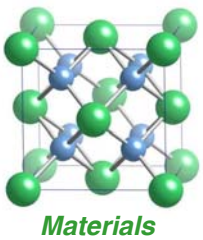
Distributed Energy Program

DE Quarterly Progress Report

For the Period

April 1, 2005 to June 30, 2005



OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

DE QUARTERLY PROGRESS REPORT

For the Period
April 1, 2005 to June 30, 2005

Prepared by:

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For:

Department of Energy
Office of Distributed Energy

SECTION 1. Advanced Natural Gas Recipricating Engine Development

Subtask 1.1 Rotating Arc Spark Plug RASP (PIC 466)

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Objective

Stable operation of an engine at extremely lean conditions depends upon the ability to consistently ignite the air and fuel mixture in the cylinder. The Rotating Arc Spark Plug (RASP) uses a magnetic field to rotate the spark, therby increasing the volume occupied by the spark during each event. The increased spark volume may improve ignition characteristics at lean conditions. The rotation may also result in improved wear and extend plug life.

Highlights

1. Multiple iterations of the Rotating Arc Spark Plug were evaluated in a small natural gas engine. No improvement in performance over either standard J-plugs or annular gap spark plugs was detected.
2. The results have been summarized and will be presented at the ASME Fall Conference in Ottawa in September. The final report has been submitted to the conference organizers as paper number ICEF2005-1293.

Technical Progress

In collaboration with Champion, a series of Rotating Arc Spark Plugs with multiple configurations and air gaps was developed. The first set of observations, using the stock Kohler ignition system, developed insight into the performance of the different RASP configurations and set the baseline for comparison with the optimized ignition system. The stock ignition system produced no rotation in the RASP so no difference in performance was observed.

A second ignition system was developed using an MSD Blaster high power inductance discharge unit. Using a Labview field programmable gate array board to control timing, a high current, long duration spark was produced. The spark plugs were thoroughly evaluated, and though there was significant improvement in the performance over the stock ignition system of all the plugs at lean conditions, no improvement could be seen in the RASP over the Standard J-plug or the annular gap plug with no magnet. The results have been summarized, were circulated to outside ignition experts for review, and will be presented in September. Based on the results to date and industry feedback we do not plan to aggressively pursue an additional RASP design at this time.

Status of Milestones

1. Complete evaluation of RASP using multiple ignition systems. Compare RASP to standard J-plug in small 2-cylinder natural gas engine. June 2005 – complete
2. Report results of RASP evaluation. June 2005 – complete. Final paper has been submitted and will be presented at the ASME Fall Conference in Ottawa, September 2005.

Industry Interactions

Industry and academia were given the opportunity to review the performance data of the RASP. The RASP concept has been patented so technology transfer can take place through a licensing agreement if our industry partners see value in continuing the RASP research.

Subtask 1.2 Spark Plug Erosion & Degradation Investigation (PIC690)

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Objective

Spark plug lifetimes in advanced natural gas engines are on the order of only 1000-4000 h, which result in loss of performance and necessitate frequent, costly downtime maintenance. Spark plug durability will become even more critical as future engines are pushed to leaner-burn conditions to reduce emissions. The goals of this effort are to gain insight into spark plug life- limiting wear processes, and to use this understanding to develop new electrode alloys to achieve lifetimes of ≥ 8000 h.

Highlights

To expand the database characterizing the spark plug erosion/failure process, plugs operating in two engines with EGR were examined. Differences between the EGR and non-EGR operation were found in the impurity quantities in the spectroscopic investigation. Metallurgical examination also indicated a significant difference in the cracking between these plugs and plugs previously characterized. The cause of the difference is not known and warrants investigation.

Technical Progress

The database characterizing spark plug erosion/failure characteristics has been expanded with the inclusion of two sets taken from engines with EGR system. Optical spectroscopic results showed that the plugs operating under EGR exhibited a reduction in calcium and oxygen and an increase in hydrogen intensity as compared with those plugs without EGR. The significance of these differences is being examined for better understanding the erosion/failure process of nature gas engine spark plugs.

A high-pressure (2500 psi) chamber capable of testing spark plugs at elevated temperatures (1200°F) has been designed and ordered. This chamber will allow the characterization of spark plugs under conditions not currently available in existing nature gas engines.

In collaboration with Federal Mogul (Champion), oxidation studies were conducted for a series of 95% Ni base and 80% Ni base commercial alloys as alternatives for currently used Ni-base electrode alloys. Based on insights gained, a model Ni-base alloy was delivered to Federal Mogul for manufacture into spark plug electrodes for engine testing. Laboratory gasoline engine testing at Federal Mogul reached 300 h for the 95% Ni base series spark plug electrodes, and will be compared with oxidation test results.

Status of Milestones

1. Characterize wear of currently used spark plugs as a function of time/ignition system, and engine exposure conditions to firmly establish key issues controlling wear in natural gas engines. Disseminate results in at least 1 open literature publication. Sept 2005 – on track
2. Manufacture electrodes from at least one new developmental alloy and evaluate and characterize under ignition conditions. Benchmark results compared to currently used Pt and Ir alloys. Sept. 2005 – on track.
3. Develop detailed database of spark plug erosion characteristics from spectroscopic and metallurgical measurements for modeling the erosion process. Dec. 2004 – completed.
4. Develop a detailed model of the erosion/failure process for NG engine spark plugs based on database results from above. Sept. 2005 – on track.
5. Develop an advanced test chamber to simulate spark plug wear under condition found in existing and future NG engines. June 2005 – on track

Industry Interactions

Conference calls and communications with Drs. Iryna Levina and Jim Lykowski at Federal Mogul (Champion) to discuss the engine testing of the spark plugs using ORNL developmental alloys.

Subtask 1.3 Adaptive Controls for Lean Burn Engines

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Objective

A drawback of lean-burn operation is that, under these conditions, combustion becomes increasingly unstable resulting in an increase in cycle-to-cycle variations. These instabilities are responsible for decreased engine performance, decreased fuel efficiency and increased emissions of unburned fuel and nitrogen oxides. The goal of this task is to maintain stable combustion using adaptive controls while extending the lean limit as much as possible. An adaptive control strategy reduces cycle-to-cycle combustion fluctuations in lean burn engines with active feedback control to make small, but precisely timed, perturbations to one or more engine parameters (e.g., quantity of injected fuel, ignition timing, valve timing).

Highlights

To address industry requests, we have developed a technique to estimate the fuel efficiency and emissions reduction benefits that may be achieved with application of adaptive control to a specific engine platform. Papers detailing the hybrid model used in the estimation technique have been accepted for the ASME ICE Division 2005 Fall Technical Conference (11-14 Sept 2005 in Ottawa, Canada) and the 2005 SAE Powertrain & Fluid Systems Conference and Exhibition (24-27 Oct 2005 in San Antonio, TX).

Technical Progress

Industry partners have frequently requested an estimate of the level of improvement adaptive control can provide for their particular engine application. To that end, we have developed an SI engine model based on commercially available and industry-accepted engine modeling software (WAVE from Ricardo, Inc.) coupled with an advanced two-zone combustion model that can be calibrated to model the behavior of a specific engine platform. Detailed engine geometry information and data collected during lean or high-EGR, stoichiometric operation is used to calibrate the model to accurately simulate the behavior of the specific engine. Specifically, the model is capable of accurately predicting the development and effects of combustion instabilities that occur in highly dilute combustion. Application of adaptive control to the model through a Matlab/Simulink interface allows direct estimation of the gains in fuel efficiency and emissions reduction achievable with adaptive control. Simulation of a Waukesha, single-cylinder, gasoline engine has been performed to validate the model and the estimation technique. We are currently pursuing collaborations with industry or university partners to provide the data necessary to apply the technique to an ARES engine.

Status of Milestones

1. Demonstrate technique for estimating potential benefits of adaptive control. June 2005 – Complete

Industry Interactions

1. Interacting with each engine manufacturer and other research labs (GTI, SWRI) to collect engine data under very lean conditions for analysis.

Subtask 1.4 NOx & NH3 Sensor Development (PIC 714, 639, 635)

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Objective

To develop non-catalytic and catalytically selective electrodes for use in NOx and ammonia sensors and to build and test sensors using the materials and technology developed

Technical Highlights

Most work was driven by need to identify alternative electrode/substrate combination, pursuant to observation that $La_{1-x}Sr_xCrO_3/Zr_{2-x}Y_xO_{2-\delta}$ sensing elements showed evidence of decomposition after long-term operation in the presence of NO_2 and H_2O. Two main alternatives were explored:

1. $La_{0.85}Sr_{0.15}CrO_3$ (LSC) electrodes on $Ce_{0.8}Gd_{0.2}O_{2-\delta}$ (GdC) substrates.
   a. Sensing elements using this materials combination could yield "total NO_x" sensing at 600°C. Results also show that the $[O_2]$ sensitivity is a decreasing function of $[NO_x]$, similar to the behavior of elements with LSC electrodes and $Zr_{2-x}Y_xO_{2-\delta}$ (YSZ) substrates.
   b. The DC resistance of this materials combination tended to increase with time. The changes in DC resistance due to the presence of NO, however, stayed relatively constant.
   c. No decomposition was observed after exposure to H_2O (g), NO_x, and electrical stimulus for ~100 hr. at 600°C.

2. $LaCr_{0.85}Mg_{0.15}O_3$ (LMC) electrodes on $Zr_{1.84}Y_{0.16}O_{2-\delta}$ (YSZ) substrates.
   a. This materials combination could not yield "total NO_x" sensing performance. Although the responses to NO and NO_2 were of the same algebraic sign, the response to NO_2 was greater in magnitude.
   b. The DC resistance of these sensing elements decreased slowly at 600°C under the condition of constant applied current (0.25 μA). Changes induced by NO (20–190 ppm) were constant over a period of 3 days.
   c. No decomposition was observed after exposure to H_2O (g), NO_x, and electrical stimulus for ~100 hr. at 600°C.

Status of Milestones

1. Determine kinetics of NO reaction on electrode as a function of temperature and environment.
   This is ongoing and will continue as new electrode materials are developed and tested as well as new sensor designs.

2. Fabricate and test a prototype NOx sensor (09/03)
   We are focusing on refining the NO and total NOx sensors. Testing of these sensors is ongoing.

Industry Interactions

1. Biweekly teleconference were initiated this quarter between DOE, Ford, LLNL, and ORNL.

Subtask 1.5 Emissions Characterization: Lube Oil/Catalysts Interactions

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Objective

ORNL and the Gas Technology Institute (GTI) seek to develop critically needed data that can be utilized by engine companies as well as catalyst and lube oil suppliers to meet the reliability and maintainability goals of catalyst systems that would be required for future ARES products. To achieve this, the mechanisms of catalyst failure will be fully investigated, and then applied to an engine-catalyst combination that can be demonstrated first on a pilot scale and then with long term field validation testing.

Highlights

An advisory committee, with representatives from the three ARES engine manufacturers, academia, a catalyst company, and a lubricant additives company was formed. The advisory team's role is to ensure that the project provides data that will enable the ARES program to meet its goals.

Technical Progress

1. In late April, a successful ARES Catalyst Workshop was held. Representatives from Miratech and DCL attended. Valuable discussions were held between ORNL, GTI and the catalyst companies during sidebar conversations.

2. At GTI, the single-cylinder research engine that will be used in Phase 1 and Phase 2 testing continues to be converted to spark ignition .Field aged catalysts suitable for Phase I of this project have been identified by Miratech and will be delivered to ORNL for post-mortem analysis after non-disclosure agreements have been signed

Status of Milestones

1. Characterize available aged NG catalysts for lube oil impact – Sept 2005. On track. (NDAs will need to be formalized before catalysts can be examined. Delays in these could delay milestone)
2. Conduct tests on a single cylinder engine measuring the impact of lube oil on catalysts – Sept 2005. On track.

Industry Interactions

The technical Advisory Committee has been formed with representatives from each ARES engine manufacturer, Miratech, Chevron Oronite, MIT, and University of Alabama agreeing to participate. A formal kick-off conference took place in which we established the needs for Non-Disclosure Agreements (NDAs) between ORNL and the industrial companies.

