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

Quarterly Report
May 1 - July 31, 1995

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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 May through July 1995 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 completed.

Technical Papers: The manuscript of the paper presented at the Advanced Coal-Fired Power Systems '95 Review Meeting at DOE METC, June 27, was submitted for inclusion in the published proceedings. The paper focused on the building of the pilot plant in Kennebunk, Maine, and the proof of concept tests performed to date.

Slide shows and tours of the Kennebunk Test Facility were held for local community leaders, many of whom were concerned about plant noise levels. The Kennebunk Rotary Club was addressed on July 18. On July 24, a town manager attended a demonstration of noise abatement measures Hague had taken to address complaints about the sound of the facility's ID fan. This resulted in a favorable newspaper story published in the Biddeford - Saco *Journal Tribune* on July 26.

Slides and videotapes of technical details of the Kennebunk Test Facility were taken for incorporation in future reports and presentations.

Consortium: A letter to inform Consortium members of the results of the April 25 - 30 run was posted on 3 May. This letter discussed the first demonstration with a full pass of ceramic tubes (72 tubes).

Scheduling and logistics planning for the fall 1995 EFCC Consortium Meeting to be held in southern Maine were begun.

Task 2 - Component Development

Task 2.4 - Heat Exchanger Development

Task 2.4.1 - Tube-String Development:

Improve Tube Toughness: Evaluation of an improved containment system is proceeding. Several prototype samples fabricated some time ago have been 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®.

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. The results of these tests

Tensile stress/strain measurements performed by an external laboratory on various combinations of containment materials yielded essentially identical results to those obtained previously at HI. This will increase the credibility, and therefore the usefulness, of such in-house tests in future

A dynamic analysis of tube failure has been performed and numerically solved. The numerical model has been updated to include details of the two containment schemes currently under investigation. Samples for one of the containment schemes have been obtained for the experimental verification of model predictions.

CPI Test Rig: Designs modifications are under way to upgrade the CPI test rig. These modifications will result in reduced down time between test setups and will provide increased testing flexibility. The preliminary designs have been completed. Detailed designs will be completed by the end of July, and it is anticipated that the CPI rebuild will be completed by mid-August.

Task 2.4.2 - CerHx Tube-String Components:

Gaskets: CPI tests have been performed to determine the minimum gasket curing parameters (temperature and time) to achieve good sealing, using current gasket choices, under CerHx operating conditions. The tests indicate that acceptable leakage rates, of the order of 0.3% over the entire CerHx, can be obtained by curing at 250°C for 24 hours.

In addition, alternative materials have been investigated in an attempt to identify gasket materials which do not require curing and which will seal at the elevated temperatures expected for the CerHx. Several ceramic based gasket materials have been evaluated and at least one meets the necessary criteria. Gaskets fabricated from this material will be used in some locations in the CerHx in the next KTF test.

Ceramic Tubes: The 72 first pass tubes were pressure tested after the CerHx integration tests. Two tubes failed in the pressure test rig, however the shrapnel was fully contained indicating the continued effectiveness of the tube containment system after repeated thermal cycling. In both cases small chips on the machined end of the tubes, presumably caused during disassembly, were identified as the fracture origins.

58 of the 80 second pass tubes, for the upcoming two pass ceramic test, have been received and inspected. 26 tubes have been machined and pressure tested to 225 psig. One of the tubes failed on pressure testing.

Hex Inserts: The sealing surfaces of the male end of the male/female hex inserts were improved. Fabrication of spare male/female hex inserts has been initiated.

The 256 hex inserts used in the CerHx integration tests were pressure tested at 200 psig under 3500 lbf of axial compression. A total of 4 pieces failed under axial compression. After the failure of several consecutive hex inserts, problems with the metal end fittings in the pressure test equipment were identified. Re-machining of the end pieces rectified these problems and no subsequent hex failures occurred.

Some of the female/female hex inserts used during prior tests have been re-cast.

