TECHNICAL PROGRESS REPORT

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For:

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Pittsburgh Energy Technology Center

Under:

DOE Contract No. DE-AC22-86PC90278
Development of a Coal Fired Pulse Combustor for
Residential Space Heating (Phase 1-A)

By:

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PREFACE

A detailed description of the background, technology and application for the development of a coal-fired pulse combustor for residential space heating was provided in the first quarterly report for the period October 1986 - December 1986. That material is omitted from this report. In May of 1988, DOE Contract No. DE-AC22-86PC90278 was modified with the addition of two new Tasks - 1.6 and 1.7 - as a Phase IA to bridge the gap between Phase I and II of the program. The descriptions of these tasks are now included in Section 1.1.

Testing activities during this period were minimal with all effort focused upon resolving the issues associated with the extremely low slurry feed rates required for the unit. The use of a constant pressure slurry feed system followed by a low head peristaltic pump was successful for short periods of time providing the required slurry atomization but exceeded pump design specifications leading to rupture of the peristaltic tube.

An attempt was made to locate a commercial pump with the required duty; delivering 1 to 2 gallons per hour at up to 100 psi but could not be located. Design modifications for the peristaltic pump were therefore initiated to meet the system and cost requirements.

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SECTION 1.0

PROGRAM DESCRIPTION AND WORK STATUS

1.1 PROGRAM DESCRIPTION

The systematic development of the residential combustion system is divided into three phases. Only Phases I and IA are detailed here. Phase I constitutes the design, fabrication, testing, and evaluation of a pulse combustor sized for residential space heating. Phase IA includes additional testing with coal-water slurries and the design and evaluation of integrated systems using DUC and slurry. Phase II is an optional phase to develop an integrated system including a heat exchanger. Phase III is projected as a field test of the integrated coal-fired residential space heater. The program logic is depicted in Figure 1.

The objective of Phase I is to develop an advanced pulse coal combustor at the 100,000 Btu/hr scale which can later be integrated with a heat exchanger and controls to form a residential space heater. Phase I is comprised of four technical tasks and Phase IA is comprised of two technical tasks all of which are described below.

The initial test fuels for the Phase I and II effort were expected to be coal slurries. However, it soon became obvious that the availability of the slurries during the development stage would be somewhat problematic and could become an impediment to maintaining progress and schedule. It was therefore decided, after discussions with the DOE Project Manager, to focus the Phase I effort upon the use of DUC and to consider the slurries for a product improvement activity in a later phase of the program. This change did not affect the cost, schedule, or technical objectives of the Statement of Work. Task 1.5 is a management and reporting task and is omitted from the following task descriptions.

FIGURE 1: PROGRAM LOGIC FOR THE DEVELOPMENT OF AN ADVANCED PULSED COAL COMBUSTOR FOR RESIDENTIAL SPACE HEATING

TASK 1:

TASK 1.1 Design of 100,000 Btu/hr Pulse Combustor

Although small pulse combustors (100,000 Btu/hr) have been built for natural gas and oil, none have been built for coal firing. Coal combustion requires more residence time than oil and gas. This is more of a factor for coal-mixtures, since the water needs to be evaporated first before the coal can burn. The design of the small pulse coal combustor should allow for the longer residence time requirements of slurry fuels, as well as the need for proper atomization of the slurry into the combustion chamber. In this regard, micronized coal slurries, such as the OTISCA coal slurry, may be better for small combustors since smaller coal particles would require less residence time for complete combustion.

Similarly, two chamber geometries will be designed and tested to arrive at a suitable combustor. With regards to the tailpipe, a single-tube tailpipe and multi-tube exhaust system will be designed for evaluation. A cyclone will also be designed to remove the particulate matter. In one case, the cyclone may be used as a second-stage combustor as well. All the components shall be made of metal and shall be capable of high temperatures. All accessories such as the slurry feeding system for the development unit will be specified.

An ignitor, pressure fluctuation monitoring sensor, temperature sensors, and other necessary control and monitoring instrumentation will be specified. SUR-LITE Corporation will be employed on a consulting basis for their expertise in ignitors and control instrumentation.

TASK 1.2 Fabrication of a Pulse Coal Combustor

Pulse combustor components specified in the design in Task 1 will be fabricated and/or procured. Efforts will be made to utilize off-the-shelf components to the greatest extent possible. Kistler pressure transducer instrumentation will be used and a coal-slurry pump and baghouse will be procured. During this stage of the program, arrangements will be made to obtain different types of coals. Initial test configuration will be setup

after completing the procurement. The combustor hardware will be assembled and unit operability determined.

TASK 1.3 Testing the Pulse Coal Combustor

This is the major and most important task of this program. After completion of the setup of the test unit, shake-down testing will be done to ensure safety during the regular test. The test plan developed under Task 1.1 shall consist of three major elements: 1) combustor geometry (including the tail pipe and aerodynamic valve) variations, 2) fuel types, and 3) controls evaluation. For the combustor geometry variations, two aerodynamic valves, two chambers and two tailpipes will be evaluated. In the case of the fuel types, first the combustor will be tested with natural gas and then with No. 2 fuel oil. Combustion air/fuel ratio, pressure boost, frequency, peak pressure variations, noise levels, temperatures and analysis of exhaust gases for O₂, N₂, CO, CO₂, and NO₂ will be performed. Combustion efficiency will be calculated. The unit will then be tested on three coals, chosen in consultation with DOE. Table 1 provides the fuels test matrix. Particulate loading of the exhaust gases will be determined by EPA Method 5. Operational noise levels will be measured at various points in the laboratory.