Subtask 1.6a Natural Lean Aftertreatment (PIC 687)

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Objective

The main objective of this project is to study lean NOx trap catalysis for emissions control from natural gas engines. Key emission control areas of interest include: NOx reduction efficiency, operational (fuel) penalty, and cost basis of lean NOx traps for ARES applications. The initial phases of the project involved testing of lean NOx trap catalysts on a bench flow reactor with encouraging results. Efforts shifted to the engine platform where a lean NOx trap catalyst system has been installed on a Cummins C8.3G natural gas engine.

In FY04, NOx reduction in engine exhaust was demonstrated. ARES program target emission levels of <0.1 g/bhp-hr NOx were demonstrated, and NOx reduction efficiencies of >90% were obtained with the lean NOx trap catalyst.

Highlights

1. In Q1FY05, the primary focus shifted to research and development of multiple technical issues related to the practical and cost-effective implementation of the lean NOx trap technology.

2. In Q3FY05, experiments characterizing the utilization of methane in natural gas for regeneration of the lean NOx trap catalyst were completed; results showed high levels (>10%) of H_2 produced from partial oxidation and reforming processes and consumption during lean NOx trap regeneration.

3. A paper has been submitted and accepted for the special ARES-ARICE session at the ASME Fall Technical Conference in Ottawa, Canada on September 11-14, 2005.

Technical Progress

- Completion of Methane Utilization Studies

  Experiments studying the utilization of methane in natural gas for lean NOx trap regeneration were conducted on the engine test platform. Exhaust species were characterized at positions in the catalyst system before and after oxidation, reformer, and lean NOx trap catalysts. An array of analytical equipment allowed full characterization of all species of interest in the methane process chemistry; analyzers included: paramagnetic O_2, NDIR CO, magnetic sector mass spectrometry (H_2), and FTIR (CH_4, etc.). Experiments were performed for different engine loads and regeneration air-to-fuel mixtures. Data has been analyzed, and results have been reported.

Status of Milestones

Characterize methane reforming and oxidation by products on the lean NOx trap on operating NG engines. June 2005 – complete.

Industry Interactions

ORNL hosted an ARES Catalyst Workshop on April 27-28, 1005 in Knoxville, Tennessee. The workshop provided valuable exchange of information related to natural gas reciprocating engine applications. A presentation on the lean NOx trap project was given, and a tour of the facilities at ORNL was given that included a demonstration of the lean NOx trap catalyst operating on a lean natural gas engine.

A teleconference between all active catalysis researchers in the ARES program was held on April 25, 2005 to discuss as a group issues related to catalysis in ARES applications. Participants included representatives from ORNL, Univ. of Maryland-College Park, PNNL, ANL, Ohio State Univ., Univ. of Tennessee, and West Virginia Univ.

Section 2. Materials Based Technology for Distributed Generation

Subtask 2.1.1 Advanced Alloys for High Temperature Recuperators

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Objective

The main objective is for ORNL to work with recuperator OEMs and commercial foil and sheet suppliers to test, evaluate, and enable recuperator manufacturing with alloys that have improved temperature capability and performance at a reasonable cost. The near term goal is meeting reliability goals of 40,000-80,000h at about 700°C, while the longer term goal is performance up to 750°C or higher, without sacrificing lifetime. Last year, ORNL began a collaborative project with Allegheny-Ludlum to produce a wide range of commercial sheets and foils of their new AL20-25+Nb stainless alloy, for properties characterization testing and recuperator manufacturing trials. Phase I of that project is complete, and Phase II continued this quarter to modify processing parameters to control microstructure to increase the creep-resistance of foils, and particularly sheet products. The FY2005 goal is to characterize properties and performance of recuperator air-cells manufactured from AL20-25+Nb alloy.

Highlights

Allegheny-Ludlum (AL) completed processing and delivery of various Phase I sheets and foils of AL20-25+Nb alloy to Ingersoll Rand and ORNL completed creep-rupture testing of those materials. Foils of AL20-25+Nb have good creep resistance at 700-750°C, much better than 347 steel. ORNL Microturbine Recuperator Test Facility began testing 4 mil foils of AL20-25+Nb this quarter. For Phase II, Allegheny-Ludlum sent 10 mil sheet to ORNL for creep testing and finished processing foils, some of which will be sent to Capstone Turbines.

Progress

ORNL began a collaborative program with Allegheny-Ludlum last year to produce a wide range of commercial sheets and foils of the new AL20-25+Nb alloy so that microturbine recuperator OEMs could manufacture prototype air-cells. Phase I of this project used the standard processing of this alloy, and produced materials with significantly better creep-rupture resistance at 700-750°C relative to 347 steel. Phase I material has been delivered to Ingersoll Rand Energy Systems for manufacturing testing and trials for the PowerWorks 250kW engine. ORNL and Allegheny-Ludlum have nearly completed the Phase II effort, to change the microstructure for enhanced creep-resistance of foils, and particularly sheets. Phase II 10 mil sheet production is complete, and material was sent to ORNL for creep, oxidation and microturbine probe testing. Phase II production of 5 and 3.2 mil foils, the latter to be sent to Capstone Turbines, is nearly complete.

Status of Milestones

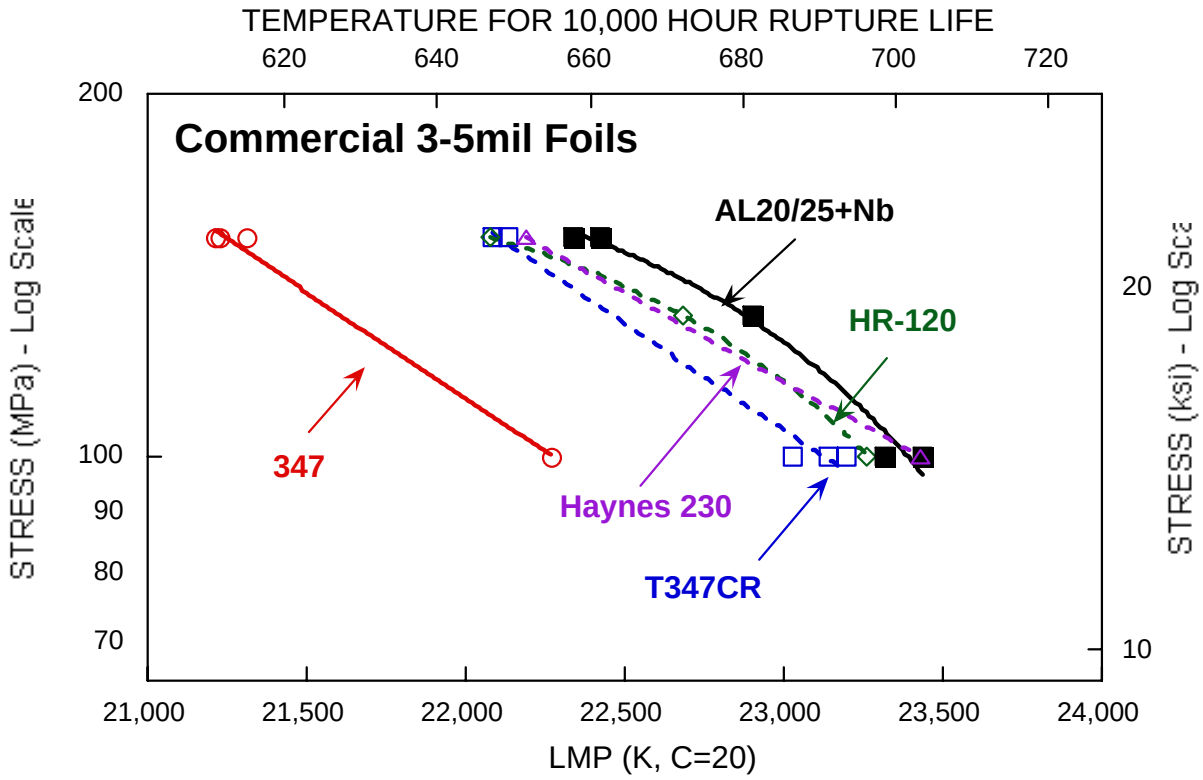
Complete mechanical testing and microstructural characterization of various foils and sheets of new AL20-25+Nb alloy and evaluate the effects of modified processing on creep resistance. Characterize trial air cells manufactured from AL20-25+Nb for engine testing.

March 2005 – Phase I creep testing is finished and microstructural characterization was completed. Air cell manufacturing trials are nearly finished at Ingersoll Rand Energy Systems. Milestone is on track to be completed by August-September, 2005.

Industry Interactions

1. ORNL communicates regularly with Allegheny-Ludlum Technical Center (Chuck Stinner) to provide

input, get feedback, share data and monitor progress of this project. ORNL also communicates as needed with Capstone Turbines, Inc. and Ingersoll Rand Energy Systems.



Subtask 2.1.2 Oxidation/Corrosion Characterization of High-Temperature Recuperator Alloys and Field Exposed Recuperators

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Objective

Commercially-available alloys for high temperature recuperators (650°C-750°C) to replace 347SS are being mechanically tested, microturbine engine- and laboratory-exposed (corrosion-tested) at ORNL as part of 3 separate Recuperator Materials Subtasks: 2.1.1 P.J. Maziasz "Advanced Alloys for High Temperature Recuperators," 2.1.3 B.A. Pint "Composition Optimization for Corrosion Resistance to High Temperature Exhaust Gas Environments," and E. Lara-Curzio "Recuperator Testing and Evaluation."

Microstructural characterization will play a critical role in understanding the corrosion/oxidation behavior of the different alloys in high H_2O-content (laboratory) and microturbine operating environments and will be used to determine the extent of oxidation of the alloy compositions, to identify the reaction products formed, and to evaluate changes in the base alloy microstructure accompanying long-term exposures.

Highlights

As part of an ongoing ORNL/industry collaborative recuperator project, Wendy Matthews from Capstone Turbines visited ORNL in June 2005 to conduct microstructural characterization of field-aged 347SS and alloy 120 recuperator foils.

Technical Progress

During the reporting period, extensive characterization has been conducted in collaboration with Capstone Turbines to evaluate and quantify the amount of degradation (oxidation) of several recuperators, which were field-tested in a Capstone microturbine for extended periods. This study was conducted to compare the oxidation-resistance of recuperators fabricated from 347 stainless steel and alloy 120 and to estimate foil lifetimes based on these observations. Wendy Matthews has visited ORNL three previous times during FY2005 to conduct similar studies of alloy performance as a function of microturbine operating conditions. This work has been extremely beneficial to ORNL's research on the oxidation and creep behavior of commercial alloys for recuperators, which have been exposed to laboratory conditions (high temperature and H_2O) and in ORNL's MRTF.

Status of Milestones

Report on the microstructural characterization of commercial alloys, which have been laboratory-exposed (elevated H_2O) and engine-tested (in ORNL Microturbine Recuperator Test Facility) at Temp. >600°C. *June 2005 – completed. Characterization results were reported in a presentation at The 6th Microscopy of Oxidation Conference in April and in 3 separate IGTI TurboExpo 2005 presentations in June 2005.*

Industry Interactions

1. Conducted microstructural characterization of Capstone engine-tested recuperators in June, 2005. Wendy Matthews of Capstone Turbines visited ORNL during evaluation of alloys.

2. Work with Ingersoll Rand to characterize braze joints continued during reporting period.

Subtask 2.1.3 Composition Optimization for Corrosion Resistance to High Temperature Exhaust Gas Environments

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Objective

In order to provide a clear, fundamental understanding of alloy composition effects on corrosion resistance of stainless steel components used in microturbine recuperators, the oxidation behavior of model and commercial alloys is being studied. Low alloy steels exhibit accelerated corrosion attack caused by water vapor in exhaust gas at 650°-800°C. An improved mechanistic understanding will improve life-prediction models and will assist in the selection and/or development of cost-effective alloys for recuperators. Issues that continue to be investigated include the effects of temperature, alloy grain size, phase composition, and minor alloy additions.

Highlights

Mass transfer calculations have been made showing that the measured mass losses observed in alloy 709 (Fe-20Cr-25Ni) foils are consistent with thermodynamic data for $CrO_2(OH)_2$. An extrapolation to the expected conditions in a microturbine recuperator suggest that the Cr evaporation rate will be a factor of ~2X higher than that measured in 650°C laboratory tests.

