Utility Advanced Turbine System (ATS) Technology Readiness Testing and Pre-Commercialization Demonstration

**Quarterly Report
January 1 - March 31, 1996**

**RECEIVED
MAR 31 1997
OSTI**

Work Performed Under Contract No.: DE-FC21-95MC31176

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
Power Generation System
General Electric Company
1 River Road
Schenectady, New York 12345

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

UN

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161; phone orders accepted at (703) 487-4650.

This report has been reproduced directly from the best available copy.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

Section 1 Executive Summary	1
Section 2 Technical Progress Reports	2
Section 2.1 (NE) NEPA	2
Section 2.2 (GT) Gas Turbine Design	3
Section 2.2.1 (GTAD) Aerodynamic Design	3
Section 2.2.2 (GTFF) Gas Turbine Flange-to-Flange Design	3
Section 2.2.2.1 (GTFFCP) Compressor Design	3
Section 2.2.2.2 (GTFFCB) Combustor Design	4
Section 2.2.2.3 (GTFFTR) Turbine Rotor Design	5
Section 2.2.2.4 (GTFFTB) Turbine Bucket Design	6
Section 2.2.2.5 (GTFFTS) Turbine Stator Design	7
Section 2.2.2.6 (GTFFST) Structures Design	8
Section 2.2.2.7 (GTFFMS) Mechanical System Design	9
Section 2.2.2.8 (GTFFPP) On-Base and External Piping Design	9
Section 2.2.2.9 (GTFFIT) Instrumentation and Test	10
Section 2.2.3 (GTET) Technology Validation	10
Section 2.2.3.1 (GTETNC) First-Stage Nozzle Design	10
Section 2.2.3.2 (GTETRS) Rotor Steam Transfer	11
Section 2.2.3.3 (GTETSE) Rotor-Bucket Steam Transfer Spoolie	11
Section 2.2.3.4 (GTETRH) Rotational Heat Transfer	12
Section 2.2.3.5 (GTETIH03) Surface Enhanced Internal Heat Transfer	12
Section 2.2.3.6 (GTETEH02/03) Surface Roughness and Combustor-Generated Flow Effects on Heat Transfer	13
Section 2.2.3.7 (GTETCP) LCF Coupon Tests	14
Section 2.2.3.8 (GTETSP) Steam Particulate Deposition	14
Section 2.2.4 (GTMT) Materials Technologies	15
Section 2.2.4.1 (GTMTSE) Steam Effects on Mechanical Properties	15
Section 2.2.4.2 (GTMTSO) Oxidation Due to Steam	16
Section 2.2.4.3 (GTMTCE) Corrosion Rate Evaluations of Airfoil Overlay Coatings	16
Section 2.2.4.4 (GTMTBV) Compressor Blades and Vanes Materials and Processes	17

Section 2.2.4.5 (GTMTVG) Compressor Variable Guide Vane System Design Support and Process Development.....	18
Section 2.2.4.6 (GTMTCS) Compressor Structural Materials and Processes	18
Section 2.2.4.7 (GTMTRF) Turbine Rotor Forging Materials and Processes	19
Section 2.2.4.8 (GTMTRS) Turbine Rotor Spoolies and Transfer Devices Materials and Processes.....	20
Section 2.2.4.9 (GTMTSB) Structural Bolting.....	21
Section 2.2.4.10 (GTMTTA) Turbine Airfoils Materials and Processes	21
Section 2.2.4.11 (GTMTCB) Combustion Materials and Processes	23
Section 2.2.4.12 (GTMTST) Turbine Structures Materials and Processes	24
Section 2.2.4.13 (GTMTSH) Turbine Shells	24
Section 2.2.4.14 (GTMTSR) Seal Technology	25
Section 2.2.4.15 (GTMTAR) Airfoil Repair	25
Section 2.2.5 (GTTT) Thermal Barrier Coating Technology	26
Section 2.2.5.1 (GTTTSD) Coating System Development.....	26
Section 2.2.5.2 (GTTTRR) TBC Risk Reduction	28
Section 2.2.5.3 (GTTTDD) TBC Design Data and Life Analyses	29
Section 2.3 (CC) Combined Cycle Integration.....	30
Section 2.3.1 (CCSD) Combined Cycle Systems Design.....	30
Section 2.3.2 (CCUA) Unit Accessories.....	31
Section 2.3.3 (CCCL) Controls.....	33
Section 2.3.4 (CCRA) Reliability, Availability, and Maintainability (RAM) Analysis	33
Section 2.4 (MF) Manufacturing Equipment and Tooling.....	34
Section 2.5 (IG) Integrated Gasification and Biomass Fuel.....	34
Section 2.6 (DE) Pre-Commercial Demonstration.....	35
Section 2.7 (PM) Program Management	35

Section 1 Executive Summary

The overall objective of the Advanced Turbine System (ATS) Phase 3 Cooperative Agreement between GE and the U.S. Department of Energy (DOE) is the development of the GE 7H and 9H combined cycle power systems. The major effort will be expended on detailed design. Validation of critical components and technologies will be performed including: hot gas path component testing, sub-scale compressor testing, steam purity test trials, and rotational heat transfer confirmation testing. Processes will be developed to support the manufacture of the first system, which will be sited and operated in Phase 4. Technology enhancements that are not required for the first machine design but will be critical for future ATS advances in performance, reliability, and costs will be initiated. Long-term tests of materials to confirm design life predictions will continue.

This report summarizes work accomplished during the period 1Q96. The most significant accomplishments are listed below:

- Engineering design releases for all stages of 9H compressor airfoils were issued.
- 7H compressor aerodynamic design work was begun.
- 9H compressor discharge case, inlet case, and midframe design reviews were held.
- The first piece of the 9H compressor rig airfoils was delivered.
- 9H compressor rig raw material purchase orders were released.
- 7H/9H preliminary turbine rotor forging dimensions and tool steel requirements were released.
- The 9H midsection design was frozen.
- The 9H midspan compressor case casting drawing was issued.
- The 9H inlet case casting drawing was issued.
- Key 9H design reviews were held: first- and second-stage bucket, second-stage nozzle, steam delivery system piping, and combustion test stand.
- Letters of Intent were issued to vendors for the following 9H components: forward compressor stub shaft, aft compressor stub shaft, compressor discharge case, and compressor rotor wheels.
- Analysis of the 9H cooling-air cooling system for possible elimination of the boost compressor was completed.
- The 9H first-, second-, and third-stage nozzle Engineering Design Releases (EDR) were issued.
- The second-stage nozzle steam piping mock-up was received.
- The 9H compressor discharge case casting drawing was completed and issued.
- The 9H inlet plenum flow test at Nuovo Pignone was completed.
- The 9H second-stage bucket design review was completed.

- The 7H compressor rig design review was completed.
- The 7H hot flowpath component EDR release dates were established.
- The 9H first- and third-stage bucket EDRs were released.
- The 9H first-stage bucket casting was completed for the design of experiments.
- The 9H compressor discharge case diffuser casting drawing was issued.
- The 7H/9H maintenance/field service review was completed.
- The 9H Airflow Nozzle Cascade facility at GEAE was upgraded.
- A supplemental table for the ATS Phase 3 NEPA Topical Report providing the quantitative information necessary for DOE to issue the Phase 3 NEPA Comprehensive Exclusion was submitted.
- The Phase 4 NEPA "generic" Environmental Information Volume (EIV) was prepared and submitted.
- The ATS Phase 3 Program Plan was prepared and submitted.

Section 2 Technical Progress Reports

Section 2.1 (NE) NEPA

Objective

A draft topical report will be prepared which provides the environmental information associated with Phase 3, Technology Readiness Testing, as specified in the National Environmental Policy Act (NEPA). DOE will use this information to prepare the NEPA documentation for Phase 3. DOE will review the report and advise the participant of the acceptability of the report or the need for additional information. A final report will then be submitted.

A second draft topical report will be prepared which provides the environmental information associated with Phase 4, Pre-Commercial Demonstration, as specified in NEPA. DOE will use this information to prepare the NEPA documentation for Phase 4. DOE will review the report and advise the participant of the acceptability of the report or the need for additional information. A final report will then be submitted.

Technical Progress

At DOE's request a supplemental table was submitted for the ATS Phase 3 NEPA Topical Report. This table summarizes process feedstocks used and environmental releases from ATS Phase 3 Program test activities for all sites. Quantitative information necessary for DOE to issue the Phase 3 NEPA Comprehensive Exclusion was provided.

The Phase 4 topical NEPA report, the "generic" Environmental Information Volume (EIV), was prepared and submitted. The technical basis for the report is the 7H Base

Reference Plant. After review by DOE, the report was resubmitted after proprietary data were removed.

Work Planned for Next Report Period

The "generic" EIV is complete. After a site is selected, the "site specific" EIV will begin. The date has not been determined at this point.

Section 2.2 (GT) Gas Turbine Design

Section 2.2.1 (GTAD) Aerodynamic Design

Objective

To achieve ATS performance goals, a four-stage turbine will be designed. Advanced aerodynamic technology (sometimes called 3D aerodynamics) pioneered at GE Aircraft Engines will be applied to each stage to maximize performance and meet mechanical design requirements required by steam cooling technology.

The 7H (60 Hz) and 9H turbines (50 Hz) have similar flow paths and a common rotor, but require different aerodynamic designs. Performance requirements for the 7H turbine aerodynamics are the same as the 9H.

Technical Progress

Mechanical design continues to be supported for studies involving heat transfer calculations and performance-related issues. A complete review of the turbine performance has been initiated that takes into account all the current cycle, cavity, and cooling flows, and mechanical deviations that make up the final turbine definition.

