

**Development & Testing of Industrial Scale, Coal Fired  
Combustion System, Phase 3**

**Quarterly Report  
January 1 - March 31, 1998**

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## ABSTRACT

In the first quarter of calendar year 1998, 4 days of tests on the 20 MMBtu/hr combustor-boiler facility were performed as part of a parallel project on sulfur capture in slag. No work was performed on the present project in this quarter. The total test days on the Philadelphia facility to the end of March 1998 was 108, of which 34 tests were part of the other DOE project. This exceeds the planned 63 test days for this project. All key project objectives have been exceeded including combustor durability, automated combustor operation, NO<sub>x</sub> emissions as low as 0.07 lb/MMBtu and SO<sub>2</sub> emissions as low as 0.2 lb/MMBtu. In addition, a novel post-combustion NO<sub>x</sub> control process has been tested on a 37 MW and 100 MW utility boiler. Any further tests will depend on the results of evaluations of current and prior tests. The only effort remaining on this project is facility disassembly and Final Report.

Almost all of the effort in the present quarter focussed on applying the results of this project and the parallel sulfur capture in slag project on new applications of this technology. Several very promising areas were identified and a number of proposals to implement them were prepared.

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## **1. EXECUTIVE SUMMARY**

In the first quarter of calendar year 1998, 4 days of tests on the 20 MMBtu/hr combustor-boiler facility were performed as part of a parallel project on sulfur capture in slag. No work was performed on the present project in this quarter. The total test days on the Philadelphia facility to the end of March 1998 was 108, of which 34 tests were part of the other DOE project. This exceeds the planned 63 test days for this project. All key project objectives have been met or exceeded, including combustor durability, automated combustor operation, NO<sub>x</sub> emissions as low as 0.07 lb/MMBtu and SO<sub>2</sub> emissions as low as 0.2 lb/MMBtu. In addition, a novel post-combustion NO<sub>x</sub> control process has been tested on a 37 MW and 100 MW utility boiler. Any further tests will depend on the results of evaluations of current and prior tests. The only effort remaining on this project is facility disassembly and Final Report.

## **2. RESULTS AND DISCUSSION**

### **2.1. PROJECT DESCRIPTION**

#### 2.1.1. Objectives

The primary objective of the present Phase 3 effort is to perform the final testing, at a 20 MMBtu/hr commercial scale, of an air cooled, slagging coal combustor for application to industrial steam boilers and power plants. The focus of the test effort is on combustor durability, automatic control of the combustor's operation, and optimum environmental control of emissions inside the combustor. In connection with the latter, the goal is to achieve 0.4 lb/ MMBtu of SO<sub>2</sub> emissions, 0.2 lb./MMBtu of NO<sub>x</sub> emissions, and 0.02 lb. particulates/MMBtu. To meet the particulate goal a baghouse is used to augment the slag retention in the combustor. The NO<sub>x</sub> emission goal requires a modest improvement over maximum reduction achieved to date in the first generation combustor to a level of 0.26 lb./MMBtu. In the present second generation combustor, the best NO<sub>x</sub> levels with fuel rich conditions in the combustor was in the range of 0.3 to 0.4 lb/MMBtu. To reach the SO<sub>2</sub> emissions goal requires a combination of sorbent injection inside the combustor and sorbent injection inside the boiler, or stack.

The original plan was to meet the project objectives by a series of increasingly longer duration tests totaling up to 800 hours, with over 500 hours in the task 5 "Site Demonstration" effort. In the implementation of the first three project tasks, it was determined that this objective could met by daily cycling of the combustor in these three tasks, and by focusing the test effort on fuel flexibility and optimized combustion and environmental performance. Cycling without combustor refurbishment between cycles provides a more stringent test of combustor durability. In task 5, the steam output is also blown off. However, the option has been added to use the steam for process heat or steam turbine power generation if a means for generating revenue from this energy is developed during task 5. This last option was to be implemented after the completion of the required testing under the present project. At present this option does not appear to be likely.