Technical Progress

The mass transfer coefficient for $CrO_2(OH)_2$ volatilization into flowing air+10%H_2O was evaluated using classical gas transport theory in the viscous flow regime. The resulting values were applied to new $CrO_2(OH)_2$ thermodynamic data obtained from E. Opila at NASA Glenn Research Center. Chromium evaporation fluxes were predicted for temperatures from 650°-800°C to compare with experimental data over the same range. The calculation was found to predict correctly the Cr loss rate measured from foil specimens of alloy 709 exposed for up to 10,000h under these conditions. Due to the increased gas velocity in the recuperator, the calculation predicted that evaporation will be 8X higher in a recuperator compared to the laboratory test. However, the water vapor content is higher in the laboratory test and only one side of the foil is exposed to the exhaust gas in the recuperator. Therefore, the net increase is ~2X in the recuperator compared to the laboratory results. This work was completed in collaboration with Prof. David Young, a visiting scientist at ORNL from the University of New South Wales.

Status of Milestones

Submit an open literature publication with long-term data supporting the development of low cost, oxidation resistant stainless steels for exhaust gas environments. (July 2005, on track)

Industry Interactions

Presented experimental results at NACE Expo 2005, Houston TX in April 2005.
Discussed recuperator alloy selection with Bernard Ibrahim of STM Power in April 2005.
Presented experimental results at IGTI Turbo Expo 2005, Reno, NV in June 2005.

Subtask 2.1.4 Recuperator Testing and Evaluation

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Objective

The objective of this sub-task is to screen and evaluate candidate materials for the next generation of advanced microturbine recuperators. To attain this objective a microturbine was modified to operate at recuperator inlet temperatures as high as 850°C. The durability of candidate recuperator materials is determined by placing metallic foil test specimens at a location upstream of the recuperator, followed by determination of their physical and mechanical properties as a function of time of exposure. Test specimens can be mechanically-stressed during exposure using a specially designed sample holder. The activities of this sub-task are being carried-out in collaboration with other tasks in this program and with manufacturers of microturbine recuperators.

Highlights

In collaboration with Solar Turbines, completed long-term tests to determine the creep resistance of alloy 625 and various grades of stainless steels. Demonstrated the operation of a device to simulate intermittent microturbine operation.

Technical Progress

During the reporting period test campaigns continued to evaluate alloys Haynes 120, AL 20-25+Nb, and ORNL-modified stainless steels in ORNL's microturbine recuperator testing facility (MRTF). Also, the operation of a device to evaluate the resistance of materials to intermittent microturbine operation was demonstrated. It was found that ORNL-modified stainless steels have better durability than 347 stainless steel at 700°C, that these materials formed oxide scales of Mn, Fe, Cr and Si, and that higher Mn concentration led to the formation of thicker and more uniform oxide scales. However, it was also found that the grain boundaries of the base alloy closest to the surface had been depleted of Cr. Figure 1 shows the effect of temperature on the ultimate tensile strength of 347 and ORNL-modified stainless steels after a 500-hr exposure in ORNL's MRTF. Figure 2 shows the thermal history recorded for three foils of alloy AL 20-25+Nb evaluated in intermittent operation using thermal cycles 110-min long.

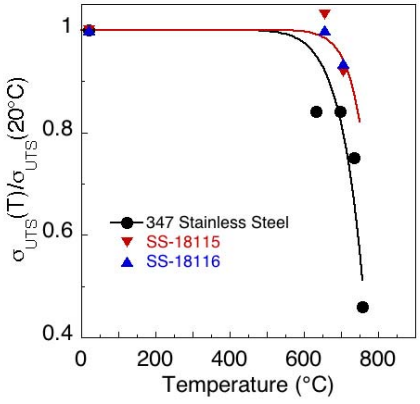

Figure 1. Effect of temperature on the UTS of ORNL-modified stainless steels after 500-hr. exposure.

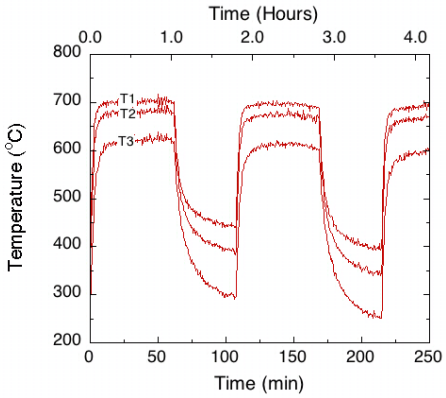

Figure 2. Thermal history of a test used to simulate intermittent microturbine operation.

Status of Milestones

1) Complete 1000-hr test campaigns and characterization of HR-120 and ORNL-modified stainless steels.

December 2004. Completed.
2) Publish a technical paper that summarizes the testing of HR 120 and NF 709 in ORNL's MRTF.
June 2005. On Track.

Industry Interactions

Completed long-term tests to determine the creep resistance of alloy 625 and various grades of stainless steels with Solar Turbines. Visited Capstone Turbine Co. and the University of California-Irvine to discuss the use of alternative fuels on microturbines.

Subtask 2.2.1 Keiser Rig Testing of CFCCs and Advanced Ceramics

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Objective

The objective of this task is to operate the ORNL slow-flow, high-pressure mixed-gas (Keiser) rigs used for the exposure part of the evaluation of the effects of high-temperature environments on monolithic ceramics, ceramic composites, and environmental barrier coatings targeted for use in various distributed generation schemes employing combustion or steam. It involves ongoing maintenance and operation of the rigs as well as continuous upgrading to improve operational and scientific reliability as well as extending their capabilities. With regard to the latter, in FY 2004, operating pressures were increased to 20 atm in one of the rigs to evaluate some volatilization issues of candidate ceramic compositions by substantially increasing the water-vapor pressure. These higher water-vapor pressures led to increased maintenance, including more frequent replacement of parts. Despite this, it is anticipated that, during FY 2005, at least 4500 h of high-temperature, high-pressure operation of the Keiser rigs will be achieved.

Highlights

The technical results from this task are reported in sections Subtask 2.2.2 – Microstructural Characterization of CFCCs and Protective Coatings and Subtask 2.2.4 – Oxidation/Corrosion Characterization of Microturbine Materials.

Status of Milestones

Complete report that includes a detailed description of the Keiser Rig facility, its capabilities and associated operating procedures, and a summary of the number and type of specimens exposed to date.
July 2005 – on track

Subtask 2.2.2 Microstructural Characterization of CFCCs and Protective Coatings

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Objective

SiC/SiC continuous-fiber ceramic composite (CFCC) combustor liners with a BSAS-based environmental barrier coating (EBC) have been exposed in several Solar Turbines engine tests for >10,000 h. The engine-exposed combustor liners have been characterized microstructurally and mechanically at ORNL to evaluate degradation of both CFCC liner materials and the EBC system. Simulated exposures of analogous materials systems have been conducted simultaneously in ORNL's Keiser Rigs at high water-vapor pressures. More recently, new EBC compositions and CFCC liners (including oxide/oxide and another SiC/SiC) have (or will be) exposed in the Solar Turbines engines as well as in the Keiser Rig and will be evaluated post-exposure. The primary objective of this project is to understand degradation mechanisms of the various EBC and CFCC materials in combustion environments (elevated H_2O pressure).

Highlights

The exposure of ATK-COI Ceramic's oxide/oxide ceramic matrix composite, designated A/N 720 CMC, for 3000 h at each of three temperatures, 1135°C, 1200°C, and 1250°C and 10% H_2O, has been completed in ORNL's Keiser Rig. Extensive microstructural evaluation was conducted following each high temperature exposure condition (1000 h exposure intervals for 3000 h total at each temperature). Nextel 720 fiber damage was evident after exposure for 3000 h at each temperature, and was most severe after 3000 h at 1250°C.

Technical Progress

The retained UTS were determined for the A/N720 CMC exposed for 1000, 2000, and 3000 h at 1135°C, 1200°C, and 1250°C. The UTS data clearly shows little effect of long-term exposure of the A/N720 CMC at 1135°C in the Keiser Rig's high H_2O pressure environment. While there appeared to be a downward trend of average strength with time for A/N720 CMC exposure at 1200°C, an analysis of variance showed that the differences among the mean values for the as-processed and 1200°C exposed test specimens was not significant at the 90% confidence level. After only 1000 h at 1250°C, an ~25% decrease in UTS was observed for the A/N 720 CMC. Microstructural analysis of the Nextel 720 surfaces showed progressive fiber surface roughening and grain growth with exposure time and temperature. While the alumina matrix exhibited no microstructural changes during exposures conducted up to 1250°C, the Nextel 720 fibers (which have been shown in previous studies to be unstable above 1200°C) show clear evidence for significant microstructural degradation, especially after exposures at 1250°C. Grain growth will have a negative impact on the UTS by weakening the fiber and fiber surface roughening will negatively impact CMC fracture toughness by increasing the fiber/matrix interfacial properties.

Status of Milestones

Prepare a report and present results on the expanded use of ORNL's Keiser Rig to evaluate the volatility resistance of EBCs. *August 2005 – completed with presentation and publication for TurboExpo 2005, ASME Paper #GT2005-69065.*

Industry Interactions

1. "The High-Temperature Stability of an Oxide/Oxide Composite at High H2O Pressures," presented at IGTI TurboExpo 2005, Reno, NV. ASME Paper #GT2005-69065.

2. “High-Temperature Stability of an Oxide/Oxide Composite Material at High Water-Vapor Pressure,” presented at 107th Annual Meeting of The American Ceramic Society, Baltimore, MD
3. St. Gobain, NASA Glenn, Ceramatec, UTRC, and ATK-COI Ceramics currently have EBCs being exposed in the Keiser Rig.

Subtask 2.2.3 Advanced Ceramics for Gas Turbines and Microturbines

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Objective

The goal of this program is to develop and optimize a high temperature silicon nitride based ceramic material (NT154) and forming process suitable for microturbine hot section component applications.

Highlights

Monoliths of novel EBC compositions completed 500 hours of testing in the high pressure Keiser Rig at ORNL with promising results.

Technical Progress

Hot pressed, monolithic, EBC samples of the novel bond coat and top coat compositions, previously defined, completed 500 hours of testing in the high pressure Keiser Rig at ORNL. The test conditions were 1250°C, 18atm water vapor pressure and 20atm total pressure. After the first 500 hours, the samples demonstrated a stable microstructure and showed very little, if any, weight change. Initial results are very promising and further testing is on-going.

Dip coating and densification development is on-going using the novel bond coat and top coat EBC compositions. Considerable progress has been made in eliminating drying cracks. Effort is now focused on eliminating processing defects and improving the thickness uniformity.

Significant effort was directed towards further improvement in the high temperature slow crack growth resistance of NT154. Mechanisms have been identified and testing is on-going. The main focus is on the proper crystallization of the grain boundary phase.

A radial NT154 rotor (see photo), manufactured during 2004, successfully survived spin testing to 97,000 RPM (the design speed). Testing to higher speeds was limited by issues with the attachment, which has subsequently been re-designed. Higher speed testing is planned in the near future.

Status of Milestones

1) Demonstrate a 40% improvement in as processed (AP) strength of NT154 microturbine grade silicon nitride (July 2004, completed).
2) Evaluate baseline recession resistance for uncoated and surface modified NT154 (September 2004, completed).
3) Develop a suitable surface modification procedure (HEEPS, PC) or EBC for test tiles and components to improve the recession resistance. (December 2004, on-going).

Industry Interactions

1) Discussions with Bill Tredway and John Holowczak of UTRC on Si_3N_4 turbine components.
2) Communications with Charles Lewinsohn, Balky Nair and Qiang Zhao of Ceramatec, Inc regarding EBC development work.
3) Communications with Terry Tiegs, H.T. Lin, Matt Ferber and Karren More of ORNL regarding NT154 and EBC development work.

4) Communications with Kang Lee of the NASA Glenn Research Center regarding high velocity rig testing of EBC compositions.

Subtask 2.2.4 Oxidation/Corrosion Characterization of Microturbine Materials

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Objective

Environmental barrier coatings (EBCs) will be required on all surfaces of Si-based ceramic and composite materials exposed to microturbine combustion (high water-vapor) environments. Numerous EBC systems are being developed for use on Si_3N_4 hot-section microturbine components. The reliability of these different EBC compositions, in terms of thermal stability, H_2O permeability, and volatility, at high temperature and water-vapor pressures, is being evaluated long-term in the ORNL Keiser Rigs.

