Utility Advanced Turbine System (ATS) Technology Readiness Testing and Pre-Commercial Demonstration - Phase 3

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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 initial report summarizes work accomplished during the period 3Q95. The most significant accomplishments reported include:

- Overall design continued, progressing from preliminary and conceptual design activities to detailed design activities.
- The aerodynamic design of six out of eight 9H turbine airfoils was completed.
- The 9H compressor design concept was finalized including:
 - rotor configuration
 - aerodynamic design of compressor
 - compressor structure
- Conceptual on-base and external piping layout was begun.
- The ATS Phase 3 Cooperative Agreement was negotiated and signed.

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

This report covers the "pre-award period". No effort was expended on this activity during this reporting period.

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

The turbine gas path has been developed to produce the work required for both 7H and 9H machines. Such a design challenge requires sophisticated technology in the blading design in order to achieve high performance. This challenge has been met, and the gas path (and blading) designs achieve optimum performance with little compromise.

The four-stage turbine incorporates state-of-the-art aircraft engine aerodynamic technology. The turbine vortex design has contributed significantly to higher performance and helped reduce risk in meeting overall design goals. To date, 6 out of 8 airfoil-blade rows for the 9H machine have completed aerodynamic design. It is anticipated that within the next reporting period, the 9H aerodynamic design will be complete and the 7H begun.

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 (GEPG) heavy-duty design practices. The designs will be based on the GE Aircraft Engines (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

During this reporting period, the 9H compressor design concept was finalized to prepare for drawing definition and release to Manufacturing of long lead time material such as case castings and rotor forgings. Progress on major components is summarized as follows:

Rotor:

The overall rotor configuration, consisting of a forward spool, individual compressor wheels, and an aft shaft was finalized. Two sets of bolts are used to achieve a high rotor stiffness. The aft rotor is cooled to control the disk thermal response and to ensure that the rotor assembly remains clamped at all operating conditions. Cooling system details such as flow amounts, flow temperatures, and cooling system geometry have been established for most of the components. All compressor rotor materials have been identified and meet mechanical design requirements. Rotor forging drawings will be prepared for release to Manufacturing during 4Q95.

Airfoils:

The Advanced Machine compressor is based on a scaled CF6-80C2 compressor with modified aerodynamics and mechanical design of the forward and rear stage blades and vanes to meet flow requirements. Minor modifications and improvements have been made to mid-stages to tailor the compressor application to Power Generation requirements. The aerodynamic design of the compressor was completed during this reporting period. Mechanical design of the blades and vanes was initiated in 3Q95 and will continue into early 1996.

Structures:

The compressor structures concept was defined during this reporting period. It includes inlet aerodynamic definition and diffuser aerodynamic definition. All interfaces of the structures to mating components have been defined. Completion of the conceptual design will allow detailed design to progress in 4Q95. Casting releases for the inlet case, compressor case, and compressor discharge casing (CDC) are expected to occur late in 4Q95.

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

Effort during the current reporting period was expended on the Phase 2 Preliminary Design Task, and technical progress was included in Phase 2 reports.

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

Effort during the current reporting period was expended on the Phase 2 Preliminary Design Task and technical progress was included in Phase 2 reports.

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

Preliminary design of the 7H fourth-stage bucket has begun. The fourth-stage bucket is uncooled and will operate at metal temperatures close to the relative stage inlet temperature; hence the creep life of the bucket, for a given material, is dictated by airfoil size and shape. The preliminary considerations were bucket creep life, producibility, and weight.

Two design options were studied: a conventional tip shrouded design and an unshrouded design. The conventional tip shrouded design is a lower risk and is the preferred design.

Preliminary analysis indicates that the tip shroud bending stress will be similar to that calculated for other large, shrouded buckets if the number of buckets in the fourth stage is set at 98. An airfoil shape was developed for the conventional tip shrouded design. Preliminary life analysis of the bucket indicates that the design is feasible and should be continued.

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

Effort during the current reporting period was expended on the Phase 2 Preliminary Design Task, and technical progress was included in Phase 2 reports.