The final objective was to define suitable commercial power or steam-generating systems to which the use of the air cooled combustor offers significant technical and economic benefits. In implementing this objective both simple steam generation and combined gas turbine-steam generation systems were considered.

#### 2.1.2. Technical Approach

##### 2.1.2.1. Overview

The work of this Phase 3 project is being implemented on Coal Tech's patented, 20 MMBtu/hr, air cooled cyclone coal combustor that is installed on an oil designed, package boiler. The task 2 and task 3 testing were performed at a manufacturing plant in Williamsport, PA, where this combustor was installed in 1987. The task 5 tests are being implemented at a site in Philadelphia, PA that was selected after the completion of the task 3 tests. The combustor has undergone development and demonstration testing since 1987. The primary fuel has been coal.

Other tests, including combustion of refuse derived fuels and vitrification of fly ash, have been successfully performed.

The combustor's novel features are air cooling and internal control of SO<sub>2</sub>, NO<sub>x</sub>, and particulates. Air cooling, which regenerates the heat losses in the combustor, results in a higher efficiency and more compact combustor than similar water-cooled combustors. Internal control of pollutants is accomplished by creating a high swirl in the combustor which traps most of the mineral matter injected in the combustor and converts it to a liquid slag that is removed from the floor of the combustor. SO<sub>2</sub> is controlled by injecting calcium oxide based sorbents into the combustor to react with sulfur emitted during combustion. The spent sorbent is dissolved in the slag and removed with it, thereby encapsulating the sulfur in slag. Part of the sorbent exits the combustor with the combustion products into the boiler where it can react with the sulfur. The spent sorbent either deposits in the boiler or it is removed in the stack particle scrubber. NO<sub>x</sub> is controlled by staged, fuel rich combustion inside the combustor. Additional reductions are achievable by reburning in the boiler or by non-catalytic sorbent injection in the post-combustion gas zone. The latter procedure has been successfully implemented in 1997.

Excellent progress had been made prior to the start of the present project in meeting several of these combustor performance objectives. One of the most important objectives of this technology development effort was to demonstrate very high SO<sub>2</sub> reduction in the combustor. Prior to the start of the present Phase 3 project, the peak SO<sub>2</sub> reduction achieved with sorbent injection in the combustor had been 56%, (+/-) 5%. Of this amount a maximum of 11% of the total coal sulfur was trapped in the slag. On the other hand, up to 81% SO<sub>2</sub> reduction has been measured with sorbent injection in the boiler immediately downstream of the combustor. Tests in the past several years have revealed the critical role played by optimum operating conditions in the SO<sub>2</sub> reduction process. Specifically, combustor operation must be automatically controlled, and solids feed and air-solids mixing in the combustor must be optimized. Progress in both areas has been accomplished in the past 5 years by using a microcomputer to control the combustion process and by testing various methods of feeding and mixing the coal and sorbents. In the summer of 1992, tests performed in a prior project indicated that in excess of 90% SO<sub>2</sub> reduction could be achieved by sorbent injection in the combustor. Recently, similar SO<sub>2</sub> reductions have been obtained with low (<2% S) sulfur coal, as measured at the outlet of the stack gas baghouse. However, this result has as yet not been achieved with higher sulfur coals.

Combustor durability is an essential requirement for commercial utility of the combustor. Due to the aggressive nature of the combustion process and the need to utilize refractory materials inside the combustor to withstand the 3000F gas temperatures, durability has been one of the key challenges in the development process. Here also the use of computer control has been the means whereby this problem is being solved. Since introduction of computer control seven years ago, the need for frequent refractory liner patching inside the combustor has been sharply reduced. The durability issue can be addressed by accumulating running time in daily cyclic operation without combustor refurbishment between runs. This approach has been used in the latter task 2 and task 3 effort. All tests between May 1 and December 2, 1993, consisting of 26 hours of operation in task 2 and 185 hours in task 3, have been performed without significant internal combustor refurbish-



ment. In the task 5 effort, 93 days of test operations have been implemented with only limited refractory wall patching.