Highlights

The exposure of several candidate EBCs to extremely high water-vapor pressures in the Keiser Rig continued during this Quarter. The St. Gobain and Ceramatec EBCs have accumulated 1000 h exposure to date and the exposures will be used to "rank" the different EBC formulations in terms of volatilization-resistance and stability in water-vapor-containing (exhaust, combustion) environments.

Technical Progress

Numerous candidate EBC formulations, supplied as "stand-alone" coupons (not on a Si-based substrate), are currently being exposed in ORNL's Keiser Rig at high water-vapor pressures (20 atm total system pressure and 18 atm H_2O) and 1250°C. The proprietary St. Gobain and Ceramatec EBC materials are currently being exposed in their second 500 h run under these extreme conditions. In addition to the proprietary EBC formulations, the following coupons are being exposed:

(1) stand-alone coupons of ORNL-produced $Y_2Si_2O_7$, $Yb_2Si_2O_7$, $Lu_2Si_2O_7$, $Sr_2Al_2Si_2O_8$
(2) BSAS and SAS stand-alone coupons supplied by Kang Lee (NASA Glenn)
(3) A/N 720 oxide/oxide composite and stand-alone FGI.

In the previous Keiser Rig run (reported on DE Quarterly Report for 01/05-03/05), several SiC/SiC substrates with plasma sprayed EBCs were included (supplied by UTRC). However, extreme damage to the CFCC substrate (likely due to a combination of temperature and H_2O pressure) was observed for each of the 4 samples, especially at the coupon edges. These samples were removed from the furnace after 500 h and returned to UTRC. New coupons of the same EBC composition will be supplied by UTRC to be run using "standard" Keiser Rig conditions (1200°C and 1.5 atm H_2O).

Status of Milestones

Report the volatilization results from the exposure of 3 different Si_3N_4 compositions to very high H_2O-pressures in ORNL's Keiser Rig. *June 2005 –completion August 2005 due to furnace problems.*

Industry Interactions

1. St. Gobain, NASA Glenn, Ceramatec, UTRC, and ATK-COI Ceramics currently have ceramics and EBCs being exposed in the Keiser Rig.
2. Presentation at Microscopy of Oxidation 6 in England "Image Analysis of Damage in EBCs."
3. Presentation at 107th Annual Meeting of The American Ceramic Society in Baltimore, MD. "High Temperature Stability & Damage in EBCs Exposed at High H_2O Pressure."
4. Presentation at TurboExpo 2005 in Reno, NV "Use of Very High H_2O Pressures to Evaluate Candidate Compositions for EBCs."

Subtask 2.2.5 Modeling of Advanced Materials for Microturbine Applications (PIC 698)

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Objective

The primary objective of this project is to evaluate the long-term mechanical and chemical stability of advanced materials of interest to the DE program. Currently the project is evaluating (1) structural ceramic, which are being considered for use as hot-section components in microturbines and (2) thick thermal barrier coatings (TTBCs) being developed for thermal management in combustor liners used in industrial gas turbines. The structural ceramics effort focuses on the development and utilization of test facilities for evaluating the influence of high-pressure and high-temperature water vapor upon the long-term mechanical behavior of monolithic ceramics having environmental barrier coatings. In the case of the TTBCs, the primary focus is on the evaluation of changes in microstructure and thermal properties arising from long-term aging tests. A secondary objective of the program is to develop and characterize the toughened silicon nitride ceramics

Highlights

The overall design of a new multi-fuel combustor facility (MFCF) was developed in conjunction with discussions with the potential vendor. This system will employ a modular burner design, which provides for the use of natural gas of variable quality. Sample holders and hardware will allow tests to be conducted under various types of thermal profiles including isothermal, cyclic, and gradient.

Technical Progress

An effort was initiated this reporting period to create a new multi-fuel combustor facility (MFCF) for the evaluation of the long-term stability of key material systems for use in fuel flexible gas turbines. The objective of creating this facility is to support the turbine engine community in their development of gas turbines that are multi-fuel capable. The primary drivers for developing this capability are (1) customers expect dual fuel capability in mature product, (2) fuel flexibility can improve competitiveness with respect to recips, (3) the potential for interrupted fuel contracts improves economics to end user, and (4) the ability to accommodate different qualities of natural gas increases market pull. The use of these alternate fuels poses a number of materials stability challenges for a variety of components including the combustor liner, combustor injector, and recuperator.

Status of Milestones

(1) Complete the characterization of commercially available environmental barrier coatings and issue report-March 2005-Complete.
(2) Complete development of baseline processing conditions together with seed content to maximize the strength-toughness response and to tailor thermal expansion confidents -July 2006-on track.

Industry Interactions

1. Discussions were held with Dave Winiki of BECON Inc concerning the design of the multi-fuel combustor facility.
2. Discussions were held with Ara Vartabedian from Saint-Gobain Ceramics & Plastics concerning the use of the Integrated Reliability Analysis Software to examine the effects of improved slow crack growth resistance on the reliability of a ceramic rotor.

Subtask 2.2.6 Characterization of Structural Ceramic Materials and Potential Coatings for Turbine Applications

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Objectives

1) Determine the tensile creep properties of Saint Gobain's latest NT154 grade silicon nitride to ensure that this batch of material has at least equivalent creep properties to the previous material made in the mid 1990s.
2) Characterize the oxidation behaviour of candidate ceramics and two phase silicon nitrides in an air/steam environment to eliminate the need for complex costly multilayer coatings. The goal of this activity is to find materials that can be used in the construction of long life microturbine hot section components that enable the engine to operate at high efficiencies with good economic payback.

Highlights

Si_3N_4, Si_2N_2O and $Sc_2Si_2O_7$ were the only crystalline phases found in Si_3N_4- SiO_2 – Sc_2SiO_5 triangle of the Si_3N_4 – SiO_2 - Sc_2O_3 phase diagram. Si_3N_4 – Barium Aluminosilicate (BAS) composites showed inferior oxidation resistance to SN282 at 1300 °C.

Technical Progress

Samples of Si_3N_4 – Barium Aluminosilicate (BAS) composites, prepared by hot pressing powder mixtures, were oxidized at 1500 °C in an air/water vapor mixture atmosphere for 51 hours. The weight gain data did not fit any of the conventional kinetics expressions probably because both oxidation and gas evolution were occurring simultaneously small bubbles on the surface of some of samples validated this conclusion. The temperature was then dropped to 1300 °C, the temperature used by UTRC to test candidate EBC coatings. A new set of samples was exposed to this environment. Initially the samples gained weight with the weight gain decreasing with increased BAS content, but after 200 to 300 hours weight loss again occurred with the compositions containing higher BAS levels showing greater weight loss. In the weight gain regime the samples still showed greater weight gain than SN282.The experiment was terminated after 646 hours.

Nine compositions in the Si_3N_4 - SiO_2 – Sc_2SiO_5 triangle of the Si_3N_4 – SiO_2 - Sc_2O_3 phase diagram were prepared by hot pressing powder mixtures at 1800 °C for 2 hours to establish the tie lines between stable compounds. Si_3N_4, Si_2N_2O and $Sc_2Si_2O_7$ were the only crystalline phases found, thus there is no tie line between Sc_2SiO_5 and either of the nitride compounds. Furthermore no metaloxynitride compound was found.

Status of Milestones

1) Compare the tensile creep properties of this generation NT154 with that of its predecessor. On track – December 2005
2) Determine the oxidation behavior of two phase silicon nitride materials in air/ steam environment. December 2005 – on track.

Industry Interactions

None

Subtask 2.2.7 Reliability Evaluation of Microturbine Components

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Objective

The objective of this study is to facilitate the successful implementation of complex-shaped ceramic components in advanced microturbines to significantly increase efficiency and reduce NOx emission. This work also provides a critical insight into how the microturbine environments influence the microstructure and chemistry, thus mechanical performance of materials.

Highlights

Microscopy analysis showed that the presence of residual glassy phase in new NT154 silicon nitride, which softened at elevated temperatures, resulted in the low fatigue exponents and thus susceptibility to slow crack growth under the test conditions employed. A post heat treatment procedure needs to be devised to improve the high-temperature mechanical performance.

Technical Progress

Studies of dynamic fatigue response of NT154 silicon nitride processed with diffusion barrier coating (DBC) at elevated temperatures were completed. Mechanical results at temperatures up to 1204°C show that the machined NT154 MOR bars with DBC exhibits comparable mechanical performance to those manufactured without DBC. The fatigue exponents (N) obtained at elevated temperatures (N ~ 36-44) are similar to those measured for samples without DBC (N = 32-40). Nonetheless, the test bars with as-processed surface and sintered with DBC still exhibited 30-40% lower strength than as-machined test bars, similar to previously reported results.

Initial SEM and X-ray analyses on samples extracted from NT154 rotor airfoils and hubs showed similar microstructure and phase content. A detailed TEM analysis is thus initiated to provide insight into the origin resulting in the poor mechanical performance of samples from as-processed airfoils.

Fractography and SEM analysis on NT154 test samples with DBC indicated that the fracture mostly initiated at the surface pits resulting from the processing and sintering steps. Procedures need to be modified to eliminate these strength-limiting surface flaws and to achieve consistent properties.

Status of Milestones

1. Complete mechanical characterization of NT154 microturbine rotors with and without EBC manufacture under optimized processing conditions. Sept 2005 – on track.

Industry Interactions

1. Communications and conference calls with Vimal Pujari and Ara Vartabedian at Saint-Gobain on the dynamic fatigue results of NT154 with DBC at elevated temperatures.
2. Communications with Vimal Pujari and Ara Vartabedian at Saint-Gobain on the X-ray results of NT154 with various post heat treatment conditions.
3. Communication with John Holowczak and Bill Tredway at UTRC to on the updated dynamic fatigue results of Saint-Gobain NT154 silicon nitride with DBC.
4. Communication with Shunkichi Ueno at AIST, Japan on the reports and publications for the high-temperature steam jet testing results of RE-disilicates.

Subtask 2.2.8 Environmental Protection Systems for Ceramics in Microturbines and Industrial Gas Turbine Applications (PIC 708)

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Objective

The use of advanced structural ceramics, such as silicon nitride (Si_3N_4), in gas turbine engines can allow operation at higher temperatures, thus improving engine efficiency. However, in the combustion engine environment, Si_3N_4 can undergo rapid degradation due to the corrosive and erosive effects of high temperature, high pressure, high gas flow rate, and the presence of water vapor. A protective environmental barrier coating (EBC) is needed for Si_3N_4 to allow these advanced materials to be utilized in microturbines and industrial gas turbine engines. The goal of this effort is to develop a method for producing a protective coating on Si_3N_4 and to evaluate the ability of the coating to protect the ceramic in an engine environment.

Highlights

Pack cementation coated samples were submitted for exposure testing in the Keiser rig. The samples included new NT154 Si_3N_4 coated to form either $Yb_2Si_2O_7$ or $Yb_3Al_5O_{12}$ on the surface. The Si_3N_4 samples had both as-processed and machined surfaces that were coated. Also included for testing were samples of SiC/SiC composite with a coating of $Yb_2Si_2O_7$ formed by pack cementation.

Technical Progress

Pack cementation was used to form coatings on samples of new NT154 Si_3N_4 that were cut from a billet of material so that each sample had both as-processed and machined surfaces. Pre-oxidized samples were packed in Yb_2O_3 powder and exposed to high temperature in air to form a $Yb_2Si_2O_7$ + SiO2 coating. Other samples were packed in a bed of Yb_2O_3 and Al_2O_3 and exposed to high temperature an Ar atmosphere to form a $Yb_3Al_5O_{12}$ garnet coating on the surface. Samples of SiC/SiC composite were also pre-oxidized, packed in Yb_2O_3 powder, and exposed to high temperature in air to form a $Yb_2Si_2O_7$ coating. Samples of the coated materials were submitted for exposure testing in the Keiser rig.

Status of Milestones

Prepare pack cementation coated silicon nitride samples for evaluation in the Keiser rig.
Sept. 2005 – completed

Industry Interactions

NT154 Si_3N_4 was provided by Saint-Gobain to make coated samples for Keiser rig testing.