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

Effort during the current reporting period was expended on the Phase 2 Preliminary Design Task, and technical progress was included in Phase 2 reports.

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

During this reporting period, a number of system trade studies were conducted to evaluate system performance vs. cost. A formal system was developed to capture the various system issues and review them with a systems team to thoroughly investigate their merit.

System level studies have been performed to optimize cost, performance, weight, size, maintainability, reliability, and manufacturability. Performance, cost, weight, and the other system level and integration issues are being monitored and tracked. The data being tracked is used and reviewed by design engineering, manufacturing, and sourcing staffs.

A mechanical interface drawing of the engine cross section has been created and is continuously revised as the various engine component designs are updated. This drawing delineates each interface of the gas turbine, both internal and external, with respect to the axial and vertical location in both the hot and cold conditions. This drawing will be expanded to include the physical and mechanical details of each of these interfaces. Once issued and incorporated into the Design Manual, these interfaces will become controlled. Any revision will require the concurrence of all parties concerned and the issuance of a revised Design Manual. The internal interfaces will be maintained, controlled, and checked via a 2D layout. The external interfaces will be maintained in 3D, thus allowing accessory and balance of plant engineering to determine their interfaces in space. All of the "design point" technical requirements for accessory equipment have been defined, including the accessory requirements, and approved for inclusion in the Design Manual.

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

During this reporting period, conceptual piping layouts were begun for the fuel, air, steam, and oil transfer systems.

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. The necessary factory test facility modifications have been identified, and cost estimates for these modifications have begun.

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 initiated.

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

No test activity was associated with this task under the ATS Phase 3 program during the current reporting period; test effort was supported by the ATS Phase 2 program and is reported in accordance with the provisions of that program.

Fabrication of the Phase 2 pressure tap nozzle cascade was completed, and the cascade shipped to the GE Aircraft Engines component test facility in Evendale, OH, for installation and test. Progress continued in manufacturing of the Phase 3 metal temperature and LCF cascades that will be installed and tested in 4Q95 and into 1996.

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 program during the current reporting period.

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

Stationary tests in air at various temperatures were initiated to define the leakage rate/wear characteristics of coated and uncoated spoolies under conditions representing relative motion between the spoolies and their seats.

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

Alternate turbulator configurations have been evaluated for the moderate aspect ratio duct in the sub-scale test rig. A configuration of the same turbulator height as the original but at one-half the radial pitch has been completed.

Two more configurations remain to be evaluated. They will be evaluated in the sub-scale test rig in 4Q95.

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

Two test sections with different aspect ratios have been designed. Fabrication of the test sections continues. The flow loop from the compressor to the test cell has been completed. Thermocouples for instrumentation are being fabricated.

Construction, machining, and assembly of the test sections will be completed in 4Q95. Once the heaters arrive and test sections are completed, the copper test surfaces will be instrumented with thermocouples and strip heaters.

Section 2.2.3.6 (GTETEH02/03) 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 nondimensional 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

During this period, heat transfer tests were performed on an airfoil having distributed roughness, with transition piece blockage modeling elements closer to the airfoil leading edge than previously tested. Blockages were tested on both the pressure and suction sides of the airfoil. These tests provided design data for use in locating the nozzles relative to the combustor transition piece. Hot-film measurements were made to determine the inlet turbulence intensity level for each Reynolds number tested. Heat transfer tests were also performed to obtain the airfoil coefficients for distributed surface roughness with various turbulence intensity levels, but without transition piece blockage models.

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. The only progress during this period has been the preparation of the fast-acting steam valves. The valve system has been plumbed and is awaiting final hook-up.

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 simulates the G-fields at the coolant entry tip of 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.

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

During this reporting period, equipment installation or modifications were made at the testing facility at GE Corporate Research and Development (CRD) to enhance the testing capabilities. Two stepping motors were installed and aligned to provide periodic unloading of creep specimens. Check-out of the new set-up was achieved using a strain-gauged LCF specimen. The ability to measure crack length by in-situ compliance methods at elevated temperatures is being developed. Data collected by this method is being compared to crack lengths simultaneously determined by electrical potential drop. Testing of crack propagation properties of structural materials and gas path materials in steam was continued to further characterize and compare the crack propagation properties of various microstructures and chemistries. Additional low cycle fatigue testing both with and without hold time was initiated on gas path and structural materials. This includes notched, sustained peak low cycle fatigue (SPLCF) testing of structural materials. Creep testing continues in both air and steam to evaluate the effect on creep behavior of cast grain boundaries. Additional creep tests, both smooth and notched, of structural materials were initiated.