Work Planned for Next Report Period

Work has begun on optimizing the 7H gas path and performance estimates. Several aerodynamic issues are being investigated concurrently so that work may progress smoothly during the design phase.

Section 2.2.2 (GTFF) Gas Turbine Flange-to-Flange Design

Section 2.2.2.1 (GTFFCP) Compressor Design

Objective

Mechanical design of the 7H and 9H compressor rotor and stator structure will be performed with the goal of achieving lower cost and greater durability by applying proven GE Power Generation heavy-duty design practices. The designs will be based on the GEAE CF6-80 compressor. Transient and steady-state thermomechanical stress analysis will be performed to ensure compliance with GEPG life standards. Drawings will be prepared for forgings, castings, machining, and instrumentation for full speed, no load tests of the first unit.

Technical Progress

Drawings for most components of the 9H compressor that initiate component manufacture are complete. The large casing casting drawings for the inlet frame compressor case and compressor discharge case (CDC) are complete. Casting patterns will be reviewed at the supplier in early 2Q96 to assure that design intent is achieved before committing the casings to metal.

Rotor forging drawings are complete for the 9H compressor, and manufacturing is progressing on schedule. Blade electronic data releases are complete.

The 7H preliminary aerodynamic design is complete with flowpath and airfoil definitions. This preliminary design included redesigning stages 0, 1, and 2 and stages 15, 16, and 17 from the 9H compressor design, with the remaining stages directly scaled from the 9H compressor design.

The final design review for the 9H compressor sub-scale rig program was completed in preparation for initiating testing in 4Q96. No issues were identified. Routine follow-on actions were identified and are being completed.

The 9H sub-scale compressor rig hardware is being manufactured. Some airfoils (rotors 6, 7, 8, 12, 16, 17, and 18) have been received and are being instrumented in preparation for rotor assembly.

Work Planned for Next Report Period

Vane electronic data releases will be completed. Remaining hardware drawings to be released in this period include the diffusers, variable guide vanes (VGV) system, and inner barrel. Mechanical analysis of 7H stages 0, 1, 2, 15, 16, and 17 to evaluate blade and vane aeromechanics will be completed. The dovetail on rotor 0 will be analyzed to ascertain that the blade will not induce unacceptably high stresses on rotor 0.

Section 2.2.2.2 (GTFFCB) Combustor Design

Objective

A combustor will be designed based on the commercial DLN2 combustion system, with modifications made for improved use of available air, reduced cooling, and greater load turndown capability. This design will be similar for both the 7H and 9H machines. It will be configured to ensure the ability to use preheated fuel. Rig testing of full-scale and scaled components will be conducted at 7H and 9H cycle conditions. The final configuration will be validated in single-combustor, full-scale tests under full operating conditions.

The premixer-burner design will be optimized to use minimum pressure drop, achieve required fuel/air mixing, maintain stable flame, and resist flashback. The basic design will be developed and evaluated in full-scale single burner tests and then implemented in full-scale combustors. The ability to meet high cycle fatigue (HCF) life goals depends on understanding the effects and interrelationships of all combustion parameters. Existing

dynamics models used in parallel with laboratory-scale and full-scale testing will be used to predict combustor dynamic behavior.

Chamber arrangement, casings, cap and liner assemblies, flame detectors, and spark plugs will be designed and analyzed to ensure adequate cooling, mechanical life, and aerodynamic performance. Fuel nozzles will be designed for operation on gas alone or on gas with distillate as a backup fuel. The transition piece will be designed and integrated with the design of the machine mid-section, transition duct cooling, and mounting.

A full-scale, single-combustor test stand will be designed and fabricated to verify performance of the combustion system. Facility modifications will be made to support the test. These include installation of the test stand, installation of high-temperature stainless steel air piping, an additional air heater, control systems, upgrades to the combustion video system, and tooling.

Technical Progress

Design and design review of the test stand pressure vessel were completed. Pressure vessel fabrication was ordered. Specification of test stand performance requirements to enable the start of internals design (e.g., nozzle box, nozzle bars, baffles, inlet profiler, and profile measurement) was completed. GEAE test stand support facilities procurement and installation were begun.

A design freeze was placed on the 9H and 7H midsection major interfaces, thereby allowing component design to proceed.

Transition piece body fabrication was completed for cold flow testing. A flow model of a 3-passage radial diffuser was received, and instrumentation was completed in preparation for flow testing.

Conceptual design of the transition piece/first-stage nozzle seals and seal arrangement was completed. This allows release of the nozzle casting; detailed design of the seals is done more efficiently at a later time.

Work Planned for Next Report Period

Flow testing, stress analysis, and design of the 9H transition piece will be completed. The design for fabrication of development pieces will be released. The design of development hardware and combustion testing of various concepts using the Power Generation Engineering (PGE) laboratories will be started. Instrumentation and fired testing evaluation of the radial diffuser design will be completed. The cold flow test of the scaled 3-passage radial diffuser model will be completed. The design of initial concepts for full speed no load (FSNL) combustion will be completed.

Section 2.2.2.3 (GTFFTR) Turbine Rotor Design

Objective

The turbine rotor components (wheels, spacers, aft shaft, transition discs, coolant systems, and fastening devices) will be designed. Transient and steady-state stress analyses will be

used to calculate parts lives. Rotor and system vibratory characteristics will be evaluated. The coolant flow circuit for routing the cooling steam to and from buckets will be designed and performance calculated. Test results will be incorporated concurrently. Drawings and specifications will be developed in preparation for manufacturing.

Technical Progress

The wheel rim dovetails have been sized for the bucket weights and sizes that are anticipated. Wheel sizes were determined in sufficient detail to allow forging sizes to be established.

The concept for the flange where the turbine rotor meets the compressor rotor has been revised to allow improved rotor balance. The concept for the aft shaft has been revised to reduce thermal stress.

Preliminary steam pressure drops have been established for the steam supply circuit through the rotor.

Work Planned for Next Report Period

Initial transient heat transfer analysis for the rotor structure will be completed. The details of the steam delivery circuit concept will be defined.

Section 2.2.2.4 (GTFFTB) Turbine Bucket Design

Objective

Buckets for the four rotating stages will be designed. The heat transfer and material databases for steam-cooled first- and second-stage buckets continue to expand and will be integrated concurrently with the design. Cooling passages will be sized consistently with manufacturing practicalities and the bucket life requirements. Flow variation and consistency will affect life calculations and will be considered. Current practices for thermomechanical steady-state and transient analyses, dynamics and vibration analysis (which can deal with anisotropy), and corrosion/oxidation analysis will be applied throughout. Drawings and specifications will be developed in preparation for manufacturing.

Technical Progress

No progress was made on the 7H turbine buckets during this reporting period.

Detailed design proceeded on all four stages of buckets for the 9H turbine. The first- and third-stage bucket modal analyses were completed, and natural frequencies were predicted. Design reviews of the first- and third-stage buckets were completed. CAD models of these two buckets were completed and released to initiate production of tooling to make bucket castings.

Work Planned for Next Report Period

The modal and life analyses will be completed for the second-stage bucket. A CAD model of the second-stage bucket will be completed and released to initiate production of tooling to make second-stage bucket castings. Modal and tip shroud bending analyses will be completed for the fourth-stage bucket. A CAD model of the fourth-stage bucket will be completed and released to initiate production of tooling to make fourth-stage bucket castings.

Section 2.2.2.5 (GTFFTS) Turbine Stator Design**Objective**

The inner and outer turbine shells will be designed, including a turbine stator cooling system to provide rotor/stator clearance control. A closed circuit coolant delivery and return system for the turbine flow path stator components will be designed. Component, sub-assembly, and assembly flow tests will be incorporated concurrently. Implications for handling equipment (crane and manipulators) will be included in design considerations.

Steam-cooled turbine nozzles will be designed. Thermomechanical transient and steady-state analyses will be performed to determine parts lives. Material, manufacturing, and heat transfer database expansion is planned and will be integrated concurrently.

Shrouds will be designed. Sealing systems will be selected for minimum leakage. Thermal and structural analysis of equiaxed or anisotropic materials will be applied as appropriate.

Calculations will be made of all flow in the cooling systems, including leakage flows, to support performance, thrust balance, and component temperature calculations.

Design of hot-gas-path seals will be based on laboratory tests. Seals developed for transition-piece-to-nozzle segment and intersegment interfaces will be evaluated in cascade tests. Both sealing and wear performance will be assessed. Manufacturing drawings and specifications will be produced.

Technical Progress

The second-stage steam delivery system preliminary design was completed, and in-depth technical design reviews were completed on detailed concepts for all four stages of turbine stator airfoil castings, the first-stage inner and outer shrouds, and the turbine internal steam delivery system. These design reviews were held with experts from GEPG, GEAE, and CRD to ensure that all of GE's relevant expertise is applied to making designs that will help achieve the cost, durability, efficiency, and emissions goals for the ATS machine.

Work Planned for Next Report Period

The detailed design work on the turbine 7H flowpath aerodynamic definition will begin, and the initial iteration of stator airfoils will be completed.

Section 2.2.2.6 (GTFFST) Structures Design

Objective

The exhaust frame, steam box, and aft bearing housing will be designed. Instrumentation and test plans for component model, factory, and field testing will be prepared.

Technical Progress

Exhaust Frame and Diffuser

The CAD 3D solid model of the exhaust frame and forward diffuser has been completed. Detailed fabrication and casting drawings, based on this model, have been started. Following meetings with Greenville manufacturing personnel, a vendor has been selected to produce the exhaust frame.