Subtask 2.2.9 Environmental Protection Systems for Ceramics in Microturbines and Industrial Gas Turbine Applications (PIC 709)

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Objective

order to be cost competitive, microturbines will have to meet aggressive durability targets. Ceramic components without an EBC will not be able to meet the goals of > 20,000 operation hours. An EBC may enable these components to meet the expected lifetimes provided the EBC can be applied at low cost. The goal of this project is to continue to develop a low cost, slurry-based process to apply protective coatings for silicon based ceramic materials for use in microturbine and/or industrial gas turbine applications. This effort will be coordinated with industrial partners to assist in the development of an ideal coating material or material system for steam and high velocity resistance.

Highlights

Slurry development of collaborator's material systems continues. Coated samples are being evaluated after densification for appropriate thicknesses and densities. Samples that met the collaborator's specifications are being submitted for simulated exposure and characterization.

Technical Progress

Work continues on the collaborator's candidate materials systems. Dipping studies continue. Iterations of coating, sintering, and characterization to minimize sintering temperatures and maximizing coating uniformity, desired thicknesses and densities are in process. Promising systems will be submitted to collaborator's for simulated exposure testing. ORNL material system evaluation of coated bend bars of AS800, SN282, and NT-154 were removed from 500 hours simulated exposure testing in HT Lin's steam rig. Post-mortem analysis has been completed on coatings that remained adherent. Process changes have been initiated to improve adherence issues. Additional test specimens will be coated via the updated process to evaluate the benefit after exposure testing.

Status of Milestones

Evaluate the corrosion resistance of rare earth doped silicate materials in a simulated combustion environment. September 2005 – on track

Industry Interactions

Collaboration with Honeywell and Ceramatec continues.

Subtask 2.2.10 Life Prediction Development and Support for Microturbines OEMS

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Objective

Update and enhance various software algorithms (ANSCARES, CARES, and WeibPar) that are provided to DE industrial partners. Provide technical support (e.g., theoretical development and modeling advice) to DE industry partners. Support interfacing the ORNL software algorithm IRASoft with CARES and WeibPar.

Highlights

ANSCARES, CARES, and WeibPar have each undergone significant upgrades this quarter. ANSCARES now creates binary neutral files, CARES has been upgraded to utilize the binary neutral file, and the exporting functions and the component reliability module have been upgraded in WeibPar.

Technical Progress

ANSCARES: The new multiple load step binary neutral file is more efficient than the previous text neutral file. Previous versions of ANSCARES created an individual neutral file for each load step then combined them into a single neutral file. The binary neutral file is more efficient since it is created directly, and in general, reading and writing to binary files is more efficient both in CPU time and in total storage space. Additionally, the limits on the number of elements and number of nodes have each been increased to one million. Finally, the user may select a range of materials and a range of load steps to place in the neutral file. Finite element models often contain materials and/or load steps that are not to be analyzed in CARES.

CARES: Besides the upgrade to read the new binary neutral file, the risk of rupture module has been updated. The RRI file has been reformatted and the ANSYS macro has been updated. Other minor updates have also been performed.

WeibPar: The component reliability module has been updated to run with the most recent version of CARES. The dialog was reorganized based on user comments to make it more user friendly. The export results and export graph functions have been updated. The user may now export dynamic fatigue graphs and pooled Weibull graphs to JPEG, Bitmap, Windows Metafile, and Enhanced Windows Metafile formats. The user may also export the results of dynamic fatigue estimation and pooled Weibull estimation to either the WPR text file or the CMP file. The WPR file contains plotting information for use in other commercial graphics packages. The CMP file is a CARES Material Parameter file for direct use in CARES.

Status of Milestones

1. Add loading factors to WeibPar/CARES – December 2004

Industry Interactions

None this reporting period.

Subtask 2.2.11 Evaluation and Application of High Thermal Conductivity Carbon Materials for Use in Microturbine Heat Recovery Systems

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Objective

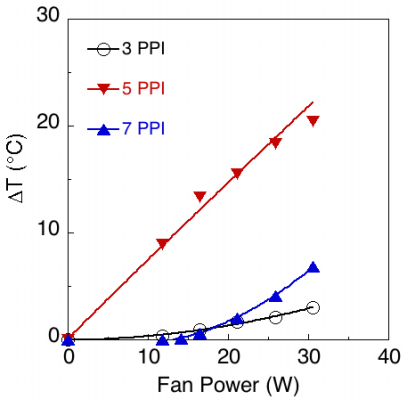
Because of low efficiency in power generation, as much as 90 GWh of energy are lost in the United States every year. However, by recovering waste heat, the efficiency of power generation systems can be significantly improved. In the case of recuperated microturbines, heat in the exhaust gases can be captured to dry humid air and/or to produce hot or chilled water for use in space heating, or air conditioning. The objective of this project is to design, fabricate and evaluate graphite fiber-based heat recovery systems for microturbines, which currently use aluminum fin heat exchangers. Through modeling and experimental work, the architecture of woven fiber structures that maximize heat transfer while minimizing pressure drop and cost will be identified.

Highlights

The feasibility of removing heat from hot water using woven graphite fiber structures was demonstrated.

Technical Progress

The effect of fiber architecture on the rate of heat removal from hot water using woven graphite fiber radiators was investigated and the feasibility of removing heat from hot water using woven graphite fiber structures was demonstrated. Woven graphite fiber structures with embedded copper tubing were evaluated in a test rig in which hot water was flown through the tubing while a variable speed fan was used to blow air through the woven structure. The change in water temperature and pressure drop across the woven fiber structure was recorded as a function of the initial water temperature and fan power. It was found that the change in temperature increased as the fan power, and hence air flow through the woven structure, increased. The feasibility of using thermally conductive epoxies to reduce the thermal resistance between the fibers and the tubing was investigated and it was found that heat transfer could be increased by as much as 25% when the fibers were bonded to copper tubing using these epoxy adhesives. While the thermal performance of woven graphite fiber structures is expected to increase with fabric density, the fact that the performance of woven structures with 5 PPI was superior to those with 7 PPI can be explained by the distortion in the fiber architecture induced by tubing. Work is in progress to determine the temperature increase in water flowing through the copper tubing while hot air flows through the woven structure.



Status of Milestones

Complete the fabrication of a prototype advanced heat exchanger using high conductivity fibers. (June 2005) Completed.

Industry Interactions

Continued collaboration with 3-Tex, Inc. (Rutherford, NC)

Subtask 2.2.13a Silicon Carbonitride EBC Development

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Objective

The need for environmental barrier coatings (zirconia/ hafnia) for silicon nitride turbine components exposed to hot humid active oxidation conditions is well established. Polymer derived silicon carboxynitride based composites are candidate materials for bond coats between silicon nitride and the protective top coats because they show good adhesion to these materials and the composite microstructure can be tailored to accommodate the thermal expansion mismatch stresses. The aim of the present study is to optimize (polymer derived) Silicon Carboxynitride (SiCNO) porous composite bond coat for silicon nitride from studies on particulate composites made from transition metal oxides (hafnia/zirconia) and SiCNO.

Highlights

Mechanical tests on the SiCNO composites have shown that the particulate composites show a significant degradation in strength during hydrothermal testing. Such strength degradation was not observed when the SiCNO phase is present as a continuous coating on the hafnia/zirconia particles. Fractrographic studies on these samples revealed that SiCNO particles cracked during hydrothermal oxidation. However, such cracks where not observed when SiCNO is present as a thin (<1 μm) coating on the hafnia/zirconia particles.

Technical Progress

1. Fractographic studies were conducted on SiCNO-Hafnia/Zirconia composites that were hydrothermally tested at 1300 °C at a steam velocity of 17.6 $cm.s^{-1}$. These studies revealed that the strength degradation in these composites was due to the cracking of the SiCNO particles on oxidation to form silica. In contrast, in composites where SiCNO is present as a thin layer on the hafnia particles, there is no such strength degradation.

2. In order to understand the phase evolution in the tested composites, XRD studies were carried out on the composites that were hydrothermally tested at 1300 °C and a steam velocity of 17.6 $cm.s^{-1}$. The XRD results showed that in SiCNO-Hafnia composites hafnium silicate was observed only after 100 hours of testing. In contrast, zircon forms within the first hour in the case of SiCNO-Zirconia composites. The sluggish reaction of hafnia and silica could be related to the higher stability of hafnia in comparison to zirconia.

3. Extended hydrothermal oxidation studies (up to 500 hours at 1300 °C, 17.6 $cm.s^{-1}$ steam velocity) have shown that there is no change in weight of the samples despite the presence of silica, reinforcing the view that the vapor velocity profile tends to zero after a certain depth into the sample.

Status of Milestones

1. Understand phase and mechanical strength evolution of the composites. Sept, 2005; on track.
2. Test the stability of the composites at vapor velocities >100 $cm.s^{-1}$. Sept, 2005; on track.

Industry Interactions

None

Subtask 2.2.13b EBC Development for Silicon Nitride Ceramics for Enhanced Hydrothermal Corrosion Resistance

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Objective

The goal of the current program at Ceramatec is to develop a functional environmental barrier coating system for silicon nitride ceramics, processed using non-line of sight techniques, which will provide substantially improved hydrothermal corrosion resistance without degradation of bulk mechanical properties.

Effective protection of silicon nitride ceramics from hydrothermal corrosion will enable components for microturbine engines, manufactured from these materials, to be operated at conditions that will provide improved efficiency for microturbine power generation systems.

Highlight

A design of experiments approach was used to determine the process variables controlling the thickness and adhesion of the Ceramatec bond coat.

Technical Progress

The results of statistically designed experiments to determine the process variables that control the thickness and adhesion of the Ceramatec bond coat indicated that solids loading and binder level had significant effects on bond coat thickness and adhesion. The effect of bond coat and top coat thicknesses on coating stresses were calculated using a published, elastoplastic analysis for coatings (Giannakopoulos, Suresh, et al.). The analysis indicates that stresses in the coating system can be minimized with thicker bond coats that accommodate thermophysical property mismatches, and a thin top coat that reduces the magnitude of any property mismatch.

Fully dense specimens of top coat material, batched to produce five minor compositional variants within the ternary phase stability diagram of the components of the top coat were prepared and sent to Dr. Karren More at The Oak Ridge National Laboratory for hydrothermal corrosion testing in the Keiser Rig. Additionally, bond coat layers were applied to specimens of AS800 and SN220 silicon nitride provided by Dr. Kang Lee, at The NASA Glenn Research Center. These latter specimens were returned to NASA Glenn where mullite (AS800) and ytterbium-silicate (SN220) top coat layers were applied. The samples subsequently underwent thermal cycle testing and preliminary observations, by Dr. Lee, indicate that the bond coat adhered well to both substrates and top coat materials.

Status of Milestones

Industry Interactions

Frequent conference calls and e-mail communications occur between Ceramatec, Inc. and Dr. Vimal Pujari and Mr. Ara Vartebedian at Saint Gobain, Ceramics and Plastics. Additionally, interaction with Dr. Kang Lee, at The NASA Glenn Research Center has begun.

Subtask 2.3.1 Advanced Materials for Reciprocating Engine Components

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Objective

Next generation NG reciprocating engines will have higher in-cylinder pressures and temperatures to provide higher power density and efficiency, and lower emissions. Component materials face the paradox of increased life and reliability, while withstanding higher temperatures, which tends to reduce both, all with the constraint of reasonable costs. In collaboration with ARES OEMs and their component suppliers, ORNL is characterizing the effects of long-term engine exposure on exhaust valves, seats, and other exhaust components. Current materials/component mechanical and oxidation properties, and the underlying microstructural changes, all provide the baseline against which to measure improved performance of other alloys. ORNL characterization of current exhaust valves with long-term engine exposure will clearly determine their performance limitations. Such data will then enable selection of advanced alloys with more temperature capability and performance. Similarly, ORNL is also engaged with engine OEMs and steel foundries to compare exhaust components (manifolds, turbocharger casings) made from a new cast stainless steel, CF8C-Plus, with current cast-iron components.