All specimens for this testing were machined by outside vendors under the direction of GEPG. A program for LCF testing of surface-treated structural materials was developed. The treatment on the first set of specimens for this program was found to be unsatisfactory. The samples are being re-machined to remove the treated surface layer and will be re-treated with more stringent controls. Auger analysis and transmission electron microscopy (TEM) were used to identify and characterize the complex surface layers on fracture surfaces of fatigue crack propagation specimens for evaluation of oxidation and mechanical response of materials in the steam environment.

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

Plans were made for the next series of tests. Data collected in previous tests were reviewed for this planning stage, and a matrix of materials was developed for the next series. This matrix consists of a large number of structural materials, hot gas path materials, materials with surface treatments, and joined (welded, brazed) materials. During 4Q95-1Q96, oxidation testing of samples of bend specimens and mechanical property samples will begin. The matrix defined the sample needs, and plans for acquiring the raw material and machined samples were initiated.

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

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

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

During this reporting period, HCF testing was initiated at stresses and temperatures specific to the ATS forward compressor stages. This testing was conducted in air

(subsequent tests will be in other environments) in both smooth and notched specimen conditions. Initial data were collected and analyzed. It was determined that increased sampling of data is required at a given test condition, to better understand observed results. This sampling will be initiated 4Q95. Evaluation of an alternate, less expensive material for use in the latter stages began during this reporting period. Tensile testing was completed on three heats of material. Additional testing on this material was planned and a matrix of types of tests and test conditions was agreed upon for initiation of sample machining during 4Q95.

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

During this reporting period, consultations were held with design engineering and material suppliers to select the prime materials for the major components in the variable guide vane system. Under the guidance of design engineers, a list of candidate materials for the bushings and washers to undergo wear testing was prepared. This list includes materials that are expected to have exceptional wear characteristics, and materials that offer a potential for cost savings and improved reliability over conventional bushing materials.

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

Cast compressor discharge casing material LCF testing was completed for the first material heat. Three temperatures and two A-ratios (i.e., conditions used to evaluate the effect of mean strain) were used in the test matrix to cover ATS conditions. All testing is being conducted under continuous cycling conditions. The second material heat for the same testing was acquired and sent to a vendor for specimen machining. Smooth high cycle fatigue specimens of compressor rotor material were machined, and testing was initiated from one material heat. The testing is being performed at one temperature and at

three mean stresses to develop a database for design use. The second material heat has been sectioned from a larger segment and was sent to a vendor for specimen machining. A low cycle fatigue testing program was planned for rotor material at two A-ratios and three temperatures to assess this mechanical behavior. Other variables will include position in the component, specimen orientation, and hold times at one A-ratio. The testing of the second material heat was initiated during this reporting period, and preliminary data were acquired and analyzed.

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

Process development activities concentrated on working closely with vendors to develop and optimize processing parameters for a full-size prototype forging. This involved review of the vendors' analyses and production of the full-size prototype part. Data were collected at each step of processing to ensure full understanding and to develop methods for improvement. The full-size part was produced and tested. Testing included standard testing that would be carried out on a production part as well as detailed ultrasonic testing. Data were collected and analyzed. Additionally, six lab heats (including two control heats) were successfully melted and rolled into bars for subsequent processing and testing to evaluate the effects of chemistry variations. The sectioning of the full-size part was initiated to measure properties at multiple locations. Notched specimen rupture testing of a heat of the turbine rotor material was completed. This material was acquired from sub-scale forgings produced from a full-size ingot. These data were combined with previously collected SPLCF data generated from the same heat and used in analyses for development of design life data. A formal test matrix was developed for the full-size prototype forging. Requests for quotes for machining of test specimens were sent to vendors, and quotes were received.