Steam Gland

A revised CAD 3D solid model of the steam gland has been completed. Floating seal design, including leakage and mechanical analysis, based on the new steam supply conditions has been completed. Steady state 2D axisymmetric finite element analysis (FEA) is also complete. Transient startup and shutdown analysis using a 2D axisymmetric finite element model (FEM) is progressing.

#2 Bearing

Initial mechanical design of supports and bolting is complete. A 2D steady state analysis has also been completed to evaluate the structural integrity of the housing under dynamic loading (i.e., shipping and blade out). Flow analysis of the oil and air seals is complete.

Work Planned for Next Report Period

Exhaust Frame and Diffuser

Structural, thermal, and cooling flow analyses of the exhaust frame will continue. Fabrication and casting drawings are scheduled for completion. An inner barrel mock-up will be constructed and sent to personnel in Greenville to develop accessibility and maintainability methods. A field test of a 9F unit with tapered exhaust frame struts for acoustic noise reduction will be completed.

Steam Gland

Transient startup and shutdown conditions will be analyzed for mechanical effects. A 3D finite element model will be created to evaluate the effect of non-symmetric features on stress and distortion. A computational fluid dynamics (CFD) analysis of the steam inlet scroll will be performed to confirm pressure drop calculations for the steam supply entering the rotor cooling circuit.

#2 Bearing

Work will continue on the heat load being added to the bearing due to steam supply through the rotor bore. A detailed 3D FEM of the bearing housing will be built for detailed dynamic/emergency stress analysis.

Section 2.2.2.7 (GTFFMS) Mechanical System Design

Objective

System level studies will be performed to optimize cost and performance. Performance, cost, weight, and other system level integration issues will be monitored and tracked. A flange-to-flange cross-section drawing will be maintained, and all mechanical interfaces will be controlled. All gas turbine systems, as well as the technical requirements for accessories, will be defined and specified.

Technical Progress

System level studies continue to be performed to optimize cost, performance, weight, size, maintainability, reliability, and manufacturability. Performance, cost, weight, and other system level and integration issues are being monitored and tracked. The systems review team, which includes engineering, manufacturing, sourcing, and maintainability personnel, continue to meet to review system issues.

A maintainability, reliability, and serviceability team has been established and is working full time to ensure that all of the "lessons learned" for field operation are being incorporated into the Advanced Machine. Team meetings have been held with all groups associated with maintainability, reliability, and serviceability to review the design as it progresses to ensure that the design will meet requirements. This team is also in the process of procuring full- and partial-scale mock-ups of critical sections of the machine to ensure that the assembly and maintainability issues are resolved prior to hardware procurement. Purchase orders have been placed for many of the components with deliveries expected to begin by the end of April 1996. These mock-ups will also be used to design and fabricate assembly and maintainability tooling as well as to develop assembly procedures.

Another team has been established to design, fabricate and/or procure all of the "on-base" equipment for the unit. The "on-base" equipment is defined as the equipment that will be in and/or around the turbine enclosure that is not plant specific. This includes piping, valves, controllers, instrumentation, etc. This team meets weekly. They have started the designs.

The mechanical interface drawing, which includes the internal and external mechanical interfaces, continues to be updated and modified as the design progresses toward hardware. This cross-checking and updating will ensure that when the machine is in hardware, all interfaces are compatible.

Section 2.2.2.8 (GTFFPP) On-Base and External Piping Design

Objective

Piping will be designed for fuel, air, steam, and oil transfer.

Technical Progress

Development of conceptual designs for piping systems continued. System requirements were defined.

Work Planned for Next Report Period

Systems requirements will continue to be addressed and reviewed. Work on conceptual piping designs will continue. Conceptual turbine base and foundation interface design will be started.

Section 2.2.2.9 (GTFFIT) Instrumentation and Test**Objective**

Test plans will be formulated and instrumentation will be specified. Compressor and turbine rotor telemetry systems will be developed and acquired.

Technical Progress

Preliminary instrumentation and test plans have been identified and defined. Factory test facility modifications have been identified.

Work Planned for Next Report Period

Instrumentation requirements for factory and field tests will be defined fully.

Section 2.2.3 (GTET) Technology Validation

The overall objective of this task is to provide confirmation of critical component design and technology. The validations include hot gas path component testing, sub-scale compressor testing, steam purity test trials, and rotational heat transfer testing. Technology enhancements that are not required for the first machine design but will be critical for future ATS advances in performance, reliability, and costs will be conducted.

Section 2.2.3.1 (GTETNC) First-Stage Nozzle Design**Objective**

A full-scale sector of the first-stage nozzle will be operated at full engine conditions to demonstrate the validity of the design concept. Temperatures will be measured and any distress to the thermal barrier coating (TBC) will be quantified. The combustor exit conditions in the premix combustor mode will be characterized by testing. Internal cooling circuitry conditions and airfoil metal temperature distributions will be determined. Life-prediction models will be validated and low cycle fatigue (LCF) failure mechanisms will be characterized with LCF tests.

Technical Progress

There was no test activity associated with this task under the ATS Phase 3 Cooperative Agreement during the current reporting period.

Manufacturing effort on the heat transfer (metal temperature) and LCF nozzle cascades continued. Delivery of the heat transfer cascade to the test facility is expected during the first week of April. The work associated with coating the nozzle airfoils is nearing completion. The airfoils will then be assembled in the cascade mounting fixture with the end pieces. Final measurements will be taken, and the entire assembly will be shipped.

Completion of the manufacturing effort on the LCF nozzle cascade is currently projected for July, with tests scheduled to begin before the end of the month.

Work Planned for Next Report Period.

Preparation for the heat transfer cascade tests, including mounting the cascade in the test stand, instrumentation lead termination, and system and mechanical checkouts are expected to be completed by the middle of May. A 100-hour duration test will then be run to provide information on nozzle cooling system performance and metal temperature distribution. Manufacturing of the LCF cascade will continue and should be completed by the end of June.

Section 2.2.3.2 (GTETRS) Rotor Steam Transfer

Objective

For stable cooling of the turbine buckets, static flow tests will be conducted to validate the steam flows in the circuit to and from the buckets, through the rotor. These will establish flow losses for the unique components in the steam delivery circuit

Technical Progress

There was no activity associated with this task under the ATS Phase 3 Cooperative Agreement during the current reporting period.

Work Planned for Next Report Period.

Work will be initiated at the appropriate point in turbine rotor design, i.e., when the test rig configuration is set and specimens are provided.

Section 2.2.3.3 (GTETSE) Rotor-Bucket Steam Transfer Spoolie

Objective

Rotating air test rig tests will be completed to validate the steam transfer spoolie design concept (Spoolies are the hollow, spool-shaped ducts that bridge the gap between the steam delivery channels in the turbine rotor and cooling channels in the buckets). A stationary steam test rig will be used for evaluation of durability and alignment effects on leakage.

Technical Progress

Work has continued on the latest phase of the rotating air test program for verifying the leakage performance of spoolies.

Progress continues to be made on this test program to define leakage characteristics of the spoolies. Fabrication of a heated enclosure to enable tests that provide information on thermal differential expansion of the components on leakage rate was completed.

Test activity to verify spoolie leakage characteristics associated with alignment and relative motion was continued. Previous results of durability testing without side loads were acceptable for the coated spoolies; two different coatings were tested. Tests for one of the coatings have been completed with side loads, at two temperatures; the leakage rate results are acceptable.

Work Planned for Next Report Period

The rotating air test heated enclosure is complete and tests are about to start. Coating durability testing will continue through 2Q96, investigating interference, bore coating, bore base material, and an alternative coating.

Section 2.2.3.4 (GTETRH) Rotational Heat Transfer

Objective

Local heat transfer coefficients in a high aspect ratio rectangular duct will be measured in the Rotational Heat Transfer Test Rig. Turbulator geometries will be evaluated.

A limited database exists on the effect of rotation on heat transfer in turbine blade cooling passages. The objective of this task is to construct, install, and test a high aspect ratio cooling passage in a full-scale rotating test rig. A sub-scale test rig will be employed in parallel to evaluate alternate turbulator designs in order to identify the best configuration for subsequent evaluation in the full-scale test rig.

Technical Progress

There was no activity associated with this task under the ATS Phase 3 Cooperative Agreement during the current reporting period.

Work Planned for Next Report Period

Further effort to develop an alternate configuration for a duct of different aspect ratio will be resumed in April, after the Phase 2 activity is completed.

Section 2.2.3.5 (GTETIH03) Surface Enhanced Internal Heat Transfer

Objective

The objective of this task is to evaluate impingement heat transfer coefficient enhancements for validation and improvement of turbine airfoil design.

Tests of enhanced flat-plate surfaces with impingement at moderate pressure levels will be conducted for various impingement jet array parameters, providing both heat transfer performance and pressure loss data. Acrylic test models and liquid crystal techniques will be used to study those surface treatments that give the best performance.

Technical Progress

A rectangular test section with a specific turbulator configuration has been tested for pressure drop and heat transfer in two Reynolds number ranges. Preliminary analyses of the results from the lower Reynolds number range were completed.

Work Planned for Next Report Period

A rectangular test section with the second and third turbulator configurations will be tested for pressure drop and heat transfer over the appropriate Reynolds number range.