Highlights

Characterization of an initial set of unfailed exhaust valves with significant, long-term ARES engine exposure is complete, and analysis of a failed valve is in progress. Ni-based superalloy exhaust valves show significant coarsening of the γ' structure, which reduces high-temperature strength. The first casting trials of exhaust components made from the new CF8C-Plus austenitic stainless steel were successful, and components made from Ni-resist cast-iron and CF8C-Plus stainless steel have been sent to Waukesha. Creep specimens from these same heats of material have been tested at ORNL this quarter, and the CF8C-Plus steel has significantly more creep strength than Ni-resist cast-iron.

Technical Progress

Comparison of unused exhaust valves with a series of unfailed exhaust valves exposed to engine testing ranging from several thousand to up to twenty thousand hours was completed, and during this quarter, the analysis was extended to a failed exhaust valve. Detailed microstructural analysis has shown that these Ni-based superalloy exhaust valves show significant effects of aging after only a few thousand hours of engine service. Grain boundary $M_{23}C_6$ carbide precipitation increases, and there is significant coarsening and some dissolution of the γ'(Ni_3Al) precipitates that strengthen the alloy at high temperatures. Last quarter, casting trials were initiated by WED at Stainless Foundry and Engineering, Inc. to make exhaust components from the new CF8C-Plus cast stainless steel for comparisons to standard manifolds made of Ni-resist austenitic cast-iron. The first casting trials with the new CF8C-Plus austenitic stainless steel were very successful (Fig. 1), and the components were sent to Waukesha for engine testing. Test bars of both alloys were also sent to ORNL for tensile and creep testing. Creep testing at 750-850°C showed a large strength advantage of CF8C-Plus cast steel compared to Ni-resist cast-iron.

Figure 1 – First successful cast trial of an exhaust component made from the new CF8C-Plus cast stainless steel by Stainless Foundry and Engineering, Inc. for Waukesha Engine Dresser, Inc.

Status of Milestones

Complete initial characterization of fresh and engine-tested intake and exhaust valves, and their corresponding seats, to determine aging effects and degradation/failure mechanisms. Interact with engine designers to identify avenues for improved performance. *January 2005 – completed*.

Industry Interactions

Conference calls and communications with principal investigators at WED occur regularly (1-2 times/month) to guide this project.

1) Phil Maziasz visited TRW Automotive Division in Cleveland, OH on April 27, 2005 to discuss a new collaborative program on exhaust valve development for WED.
2) John Shingledecker of ORNL visited Stainless Foundry and Engineering in Milwaukee, WI on June 16, 2005 for a meeting with WED on casting of CF8C-Plus steel exhaust components.
3) ORNL team met at WED in Waukesha, WI on June 28, 2005 for project review.

Subtask 2.3.2 Characterization and Development of Spark Plug Materials

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Objective

Spark plug lifetimes in advanced natural gas engines are on the order of only 1000-4000 h, which result in loss of performance and necessitate frequent, costly downtime maintenance. Spark plug durability will become even more critical as future engines are pushed to leaner-burn conditions to reduce emissions. The goals of this effort are to gain insight into spark plug life- limiting wear processes, and to use this understanding to develop new electrode alloys to achieve lifetimes of ≥ 8000 h.

Highlights

To expand the database characterizing the spark plug erosion/failure process, plugs operating in engines with EGR were examined. Differences between the EGR and non-EGR operation were found in the impurity quantities in the spectroscopic investigation. Metallurgical examination also indicated a significant difference in the cracking between the EGR and the non-EGR plugs.

Technical Progress

The database characterizing spark plug erosion/failure characteristics has been expanded with the inclusion of two sets taken from engines with EGR system. Optical spectroscopic results showed that the plugs operating under EGR exhibited a reduction in calcium and oxygen and an increase in hydrogen intensity as compared with those plugs without EGR. The significance of these differences is being examined for the role EGR may have in the erosion/failure process of nature gas engine spark plugs.

A high-pressure (2500 psi) chamber capable of testing spark plugs at elevated temperatures (1200°F) has been designed and ordered. This chamber will allow the characterization of spark plugs under conditions not currently available in existing nature gas engines.

In collaboration with Federal Mogul (Champion), oxidation studies were conducted for a series of 95% Ni base and 80% Ni base commercial alloys as alternatives for currently used Ni-base electrode alloys. Based on insights gained, a model Ni-base alloy was delivered to Federal Mogul for manufacture into spark plug electrodes for engine testing. Laboratory gasoline engine testing at Federal Mogul reached 300 h for the 95% Ni base series spark plug electrodes, and will be compared with oxidation test results.

Status of Milestones

1. Characterize wear of currently used spark plugs as a function of time/ignition system, and engine exposure conditions to firmly establish key issues controlling wear in natural gas engines. Disseminate results in at least 1 open literature publication. Sept 2005 – on track
2. Manufacture electrodes from at least one new developmental alloy and evaluate and characterize under ignition conditions. Benchmark results compared to currently used Pt and Ir alloys. Sept. 2005 – on track.
3. Develop detailed database of spark plug erosion characteristics from spectroscopic and metallurgical measurements for modeling the erosion process. Dec. 2004 – completed.
4. Develop a detailed model of the erosion/failure process for NG engine spark plugs based on database results from above. Sept. 2005 – on track.
5. Develop an advanced test chamber to simulate spark plug wear under condition found in existing and future NG engines. June 2005 – on track

Industry Interactions

Conference calls and communications with Drs. Iryna Levina and Jim Lykowski at Federal Mogul (Champion) to discuss the engine testing of the spark plugs using ORNL developmental alloys.

Communications with Preventive Maintenance Services, Inc. on the characterization results of tested spark plugs with EGR and HRU system.

Subtask 2.3.3 Optimization of In-Cylinder Materials for Reciprocating Natural Gas Engines

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Objectives

- Match in-cylinder materials to lubricant composition to reduce or eliminate deposit formation.
- Develop a metric to track oil composition for its tendency to form deposits.
- Reduced deposits will improve compression and reduce emissions by reducing oil blow-by

Highlights

A technique using thermogravimetric analysis (TGA) was developed to measure the concentration of sludge which can act as a precursor to deposit formation. This technique was applied to progressively aged oil samples from a NG engine showing excellent correlation to oil oxidation and nitration levels.

Technical Progress

The characterization of the oil deposits on NG-fired intake valves was completed. The results indicated that the deposits were oxides and salts from the oil additive package rather than carbonaceous material. These deposits were only loosely adherent, which resulted in localized spallation and hot gas jet impingement, which eroded the valve sealing surface. These results will be presented at the World Tribology Congress meeting to be held on 9/05.

A TGA method, based on an ASTM standard to measure soot in diesel oil was adapted to measure the concentration of organic contaminants, otherwise known as sludge, resulting from oxidation and nitration. The sludge concentration in progressively aged oil samples showed a linear relationship with run time, viscosity, oxidation, and nitration as measured by conventional oil analysis.

Status of Milestones

Report on the characterization of current valve materials and deposits as well as used oil
June 2005 – completed.

Industry Interactions

A project review was held at Waukesha Engine, Dresser (WED) on 6/28/05 to review the status of both alternate valve materials for increased durability and the sludge measurement development. Based on our results, WED is planning additional engine tests using various levels of oil and oil filtration quality to monitor the different rates at which sludge can build. These build-up rates will be correlated to the tendency for in-cylinder deposit formation.

Subtask 2.4.1 Reactive Power in Grid Connect with Distributed Energy

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Objective

Task 1. Reactive power is produced when current is out of phase with voltage due to inductive or capacitive loads, and places undo stresses on the utility system. Power electronics in combination with Distributed Energy Resources (DER) could be used to correct the current phase angle and eliminate reactive power flow by generating or absorbing reactive power, and they can also be used to regulate local voltage. The objective of this task is to determine the requirements for inverter based machines to demonstrate and inject reactive power to the grid.

Task 2. Power electronics (PEs) are instrumental to the exploitation of DER; therefore, distributed systems can be controlled by PEs to implement a variety of ancillary services such as uninterruptible power supply, voltage sag compensation, power factor correction, reactive power supply, frequency regulation, active filtering of harmonics, and stability control. This study will determine which of these services can be supplied by power electronics connected to DER and have the greatest economic impact in making the grid more reliable.

Highlights

Task 1: Modeling of inverters using MATLAB/SIMULINK is complete. Control methods for supplying reactive power by PEs are being studied.

Task 2: 70% of ancillary services report complete.

Technical Progress

Task 1: Modeling of inverters using MATLAB/SIMULINK is complete. Both a voltage source and a current source inverter were modeled. May 11 and 12, J. Campbell attended a training class for the dSPACE system. A circuit was designed that interfaces the dSPACE hardware and inverter gate drives, because the dSPACE output of 10 V does not produce a 20 V signal needed to turn-on the gate.

Task 2: The study for ancillary services from DER is nearing completion which includes the introduction, background material, and description of each ancillary service and how they are produced either by PEs or non-PEs based systems.

Status of Milestones

Task 1: Set up control system for the PEs in the Reactive Power Lab- Sept. 2005 -on schedule.
Task 2: Prepare a report on viable ancillary services from DER – Sept. 2005

Industry Interactions

J. Campbell attended the IEEE Power Engineer Society (PES) General Meeting, Jun 13-16 in San Francisco. There he met with representatives from ABB, KEMA, New Energy Options, AEP, PG&E, and Con Edison.

Subtask 2.4.2 Power Electronics Strategic Plan

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Objective

Power electronics (PEs) are instrumental to the exploitation of DE. PEs control both the conversion of power and its flow from the DE system to the utility grid. Therefore, distributed systems can be controlled to implement a variety of services such as reactive power, voltage regulation, black-start capability, harmonic compensation, and other ancillary services.

Unfortunately, existing PEs are susceptible to thermal limits, forward currents, reverse voltages, and packaging techniques that hamper advancements in DE implementation. Thermal management is a critical element in PE reliability, especially as PEs become smaller even as their power densities increase. Advanced materials such as silicon carbide (SiC) are pushing PEs beyond the barriers of current silicon semiconductors, and SiC semiconductors could have a dramatic effect on DE technology. However, PE costs must be constrained to reap the potential cost benefits of DE implementation.

Highlights

- Technical leads have been gathering data, visiting companies, and contacting experts in several areas.

Technical Progress

Technical leads have been gathering data and contacting companies in the following areas: materials development & processing, wide band gap materials, topology, thermal management, controls and system applications.

This work is being leveraged with activities from the Gridworks program in the Office of Electricity and Energy Assurance.

Hardware testing of the PE modules has begun and development of the interface control electronics between the dSpace system and the modules is in progress.

Status of Milestones

Complete analysis of power electronics strategy – September 2005 – on track

Industry Interactions

Visited Powerex June 29. Met with several companies at IEEE Power Engineer Society (PES) General Meeting, Jun 13-16 in San Francisco including ABB, KEMA, New Energy Options, AEP, PG&E, and Con Edison.

Subtask 2.4.3 Solid-State NOx Sensor Development

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Objective

To develop non-catalytic and catalytically selective electrodes for use in NOx and ammonia sensors and to build and test sensors using the materials and technology developed

Technical Highlights

Most work was driven by need to identify alternative electrode/substrate combination, pursuant to observation that $La_{1-x}Sr_xCrO_3/Zr_{2-x}Y_xO_{2-\delta}$ sensing elements showed evidence of decomposition after long-term operation in the presence of NO_2 and H_2O. Two main alternatives were explored:

1. $La_{0.85}Sr_{0.15}CrO_3$ (LSC) electrodes on $Ce_{0.8}Gd_{0.2}O_{2-\delta}$ (GdC) substrates.
   a. Sensing elements using this materials combination could yield "total NO_x" sensing at 600°C as shown in Figure 1. Fig. 1 also shows that the $[O_2]$ sensitivity is a decreasing function of $[NO_x]$, similar to the behavior of elements with LSC electrodes and $Zr_{2-x}Y_xO_{2-\delta}$ (YSZ) substrates.
   b. The DC resistance of this materials combination tended to increase with time (Fig. 2). The changes in DC resistance due to the presence of NO, however, stayed relatively constant.
   c. No decomposition was observed after exposure to H_2O (g), NO_x, and electrical stimulus for ~100 hr. at 600°C. See Fig. 3.