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

Discussions were held with vendors to evaluate processing limitations of various concepts for some components in the rotor cooling delivery system. These processing limitations will be used in determining the details of the design. Candidate wear-resistant coatings for spoolies were identified after a literature search and discussions with experts in the field to choose an appropriate coating that can be applied easily.

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

Long-term creep tests initiated in 1994 continued through this reporting period. The four tests in progress reached over 10,000 hours at three different temperatures. Additional specimens were machined, and relaxation tests were begun on one bolting material at three temperatures and three different initial strains. The data from these tests are being analyzed and evaluated as they are received. Machining and testing of tensile, thermal expansion, and dynamic modulus of elasticity specimens on a second ATS turbine bolting material candidate were completed. Specimens were machined, and relaxation tests were begun at three temperatures and four initial strains. The data being generated will be used to develop new design data curves.

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

In large castings, careful attention to microstructural details is necessary in analyzing mechanical test results and, ultimately, in improving casting performance. A number of tests were conducted to quantify and optimize prototype casting and airfoil materials. Dendrite arm spacings (DAS) were measured at various locations in several buckets and slabs of various ATS materials, and the results indicate reasonable consistency in the DAS of bucket castings for all alloys. Creep testing was initiated on specimens machined from one of the buckets. The results received to date compare favorably with previous results on slabs of the same material. Additional work was conducted to better understand the behavior and castability of latter-stage bucket alloys. Long-term aging of one slab was initiated to determine the extent of creep property degradation, if any. Other material is under investigation following mechanical deformation and heat treatment at various temperatures to determine the propensity for recrystallization at these temperatures. The recrystallization temperature will be defined on completion of the microstructural evaluation.

An experimental casting with chemistry modifications within specification was made at CRD. Some of the material has been sent out for machining and standard heat treatment. Subsequent creep testing will be conducted to determine the effect of the various element reductions on creep properties. Alternative heat treatments are also planned for this material to determine whether the reduction extends the heat treatment range. Work is also underway to improve the solution heat treatment of second-stage bucket material to enhance properties. Creep tests were conducted on several samples of the alloy with alternative heat treatments to determine the feasibility of the technique. Results of creep tests indicate a significantly longer time to 1% creep with the alternative heat treatment. Further heat treatment experiments are planned. Specimen preparation has been initiated.

Pressurized and non-pressurized LCF tests were initiated on tubular samples intentionally cast with defects in the gauge section to evaluate their effects in ATS alloys. Some defect-free specimens were also included for comparison. Several tests of each specimen type were conducted. Initial results have been collected and compared to solid bar design data. Microstructural and fractographic evaluation of the tested specimens was initiated.

Casting trials on the first- and second-stage nozzles and first-stage shrouds, using prototype tooling, were conducted at two candidate casting vendors. Plans were finalized for the next series of bucket casting trials. A program was developed and initiated to look at the effects of various methods of core manufacturing to improve quality.

Critical property measurements of ATS alloys at expected operating conditions continued. Creep-rupture and LCF tests were run on the first-stage airfoil material to analyze the effects of heat treatment, geometry, and coatings. LCF tests with hold times were initiated on the second-stage bucket alloy on both notched and smooth bar specimens to evaluate the fatigue notch sensitivity factor (q). The notched specimens had double side notches resembling a typical bucket dovetail geometry. Long-term creep tests continued during

this reporting period on latter-stage bucket alloys at three different temperature/stress conditions, and additional creep-rupture tests at two temperatures were initiated. These tests are evaluating various orientation and geometry effects to represent real component material conditions. LCF and creep tests were also conducted on samples with post-casting processing to evaluate any effects on properties.

Effort was expended in optimizing and improving the candidate processes for coating of ATS parts. This development is using trial parts that incorporate a number of different internal/external non-TBC coating configurations. These results will be coupled with laboratory data to establish the viability of the vapor phase coating processes for both internal and external coatings. Trials and qualifications of various coating techniques were initiated at two vendors to ensure process repeatability. A laboratory test for the candidate processes to establish strain-to-cracking as a function of temperature has been developed, and tests have been initiated to rank developmental coatings for cracking susceptibility. Long-term burner rig testing will be used to rank their oxidation resistance. Development of an organometallic aluminide coating continued. Studies of deposition as a function of pressure and temperature on small samples have identified the range of parameters over which uniform deposition of aluminum can occur. Long-term burner rig testing of coatings applied by various techniques continued.