Preliminary fracture analysis of the hex insert which failed during operation of the KTF CerHx has been performed. Initial results are inconclusive. Further testing is planned to identify the cause of failure.

"Check-Valve" System: A preliminary design for QA/QC testing of ceramic check valves has been proposed. The test rig will model the temperature and flow conditions predicted for the valve in the hot header. The design will be finalized in August.

QA/QC Procedures: Inventory and visual inspection of ceramic hot header valve components has been performed. A procedure is being developed to evaluate these components in simulated service conditions.

A QA/QC tool has been designed and manufactured to allow the determination of tube contact length for all tubes to be used in the CerHx. This will allow more accurate calculation of total tube string length and therefore compression forces in the CerHx.

The 72 ceramic tubes used in the EFCC integration tests in April and May were successfully pressure tested with an axial compression of up to 5600 lbf with an internal pressure of at least 1.5X the CerHx operating pressure.

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: : The installation of the "ground level" grating and walkway have been completed.

CerHx Tube-String Assembly: The April run was cut short due to leaks in gasket joints located outside the shell of the CerHx, that is, outside the combustion gas stream. The gaskets for these joints have been replaced. CerHx re-assembly was completed.

High Pressure Air Supply/Discharge System: ASME flow nozzles to measure the air inlet flow to the gas turbine have been designed and fabricated. These nozzles were calibrated at low flow conditions.

Designs and performance analysis for the turbine control valve (TCV) system continues. Fabrication of the TCV components continues.

Task 3.2 - Testing and Analysis

Task 3.2.1 Systems Test:

Gas Turbine Baseline Tests: As per standard checkout procedures, baseline tests of the gas turbine with the high pressure piping are normally performed prior to each integration test. These tests were performed prior to each of the integration tests, performed during this reporting period. There was no measurable difference in the turbine performance characteristics during these tests. More importantly, there was no measurable difference in performance between these tests and the baseline tests with gas turbine in its standard configuration.

Integration Tests: Three integration test were initiated during this quarter. The first pass of the CerHx was composed entirely of ceramic tubes. First pass shell-side inlet temperature was limited by the second pass metal tubes.

The first test was initiated on June 22 and terminated on June 27. Hot pressure integrity tests of the CerHx were performed on June 25. A CerHx leakage rate at 100 psig less than 5% was measured. The source of the leaks were identified to be a few of the gasket joints outside the shell of the CerHx.

Subsequently, after cool down, three leaks at the top of the CerHx were discovered. These leaks were caused by a misalignment of a male/female hex insert. Minor modifications to the tube sting assembly procedures corrected this problem. These leaks were repaired in short order.

The second of these integration tests was initiated on July 5 and terminated on July 9. Hot pressure integrity tests of the CerHx were performed on July 8. The CerHx leakage rate at 105 psig of less than .3% was measured. The gas turbine was started and the system ran in the EFCC mode for approximately 30 minutes. The CerHx was being thermally equilibrated when a CerHx hex insert failed. The test was terminated and the failed component replaced.

Subsequently, after CerHx repairs were completed, the second integration test was initiated on July 11. Hot pressure integrity tests of the CerHx were performed on July 13. The CerHx leakage rate at 10 psig once again measured less than .3%. The gas turbine was started and the system ran in the EFCC mode for approximately two hours. Thermal equilibration of the CerHx was achieved after about one and half hours of operation. CerHx leaks developed during the test. The leakage rate was smaller than the previous test. The second integration test was terminated and the system cooled down.

Subsequently, after cool down, a few leaks located at the top of the CerHx outside the shell of the CerHx were discovered. These leaks were caused by a failure of the gaskets at these locations. The types of gaskets currently used and their curing procedures are being reviewed.

Integration testing will resume in early August once these issues are resolved.

Task 3.2.2 - Data Analysis:

Data from these integration tests are being evaluated to fully determine system and subsystem performance.

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