2. $LaCr_{0.85}Mg_{0.15}O_3$ (LMC) electrodes on $Zr_{1.84}Y_{0.16}O_{2-\delta}$ (YSZ) substrates.
   a. This materials combination could not yield "total NO_x" sensing performance. Although the responses to NO and NO_2 were of the same algebraic sign, the response to NO_2 was greater in magnitude (Fig. 4).
   b. The DC resistance of these sensing elements decreased slowly at 600°C under the condition of constant applied current (0.25 μA) as seen in Fig. 5a. Changes induced by NO (20–190 ppm) were constant over a period of 3 days (Fig. 5b)
   c. No decomposition was observed after exposure to H_2O (g), NO_x, and electrical stimulus for ~100 hr. at 600°C. See Fig. 6.

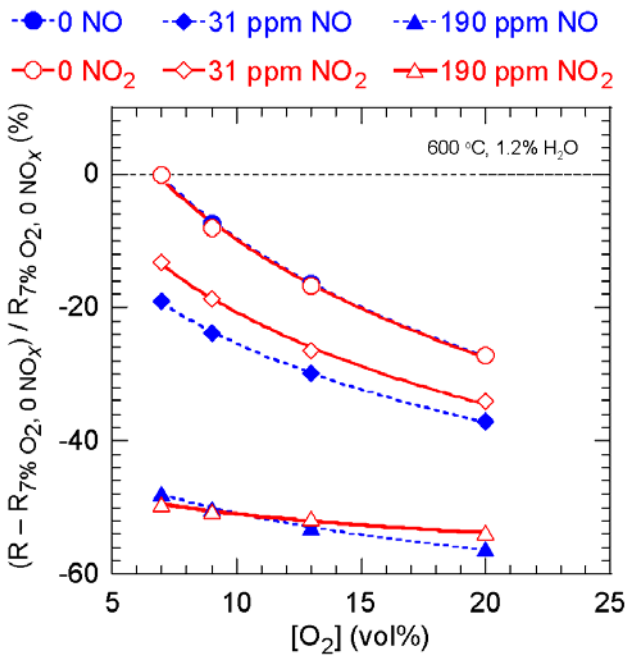

Figure 1. Sensing performance of prototype LSC/GdC element. 15 mV was applied as a DC electrical stimulus.

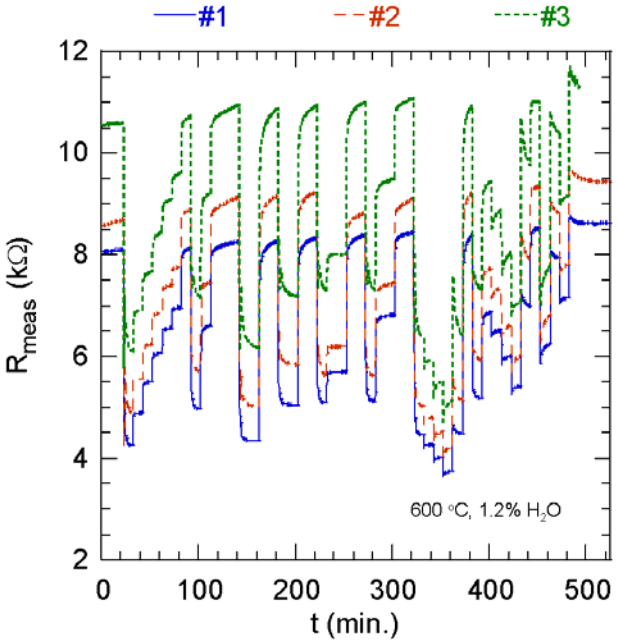

Figure 2: Response of a prototype LSC/GdC element (15 mV electrical stimulus) to varying [NO] and [O_2]. The [NO] and [O_2] variations (0–190 ppm_V and 7–20 vol%) were identical for each of the three runs.

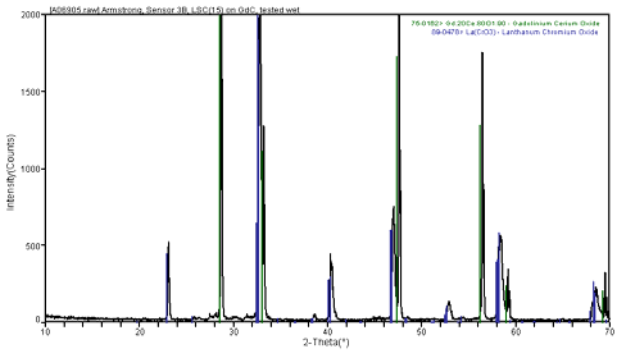

Figure 3: X-ray diffraction (Cu K_α) pattern from a tested LSC/GdC sensing element. All peaks in the pattern can be assigned to LSC or GdC, indicating that no decomposition has occurred during use.

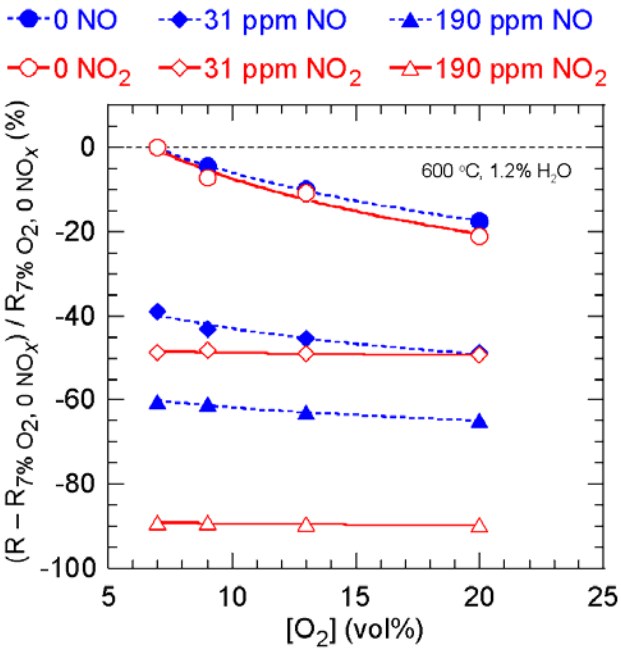

Figure 4: Sensing performance of prototype LMC/YSZ element. 0.25 µA was applied as a DC electrical stimulus. Note the stronger NO_2 response, particularly for 190 ppm.

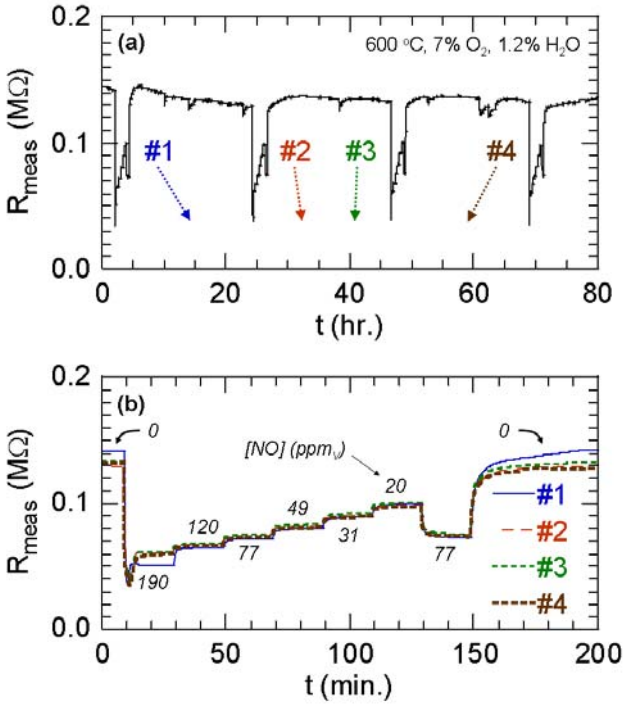

Figure 5: Measured response of a LMC/YSZ sensing element with constant applied current (0.25 μA). No NO was present except at the times indicated by the numbers in the upper figure (a). The lower figure (b) shows the changes induced by NO concentrations between 20 and 190 ppm_V.

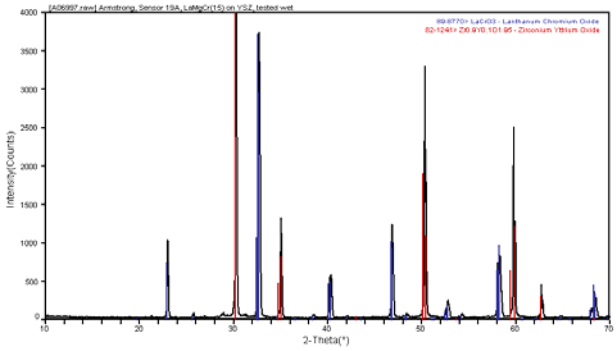

Figure 6: X-ray diffraction (Cu K_α) pattern from a tested LMC/YSZ sensing element. All peaks in the pattern can be assigned to LMC or YSZ, indicating that no decomposition has occurred during use.

Future Plans

- Continue investigation of alternate substrates and electrode materials. In particular, plan to examine Cr-deficient $LaCrO_3$. (Cr deficiency should enhance electronic conductivity, as Cr deficiency leads to formation of Cr^{4+}.)

- Work with CRADA partners to develop methods of quantifying and characterizing sensing element "drift" (as exemplified in Fig. 2). "Drift" is becoming increasingly important to industry member of CRADA team (Ford).

- Investigate acquisition of equipment that would allow of the application of low-frequency (1-100 Hz) AC stimulus.

Status of Milestones

1. Determine kinetics of NO reaction on electrode as a function of temperature and environment.

This is ongoing and will continue as new electrode materials are developed and tested as well as new sensor designs.

2. Fabricate and test a prototype NOx sensor (09/03)

We are focusing on refining the NO and total NOx sensors. Testing of these sensors is ongoing.

Industry Interactions

1. Biweekly teleconferences were initiated this quarter between DOE, Ford, LLNL, and ORNL.

SECTION 3. Thermally Activated Technologies

Section 3.1 TAT Ammonia-Water Absorption

Bob DeVault & Abdi Zaltash
Oak Ridge National Laboratory

Objective

Historically, energy savings was the primary programmatic emphasis for the natural gas fired ammonia-water absorption technology for individual chillers and heat pumps. This technology is currently moving out of the laboratory into pre-production prototype development and field-testing. The benefits of the program include:

- These heat pump systems offer 40% to 50% higher heating efficiency than the best existing furnaces or boilers for heating small buildings in the winter.
- Adaptation to IES applications using recovered heat promise residential and small to medium size commercial systems at the highest possible energy efficiency levels.

For the residential and light commercial space conditioning market, the technology is based on the ammonia-water absorption cycle with generator-absorber recuperative heat exchange. Performance levels (1.4 COPh and 0.7 COPc) favor a primary market in the northern half of the country due to its exceptional heating efficiency.

Transfer of contract activity with Rocky Research to NETL

ORNL will assist with contract transition and provide technical support and guidance for the NETL managed subcontract with Rocky Research.

In-House ORNL Lab and Performance Evaluations

ORNL will continue lab testing to independently verify the performance of the beta prototype *heat pump* Units on an as-needed basis.

Highlights

Testing on the advanced ammonia-water absorption heat pump unit (heating only) will start after the conclusion of tests on the 10-ton GEDAC heat pump unit.

Technical Progress

ORNL has been working with NETL on the transfer of this subcontracted activity from ORNL to NETL. The current contract with Rocky Research is being extended on a month-to-month basis, while negotiations continue between Rocky Research and NETL.

Status of Milestones

Provide technical evaluation report to NETL on in-house testing performed on advanced ammonia-water chiller from Rocky Research. September 2005
On schedule

Section 3.2 Solid-vapor Sorption Commercial Refrigeration

Bob DeVault & Abdi Zaltash
Oak Ridge National Laboratory

Objective

The Heat Activated Solid-Gas Sorption Commercial Refrigeration focus is on development of a complex compound sorption system for commercial refrigeration. The work will result in design-for-manufacture (DFM) and demonstration and testing of a heat-activated prototype having capacity up to 3 tons of refrigeration with possible option of waste heat activation. The work builds upon progress made on several previous projects, Phases I and II Hi-Cool and Utility funded sorber development projects. The goal of the Phase 2 project was to design, fabricate and test an engineering prototype in Laboratory environments. Phase 2 will be completed in FY05 under the current contract managed by ORNL with Rocky Research/Mississippi Energies. Any future work will occur contractually through NETL.