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

Prototype tooling was completed to produce cast combustion liners. A new process/material combination will be examined for production of this component, and a prototype part is necessary to develop the needed properties.

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

Candidate materials were identified for turbine structures during this reporting period. This information and supporting materials properties were supplied to design engineers for their use.

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

A coefficient of friction testing matrix for components on the turbine shell system was identified during this reporting period. The matrix consists of five combinations of base materials, wear pads, and coatings. Raw material was received and machining on the base materials was completed. A vendor was identified for the coating and a request for quote was initiated. Fabrication options for producing the inner shell were reviewed and evaluated for design. A fabrication supplier was visited and all welding and fabrication related details were discussed. Processing options were reviewed. This discussion led to the identification of a trial program to develop the appropriate procedures and inspection techniques.

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

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

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

An extensive analysis was made of the current GE airfoil repair processes and their applicability to ATS components. A matrix was developed identifying where evaluations must be made to adapt the process parameters to meet the requirements for parts with ATS geometry and size.

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 process conditions critical to the properties of the TBC system will be evaluated. The initial work will focus on three major areas: 1) deposition temperature effects, 2) off-angle deposition, and 3) plasma gun velocity effects. The primary objective will be to identify critical process parameters as they apply to the coating of ATS components.

The TBC Non-destructive 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

The spray gun motion for a first-stage nozzle was developed. The basic spray gun motion developed in software was manually adjusted to produce the most uniform coating thickness. Two nozzles were coated with the best motion. The first nozzle had samples attached to the airfoil; the samples will be used to characterize the physical properties of the coating. The second nozzle is being sectioned for metallographic evaluation of the coating microstructure. After coating the nozzles for property evaluations, additional iterations on the motion program were made to further improve the uniformity of the coating thickness.

Spray gun motions for two styles of first-stage bucket were developed. GE production buckets were obtained for spray trials.

Development work for the transition piece (TP) continues. A series of samples coated at the anticipated deposition temperature are being evaluated. A second series of samples were coated at the leading candidate parameter sets to demonstrate reproducibility of the

coating process and provide the data for the final choice of spray parameter set. Development of the gun motion to coat the TP was started. Samples were coated in an actual TP to evaluate the properties of the coating that will be achieved. Gun motion development is continuing.

Initial discussions with a vendor concerning a test program to establish the process control window and optimal spray conditions for the vendor's TBC have taken place. Samples were machined and are being coated.

TBC Manufacturing Technologies:

Two software packages for gun motion definition and simulation have been obtained and are being evaluated.

Fixturing and masking for the TP were made. The post-application heat treatment for the TP was chosen, and samples were coated to determine the properties of the TBC at the chosen heat treatment. A vendor for the post-coating heat treatment was selected.

The program plan for developing a TBC finishing process was developed. The panel samples to be used in evaluating polishing procedures were sprayed and are being heat treated. Initial discussions with the polishing vendors have taken place. Additional airfoil components are being machined for use in vibratory polishing development.

TBC Process and Diagnostics:

Work to evaluate the effect of deposition temperature on coating properties continued. Front-face and back-face temperatures were measured during deposition. Methodologies that could be used to ensure consistency and repeatability when reading temperatures off both strip chart and videotape were developed.

Tensile testing for both plates and coupons was completed. Modulus of elasticity and furnace cycle tests (FCT) were completed for the coupon samples. Modulus and FCT tests of plate specimens are in progress.

Techniques for measuring the actual plasma gun velocities and variations in distance to the substrate over a complex geometry were developed. Experiments were performed using both an optical sensor and a laser device to determine actual speeds and distances during gun motion. Software was generated to analyze the data and compute velocity and displacement.

Experiments were performed to evaluate the effect of depositing the bond coat at a speed attainable for coating airfoils. Experiments to develop a top coat process for lower gun speeds will be initiated.