Section 2.2.3.6 (GTETE02/03) Surface Roughness and Combustor-Generated Flow Effects on Heat Transfer**Objective**

The ATS Turbine Nozzle Cascade test facility will be used to validate design data of external heat transfer coefficients on airfoils with surface roughness. The cascade will incorporate instrumented airfoils with flow conditions representative of the ATS first-stage nozzle geometry. The appropriate non-dimensional parameters for dynamic similarity will be made close to those of the engine first-stage nozzle. External heat transfer coefficient distributions will be measured through the use of embedded thermocouples, with a constant surface heat flux condition supplied by thin-foil heaters. Surface roughness elements of the appropriate size and distribution will be bonded onto the surface heaters. Data will include various roughness levels, distributions, and types in order to allow for the calibration of predictive methods. Characterization of surface roughness effects includes the interactive nature of roughness with fluid dynamic conditions such as acceleration.

The cascade will also be used to assess the effects of transition piece wake shedding on airfoil heat transfer.

Technical Progress

A method was developed to coat the ATS Turbine Nozzle Cascade airfoils to accurately model the surface roughness measured on the fully instrumented nozzle segments intended for testing in the Nozzle Cascade test rig at Evendale, Ohio. Heat transfer tests were then performed with airfoils having the desired roughness. These data will be used by design engineers to assess the heat loading for full-scale nozzle segments with extremely rough surfaces.

A test series was initiated to determine the effects of localized spall regions on airfoil external heat transfer. The first test model had a spalled region on the leading edge of the airfoil around the stagnation point. Tests were run with smooth and rough spall regions and a smooth airfoil. Suction and pressure side heat transfer effects due to the spalled region were measured and analyzed.

Additional tests were run to develop a more expeditious method of providing spallation steps.

Work Planned for Next Report Period

Tests will continue on modeled spalled regions at the leading edge and mid-chord locations on the pressure and suction sides.

Section 2.2.3.7 (GTETCP) LCF Coupon Tests**Objective**

LCF durability of TBCs for first-stage nozzles will be evaluated under simulated ATS conditions. Specimens will duplicate the alloy, coating, and principal mechanical features. Testing will be performed using the electron-beam High Thermal Gradient Test Facility. The facility will be modified for the use of steam as an alternative cooling medium for the coupons. The coupons will be geometrically representative of a section of the turbine first-stage nozzle airfoils. The test rig will be refitted for the new test piece geometry. Coupons will be instrumented for evaluation of the thermal conditions during testing. Tests will be performed to evaluate various TBC coatings as well as metal durability. Post-test evaluations of the TBC and metal will be performed.

Technical Progress

Emphasis on LCF testing has shifted from this task to the more immediate Phase 2 task of "LCF Life and Crack Propagation". Further work within the present LCF coupon task will take place after the Phase 2 efforts have been completed.

Depending on design testing priorities, installation of the remaining steam system hardware and safety reviews for operational specifications with steam will be scheduled.

Work Planned for Next Report Period

There is no planned activity for this period.

Section 2.2.3.8 (GTETSP) Steam Particulate Deposition**Objective**

Tests will be performed to verify the adequacy of the steam purity system. Long exposure at near-7H steam conditions will be used to evaluate performance of steam filters under various steady-state and transient conditions, verify power plant steam purity assumptions and deposition characteristics, and evaluate performance of steam delivery components. An additional objective of this task is to measure the rate and location of steam particulate deposition in bucket tip turns.

Technical Progress

A centrifugal deposition rig with two specimens at each end of a rotor arm that exposes them to the same G-fields as the coolant entry tip encounters in a steam-cooled ATS gas turbine second-stage bucket is being installed and separately reported on as part of the Phase 2 activities of this program. Since the installation of the rig is still in process on the Phase 2 task, there is no progress to report on exposures of the specimens.

Work Planned for Next Report Period

The centrifugal deposition rig will be made fully operational. The steam seals will be changed to reduce leakage, and a second improved sample will be acquired for turbulated specimen testing

Section 2.2.4 (GTMT) Materials Technologies**Section 2.2.4.1 (GTMTSE) Steam Effects on Mechanical Properties****Objective**

This task will be conducted to evaluate any effects on the operation in a steam environment of candidate turbine materials. Tests of materials that are exposed to steam will be performed to measure fatigue crack propagation, low cycle fatigue, and creep. Additional tests deemed necessary to meet design criteria will be performed. Comparisons will be made to data collected in air. Where necessary, the program will evaluate the roles of alternate heat treatments and/or surface treatments.

Technical Progress

New, higher temperature furnaces in two creep stations with steam capability have been installed. This will enable the evaluation of materials at higher values of Larson-Miller creep parameters (LMP) than previously possible. The first tests in these furnaces on airfoil materials have been successfully initiated.

Low cycle fatigue (LCF) testing of solid bar structural material specimens with various surface conditions has continued. Testing under load control of these specimens in steam is intended to reveal any effects of the conditioning parameters on fatigue crack initiation in steam. Since the last reporting period, two tests have been completed and a third is continuing.

Evaluation of material properties of a full-size prototype structural component in a steam environment is underway. Fatigue crack propagation (FCP) tests at three temperatures have been completed on material from five locations in the prototype part; three different specimen orientations were used. Sustained load crack propagation testing at one temperature and specimen orientation has also been completed on material from the same five locations. After testing, the microstructures were carefully evaluated in order to compile the material property results in conjunction with the microstructural data. This evaluation has been done for all completed crack propagation tests.

The effect of heat treatment on material properties in steam is being evaluated by conducting LCF and FCP tests on materials with various grain sizes and strengthening phase quantity and morphology. A small heat treat study was conducted to assess the grain growth behavior of a structural material. Grain sizes spanning an order of magnitude were achieved. FCP testing of another structural material heat that was treated to produce a large grain size and suppress strengthening phase precipitation was completed.

Additional low cycle fatigue testing of structural materials in steam has been completed. Two tests of hollow specimens were completed this reporting period, as was a notched LCF test.

Auger spectroscopy is being used to study the oxide and metallic layers which form during crack propagation tests in steam and in air. The oxides formed in the crack, as well as those on an unstressed region of the sample, have been quantified for five different materials that were tested in steam and for one that was tested in air. Differences have been noted in the oxide formed; the mechanism responsible for these differences is being investigated.

Work Planned for Next Reporting Period

Mechanical property testing and associated microstructural analyses of the full-size prototype structural component will continue. Testing for database completion of other materials will also be conducted. The Auger analysis of tested samples will continue for a complete understanding of the behavior of the materials in a steam environment. These analyses will be supplemented with scanning electron microscopy (SEM) if deemed necessary.

Section 2.2.4.2 (GTMTSO) Oxidation Due to Steam

Objective

Testing of ATS materials in steam will be performed to evaluate the long-term oxidation responses to this environment. Specimens will be subjected to steam exposure in an autoclave and removed at specified intervals for examination of oxidation characteristics.

Technical Progress

Definition of the next phase of testing has been completed. This phase will include very long-term steam oxidation exposure as well as samples containing repairs expected on field-serviced parts. The testing vendor was consulted, and specimen and equipment needs were finalized.

Work Planned for Next Reporting Period

Specimen machining and equipment fabrication for testing will be completed. The next phase of testing will begin.

Section 2.2.4.3 (GTMTCE) Corrosion Rate Evaluations of Airfoil Overlay Coatings

Objective

To evaluate the performance of ATS materials in potentially corrosive environments, various overlay coatings, and substrate materials, initial evaluations will be performed in small burner rigs with known contaminants. This will allow ranking of the corrosion rates of materials and coatings. Subsequent testing will be performed in facilities that better simulate gas turbine service conditions, including high gradients, for confirmation of burner rig results.

Technical Progress

Burner rig testing was run on airfoil material samples, with approximately 2100 hours accumulated in this reporting period. The test matrix of samples includes five different base metals and fourteen different coating combinations. The coatings used in this testing were applied by various techniques to evaluate the effects of processing variables on corrosion.

Work Planned for Next Reporting Period

Long-term burner rig corrosion testing will continue, with specimens accumulating additional test hours. Some specimens will be removed and metallographically examined and measured for corrosion penetration. Selected specimens will be submitted for electron microprobe evaluation to determine whether any compositional changes are occurring as a function of exposure.

Section 2.2.4.4 (GTMTBV) Compressor Blades and Vanes Materials and Processes**Objective**

Although material selections have been completed, this task will examine potentially less expensive materials for use in blades and vanes in the latter stages of the ATS compressor. These evaluations of alternate materials will be based on results of tests of mechanical properties, with emphasis on high cycle fatigue properties. For materials that have been selected, tests of critical properties will be conducted under ATS-specific conditions. Component tests of selected parts will be conducted for life verification purposes and establishment of final manufacturing parameters.

Technical Progress

Smooth bar high cycle fatigue (HCF) testing in air of three heats of the forward compressor blade material at the expected ATS operating conditions was completed. All of the material was processed to simulate what the ATS components will see, taking into consideration the critical parameters of design configuration, including size and cross-sectional thickness. These smooth bar results show that the proposed processing of this material will increase the HCF endurance limit above existing handbook data.

Material from three heats of a less expensive material for potential use in the latter stage has been machined into tensile, LCF, HCF, and creep specimens. The elevated temperature tensile tests and LCF testing at two temperatures were completed. The data were supplied to Design Engineering for evaluation. Creep specimens were loaded at three temperatures. Three short-term creep tests were completed; longer term testing continues.

Work Planned for Next Reporting Period

Smooth bar and notched bar HCF testing of the forward compressor blade material processed to simulate actual component manufacturing parameters will be completed. The smooth bar tests will be run in a salt environment to simulate potential operating conditions. The notched bar tests will be run in air. HCF testing of the less expensive latter-stage blade material is also expected to conclude next reporting period. The longer-

term creep testing will continue, with many tests expected to be completed by the end of 2Q96.

