Advanced Turbine System Conceptual Design and Product Development

**Quarterly Report
May 1 - July 31, 1997**

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For
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I. Introduction

II. WBS 1 - Project Plan

The Project Plan for the subject program was submitted (mailed) to the Department of Energy (DOE) on May 18, 1995. This task is complete.

III. WBS 2 - NEPA Report

The information required for the NEPA Report was submitted (mailed) to the DOE on June 22, 1995. This task is complete.

IV. WBS 3 - GFATS Selection

The technical work on this task has been completed and presented to the DOE. Final report is in preparation for this task and was also be presented to the DOE.

V. WBS 4 - Conversion to Coal

Surveys of potential Task 4 CFATS cycles were completed by ABB Power Plant Laboratories (PPL). A brief overview of the results of this work to date were also presented at the September 27, 1995, briefing with the DOE. No further efforts will be expended on this task as indicated in the 5th quarterly report.

VI. WBS 5 through WBS 8 Replanned Tasks

The following tasks are included in the revised contract:

- Turbine Aerodynamics& Aero-Thermal Integration
- Advanced Steam Cooled Vanes
- Advanced Air Cooled Blading
- Thermal Barrier Coating and Steam Oxidation

The following tasks were referenced in the contract and the completion status was part of the monthly reports since July 1996. The references correlate with the contract and the task numbers with the monthly reports.

Ref. 3.4.1 - Turbine Aerodynamics and Aero-Thermal Integration (Task 8.5)

- Hardware Design and Manufacturing:
 - * Manufacturing of all components to fit the uncooled ABB turbine stage in the MIT test rig has been completed.
 - * Final assembly of the test rig has been completed.
- Instrumentation manufacturing and calibration:
 - * this task has been completed.
- The test rig is now ready to start measurements
- The development of computational procedures for data reduction is ongoing.

Ref. 3.4.2 - Advanced Steam-Cooled Vanes**(Task 8.6)**

- overall cooling flow circuit is defined as a two-pass airfoil cooling scheme reflecting the concurrent requirements for inner and outer platform cooling as well as steam delivery and sealing features.
- The proposed cooling concept is based on rectangular spanwise cooling channels with variable aspect ratios and spacing.
- The test apparatus design has been completed.
- Detailed cooling model design has been delayed due to lack of input data required from the cycle performance team. It is imperative to have initial information for the complete thermodynamic cycle to define the cooling geometry which will be tested.
- ABB has previously designed an upgrade turbine for ABB's GT11N called GT11NM using advanced air cooling schemes. The turbine hardware has been installed and tested at Midland Cogeneration Venture (MCV). The test results showed that the power output has been increased by 10% and the thermal efficiency has been increased by 6% (multiplicative). This values exceed the expectations. The engine has accumulated 1500 operating hours, inspections at 50 operating hours and 500 operating hours showed that the components were in excellent conditions.
- Planning is under discussion with MCV for installation and testing of a steam cooled component in FY 1998. Together with the baseline measurements of the advanced air-cooled turbine the efficiency benefit of steam cooled components can be demonstrated.

Ref. 3.4.3 Advanced Air Cooled Blading**(Task 8.3)**

- Impingement cooling test matrix has been extended and tests are progressing.
- Activities to investigate the influence of the blade cooling air feed system.(cooling air transfer from the stationary to the rotating plane) have been completed. The final report is delayed, the results will be reported in the next quarterly report..

Ref. 3.4.4 Thermal Barrier Coating and Steam Oxidation

- **Evaluation of TBC-Coating Systems in High Temperature Gradients**
 - * Test bars with different coating systems i.e. SV20, SE20, Pt-Al, SV20 + Si, Pd, Al and SV20 + Vapor Phase Overaluminide have been mounted into the test bed. Fast cyclic oxidation has been completed.

- * The extent of the degradation has been determined by SEM/Metallography. Preliminary results of the SV-20 + Vapor Phase Overaluminide system indicate a depletion of the NiAl (Beta phase) and transformation to γ and γ' . The SV-20 underneath also appears depleted.
- * The testing on the TBC coated test bars (PVD TBC, Plasma sprayed standard thickness and plasma sprayed 1 mm TBC) has been started. The 1mm TBC coated samples have failed after 370 cycles (average).
- **Monitoring of Degradation of TBC Coating Systems**
 - * “As received” test specimen have been assessed to establish a baseline for the degradation of the TBC / bond coat
 - * Test specimen have been run for 300 hours at 1100 C and NDE evaluation has been started. Additional “engine run” TBC coated airfoils have been sectioned and metallographic measurements taken to assess the extent of degradation. These samples will undergo NDE as well to extend the data base obtained by the laboratory samples.
- **Thermomechanical Fatigue (TMF) of TBC Systems.**
 - * Test rig was modified to simulate internal cooling
 - * Testing of specimen under strain controlled conditions were started.
 - * Baseline tests with uncoated samples have been completed. Results:
 - 1% strain rate 536 cycles to crack initiation
 - 0.85 % strain rate 1827 cycles to crack initiation
 - 0.65 % strain rate > 5000 cycles to crack initiation (test have been stopped after 5000 cycles)
 - * Tests with coated samples and 0.65 % strain rate were tested, crack initiation started after 299 respectively 459 cycles. Further samples are in the test bed to substantiate this numbers.
- **Kinetics of Oxidation in Steam.**
 - * Test were done in steam atmosphere at 800 C and 950 C in steam oxidation furnace
 - * samples have reached 5000 hours of exposure and the tests are completed.
 - * The metallographic assessment has started.

VII. WBS 9 - Program Management/Reports

Work accomplished under this task during the subject period includes the following:

- ABB Monthly Status Reports including Summary Report, Milestone/Schedule Status, Labor Management Report, and Cost Management Report for the following months:
 1. May 1997 delivered (mailed) to the DOE June 20, 1997
 2. June 1997 delivered (mailed) to the DOE July 11, 1997
 3. July 1997 delivered (mailed) to the DOE August 20, 1997
- ABB's ninth Quarterly Technical Progress Report (Final) was submitted (mailed) to the DOE on July 22, 1997.
- ABB's second Annual Technical Progress Report (Final) was submitted (mailed) to the DOE on July 22, 1997.

VIII. General Discussion

The confirmation for the contract modification M004 was received on June 6, 1997. Technical highlights for the reporting period are:

- The turbine stage hardware has been delivered and the final assembly is completed. The test rig at the MIT is now ready for measurements on the uncooled turbine stage.
- The GT11NM retrofit turbine has been successfully installed and tested at MCV. The performance improvement exceeds the expectations.
- The experimental work on advanced cooling technology is nearly completed.
- All base line experiments for evaluation of TBC life time performance has been completed. The testing on TBC coated test specimen is well under way.
- The work on NDE methods to evaluate TBC degradation is in the final phase.
- The experimental work on kinetics of oxidation in steam has been completed and the metallographic assessment is ongoing.

IX. Program Redirection

Key Dates:

ABB Proposal mailed to DOE:	January 26, 1996
DOE Concurrence received:	April 29, 1996
Contract extension granted:	May 29, 1997

The revised program has been implemented in all ABB's development plans and the monthly reports since May 1996 report on the progress and actual status.