Utility Advanced Turbine Systems (ATS) Technical Readiness Testing and Pre-Commercial Demonstration

**Quarterly Report
April 1 - June 30, 1996**

Work Performed Under Contract No.: DE-FC21-95MC32267

For
U.S. Department of Energy
Office of Fossil Energy
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QUARTERLY STATUS REPORT

ATS Phase 3

Date: September 9, 1996

Report No. TPR-03

Reporting Period: April-June, 1996

CONTRACT TITLE AND NUMBER: Utility Advanced Turbine Systems (ATS)
Technical Readiness Testing and
Pre-Commercial Demonstration
DE-FC21-95MC32267

CONTRACTOR'S NAME: Westinghouse Electric Corporation
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CONTRACT PERIOD: September 30, 1995 to December 30, 1999

TECHNICAL REVIEW MEETING

A technical review meeting summarizing ATS phase 2 & 3 progress was held with METC personnel on April 25 & 26, 1996 in Orlando FL.

1.0 NEPA INFORMATION

Documents explaining the most frequently asked questions about NEPA submittals on DOE projects was received from METC. Review of these documents has proceeded. No host site has been selected to date, so only generic preparation of key documents has begun.

2.0 ATS ENGINE DESIGN

A risk analysis has identified the areas where the highest probability and consequences of risk exists. Mitigation plans to counter any identified risk have been initiated.

8.0 INTEGRATED PROGRAM PLAN

The integrated program plan was developed during the reporting period and will be officially submitted after program and schedule optimization have been completed. A draft of the plan was submitted to the METC on March 8, 1996. Comments to the draft were received on May 29, 1996.

9.1 CLOSED LOOP COOLING

The existing combustor test rig at AEDC will be replaced by an integrated combustion/hot cascade test rig as a cost saving measure. The integrated test rig will accommodate ATS combustor tests as well as closed loop cooling vane tests. Cooling circuits for test vane 1 has been designed..

9.2 THIN WALL CASTING DEVELOPMENT

Aerodynamics modeling of test vane 1 was completed. A 3-D model database for the vane airfoil was submitted to Allison for manufacture. Manufacturing development work for the first vane has been initiated.

9.3 ROTOR AIR SEALING DEVELOPMENT

An evaluation of the manufacturers to produce the prototype turbine rear face seal has been ongoing. The evaluation will be completed next quarter.

9.4 COMPRESSOR AERODYNAMIC DEVELOPMENT

A meeting with the Navy to discuss the division of responsibilities for the compressor tests was completed. Compressor/combustor cylinder design has progressed with an anticipated completion next quarter.

9.5 TURBINE AERODYNAMIC DEVELOPMENT

A review meeting with Calspan, the blade test facility, was held to discuss procedures and schedule. Stage 1 airfoil definition has been completed and transmitted to the blade manufacturer and Ohio State University. Stage 1 aluminum test vane has been machined to verify the steel vane manufacturing process. Disk design is in progress to support the assembly date.

9.6 PHASE 3 ADVANCED AIR SEALING DEVELOPMENT

Static testing of the subscale compressor diaphragm seal were completed. Preparations for dynamic tests are underway. Tribology testing for the turbine rim seal and compressor diaphragm seal studies were initiated.

9.7 ACTIVE TIP CLEARANCE CONTROL

Ceramic abradable coating development work done as part of Task 8.15 has transitioned to validation testing in Task 9.7. The validation will be done in row 1 turbine ring segments of a 501FC engine to be assembled in early 1997. During 1996, a set of engine ring segment

hardware will be coated and any necessary blade tip treatments will be applied. During April, 1996, detailed planning of the effort was completed.

9.8 COMBUSTION SYSTEM DEVELOPMENT

Several atmospheric pressure tests were conducted with the Piloted Ring and Multiswirl combustors at the Casselberry test facility. A variation of the Multiswirl combustor, Multi Ring, showed improved performance, greater flashback resistance and lower emissions.

The active combustor noise cancellation of lean premix combustion instabilities under combustion turbine operating conditions was successfully demonstrated. A four fold decrease in sound pressure level was observed.

A third generation optical probe was successfully tested in a full scale K point combustor. Data is being analyzed against CFD analytical data, initial results are encouraging.

9.9 CERAMIC RING SEGMENT

Studies on ceramic ring segment sealing and attachment arrangements have continued. Stress analysis and manufacture of the subelements has progressed. A Si/C/Alumina cylinder was received for environmental exposure testing. Creep rupture tests continue to accumulate hours at ORNL and UDRI under the User program.

9.10 ADVANCED THERMAL BARRIER COATING DEVELOPMENT

Long term testing of bond coat candidates at nominal service temperatures has continued with accumulated exposure times approaching 9500 hours. A limited number of coatings have failed, consistent with accelerated temperature studies. Two new ceramic candidates have been deposited via Air Plasma Spray(APS). Specimens for thermal conductivity have been fabricated and prepared for testing at ORNL.

9.11 STEAM COOLING EFFECTS

Design of the test rig was completed, a design review was conducted, resulting in several modifications to accommodate multiple test specimens. Test procedures have been developed. Test specimens have been machined.

9.12 DIRECTIONALLY SOLIDIFIED BLADE DEVELOPMENT

Tensile and fatigue tests for CC CM247 material are completed. Only long term creep tests remain. HCF and creep test specimens of DS CM247 have been received, high cycle fatigue and creep tests for this material is in progress. For the evaluation of withdrawal rate effect, more test slabs of DS M002 and DS CM247 were received from casting supplier and several slabs were

being heat treated, and machined in preparation for mechanical testing. DS CM 247 and DS M002 blades are being machined for tensile, creep and fatigue test specimen.