Section 2.2.4.5 (GTMTVG) Compressor Variable Guide Vane System Design Support and Process Development

Objective

Information to support selection of materials for the variable guide vane bushings and thrust washers will be gathered to support a robust and reliable design. Testing will be conducted to confirm materials selections, cover any parameters outside of existing data, and gather data for new materials.

Technical Progress

A number of materials with possible enhanced wear resistance for improved reliability over currently used bushing and washer materials were chosen for testing. A testing vendor was contacted to perform wear testing. A test matrix and material requirements were defined. Test material from one vendor was received.

Work Planned for Next Reporting Period

Material from an additional test vendor for wear testing will be received and testing will proceed. If test data warrants, additional discussions will be conducted with the material suppliers so that the processing parameters of promising new materials can be reviewed.

Section 2.2.4.6 (GTMTCS) Compressor Structural Materials and Processes

Objective

Mechanical and physical property tests will be performed on ATS compressor structural materials to provide an expanded mechanical and physical property database for design validation and enhancement. Material processing parameters for prototype manufacturing of the components will be selected based on design requirements and discussions with vendors. When necessary, material and processing specifications will be modified or new ones written.

Technical Progress

The ultrasonic testing specification for compressor rotor components was revised to take into account the unique configurations of the ATS compressor forgings. Changes were necessary to ensure design intent and adequate inspection coverage. The revision was sent to the component designers and the forging suppliers for review.

The mechanical test results completed on the compressor rotor materials in the last reporting period were reviewed with the component designers. The data showed that test results were favorable at the design conditions. Additional HCF testing was requested to expand the database for final design validation. A proposed test matrix was created and sent to the designers for review.

The metallurgical and processing review of the compressor discharge casing was completed. Weld nondestructive testing (NDT) requirements and post-weld heat treatment requirements to meet the design criteria were furnished. The component layout and manufacturing process parameters were reviewed with the casting supplier, and a manufacturing process plan for the component was developed. The material specification, general casting part requirements, and metallurgical acceptance criteria were identified for the compressor casing after review and discussion with the component designer. The drawing for this component was reviewed and signed as metallurgically acceptable.

Final material selection was made for the cast compressor discharge diffuser after a review of properties and producibility versus the design requirements. A process specification was then written for the part to define the requirements for casting, qualification, and production. The specification was sent to the design and manufacturing engineers for the components for review.

Work Planned for Next Reporting Period

The additional compressor rotor HCF testing plan will be finalized, and work will begin to machine the samples and initiate testing. Processing support will continue at the casting suppliers to ensure all quality and material requirements are met. HCF testing will be conducted on the compressor diffuser material for design validation, and the final process specification will be issued for the component after a review by the casting suppliers.

Section 2.2.4.7 (GTMTRF) Turbine Rotor Forging Materials and Processes

Objective

Processing parameters of forged large turbine rotor components will be optimized to achieve the desired forging attributes. These parameters include chemistry and processing temperatures as well as post-processing surface treatments. Sub-size and full-size forgings will be produced to verify and evaluate the processing approaches, and forging supplier process plans will be developed for all components. Forging acoustic properties will be determined by ultrasonic testing on test block and prototype parts. The attenuation, anisotropy, frequency bypass, and signal-to-noise ratio will be measured and used in fracture mechanics analyses to support rotor design. Optimized inspection methods, any necessary software, and scan plans will be developed based on the work with prototype parts. Property evaluations will be conducted to ensure that material behavior models used for design accurately reflect properties in parts made by the chosen manufacturing process.

Technical Progress

A method of analysis and a definition of the data required to evaluate a manufacturing operation on the turbine rotor components were established. Additional material property curves for tensile values and low cycle fatigue were assembled and distributed. Machining of samples and testing of the full-scale prototype forging continued. This testing is being conducted to supplement the properties already measured on this part in order to assure a

comprehensive assessment of a full-size part in an ATS forging configuration. Disk blanks were produced that will be tested to quantify the burst capability of the material. Low cycle fatigue testing using samples oriented in two different orientations were tested at two temperatures. Samples were supplied to the testing vendor for creep and notched rupture testing. These tests were initiated, and time at temperature has been accumulated. As test results are received, analyses are made to correlate the properties measured with the microstructure of the material to understand the effect of processing on properties.

Production of the turbine rotor forgings for the first machine has begun. Processing steps and progress were reviewed with the suppliers this reporting period to fully evaluate the parts and ensure quality. Tooling necessary for production was defined by working with the forging suppliers. A testing program definition for the first production part was completed. As production parts are made, property testing will be conducted to assure processing and property repeatability.

Melting and forging progress at an alternate supplier was reviewed. This supplier has melted three ingots and made one sub-size forging. The results are promising, but further work is needed before the supplier can become qualified. Plans for making a full-size forging were completed.

A study to evaluate the effect of heat treat time and temperature was completed to evaluate alternatives for future study to gain additional design margin. Three laboratory heats of material have been cast and forged so that the effect of heat treatment temperatures on the material can be studied.

Work Planned for Next Reporting Period

Work will continue to support the design analysis of manufacturing processes by conducting the necessary material tests. The final machining of the burst disks is expected to be completed, as well as all specimen machining of the full-size prototype forging, which will be tested to supplement the design data curves in order to obtain better statistical data. Testing planned for completion next reporting period includes tensile, fracture toughness, crack growth, and low cycle fatigue testing. The initial evaluations of properties and microstructure of the production forgings will begin, as well as processing of additional components; their progress will be monitored. Small-size compression tests will be performed to better understand the effects of processing variables on microstructure. The laboratory heats produced this reporting period will be heat treated to study parameter effects. Post-processing NDE techniques will be verified on both laboratory- and production-scale specimens.

Section 2.2.4.8 (GTMTRS) Turbine Rotor Spoolies and Transfer Devices Materials and Processes

Objective

Although material selections for the cooling system delivery systems have been completed, this task will perform testing to verify properties and identify potentially better materials.

Any applicable or needed coatings or joint materials will also be identified. Procedures for joining delivery components together and inspecting them will be evaluated.

Technical Progress

The manifold component layout was reviewed with three suppliers to receive their feedback on the producibility of the component. The tubing and joint designs were reviewed, and property curves over the expected operating parameters were supplied to the component designers.

Work Planned for Next Reporting Period

Work will begin with the manufacturers of the components to define the processing parameters and requirements for the steam delivery components. Preliminary process specifications will be written for these components.

Section 2.2.4.9 (GTMTSB) Structural Bolting**Objective**

Mechanical and physical property tests on high strength bolting materials will be conducted at ATS turbine conditions. If required, manufacturing trials will be conducted to optimize forming processes.

Technical Progress

Information was supplied to design engineers that supports additional design analysis of bolt relaxation. This information consisted of property curves based on existing handbook data and data generated recently. Bolt relaxation testing continues in order to obtain long-term test data on both high temperature and lower temperature bolt materials within the expected service operating temperature ranges. Over 2000 hours of test time were accumulated on the samples this reporting period.

Work Planned for Next Reporting Period

An additional heat of bolt material will be obtained. Specimens will be machined and added to the stress relaxation test program to enhance the statistical quality of the ongoing testing.

Section 2.2.4.10 (GTMTTA) Turbine Airfoils Materials and Processes**Objective**

Microstructure and mechanical properties will be evaluated for full-size castings processed in this program. A comprehensive program will yield final specifications with appropriate heat treatments, and will quantify the effects of ATS airfoil geometry and structure/property variability. Casting processes will be developed for all airfoils utilizing developmental casting trials. Critical nozzle and bucket long-term material properties will be measured at elevated temperatures. Metallic coating systems will be developed for

internal and external oxidation protection of the airfoils. Samples will be coated using various techniques for optimization studies and process verification.

Technical Progress

Specimens designed to accurately represent the actual component geometry factors and operating conditions of the first-stage airfoils were low cycle fatigue (LCF) tested; eight tests were completed. Some samples were tested to evaluate various finishing operations, while others contained intentionally produced defects to evaluate the effect that casting defects have on properties in airfoils with ATS configurations. A comprehensive test program was formulated to improve understanding of the effect of casting defects on LCF properties. The program scope was established, and discussions were held with casting vendors to define specific material and specimen needs for the program.

Work was completed on latter-stage bucket material processing. Creep tests are being conducted at two different temperatures and stress levels to analyze the properties from a latter-stage bucket casting. Results from this testing were compared to results from test slab material for correlation of actual component properties to handbook data. Creep evaluation was completed on a casting produced to study chemistry variations within specification limits. Six creep tests at three different temperatures (two tests at each temperature) were conducted to determine the effect by comparison to nominal chemistry creep data. This testing was conducted to finalize and optimize the alloy specification for the latter-stage buckets. Differential thermal analyses (DTA) for determination of the alloy transformation temperatures relative to nominal chemistry material were also completed. The DTA information will aid in setting heat treatment temperature limits. Microstructural evaluations of several samples of standard and non-standard material chemistries with various heat treatments were completed this quarter. This was done to determine the effect of heat treatment on the strengthening phase precipitates. Additionally, experiments were conducted to gain an improved understanding of the solidification behavior and process defect map for latter-stage bucket materials. Fourteen experimental castings were made at a range of cooling rates.