TBC Non-destructive Evaluation:

The coating of GE TBCs with a range of bond coat and top coat thicknesses will be performed in 4Q95.

An infrared (IR) radiometric system for thermal imaging of coated components was purchased by GE. An air line is being installed to cool the high temperature source for the thermal tests.

Eddy current probes were received. Commercially-available probes will be evaluated first, and a determination will be made of the need to fabricate custom-built probes. Several papers are being reviewed to provide guidance on probe selection.

A portable capacitance gauge was received. A capacitance probe is being designed for use in trials on the specimens being built for the eddy current thickness method testing.

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

Two sets of four "TBC limit testing" samples were machined to produce various stress levels at the TBC/bond-coat interface by control of the tophat face and wall thicknesses. Test coupons for properties characterization by tensile strength, elastic modulus, compression, and furnace cycle test were coated simultaneously.

The temperature and strain response of the sample to heat input was mapped in the Phase 2 "Validation" task. The map, which was obtained at temperatures suitable to preserve the low temperature back-face strain gauges, was used to predict the sample strain state at the elevated temperature ATS conditions.

Testing of the four TBC-coated tophats has begun. The first sample was tested at the "validation" conditions to confirm sample temperature and strain response to heat input for modeling purposes. The sample was then tested under ATS conditions.

The test sample has undergone approximately 1000 high temperature cycles.

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.

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

Stress Analysis of FCT Specimens and Bond Coat Roughness:

Finite Element Analyses of the FCT specimen were conducted. A full cycle was modeled. This analysis shows a mechanism that may cause the stress state seen in TBC experiments.

Finite Element Analyses of the FCT specimen will be conducted using bond coat steady-state creep properties. Creep properties of GE bond coats will be available in 1996.

A wavy interface model was developed for further stress analysis. The model includes the metal substrate, bond coat, oxide layer, and top coat.

Establishment of Experimental Matrix and Sample Preparation:

Test specimens were sprayed using two different bond coat chemistries. Before specimens were prepared for the long-term tests, various specimen preparation conditions were evaluated. A baseline set was sprayed using standard conditions, and additional sets were sprayed using non-standard conditions. The samples were examined metallographically.

Numbered first-stage airfoil material specimens were mounted on metal foil for application of bond coats and top coat. The complete sample matrix was air plasma sprayed (APS) at CRD. The coated specimens were heat treated and furnace cycling was begun. FCT tests and furnace exposure tests (FET) are underway. Other furnaces are being sought so that additional tests can be conducted simultaneously.

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

A gas turbine performance prediction program (i.e., cycle deck) has been used to prepare a model of the preliminary steam system. This model and models of the fuel heating and cooling-air cooling systems, generator, major mechanical auxiliaries, and unit control have been incorporated into a steady-state performance model (SSPM). This model has been used to predict performance and cycle parameters at specific load points over the operating range from full speed no load (FSNL) to base load and over the ambient temperature and pressure range.

The gas turbine characteristics and requirements have been used as the basis for the combined cycle system design. Steam conditions have been chosen to be suitable to the gas turbine and to the steam turbine and heat recovery steam generator (HRSG). A preliminary combined cycle system has been defined to provide adequate cooling steam to the gas turbine over the operating range, including startup and shutdown. The combined cycle system design provides features for ensuring purity of steam entering the gas turbine cooling system. These features include: 1) purification of cooling steam by evaporation in a steam drum, 2) high pressure steam temperature control by steam attemperation, 3) full flow filtration and demineralization of feedwater, 4) inerting of piping in the high pressure and cooling steam system during standby periods to prevent corrosion, 5) application of non-corrosive materials in piping, filters, and equipment downstream of the steam cooling system shutoff valves, 6) full flow filtration of steam before it enters the gas turbine.

Control and protective strategies are being developed in conjunction with development of the gas turbine.

Preliminary steam turbine and generator requirements have been prepared to allow initiation of preliminary design and cost estimation. A preliminary HRSG functional specification has been prepared and will be used to obtain supplier cost estimates and to further design discussions with potential suppliers. Preliminary functional specifications have been prepared for mechanical auxiliaries and major balance of plant equipment to estimate cost and physical characteristics. Preliminary piping data blocks have been prepared to estimate cost of piping.