TABLE 1: TEST MATRIX - PHASE I

<u>TEST SERIES NO.</u>	<u>FEED</u>	<u>CONFIGURATION EVALUATION</u>	<u>CONTROL EVALUATION</u>	<u>EMISSIONS MONITORING</u>
1.	Natural Gas	Yes	No	Yes
2.	#2 Fuel Oil	Yes	No	Yes
3.	Coal Fuel #1	Yes	Yes	Yes
4.	Coal Fuel #2	No	Yes	Yes
5.	Coal Fuel #3	No	Yes	Yes

In each test series, there will be a number of tests dictated by the variations in configurations to be tested. The above test matrix does not give the details of the individual tests. In early testing series, some of the configurational variation may be found useless to pursue and such combinations will be eliminated in the later series. When feeding coal-based fuel to the pulse combustor, the particulates collected and flue gases will be analyzed to determine unburned carbon and combustion efficiency. MTCI will use gas chromatograph and instrumentation equipment already on-hand for gas analysis.

TASK 1.4 Evaluation and Selection of Optimum Configuration for Integrated Testing

The test data collected in Task 1.3 will be analyzed carefully. Based on the test results, an optimum configuration will be selected for further study as an integrated system in Phase II. This configuration will have the potential to meet or exceed the performance criteria and, in addition, will have the capability for fuel flexibility.

Whereas the emphasis in Phase I will be on the pulse combustor development, the emphasis in Phase II will be on testing and evaluating heat transfer/heat exchange equipment as integrated with the pulse combustor. Based on the level of success achieved during Phase I work, progressive development and testing of integrated combustor/heat exchanger subsystems will be performed.

TASK 1.6 Slurry Fuel Evaluation Tests

The Contractor shall perform pulse combustion tests in the tandem pulse combustor unit utilizing several coal-water slurries prepared by the AMAX Research and Development Center under DOE Contract No. DE-AC22-85PC80262. The tests will evaluate those AMAX CWM preparations made available to this project that have properties appropriate for residential use or will provide necessary baseline comparisons. An additional slurry will also be provided by DOE and shall be used to shake down the unit. The actual slurries tested under this

task shall be determined by the DOE Project Manager. These tests shall obtain the following performance data: fuel firing rate, effluent gas analysis (CO , CO_2 , N_2 , O_2 , NO , and SO_2), particulates after cyclone separator, frequency of pressure fluctuation, average boost pressure in combustion chamber, carbon in ash, and temperatures in combustor, resonance tubes and flue gas. These shall be taken for several combustor firing rates and data shall be analyzed and compared to produce an evaluation of the relative performance of these slurry preparations on the tandem residential-scale pulse combustor.

In implementing this task, the Contractor shall prepare a test plan detailing the combustor run conditions and test sequence for evaluating the slurries. The test plan shall be supplied to the DOE Project Manager for review and approval.

TASK 1.7 Design and Evaluation of Integrated Systems

The Contractor shall design two integrated pulse combustor/heat exchanger systems to simulate residential space heaters using the experimental information gathered from previous tasks: one for a slurry fuel firing, and the other for dry ultra-fine coal (DUC) firing. Complete heat and material balances, including temperatures at different points of the system shall be calculated and presented. The Contractor shall perform preliminary comparative evaluation of the two systems.

1.2 STATUS

The low level of effort during this reporting period was focused upon resolving the slurry feed issues encountered. The very low slurry feed rates as well as cost restraints for a commercially configured system require a reliable feed system for slurry fuels in order to provide proper atomization into the combustor. Although a constant pressure feed system used in conjunction with a peristaltic pump provided successful operations for short periods of time, it was considered inappropriate from both reliability and cost for the residential system being developed. Although attempts at locating a commercial system meeting the requirements were unsuccessful to date, that effort as well as a pump redesign effort will be continued during the next period.

SECTION 2.0

TECHNICAL DISCUSSION OF WORK COMPLETED DURING THE REPORTING PERIOD

During this reporting period, all test activities were curtailed with the exception of those associated with resolving the low slurry rate feed issues. The overall system has been operated as designed with all fuels including slurries. However, the low slurry feed rates and the pressures required for proper atomization at the injector tip were considered to be critical for the commercially configured system from the standpoints of cost and reliability. All effort was therefore focused upon determining the best approach toward resolving this feed issue.

Suitable direct injection methods were initially utilized for exploring the constraints and bounding the problem. However, the maximum pump head achievable in this system was insufficient for maintaining proper atomizer operation.

The next step consisted of testing a constant pressure slurry feed system in conjunction with a low head peristaltic pump.

These tests were conducted using a slurry feed system consisting of the nitrogen pressurized feed tank followed by the commercial off-the-shelf, low-pressure head peristaltic pump. Pressure loading was applied upstream of the pump to overcome the maximum head limitations of the unit and to reduce flow pulsations. The higher slurry delivery pressures were found to be a necessity for proper atomization at the injector tip.

With this configuration, successful operation of the feed system was demonstrated at delivery pressures exceeding 60 psig for short periods of time. However, as these pressures exceeded the design specification for the pump, rupture of the peristaltic tube could not be avoided.

A search was then undertaken to locate commercial peristaltic pumps in the low-flow range (1-2 gph) capable of delivering up to 100 psi. While large capacity, industrial-duty, peristaltic pumps were identified which could achieve the specified delivery pressure, pumps suitable for the residential flow range and cost restraints could not be located. Investigations into alternative pumps, including progressive cavity type, indicated that the high capital cost of these units would not meet the needs of the residential unit.

The peristaltic pump is therefore being redesigned and modified specifically for residential unit testing. This activity is currently underway and should resolve the aforementioned issues.

SECTION 3.0
PLANS FOR NEXT QUARTER

The design and modifications of the peristaltic pump should be completed and tests in the residential system resumed. Activity to locate a commercial system will also continue.