The work on developmental heat treatments for the second-stage bucket material progressed; 12 additional creep tests were loaded. Three different solution heat treatments are being studied to evaluate whether properties can be enhanced above current ATS-required levels. Six of the 24 total creep tests were completed. Comparison plots of the available data were constructed, and preliminary results show that an enhancement in creep properties may be possible. Three transverse tension tests, one per heat treatment, were also completed.

Casting processing trials on the first- and second-stage nozzle and first-stage bucket were conducted. Dimensional and metallurgical evaluations were conducted on the cast parts for feedback to the casting process optimization and tooling configuration layouts. Metallurgical acceptance criteria for the buckets and nozzles were defined and submitted to the casting suppliers. A part specification for the first-stage inner shroud was written and submitted for review to the casting suppliers and design and manufacturing engineers.

NDE techniques are being developed to allow comprehensive inspections of the unique ATS configurations. Trials were conducted on both manufactured samples and full-size parts to determine the feasibility of various techniques to optimize production part inspections. The methods being examined were reviewed with the casting suppliers for feedback on special considerations for a production environment.

The final batch of full-size buckets to be used to evaluate a number of candidate non-TBC coatings systems and application processes in the field were completed. These parts will be used to obtain performance information on the coating systems on full-size components and are using parameters down-selected from the previous laboratory-scale studies and tests. Laboratory oxidation testing on ATS material/coating combinations accumulated over 2000 hours of burner rig time. Overlay coating operations on additional strain-to-crack specimens to screen potential new coatings were completed.

Critical mechanical property testing of airfoil materials progressed, 22 additional long-time creep tests were completed on bucket and nozzle alloys at a variety of temperatures and stresses to cover a range of operating conditions expected for ATS turbine components. The effects of specimen orientation and service exposure are included in this test program.

Work Planned for Next Reporting Period

Microstructural evaluations of full-size parts produced in casting trials will be conducted for feedback into the process optimization. The LCF tests to evaluate finishing operations on airfoils will be completed, as will the baseline tests of casting defects. Microscopy will be performed on all tested samples. The program scope of the comprehensive casting defect testing plan will be finalized, and orders will be placed for samples. The latter-stage bucket solidification experiments will continue in order to determine the optimum process window. An etching procedure will be established to aid in that investigation as well as future component evaluations. The remaining creep tests to evaluate the effect of heat treatment on the second-stage bucket material will continue. The strain-to-crack specimens will continue receiving trial coating processes, and will be tested. Long-term burner rig oxidation testing will continue, and some specimens will be removed for metallographic evaluation of oxidation penetration. Additional casting trials will be conducted on airfoil components, and the components evaluated nondestructively as well as through cut-ups. Long-term creep testing will also continue.

Section 2.2.4.11 (GTMTCB) Combustion Materials and Processes

Objective

Properties of materials for combustion components will be evaluated at ATS conditions. Where necessary, trial components will be made in order to acquire material of the appropriate size using full-scale manufacturing processes.

Technical Progress

Four combustion liner wax patterns were successfully injected using existing prototype tooling. Two of the four patterns were cast to continue the evaluation of the

manufacturing processing for these parts. The potential for cost-savings on these parts is also being evaluated in these trials by casting on features that are typically welded on.

Work Planned for Next Reporting Period

One of the castings produced in the current reporting period will undergo destructive evaluation to determine the metallurgical quality of the component. The other casting will undergo manufacturing processing for evaluation of the component.

Section 2.2.4.12 (GTMTST) Turbine Structures Materials and Processes**Objective**

Producibility evaluations for the turbine structures will include selection of materials processing parameters and chemistry, and preparation of material and process specifications. Processing trials will be used to confirm producibility and verify capabilities of suppliers. Testing will be conducted where necessary to evaluate the materials under ATS conditions.

Technical Progress

Steam gland producibility was reviewed with a potential casting supplier. Material, part specification, and inspection requirements were reviewed. The qualification requirements were explained and discussed. The key chemistry limits for this component were identified and the supplier reviews were completed. The final material selection and weldability requirements were defined for the gib key and trunnion supports for exhaust end components.

Work Planned for Next Reporting Period

Final acceptance requirements will be set for the steam gland; applicable specifications will be revised or new ones written if needed. Producibility and final process selections will be made for the exhaust end components.

Section 2.2.4.13 (GTMTSH) Turbine Shells**Objective**

Materials and processes will be identified for the production of the turbine shells. Specifications will be produced after material property testing and process verification/optimization trials are conducted to achieve the best quality part to meet all design criteria.

Technical Progress

Updated material property curves were supplied to the design engineers to support their detailed design activities on the inner and outer turbine shells.

Work Planned for Next Reporting Period

Coefficient of friction/wear testing currently in progress will be completed to determine the material/coating combinations for inner shell attachment features. Additional testing to expand the database beyond current ATS conditions for joints and inner shell materials will be defined and initiated.

Section 2.2.4.14 (GTMTSR) Seal Technology**Objective**

Improved gas path seals will be developed for the ATS turbine using seal technology from aircraft engine components where applicable. The technology will be evaluated using developmental hardware and samples. These advanced seals will provide evolutionary advances in machine performance.

Technical Progress

Sealing techniques on developmental hardware were reviewed for robustness by performing both full-scale and coupon testing. Potential changes in processing parameters were identified for further investigation.

Work Planned for Next Reporting Period

Studies on processing parameter optimization for robustness will continue. Based on the outcomes of these studies, specifications for seals and sealing techniques will be written, and producibility reviews held with suppliers and manufacturers.

Section 2.2.4.15 (GTMTAR) Airfoil Repair**Objective**

Existing techniques will be evaluated and adapted for the material/geometry combinations unique to the ATS turbine airfoils to extend component life.

Technical Progress

Material for processing trials was received and submitted for machining of coupons. Machining parameters were identified to ensure that the samples would be representative of the component geometry and condition. The repair trial and test matrix for this phase of development were finalized and reviewed with management.

Work Planned for Next Reporting Period

Processing trials to define and optimize the processing parameters will begin. If initial trials are successful, the samples will be tested to determine the material properties in the repaired area and to guide further adaptation of the process development.

Section 2.2.5 (GTTT) Thermal Barrier Coating Technology

Section 2.2.5.1 (GTTTSD) Coating System Development

Objective

Plasma spray TBC coating processes will be developed for specific ATS combustion and turbine components. Both axisymmetric and non-axisymmetric plasma gun and part motions will be developed. The approach will be to conduct iterative spray trials using specimens, coupons attached to the part, and trials on the part. Coating evaluations will consist of metallography, property measurements, and thermal cycling exposure. Thick thermal barrier coatings will also be evaluated in rig tests and full-scale combustor tests. Improved process monitoring will be developed to increase process repeatability and control.

The TBC Manufacturing Technologies portion of the task will focus on integration and compatibility between TBC processing and other component manufacturing steps. Techniques to prepare components for spraying will be defined. Fixturing and masking will be developed. Surface finishing techniques will be developed for the first-stage bucket and first- and second-stage nozzles.

The TBC Process and Diagnostics portion of the task will focus on achieving a better fundamental understanding of the TBC application process. *Specific robot control algorithms and process conditions critical to the thickness and properties of the TBC system will be evaluated. Continuing work will focus on improving robot path planning accuracy and identifying Key Control Characteristics (KCCs) for the ceramic top coat and metallic bond coat. The KCCs will be those directly controllable aspects of the coating process which most strongly influence process variability and TBC quality.*

The TBC Nondestructive Evaluation (NDE) portion of the task will develop NDE techniques to measure attributes and properties of TBCs on turbine hardware that are relevant to manufacturing. The primary focus will be on development of methods to measure coating thickness.

Technical Progress

Surface velocity trials on simulated ATS turbine nozzles showed that the installed robotic equipment is not adequate for achieving the thickness transition control required by the design. As a result, and to improve control of top coat thickness for all airfoil components, specifications were written for improved robotic equipment. The equipment will be installed at the Schenectady (development) and Greenville (manufacturing) sites in September. Interim coating trials will be performed using similar equipment at GEAE. Testing on this equipment showed that the design requirements can be supported by the hardware upgrade.

* The italicized portion of this paragraph indicates a modification to the Objectives in 1Q96.

Development in 1995 identified significant limitations of the TBC process developed for airfoils when applied to Transition Pieces (TPs). An evolution of the TBC used on current production TPs will be developed as an alternative.

Testing in 1995 showed that the bond coat selected on the basis of TBC thermal cycling life will not provide suitable oxidation protection to the substrate metal in the event of local TBC spallation. Alternative bond coats were selected for evaluation and applied to samples for oxidation testing. Modeling methods for bond coat oxidation and creep developed in 1995 (Section 2.2.5.3) will be used to support the experimental evaluations.

An imaging pyrometry system was purchased to monitor part temperature during TBC application. Spray booth equivalency studies showed that one of the mass flow controllers used to regulate the secondary plasma gas provided inadequate control at the flow rates required for a high quality TBC process. A new mass flow controller that meets requirements was installed in the Schenectady cell.

TBC Manufacturing Technologies

Vibratory surface finishing trials were conducted using production buckets. The desired surface finish was not achieved uniformly over the coated surface. Alternate vibratory media process conditions and alternate surface finishing techniques were identified. A second set of buckets were coated for evaluation.

Evaluations of two techniques for in-process repair were initiated. The repairs will be evaluated using coupon tests and in a component rig test.

TBC Process and Diagnostics

Statistical analysis was completed for: gun angle, preheat temperature, deposition temperature, temperature gradient, powder feed rate, substrate thickness, sample preparation, and sample location. Analysis of the coatings included tensile, modulus, furnace cycle test (FCT), and thickness. The statistical analysis was designed to yield 95% confidence in the significance of the factors. An empirical model was developed for each result.