9.13 SINGLE CRYSTAL BLADE DEVELOPMENT PROGRAM

A purchase order was issued to the Howmet Labs to perform heat treatment, inspection and mechanical testing of CMSX-4 test slabs. Test coupons in the form of approximately ½" diameter slugs have been EDM machined from the slabs, and the coupons have been etching inspected for grain defects. Acceptable coupons have been selected for the next step of aging heat treatment prior to final machining. Prospective blade coating cycles have been evaluated so they can be integrated as part of the total simulated aging cycle for the CMSX-4 base metal. Heat treatment and machining in preparation for tensile and creep testing will continue.

9.14 ADVANCED VANE ALLOY DEVELOPMENT

Baseline mechanical testing of IN-939 continued. Calculation of the creep equations for IN-939 was completed and provided to design personnel. The Work for Others contract between Westinghouse and Lockheed Martin Energy Systems (Oak Ridge National Laboratory) to complete small ingot casting and weldability testing was executed on June 3 and submitted to DOE.

9.15 BLADE AND VANE LIFE PREDICTION

Data on the relaxation behavior of bond coats for thermal barrier coatings (TBC) was collected and is in the process of being analyzed. This data is critical in predicting and understanding the stress conditions which lead to TBC spallation. Superalloy plates for radiographic strain verification have been machined and have been sent to the TBC coating supplier. Bond coat stress-relaxation data is being processed. The HOST report has been analyzed and it is now clear how the HOST model can be applied.

9.16 NICKEL BASED ALLOY ROTOR

Compressor disc forgings from Wyman Gordon have been received, specimen machining is underway. Testing of Alcoa qualification forging is in progress. An ultrasonic testing (UT) process has been developed and approved.

11.0 PROGRAM MANAGEMENT

The required Federal Assistance Reports were developed and submitted during each month of the quarter. A quarterly review meeting is planned for July 30, 1996 in Morgantown.

PLANS FOR THE NEXT REPORTING PERIOD

Tasks

1.0 NEPA Information

Continue NEPA data development for Phase 3.

Collect Phase 4 NEPA data for the selected ATS demonstration site.

2.0 ATS Engine Design

Continue design of the last stages of the ATS compressor.

8.0 Integrated Program Plan

Submit the final integrated program plan for Phase 3.

9.1 Closed Loop Cooling

Continue design of hot cascade/combustion test rig.

9.2 Thin Wall Airfoil Casting Development

Continue thin wall cooling concept design in collaboration with casting vendor.

9.3 Rotor Sealing Development

Evaluate vendor submittals.

9.4 Compressor Aerodynamic Development

Continue design of ancillary equipment.

Continue procurement of long lead time compressor components.

9.5 Turbine Aerodynamic Development

Continue work at Ohio State University on model turbine test rig.

Continue design of test rig discs.

9.6 Advanced Air Sealing Development

Continue rim seal design.

9.7 Active Tip Clearance Control System Development

Continue evaluation of low thermal expansion coefficient materials for application to tip clearance control.

9.8 Combustion System Development

Evaluate test data from high pressure test on the multiswirl and piloted ring ultra low NOx combustors.

9.9 Ceramic Ring Segments

Continue testing at University of Dayton Research Institute.

Coupon testing for developing the design database for the ceramic matrix composite material (Nicalon/Alumina) will start at Oak Ridge National Laboratory.

Property characterization of abradable layer friable insulation will continue at the Westinghouse Science and Technology Center.

Continue testing of Nicalon/Alumina material for design database development.

9.10 Advanced TBC Development

Bond coat materials currently in test will be continued.

The furnace testing will be supported by analysis, such as microscopy and compositional analysis to determine failure mode and performance attributes.

Additional bond coat chemistries are being formulated and will be deposited and brought to test.

Two new ceramic TBC powders which have been fabricated will be deposited and brought to test.

Additional ceramic compositions have been defined; powders and subsequently coating specimens, will be fabricated.

Testing procedures are being designed to determine long term TBC thermal conductivity and compliance values. Samples for these tests will be fabricated and brought to test.

9.11 Steam Cooling Effects

Develop deposition rate model.

Develop final model.

Continue fabrication of test setup.

Complete test specimen design.

Start testing.

9.12 DS Blade Development

Continue specimen creep testing for continuous cast blade evaluation.

Continue DS blade specimen tensile, low cycle fatigue and creep testing.

Continue HCF & creep testing of DS CM247 blades.

Evaluate DS M002 blades.

9.13 SC Blade Development

Test single crystal CMSX-4 cast slabs, heat treat and machine test specimens.

Continue preliminary SC blade design and cost-and-benefit analysis.

9.14 Advanced Vane Alloy Development

Continue baseline testing of alloy IN-939.

Computer modeling of alloy composition will be started.

Casting and testing of small heats of experimental alloys for weldability and mechanical properties will continue at Oak Ridge National Laboratory.

9.15 Blade and Vane Life Prediction

Refine life prediction model for a TBC system.

Critical material behavior will be defined and a plan for conducting tests to measure these properties will continue to be developed.

Testing to determine critical properties of bond coat and ceramic top coat will continue.

9.16 Ni-Based Superalloy Rotor

Continue forging design.

Develop production process steps.

Continue testing of turbine disk.

11.0 Program Management

Submit monthly reports.

Plan and prepare for third quarterly review.

Les R. Southall
Program Manager