Preliminary flow diagrams and an electrical one-line diagram have been prepared reflecting the status of the combined cycle system 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

Fuel Heating System:

To date, tests conducted at CRD have determined and continue to determine the make-up of the trace constituents and their effect on the gas turbine and fuel heating components. When complete, this information will be used in a written specification for the design of the cleanup equipment required. Investigation is also underway to determine what corrosive effects the gas fuel (when heated to 600°F) will have on the material used for the fuel heating system hardware. Preliminary specifications for the fuel heating system hardware (e.g., heat exchangers) have been based upon material selection recommended by the CRD test results. Further testing is planned to verify the efficiency of the filtration systems.

Cooling-Air Cooling System:

Currently several options have been developed for the cooling-air cooling system, some of which are in a combined circuit with the fuel heating system and operate at a lower pressure than the "non-combined" options. Preliminary specifications have been developed for each option in order to determine the system cost with suppliers and to develop the system component design. The system cost will then be balanced against a system performance study that is underway in order that the optimum system be chosen.

Steam Cooling System:

For the steam cooling system, a highly efficient prototype filtration system has been developed and is currently being tested at the Ocean State combined cycle power plant site. The intent of the test is to verify the efficiency of the filter and, if this is the level of efficiency required, measure the system performance and the longevity of the filtration system design. The filter is an integral part of the high steam purity system developed for the gas turbine. These results will be used to identify any areas of the system design requiring further refinement.

A plan has been established for the development of a more efficient exhaust diffuser design. Preliminary computational fluid dynamics (CFD) analysis and CRD model testing conducted on conceptual designs confirm that an exhaust diffuser design with an increased pressure recovery is possible. Based on this preliminary information, the plan established an expected pressure recovery increase and a stretch goal pressure recovery increase that would be based on the success of several new design features. Further analysis and testing will be conducted to develop an improved flowpath design that delivers the expected pressure recovery increase.

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 concept for an integrated control system has been formulated. Preparation of equipment specifications is in progress. Control and protection functions are being developed in parallel with the development of the advanced turbine.

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.

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 reporting period plans were made to place a coating machine in the Greenville plant. A physical layout was prepared and arrangements were made for a preheat chamber and non-destructive testing (NDT) facility as well as further modifications to the robot controls for the coater.

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.

Section 2.6 (DE) Pre-Commercial Demonstration

Objective

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

Technical Progress

Most of the activity during this reporting period supported technical and commercial evaluations of the potential host utilities. Steady-state models that incorporated the cycle deck, material heat balance (MHB), and appropriate accessory system modules were developed to support combined cycle performance evaluations over ambient and pressure ranges. Preliminary performance and emissions information was developed at site-specific conditions for several different power plant configurations (greenfield, repower, single and multi shaft).

A Utility Advisory Board (UAB) was established comprising representatives of major domestic utilities. The Board's role is to provide system level guidance on performance, operability, maintainability, reliability, availability, plant arrangements, and installed cost. The importance of operability, reliability, and availability was highlighted by the UAB's recommendation to establish a Controls Advisory Sub-Group and a Power Plant Advisory Sub-Group.

The Controls Advisory Sub-Group's initial meeting this quarter reviewed GE's Integrated Control System development program and control/protective functions. A Power Plant Advisory Sub-Group meeting with potential Engineering Constructors is scheduled for 1Q96. The second UAB meeting will be held in 2Q96 to continue the Board's guidance role, and to lay the foundation for the technical portion of the Phase 4 Demonstration Proposals.

Preliminary commercial discussions continued with several utility companies for siting the first unit under the ATS Phase 4 Program.

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

Program Management support continued in this reporting period. An Earned-Value-based tracking system was completed and fully implemented. This required a full re-plan and re-cost of the 7H and 9H programs. A process for bringing together the Quarterly Technical Reports was developed. Support of commercialization activities continued. Coordination of activities with CRD and GEAE continued.