Experiments to evaluate the effect of spatial non-uniformities in the bond coat on TBC spallation life continued. Two sample sets prepared in separate coating runs exhibited markedly different FCT lives. In the as-processed state, the bond coat was not homogeneous across each sample. Visual examination of failed specimens revealed that TBC delamination in both sample sets occurred via a mixture of black and white fracture. The white regions corresponded to crack propagation through the zirconia top coat; the black regions represented cracking along the bond-coat/substrate interface. The transition between these fracture modes occurred at locations in which the bond coat was severely oxidized. It is not yet clear why the bond coats in both sample sets reached the same critical stage of oxidation after different exposure times.

TBC Nondestructive Evaluation

Optical measurements of coating thickness on flat and curved specimens were made with the use of a scanning microscope. These measurements will provide the reference thickness values needed to compare the capability of eddy current measurement methods.

Observations showed that the optical thickness measurement was very sensitive to both bondline and surface roughness. Additional material was ordered for building compound curvature specimens and to characterize variations in bond coat and substrate resistivity.

A Fischer instrument was received for evaluation of its capability to perform eddy current thickness measurements.

Work Planned for Next Reporting Period

A selection of the method of robot motion programming will be made following trials at GEAE. Preliminary screening of candidate bond coats will be completed. Optical thickness measurements on flat and curved specimens will be completed.

Section 2.2.5.2 (GTTTRR) TBC Risk Reduction

Objective

TBC durability will be evaluated under conditions very similar to the surface temperature, thermal gradient, and stress state of TBCs in ATS applications. An electron-beam rig capable of inducing high thermal gradients will be used to assess the relative durability of various TBCs, and the controlling mechanisms of TBC failure will be characterized. TBCs with a spectrum of microstructures will be tested to determine the role of TBC thickness on stress development and failure mode in high thermal gradient conditions, the failure modes of various TBCs of differing microstructures and deposition techniques, the role of number of cycles and hold times at high temperature on TBC failure mode, and the role of bond coat composition and roughness on TBC life and failure mode. The effects of environmental contaminants on TBC performance in high thermal gradient conditions will be investigated. Numerical modeling will be used to determine the stress, strain, and thermal gradient conditions in the various TBCs during the tests.

Technical Progress

A second TBC-coated sample with pre-deposited environmental contaminant was tested. During testing, the E-beam power level was increased incrementally until surface melting was observed. The sample was tested for 20 cycles at full conditions. E-beam power was controlled via surface temperature feedback, which was measured using an optical pyrometer. Due to changing surface emissivity during melting, E-beam power was not constant during the test. TBC spallation occurred during the test due to interaction between the environmental contaminant and the TBC. Subsequent tests will be conducted such that the E-beam power is controlled directly, which will give better control of the thermal gradient through the TBC.

One TBC-coated sample was tested under full ATS conditions for 100 hours. No observable change to the TBC occurred. Two additional samples will be tested in similar fashion. Four additional samples are being furnace aged to 50% and 75% of TBC life (as determined from FCT tests) prior to E-beam endurance testing. These tests will address TBC response to ATS conditions after various fractions of TBC life.

Work Planned for Next Reporting Period

The next environmental contaminant sample will be tested either in an E-beam power level control mode or using a bare TBC region for optical surface temperature measurement and control.

One or two additional un-aged TBC endurance samples will be tested.

Section 2.2.5.3 (GTTTDD) TBC Design Data and Life Analyses**Objective**

Thermomechanical failure modes in advanced TBCs will be identified, classified, and defined using empirical methods. Experiments will be performed to find key relationships among plasma spray processing variables, coating microstructure, coating physical and mechanical properties, and coating performance under simulated ATS conditions.

Numerical analyses will be performed to determine TBC stress states expected in ATS turbine components and in laboratory thermal cycling tests. The influence of the TBC stresses on TBC failure modes will be examined. Specially developed finite elements will be used for modeling the behavior of the interface cracks and free-edge stress singularities. The effects of bond coat roughness on TBC stress state, crack driving forces, and delamination failure will be examined. Parametric studies to determine the effects of bond coat and top coat properties on the TBC stress states will be performed.

*Evaluation of the spatial and run-to-run variability of TBC thermal conductivity will be performed. Improved understanding of this variability is essential because variations in TBC microstructure result in variations in TBC thermal conductivity that can be several times greater than the variations seen in metals. Various methods of measuring thermal diffusivity and conductivity on flat and curved samples will be evaluated. The gas pressure dependence of thermal conductivity as a function of temperature will be measured. The results will be used to estimate the thermal conductivity of TBCs at ATS conditions.**

Information from this task will be used as input to other tasks. Appropriate data and modeling results from parallel GE programs will be incorporated. Design guidelines will be developed for TBCs on ATS components. Ultimately, a TBC life analysis methodology and a life-predictive model will be developed. This will include effects of long-term exposure on top coat and bond coat physical and mechanical properties.

Technical Progress

Work on the thermomechanical testing and numerical analysis subtasks was temporarily suspended pending integration of the results of work performed in ATS Phase 2.

A survey of the literature on thermal conductivity (k) measurements of zirconia TBCs was performed. For coatings, k is determined using

* The italicized paragraph was added to the Objectives in 1Q96.

$$k = \kappa \rho C \quad (1)$$

where κ is thermal diffusivity, ρ is TBC density, and C is TBC specific heat. No methods for direct measurement of k for coatings were found. The direct measurement of k involves heat fluxes that are difficult to control and measure accurately; whereas measurement of thermal diffusivity consists of the accurate recording of the time dependence of temperature (T) due to a transient or periodic thermal perturbation. Laser flash thermal diffusivity measurements are most commonly performed. Indirect values of k from the laser flash method and direct k measurements agreed within experimental uncertainties for bulk zirconia materials over 300-1500K.

The thermal conductivity of a TBC varies modestly with temperature, but temperature variations may be ignored for rough comparison of values. From the literature, values of thermal conductivity (in W/m-K) for 7-8 wt.% YSZ are 2.4 to 2.9 for single crystal or polycrystalline fully dense solids; whereas for TBCs, the values are in the range 0.8 to 1.7, depending on microstructure and porosity.

A proposal was submitted to the High Temperature Materials Laboratory of ORNL to carry out a study of the effects of gas pressure and type on the thermal conductivity of TBCs using their laser flash equipment. This work will be conducted using free-standing coatings (substrate removed by chemical etching). Evaluations of methods to directly and indirectly measure the thermal conductivity of TBCs on substrates were initiated.

Work Planned for Next Reporting Period

Initial measurements of thermal conductivity on planar samples will be completed to evaluate spatial and sample-to-sample variability and the effect of inert gases at one atmosphere vs. vacuum.

The effects of different gases on TBC thermal conductivity at ATS temperatures and pressures will be modeled.

Section 2.3 (CC) Combined Cycle Integration

Section 2.3.1 (CCSD) Combined Cycle Systems Design

Objective

Optimization analyses will be performed and the combined cycle system will be configured to optimize cost/performance characteristics of the total plant. Steady-state modeling will be used to calculate the detailed plant performance. Dynamic modeling of load change sequences (e.g., startup and load rejection) will be used to specify control system design. Operability will be assessed.

Technical Progress

Conceptual design of the fuel heating system and cooling-air cooling system has resulted in optimized configurations for each based on operability and cost/performance evaluation. The integrated steady state performance model (SSPM) and the thermal dynamic simulation (TDS) have been updated to include these optimized subsystems. The SSPM is

in checkout and is nearing release for preparation of part load and non-ISO ambient condition performance data.

Steam turbine functional requirements, including design pressures, have been released for the 109H 2x33.5 last-stage bucket configuration.

The preliminary TDS process model is nearly complete for the 109H configuration. Initial runs of hot, warm, and cold starts and normal shutdown have been made. Simulation output is being evaluated for continued refinements of control logic and algorithms.

Work Planned for Next Reporting Period

Simulation data will be released for general design purposes. The 109H HRSG functional requirements will be released. The 7H gas turbine cycle deck will be updated and incorporated with an updated steam bottoming cycle model into the first major update of the 107H reference plant SSPM. Conceptual designs for the 109H fuel heating system, cooling-air cooling system, and clearance control system will be released for detailed design.

Section 2.3.2 (CCUA) Unit Accessories

Objective

Four new accessory systems will be designed: the gas fuel heating system, the cooling-air cooling system, the clearance control system, and the gas turbine steam cooling system. Design of the heat exchanger and piping for the hot fuel will take into consideration the need to avoid coking. Deposit formation will be investigated. The effectiveness of coke barrier coatings, which have been under development for liquid-fueled systems, will be evaluated in long-term tests. Designs of remaining accessories will be conventional.

Technical Progress

Cooling-Air Cooling (CAC) System

Several design configurations had been developed for the CAC system which had been narrowed down to two remaining configurations at the end of 4Q1995. Continued performance study and cost analysis have indicated that one of these configurations is more favorable. Detailed development of the system components and piping is now underway for the chosen configuration. A preliminary piping arrangement was established in order to analyze the overall pressure drop throughout the entire system. Results of this analysis will aid in determining the design of the system components and determining whether it will be necessary to add a pump.

