High Pressure Coal-Fired Ceramic Air Heater for Gas Turbine Applications

Quarterly Report
February 1 - April 30, 1994

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Work Performed Under Contract No.: DE-AG21-94MC31327

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**High-Pressure Coal-Fired Ceramic Air Heater
for Gas Turbine Applications
DOE Contract No. DE-AC21-94MC31327**

Technical Quarterly Report for February through April 1994

Program Management

Program Management: The schedule and funding status for KTF has been internally reviewed and updated. The documentation to extend the contract has been initiated and will be completed in May.

Technical Papers: A paper entitled "Externally-Fired Combined Cycle: An Effective Coal Fueled Technology for Repowering and New Generation" has been written by Larry Stoddard (Black & Veatch), Mohammed R. Bary (Black & Veatch), Paul G. LaHaye (Hague), and Kenneth M. Gray (Pennsylvania Electric Co.). This paper was presented at the Twentieth International Conference on Coal Utilization and Fuel Systems at Clearwater, Florida, March 20-23, 1995.

Consortium: On 16 March a letter was sent to all Consortium representatives regarding the initial coal firing of the KTF facility. It was reported that the Externally Fired Combined Cycle pilot plant facility at Kennebunk, Maine successfully operated at low loads on pulverized Pennsylvania bituminous coal with ceramic tubes in the air heater. The letter of March 16 indicated that updates will be sent as demonstrations progress. This letter resulted in numerous communications regarding the details of the run.

A letter to inform Consortium members of the results of the April 25 - 30 run was posted on 3 May.

Foster-Wheeler provided an in-kind contribution to the Consortium in the form of a service engineer who supported work on the KTF coal burner during the period of March 2 through March 9. A letter indicating the service, labor and travel expenses totaling \$8,804, and that this service was provided at no cost to Hague International and represents additional in-kind contribution to the Consortium was sent on 12 April 1995.

A large percentage of Consortium member Confidentiality and Non-disclosure agreements expire on December 31, 1995. Representatives were sent correspondence to extend the expiration of these agreements to December 31, 1996. All but one Consortium member Confidentiality and Non-disclosure agreement has been extended.

Task 2 - Component Development

Task 2.1 - Technology Support

Task 2.1.3 - Erosion/Corrosion

To assist in tube lifetime predictions, the scientific literature is being reviewed to determine the predominant corrosion mechanisms which are likely to occur in different parts of the CerHx. This review will also be useful in the specification of suitable corrosion resistant materials to be evaluated as coatings for silicon carbide based tubes.

Task 2.2- Fuel and Fuel Handling

Task 2.2.2 - Procure Coal Handling System:

Designs for the coal handling system have been completed. Component fabrication and installation drawings have been completed. Fabrication of the coal piping components and their installation have been completed. Checkout of the coal handling system has been successfully completed as part of tests performed under Task 3.

Task 2.2.3 - Natural Gas Fuel system:

The natural gas fuel system provides fuel to the coal combustor and the gas turbine. The coal combustor has a separate gas train and controls from the subsystem supplying fuel to the gas turbine. Included in the gas turbine fuel train is an older model gas compressor which supplies 250 psig natural gas. Due to gas compressor's age it has been re-built.

Task 2.4 - Heat Exchanger Development

Task 2.4.1 - Tube-String Development:

Improve Tube Toughness: Two containment schemes are currently being considered. One scheme (referred to as scheme "A") is being developed for immediate use in the KTF heat exchanger; the second (scheme "B") is being considered for future heat exchanger tests.

Proof of concept tests for scheme "A" were successfully completed and the material choices for use in this scheme were finalized. Ballistics tests of heat treated samples constructed using the final material choices were initially not successful. A crude tensile stress/strain apparatus was constructed to allow correlation of material properties after heat treatment with the ballistics tests results. Results from the tensile tests indicated that the high temperature data provided by the material manufacturers was inadequate for predicting the containment design parameters.

Tensile tests were performed to determine the effect of material geometry and material interactions on the properties of the containment systems after heat treatment. Using the tensile test data, the optimum containment configuration for high temperature operation was determined and tested on heat treated ballistics test samples. The test data also indicated some configuration adjustments which increased the effectiveness of the containment scheme allowing the use of less material, and aided in the development of an erosion protection which does not adversely impact on the properties of the containment system.

As a result of these tests, a containment system was added to a full pass of ceramic tubes for the KTF CerHx to protect against sequential failure in the April test. The tubes performed adequately during the testing and none failed during the run.

Initial evaluation of an alternative containment system, scheme "B", attractive because of its relatively easy application and potentially longer lifetime, was postponed to expedite the development of scheme "A". Evaluation of scheme "B" is now proceeding. Several prototype samples have been fabricated and tested. The first round of tests successfully demonstrated the containment concept. Tests are planned to evaluate the containment scheme using so called 'high temperature' materials suitable for use in the CerHx.

A dynamic analysis of tube failure and the effectiveness of the various containment options has been initiated. It is anticipated that this analysis will allow speedier optimization of the various containment options and that it will ultimately allow lowest cost engineering of the containment system.

Task 2.4.2 - CerHx Tube-String Components:

CIET Tubes: All the ceramic tubes to be used in the KTF test were proof tested using the pressure test rig. Components tested in the pressure test rig are subjected to both the compressive force that they would be exposed to in the CerHx as well as being internally pressurized to pressures significantly higher than those likely to be encountered.

