988).

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- Bradley Maben - Research Technician
- Joel Morrison - Senior Research Assistant
- Ronald Wasco - Research Assistant
- Robert Wells - Research Assistant
- Ronald Wincek - Research Assistant

Table 1. Milestone Description

<u>Milestone</u>	<u>Description</u>	<u>Planned Completion Date</u>	<u>Actual Completion Date</u>
Phase I			
Task 1, No. 1	Identify equipment and diagnostic instrumentation	09/15/89	09/15/89
Task 2, No. 1	Review present permit	09/15/89	09/15/89
Task 3, No. 1	Develop CWSF specifications, identify operating procedures, prepare detailed test plan	10/15/89	02/15/93
Phase II			
Task 1, No. 1	Building/boiler construction and installation let for bids	10/18/89	10/18/89
Task 1, No. 2	Building/boiler construction and installation awarded	12/31/89	03/23/90
Task 1, No. 3	Prepare site, install boiler and auxiliary equipment	04/01/91	01/31/92
Task 2, No. 1	Identify coal for CWSF preparation	09/30/90	09/30/90
Task 2, No. 2	Prepare CWSF for demonstration	04/01/91	10/13/92
Task 3, No. 1	Predict boiler performance	06/15/91	02/01/92
Task 4, No. 1	Shakedown boiler and auxiliary equipment	04/31/91	06/30/92
Task 4, No. 2	Generate baseline data on gas	05/31/91	09/30/91
Phase III			
Task 1, No. 1	Perform demonstration		
Subtask 1a, No. 1	300-hour demonstration milestone	07/31/92	07/31/92
Subtask 1a, No. 2	500-hour demonstration milestone	10/31/92	11/13/92
Subtask 1a, No. 3	Redefine CWSF specifications	01/15/93	01/15/93
Subtask 1b, No. 1	Develop deposition and corrosion test plan	10/15/89	10/15/89
Subtask 1b, No. 2	Design suction pyrometer	06/01/90	08/01/90
Subtask 1b, No. 3	Construct suction pyrometer	10/01/90	10/01/90
Subtask 1b, No. 4	Deposition characterization equipment design and specification	01/01/91	02/15/91
Subtask 1b, No. 5	Acquisition of baseline data for spectroscopic analysis of deposits; acquisition of baseline data for corrosion of tubes by ash components	08/31/91	08/15/92
Subtask 1b, No. 6	Coupon testing in boiler	10/31/92	11/13/92
Subtask 1b, No. 7	Complete deposition and corrosion testing	01/15/93	01/15/93
Subtask 1c, No. 1	Develop erosion test plan	10/15/89	10/15/89
Subtask 1c, No. 2	Complete research boiler erosion evaluation	08/01/90	08/01/90
Subtask 1c, No. 3	Full-scale erosion technique decision	10/01/90	10/01/90
Subtask 1c, No. 4	Design probe for full-scale erosion study	01/01/91	02/15/91
Subtask 1c, No. 5	Construct erosion probe	05/01/91	10/15/91
Subtask 1c, No. 6	Complete erosion modeling	01/15/93	06/15/93
Subtask 1d, No. 1	Identify viscometer	10/15/89	10/15/89
Subtask 1d, No. 2	Complete preliminary viscosity and stability tests	08/15/90	09/15/90
Subtask 1d, No. 3	Complete viscosity and stability tests	11/30/92	11/30/92
Task 2, No. 1	Complete economic evaluation	01/15/93	01/15/93
Task 3, No. 1	Complete project report	03/01/93	06/21/93
Phase IV			
Task 1, No. 1	Install Burner	02/21/96	02/21/96
Task 2, No. 1	Complete construction of Fuel Preparation Facility	08/31/93	08/31/93
Task 2, No. 2	Install and shake down CWSF preparation circuit with single-stage grinding circuit	01/31/95	01/31/95
Task 2, No. 3	Install regrind circuit	03/08/96	03/08/96
Task 3, No. 1	Obtain baseline data firing No. 6 fuel oil	04/05/96	04/12/96
Task 4, No. 1	Complete testing of CWSF produced using regrind circuit	06/15/96	07/31/96
Task 5, No. 1	Complete final report	12/31/96	