

Project: " DEVELOPMENT & TESTING OF INDUSTRIAL SCALE ,
COAL FIRED COMBUSTION SYSTEM,PHASE 3"

Contract: DE-AC22-91PC91162

Contract Period of Performance: 9/30/91 to 12/31/99

Twenty Seventh & Twenty Eighth Technical Progress Report

Period Covered by Report: July 1,1998 to December 31,1998

Contractor: Coal Tech Corp.
P.O.Box 154, Merion Station, PA 19066

Principal Investigator: Dr.Bert Zauderer, Phone No.(610) 667-0442

Date Submitted: March 11,1999

Prepared for

FETC Project Manager: Arun Bose

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

ABSTRACT

In the second half of calendar year 1998, no work was performed on the present project. The 20 MMBtu/hr combustor-boiler facility was operated for 11 tests, primarily with Coal Tech resources on biomass combustion and gasification. The total test days on the Philadelphia facility to the end of August 1998 was 119. Of these, 36 tests were part of another DOE project on sulfur retention in slag, and 8 were on an in-house biomass combustion effort. The test days on the other project are listed here because they demonstrate the durability of the combustor, which is one of the objectives of the present project. Also, the test work of 1998 revealed for the first time the major potential of this combustor for biomass combustion. These tests are double the 63 tests in the original plan for this project. All key project objectives have been exceeded including combustor durability, automated combustor operation, NO_x emissions as low as 0.07 lb/MMBtu and SO₂ emissions as low as 0.2 lb/MMBtu. In addition, a novel post-combustion NO_x control process has been tested on a 37 MW and 100 MW utility boiler. The only effort remaining on this project is facility disassembly and Final Report. However, as part of the commercialization effort for this combustor technology, Coal Tech is planning to maintain the combustor facility in an operational mode at least through 2001. Coal Tech is focussing on utilizing the combustor with biomass fuels in very low cost, small (1 MW nominal) steam power plants. Worldwide application of this technology would have a major impact in reduction of greenhouse gas emissions because the energy content of agricultural biomass is equal to the energy content of the USA's annual coal production.

"This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof."

TABLE OF CONTENTS

	PAGE
ABSTRACT	ii
1. EXECUTIVE SUMMARY	1
2. RESULTS AND DISCUSSION	2
2.1. PROJECT DESCRIPTION	2
2.1.1. Objectives	2
2.1.2. Technical Approach	2
2.1.2.1. Overview of the Work	2
2.1.2.2. Task Description	4
2.2. PROJECT STATUS	6
2.2.1. Task 5: Site Demonstration	6
3. CONCLUSIONS	6

1. EXECUTIVE SUMMARY

In the second half of calendar year 1998, no work was performed on this project. However, and additional 11 tests were performed on the 20 MMBtu/hr combustor-boiler facility under another project and under internal support. The total test days on the Philadelphia facility was 119, of which 45 tests were part of another DOE project and a small in-house effort. This is double the planned 63 test days for this project. All key project objectives have been met or exceeded, including combustor durability, automated combustor operation, NO_x emissions as low as 0.07 lb/MMBtu and SO₂ emissions as low as 0.2 lb/MMBtu. In addition, a novel post-combustion NO_x control process has been tested on a 37 MW and 100 MW utility boiler. The only effort remaining on this project is facility disassembly and Final Report.

However, as part of the commercialization effort for this combustor technology, Coal Tech is planning to maintain the combustor facility in an operational mode at least through 2001. Coal Tech is focussing on utilizing the combustor with biomass fuels in very low cost, small (1 MW nominal) steam power plants. Worldwide application of this technology would have a major impact in reduction of greenhouse gas emissions because the energy content of agricultural biomass is equal to the energy content of the USA's annual coal production.

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 SO₂ emissions, 0.2 lb./MMBtu of NO_x 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_x 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_x levels with fuel rich conditions in the combustor was in the range of 0.3 to 0.4 lb/MMBtu. To reach the SO₂ 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 SO₂, NO_x, 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. SO₂ 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_x 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 SO₂ reduction in the combustor. Prior to the start of the present Phase 3 project, the peak SO₂ 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% SO₂ 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 SO₂ 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% SO₂ reduction could be achieved by sorbent injection in the combustor. Recently, similar SO₂ 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 second half of calendar year 1998, no work was performed on this project. The total test days on the Philadelphia facility to the end of August 1998 was 119, of which 45 tests were part of two other projects. The extensive test series in which the combustor was operated without any significant refurbishment demonstrates the durability of the present design.

All key project objectives have been met or exceeded, including combustor durability, automated combustor operation, NO_x emissions as low as 0.07 lb/MMBtu and SO₂ emissions as low as 0.2 lb/MMBtu. In addition, a novel post-combustion NO_x 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.

Also, as part of the commercialization effort for this combustor technology, Coal Tech has developed alternative designs of the combustor that allow its fabrication at very substantially lower cost than the present unit. This effort is being undertaken with internal Coal Tech resources, and its objective is to enhance the commercial viability of the combustor for overseas markets. We estimate that the new designs of the combustor yield combustor-boiler systems for small industrial and utility steam plants, (5000 lb/hr to 200,000 lb/hr steam rate, equal to about 200 kWe to 10 MWe) that are cost competitive with liquid and gaseous fuel, boiler systems.

Beginning in the 4th quarter of 1997 through the 3rd quarter of 1998, Coal Tech's analytical and test work on the other two projects focussed on using biomass fuel for the combustor. Test work was also initiated on a small biomass gasifier. This work, which was limited by Coal Tech's internal resources, demonstrated the major potential that this combustion technology has for biomass fuels. This is extremely important due to the current emphasis on reducing greenhouse gas emissions. A combustor design and an economic analysis of small steam plants using the combustor were performed.

The bulk of the test effort was devoted to developing methods for feeding the biomass into the combustor and into a Coal Tech designed gasifier. This work was successfully completed. Beginning with biomass feed rates that were 10% to 20% of those achievable with coal in our present feed system, the biomass feed rates were increased to a rate equal to that obtainable with coal. This despite the fact that the biomass bulk density is less than 25% of that of pulverized coal.

The current focus at Coal Tech is to seek partners that will join in manufacturing and marketing these technologies. The next step is to construct, and operate in a commercial setting, a 200 kW portable gas engine power plant fired with biomass, and a 1 MW combustor-steam power plant, fired with biomass. These systems would be used to generate distributed power in the US, South America, Africa, and Asia, using agricultural biomass as the fuel.

To implement this effort we propose to maintain the 20 MMBtu/hr combustor-boiler facility operational through 2001.

3. CONCLUSIONS

All the objectives of task 5 of the present project have been met or exceeded, including long duration of testing, 119 days versus 63 days; SO₂ and NO_x performance, 0.2 lb/MMBtu and 0.07 lb/MMBtu, respectively; and low cost combustor system designs. . The only remaining tasks are disassembly of the facility and the Final Report.

Work is proceeding to commercialize the combustor technology.