A full pass of ceramic tubes for use in the KTF heat exchanger have been proof tested to pressures at least 50% greater than the operating pressures that they will be subjected to in the CerHx. The proof test conditions were selected with a projected failure rate of ~1%. Only 2 tubes of the 80 tubes tested failed the test. This indicates the value of the tests in identifying defective tubes.

Addition of tube containment scheme A to a full pass of ceramic tubes, plus several additional tubes as spares, has been completed. No problems were encountered installing the tubes in the first pass of the KTF CerHx and the tubes performed adequately during the testing. No tubes failed during the test run.

Hex Inserts: All the male-female and female-female hex liners to be used in the April test were proof tested in the pressure test rig. None failed to hold pressure, but 2 failed as a result of the compressive force.

Check Valve System: The components of a check valve system, designed to isolate individual tube strings should a tube failure occur, have been received. QA/QC tests are being developed for these components

QA/QC Procedures: Construction of the pressure test apparatus, for the non-destructive evaluation of ceramic components prior to their installation in the heat exchanger, has been completed. Checkout and testing of all ceramic components using this apparatus have been completed.

Task 2.4.3 - CerHx Assembly:

CerHx Cooling System: The cooling system provides the required air cooling for the hex restraints and upper tube sheet. Designs for the CerHx cooling system have been completed. Fabrication of components have been completed. Component installation and checkout tests have been completed.

Task 3 - Component System Integration & Testing

Task 3.1 - Test Facilities

Task 3.1.1 Test Facility and Support System Design/Construction:

Test Facility Structure: Designs for the coal handling system enclosures have been completed. The contract for the construction of the enclosures has been awarded and construction has been completed.

The low bay area, housing the HRSG and providing support for the ID fan, has been enclosed to provide adequate weather protection to the HRSG and feedwater system and adequate ventilation.

Designs and fabrication of the catwalks and walkways have been completed. Installation of the catwalks and walkways have been completed. Installation of the "ground level" grating and walkway have been initiated. This work is expected to be completed in May.

CerHx Tube-String Assembly: A full set of ceramic tubes were installed in the first pass. The assembly procedures included pressure testing (up to 15 psig) of the individual tube strings and CerHx pressure integrity tests.

High Pressure Air Supply/Discharge System: The pneumatic air starter for the EFCC gas turbine has been re-built. Designs for the turbine control valve (TCV) system are nearing completion. Fabrication of the TCV components has been initiated.

Combustion Air System: The gas turbine exhaust air is piped directly to the combustion air system. This piping has been modified to include diverter valves and exhaust piping so if the combustor is in operation, the gas turbine can operate and its exhaust vented outside without affecting the combustor.

Controls & Instrumentation: Designs and specifications of the data acquisition system have been completed. Installation has been completed. Checkout tests of the data acquisition system have been completed.

The controls & instrumentation system for the coal handling system has been completed.

Task 3.2 - Testing and Analysis

Task 3.2.1 Systems Test:

Gas Turbine Baseline Tests: Gas turbine baseline tests for the engine utilized in the April 25-30 run were performed. These tests were performed with the gas turbine in its standard configuration. These tests included no load operation, full load operation, and cycling tests between no load and full load.

The gas turbine was then interfaced to the high pressure piping system. The baseline tests were then repeated. These tests also included no load operation, full load operation, and cycling tests between no load and full load. The gas turbine and high pressure piping system performed well during these tests.

No-Load Gas-Fired MIET Tests: No load gas fired and integration tests were resumed in March. Leakages developed in the CerHx during repeated thermal cycling and as a consequence could not be completed as scheduled.

Coal-Fired Tests: Checkout tests of the coal handling system have been successfully completed. There were some calibration problems with the weigh-belt system. The system was re-calibrated and checked out.

Between April 25 and April 30, Hague International ran the Externally Fired Combined Cycle pilot plant at the Kennebunk Test facility. The first pass of the CerHx was composed entirely of ceramic tubes. The heat exchanger operated at high temperature and high pressure, gas inlet temperature over 900°C (1652°F), pressure over 80 psi). First pass shell-side inlet temperature was limited by the second pass metal tubes. There was no damage to any of the ceramic tubes. Tube wall temperatures of approximately 750°C (1382°F) were achieved.

Stable gas turbine operation was achieved with energy input from the heat exchanger and the gas turbine combustor. The heat exchanger and the gas turbine were integrated. The coal combustor, however, was operated without preheat.

Pulverized Western Pennsylvania bituminous coal was burned (90% below 200 mesh). An analysis has been performed on the fuel. Particles in excess of 100 microns entered the slag screen. No particles larger than 23 microns exited the slag screen. Longer coal runs will be required before an adequately thorough evaluation of slag screen can be performed.

This run was cut short due to compressed air leaks in conventional gasket joints outside the shell of the heat exchanger, that is, outside of the combustion gas stream. After gasket modifications to eliminate these leaks, the pilot plant will be put back in service.

Task 3.2.2 - Data Analysis:

Data from the April run is being evaluated to fully determine system and subsystem performance.

M97002105

Report Number (14) DOE/MC/31327--5357

Publ. Date (11) 199704

Sponsor Code (18) DOE/FE, XF

UC Category (19) UC-101, DOE/ER

DOE