Fuel Heating System

Continued analysis of the fuel heating system in conjunction with analysis of the cooling-air cooling system has resulted in separation of the fuel heating system and the cooling-air cooling system into two independent systems. This separation results in higher efficiency for each system, which increases the overall combined cycle efficiency. Separation of the two systems will also make it easy to eliminate the fuel heating system from the scope of

supply for a non-gas-fuel-operating machine. The several design configurations under consideration for the fuel heating system have been narrowed down to one basic configuration in which the component design must now be refined in order to develop a system that fulfills design requirements.

Exhaust Diffuser

Based on preliminary analysis in 4Q95, a commitment has been made to design an exhaust diffuser that will realize an increased pressure recovery of 3.0 in. H₂O above the pressure recovery achieved on the GE 7FA/9FA Gas Turbine exhaust diffusers, and thus will contribute to higher combined cycle efficiency. More detailed CFD analysis will be conducted in 1996 to refine a diffuser flowpath that will achieve this increased pressure recovery goal.

Preliminary structural design work has begun. The structural design of the exhaust diffuser and expansion joint(s) will be a totally new design. The new design will not be based on the FA diffuser design because of the structural problems that the FA diffuser and expansion joint(s) have experienced due to thermal stress and vibration. To date, three new conceptual designs have been developed and are under review for preliminary structural analysis.

Work Planned for Next Reporting Period

Cooling-Air Cooling System

During 1Q96, the design of the cooling-air cooling system configuration was finalized and a preliminary piping analysis completed. During 2Q96, development and definition of the system components and their design requirements/characteristics will be conducted. With these component characteristics defined, a more detailed piping analysis will be possible. Development of the system components shall include any changes in system requirements imposed by the gas turbine during 1Q96. In 2Q96, the engineering design team will develop and release a preliminary electrical schematic for the cooling-air cooling system.

Fuel Heating System

During 1Q96, the design of the fuel heating system configuration was finalized as it became a separate system and was no longer part of the cooling-air cooling system. During 2Q96, development and definition of the system components and their design requirements/characteristics will be conducted. In 2Q96, the engineering design team will develop and release a preliminary electrical schematic for the fuel heating system.

Clearance Control System

The conceptual design/schematic of the clearance control system will be under review. The intent is to develop an improved system design that will result in a higher combined cycle efficiency than the current system design. Once this design is complete, the system components will be defined. The engineering design team will also develop and release a preliminary electrical schematic for the clearance control system.

Steam Cooling System

The filters and filter vessel for the steam cooling system will be reviewed for the best size/shape/orientation necessary to meet the requirements of the gas turbine and also accommodate an efficient plant arrangement. Under review will be the system components (the filter vessel, piping, valves, flow meter, etc.) and their location, that is, whether they should be located on a single skid, or in line with the piping. By the end of 2Q96, the engineering design team will develop and release a preliminary electrical schematic for the steam cooling system.

Exhaust System

In light of structural problems experienced in the field with existing gas turbines exhaust systems, a task force has been established to develop a new exhaust system design for the advanced machine that will not be based on existing designs. Several conceptual designs that have been developed will receive extensive analytical analysis for review by the task force and a senior review board for selection of the best exhaust system design for the advanced machine. The gas turbine design requirements for the exhaust system will be submitted to the Exhaust System Task Force, as well as any acoustic design requirements.

Section 2.3.3 (CCCL) Controls

Objectives

An integrated plant control system will be developed and designed that will be suitable for the advanced gas turbine combined cycle power plant. Specifications of control equipment requirements will be prepared. Control and protection strategies will be developed for gas turbine steam cooling and integration with the steam turbine and HRSG. Control system dynamic behaviors will be studied by dynamic simulations. Specifications of control algorithms will be prepared for implementation in the control system program.

Technical Progress

The specification for general equipment and functional requirements of the control system has been completed. This begins the development of the integrated plant control system. The preliminary control system models of the gas turbine, steam turbine, and HRSG have been completed.

Work Planned for Next Reporting Period

In the next reporting period, the documentation for the control system models will be completed. Software definition will begin. A graphics philosophy will be established for use in the configuration of operator displays.

Section 2.3.4 (CCRA) Reliability, Availability, and Maintainability (RAM) Analysis

Objective

An evaluation of the reliability, availability, and maintainability (RAM) of the 7H equipment will be performed. The basis for the work will be the EPRI High Reliability

Controls and Accessories Study. The RAM analysis will include: the flange-to-flange gas turbine, heat recovery steam generator, steam turbine, controls and accessories, electrical generator, and balance of plant equipment. A failure modes and effects analysis (FMEA) will be included.

Technical Progress

There was no activity associated with this task under the ATS Phase 3 program during the current reporting period.

Work Planned for Next Reporting Period

Although this task was not scheduled to begin until January of 1997, elements of this task may start in the next reporting period. This will enable preliminary results to influence the gas turbine and system design at an earlier time.

Section 2.4 (MF) Manufacturing Equipment and Tooling

Objective

The materials, equipment, tooling, and processes required to produce the 7H and 9H turbines will be identified. Manufacturing schedules will be established to support ATS pre-commercial demonstration goals. Manufacturing procurement schedules and cost will be defined.

Technical Progress

During this quarter further development of the forging process proceeded, a visit to the forging supplier was made, quotes for the forging dies were received, and a Letter of Intent for the tooling order was issued to allow procurement of tool steel. Authorizations were received and procurements initiated for specialized ultrasonic equipment for the rotor forgings and upgraded robotic control equipment for the TBC coater in Greenville.

Work Planned for Next Report Period

During 2Q96, orders will be placed for fabrication of a mock-up of the CDC/inner shell portion of the gas turbine enhanced transition piece seal design, assembly procedures, and steam pipe layout; rotor-forging dies will be made; and agreement will be reached on tooling required for assembly of the inner shell with steam-cooled components and piping.

Section 2.5 (IG) Integrated Gasification and Biomass Fuel

Objective

An assessment of the ATS will be performed as part of an efficient and environmentally compatible integrated gasification combined cycle (IGCC) power generation system. Modifications to the gas turbine to accommodate the high mass flow resulting from the low heating value fuel gas and nitrogen injection for low NO_x emissions will be identified. Analyses will be performed to optimize the integration of the steam cycle with one oxygen-blown entrained flow gasifier and gas cleanup system and integration of the gas

turbine with the air separation unit. IGCC system performance will be analyzed for one coal composition at ISO ambient air conditions.

Technical Progress

There was no activity associated with this task under the ATS Phase 3 program during the current reporting period.

Work Planned for Next Report Period

There is no planned activity for this period.

Section 2.6 (DE) Pre-Commercial Demonstration**Objective**

A commercial proposal will be prepared and submitted to the host utility.

Technical Progress

Two commercial offerings were submitted to potential domestic host utilities. A combination of unclear deregulation outlook, high reserve margins, and the ability to purchase low bulk power have delayed the approval to proceed.

Work Planned for Next Report Period

GE will continue to support the potential host utilities' technical and commercial evaluations.

The third Utility Advisory Board (UAB) meeting to update members on the status of Advanced Machine performance, operability, maintainability, reliability, availability, plant arrangements, and installed cost is scheduled for 10 April 1996.

Section 2.7 (PM) Program Management**Objective**

Within GEPG Engineering, an ATS Program Office will be established and a Program Manager and a Contract Administrator will be assigned. The Program Manager will direct the overall activities of the Program Office, and will have responsibility for reporting to DOE and ensuring that the program goals are achieved. The Program Office is responsible for communicating contract requirements, authorizing applied labor and expenses for material and services, scheduling, monitoring, and reporting cost and technical performance. Additional responsibilities include coordinating ATS activities with CRD and GEAE. The assigned Contract Administrator will support the Program Manager in all administrative matters. All materials and equipment acquisitions will be closely monitored by the Program Office with support from the Finance and Sourcing organizations.

Planned scope, schedule, and budget will be tracked against plan. An integrated program plan will be maintained, including a detailed Work Breakdown Structure, that accurately describes the planned work, reflecting all changes in work scope or schedule. The

integrated program plan includes the implementation and coordination of all program support procedures and initiatives such as Target Costing, Key Quality, and Design for Manufacturing.

Reports will be prepared to serve both DOE and GE needs for oversight and monitoring, including quarterly reports, annual reports, and topical reports. A final report will be prepared at the completion of the cooperative agreement. Reports specified in the Cooperative Agreements Financial Assistance Reporting Requirements Checklist will be supplied. Technical papers will be submitted for presentation to professional society meetings. Open communications will be maintained with DOE and the Industry Advisory Board.

Based on work in Phase 3, a Continuation Application will be prepared and submitted to DOE incorporating the details for the proposed Pre-commercial Demonstration including the host utility site selection, permitting, environmental factors, fuel characteristics, utilization plans, and plant arrangement constraints.

Technical Progress

The Draft Phase 4 NEPA "generic" EIV was submitted. The first monthly Federal Assistance Program/Project Status Report (F4600.6) and the Financial Status Report (Form 269) were prepared and submitted. Amendment 001 to the Cooperative Agreement was approved, amending the amount of the initial government obligated funding amount. The Draft Program Plan for the ATS Phase 3 Program was prepared and submitted. A letter containing site information for potential host utilities for the ATS Phase 4 pre-commercial demonstration was submitted. The first quarterly Federal Assistance Management Summary Report (F 46500.5) was prepared and submitted. This submittal employed a progress-measuring process based on a ratio of the milestones successfully completed to-date to the milestones planned to-date for each task. Amendment 002 to the Cooperative Agreement was executed, making editorial corrections to the statement of cooperative agreement objectives and incorporating an Advance Waiver of Patents Rights Clause.

Work Planned for Next Reporting Period

GE will prepare for and host the DOE visit to GEPG for the ATS Program Review.