The final project objective of designing the combustor into a viable industrial steam or power generating system was accomplished by detailed engineering analysis on the use of the combustor in one or more steam generating cycles. This effort included an assessment of the requirements for commercializing the combustor for several industrial applications. To assure commercialization of this technology, the final project task is being implemented in a system that duplicates a commercial prototype power plant utilizing the air-cooled coal combustor technology.

#### 2.1.2.2. Task Description

##### Task 1: Design, Fabricate, and Integrate Components

This task consisted of component design, component fabrications, and component integration, and shakedown tests. The 20 MMBtu/hr combustor was modified to allow safe and environmentally compliant operation for periods of up to 100 hours. This task is complete.

##### Task 2: Preliminary Systems Tests

The modified combustor system underwent a series of one day parametric tests of total duration of up to 100 hours to validate the design changes introduced in task 1, and to accomplish the project objectives and goals. This task is complete.

##### Task 3. Proof of Concept Tests

The durability of the combustor was studied in a series of tests of between 50 and 100 hours of accumulated operation with no combustor refurbishment between tests. The total test period was planned to be up to 200 hours. This task is complete.

##### Task 4. Economic Evaluation & Commercialization Plan

The economics of one or at most two different industrial scale steam based cycles using the combustor was evaluated. A commercialization plan was developed for marketing the combustor in an industrial environment both in the US and overseas. This originally scheduled work on this task is complete. However, efforts are continuing to commercialize the technology.

##### Task 5. Conduct Site Demonstration

This task is the final test activity in the project. Its objective is to demonstrate the durability and hence the commercial readiness of the combustor for its intended industrial application(s). The effort consists of two sub-tasks. In the first one any changes required as a result of prior tests were made to the combustor. In the second one, a series of tests were to be performed with a total test time of 500 hours. For a number of reasons, this effort was implemented in single daily shift operation with minimal combustor refurbishment between tests.

The 500 hours are thus equal to 63 days of single shift operation. As of the end of the present reporting period, 93 test days have been completed.

#### Task 6. Decommissioning Test Facility

The test facility will be removed from the boiler installation and disposed in accordance with required regulations. Due to continuing opportunities for this technology, Coal Tech is seeking resources to allow the facility to remain in place after the end of this project.

## **2.2. PROJECT STATUS.**

### **2.2.1. Task 5. Site Demonstration**

In the first quarter of calendar year 1998, 4 days of tests on the 20 MMBtu/hr combustor-boiler facility were performed as part of a parallel project on sulfur capture in slag. No work was performed on the present project in this quarter. The total test days on the Philadelphia facility to the end of March 1998 was 108, of which 34 tests were part of the other DOE project. This exceeds the planned 63 test days for this project. All key project objectives have been met or exceeded, including combustor durability, automated combustor operation, NO<sub>x</sub> emissions as low as 0.07 lb/MMBtu and SO<sub>2</sub> emissions as low as 0.2 lb/MMBtu. In addition, a novel post-combustion NO<sub>x</sub> control process has been tested on a 37 MW and 100 MW utility boiler. Any further tests will depend on the results of evaluations of current and prior tests. The only effort remaining on this project is facility disassembly and Final Report.

## **3. CONCLUSIONS**

All the objectives of task 5 of the present project have been met or exceeded, including long duration of testing, 108 days versus 63 days; SO<sub>2</sub> and NO<sub>x</sub> performance, 0.2 lb/MMBtu and 0.07 lb/MMBtu, respectively; and low cost combustor system designs. With the exception of some additional tests that may be implemented as data evaluation proceeds, the only remaining tasks are disassembly of the facility and the Final Report. This latter effort will begin in the next quarter.