Transfer of contract activity with Rocky Research to NETL

ORNL will provide technical support to NETL in development of the contract statement of work and assist with transfer of subcontract management.

Highlights

Phase 2 of this subcontracted project was sent to NETL in support of future work which will be conducted by Rocky Research under NETL subcontract.

Technical Progress

Phase 2 of this subcontracted project was sent to NETL. The Phase 2 report shows the necessary steps taken in the fabrication, testing, redesign and re-testing of the engineering prototype. By the successful end of this phase the engineering prototype was sufficiently tested so it can be replicated and tested in the field.

Status of Milestones

ORNL will provide technical support as requested by NETL. Ongoing
On schedule

Section 3.3 Desiccant Humidity Control Technology by Industry Partners

Section 3.3a Kathabar – *No FY05 Funding*

Andy Lowenstein, Kathabar
Jim Sand, Oak Ridge National Laboratory

Objective

The ORNL subcontract with Kathabar, Incorporated was closed on 3/31/2004. Kathabar and AIL Research designed, built, and performance tested a prototype packaged liquid desiccant air conditioner that could cool and dehumidify 6,000 cfm (≈15 refrigeration tons) of ventilation air for a commercial or industrial building application. The prototype unit with uniquely-designed, corrosion resistant, polymer absorber, regenerator, and intercooler components showed a COP of 0.6 with 180°F hot water regeneration.

No follow-on work with Kathabar or AIL Research has been initiated. The work built heavily on the zero-carryover, polymer heat exchanger work that AIL Research did with the National Renewable Energy Laboratory (NREL) in Colorado. Heat exchanger leaking problems were experienced with the higher temperature polymer regenerator component throughout the program. *DOE OIT research is continuing on a 1.5x regenerator component that would boost desiccant system thermal efficiency to COPs greater than 1.20.*

Highlights

ORNL is working with NREL on a joint test of liquid desiccant components developed by AIL under a DOE funded project. The test will occur at the Chesapeake Office Building at the University of Maryland. The component is a low carry-over conditioner that NREL has developed and tested in-house. **This will be the first-ever field test of the newly developed low carry-over conditioner for the Kathabar Liquid Desiccant Dehumidification Unit.** Testing is scheduled to begin in the summer of 2005.

Technical Progress

This work is the culmination of the two research activities conducted at NREL and at ORNL. Through an NREL contract with AIL, the liquid low flow absorber component was developed. It was lab-tested at NREL. Through a contract with ORNL, the component integration occurred. Relevant task completion reports include: *A Rooftop Liquid Desiccant Air Conditioner Task 1 and 2 Report, 5/8/02 and Task 4 and 5 Report, 9/30/2003*

Status of Milestones

No FY05 milestone

Section 3.3 Desiccant Humidity Control Technology by Industry Partners

Section 3.3 b SEMCO

John Fischer, SEMCO
Jim Sand, Oak Ridge National Laboratory

Objective

In this R&D project the deep drying dehumidification capability associated with an active desiccant wheel was successfully combined with an advanced vapor compression cooling system, utilizing variable speed capacity control, to create a compact, energy efficient, hybrid HVAC system. System configuration and packaging was developed to offer a simple substitute for conventional rooftop equipment for broad market appeal. Based on the positive performance results obtained in full-scale laboratory testing, several SEMCO Integrated Active Desiccant Rooftop (IADR) systems are installed at various high profile demonstration sites complete with remote, Direct Digital Control (DDC), real-time data acquisition and system control. A commercial introduction of the SEMCO, ***Revolution™***, IADR product took place in May, 2004.

Work in 2005 will include follow-up on field performance verification studies previously mentioned including an evaluation at Carnegie Mellon University's Intelligent Workplace and an evaluation at Home Depot.

Highlights

The ***Revolution™*** IADR, a unit jointly developed by SEMCO and Oak Ridge National Laboratory was recently awarded an R&D 100 Award.

Technical Progress

The design work and site engineering has been completed for the Carnegie Mellon Intelligent Workplace IADR installation. ORNL, John Fischer (SEMCO), and Steve Lee (CMU) have approved a final submittal for this unit and the production engineering paperwork has been released. CMU's hybrid desiccant/vapor-compression system is being built at the SEMCO plant in Morrilton, Arkansas.

The possibility of an IADR field installation/verification study with several other large, national account retailers has been pursued because Home Depot will not be able to respond in time for this program. Much work has been invested over the past month to promote a field demonstration installation at the Marriott Resort Hotel on the island of Kauai in Hawaii. Final cost sharing agreements for this field trial installation are being worked out with Marriott, SEMCO, the local gas utility and ORNL.

Status of Milestones

Complete performance evaluation of SEMCO/IADR. September 2005.
On schedule

Industry Interactions

Project partners are SEMCO, Inc.

Section 3.3 Desiccant Humidity Control Technology by Industry Partners

Section 3.3c Florida Solar Energy Center - *No FY05 funding*

Jim Sand, Oak Ridge National Laboratory

Objective

In previous fiscal years, ORNL worked with Trane Company to design, build, and test a new, all electric desiccant/vapor-compression hybrid HVAC product that better fits the sensible to latent load characteristics of today's commercial buildings. Research work was initiated in 2004 to demonstrate and document the energy saving and improved performance features of the Trane Active Cromer Cycle, combined desiccant system through installation and monitoring of four to six units in several demanding field applications not adequately served by current, conventional air conditioning systems.

Trane offered a new product designated the Trane CDQ™ (Cool, Dry, Quiet) HVAC system in 2005. Certified testing shows that it reduces HVAC energy use by 50% compared to systems that use reheat for humidity control and by 10% compared to heat pipe/run-around-loop alternatives. Field verification studies of this Trane CDQ™ product concept in selected building applications were initiated in 2004. Both the SEMCO and Trane desiccant hybrid concepts impact the packaged equipment, rooftop market in the United States, which accounts for 90-95% of the commercial building air conditioning marketplace.

Highlights

Internet sites displaying site background information and real time data from Trane CDQ™ product installations at St. Vincent's Hospital in Birmingham AL, a document storage facility at the University of Central Florida, and the Franklin Memorial Hospital in Farmington Maine (http://sitepower.org). Two of these field installation/verification sites have an animated data display schematic showing current operating conditions for the hybrid desiccant/vapor-compression units.

Technical Progress

Ronnie Moffitt from Trane presented some initial field performance data from these demonstration installations at the desiccant applications seminar held in conjunction with the June ASHRAE meeting in Denver. Engineering product bulletins and site application instructions for the CDQ™ product have been issued by Trane for distribution and use by their field sales offices. Additional Trane CDQ™ field trial/verification sites are being pursued.

Status of Milestones

No FY 2005 Milestones

Industry Interactions

Partners include Trane Company, Florida Solar Energy Center (FSEC), the University of Central Florida, and AirXchange, Inc.

Section 3.4 Desiccant Performance Evaluation and Industry Partnerships

Jim Sand, Oak Ridge National Laboratory

Objective

ORNL supports industries integral to the DOE TAT, IES, and CHP missions with laboratory benchmark testing and evaluation of desiccant "systems" performance. Through a User's Agreement, ORNL will generate controlled laboratory performance data on SEMCO's integrated active desiccant rooftop module (IADR) hybrid desiccant system (a) to map performance and verify control strategies for integrated desiccant/vapor-compression system operation, (b) to provide diagnostic support for field data evaluations several field installations, and (c) to verify desiccant CHP integration potential in support of a National Accounts Energy Alliance (NAEA) desiccant installations in Texas and in Pinellas Park, Florida.

ORNL will continue to independently benchmark and measure the relevant performance characteristics of thermally activated desiccant equipment regenerated with primary and/or waste heat sources in the laboratory. A DryKor liquid desiccant TAC-10, thermal air-conditioner has been ordered for installation this fall. Data and results from these contemporary systems will assure the availability of important performance results of interest to the U.S. HVAC and IES/CHP engineering communities.

Work planned for the remainder of 2005 work will include extensive in-house testing of hybrid solid-desiccant and liquid desiccant systems in the laboratory and continued promotion of desiccant and thermal system method of test and rating certification standards.

Highlights

An ORNL paper entitled "*Performance Analysis of an Integrated Active Desiccant Rooftop Air-Conditioning System Operating in Heating Mode*" was written, internally reviewed, submitted and accepted for the 2005 ASME International Mechanical Engineering Congress and Exhibition in Orlando this November. This paper is based on the performance of a hybrid desiccant rooftop unit installed and monitored at ORNL. In this installation the test unit functions to heat, cool, dehumidify, and provide ventilation air for the ORNL CHP Integration Laboratory working under naturally occurring ambient conditions.

Technical Progress

ASHRAE SPC 174, the special projects committee developing a Method of Test (MOT) for Rating Packaged, Desiccant Based Dehumidifier systems met in Denver and will present a MOT and Rating standard to the full Desiccant and Sorption Technology Committee at the next meeting. A draft ORNL Subcontractor report and ASHRAE Seminar presentation was prepared documenting the successful retrofit installation of a hybrid desiccant system at the Timber Ridge Elementary school in the Atlanta area and the indoor air quality improvements resulting from the increased ventilation and active humidity control provided by this recently introduced product.

Status of Milestones

Provide DOE a go/no-go decision relative to the Desiccant Control Van. June 2005
(In collaboration with the Energy Solutions Center (ESC), the DOE/ORNL DHC Van is scheduled to visit and be exhibited at four large gas utility companies over the summer of 2005)

Draft report on performance of DryKor desiccant air-conditioner. June 2005
-Delayed because of unit late delivery from vendor-

Industry Interactions

SEMCO Incorporated, attendees at the Denver, CO Annual National ASHRAE meeting.

Section 3.5 TAT Roadmap and Other Support

Section 3.5b TAT Controls Survey

Kofi Korsah, Bruce Warmack, Oak Ridge National Laboratory

Objective

Under previous FY funding, ORNL worked with Telaire and other industrial partners to develop combination humidity and CO_2 sensors. The sensors could not hold calibration in tests at the University of Maryland Integration Test Center and in other field tests. Additionally, GRI and other organizations have spent notable corporate funds in developing sensors for the same purpose. This task is to perform a survey of commercially available TAT sensor and control technologies, specifically those developed for humidity and CO_2 measurement, as well as previous industry experience and assess needs for future integrated TAT equipment; provide a technical evaluation of shortcomings of present controls and why previous industry projects failed to meet goals of accuracy, reliability, and cost; prepare recommendations and strategies for future sensor and control development efforts.

Highlights

A survey of humidity and CO_2 sensors revealed good new possibilities for both individual and combination units.

One manufacture (Telaire) stated the need for larger markets before committing to designing improved sensors.

Technical Progress

Some encouraging data from manufacturers show that accuracy and drift of certain inexpensive relative humidity (RH) sensors may have improved.

Analysis of specification data shows that inexpensive water-content (or dew point) sensors can be made by combining proper RH and temperature (T) sensors. Compared to an expensive high quality chilled mirror, the expected error is only a few times worse and may be acceptable from some applications.

The survey to date shows that, while there are several sensors that can measure either CO2 or humidity separately, there are currently very few products that combine both measurements. AirTest Technologies Inc., (Delta, BC) has a model (EE80 series) that combines CO2, RH and T measurements in one housing. Another model that AirTest has recently sampled from a Swedish manufacturer uses nondispersive infrared absorption (NDIR). It has significantly improved specifications for both humidity and CO2. ORNL investigators are in contact with Air Test and will acquire both modules for testing of humidity, temperature and CO2.

Miscellaneous: Experimental humidity measurement comparisons were made in the laboratory. Some novel humidity sensors were conceived and discussed internally.

Status of Milestones

Based on technical analysis and evaluation, prepare recommendations and strategy for future TAT controls and sensors development for humidity and CO2. August 2005

On-schedule

Industry Interactions

Telaire, Elektronik(tm) Ges.m.b.H., GTI (GRI), and CDH Energy.

Section 3.6a Advanced Thermal Recovery Cycles

Section Task 3.6a UTRC

Bob DeVault, Oak Ridge National Laboratory

Objective

Organic Rankine cycle equipment is emerging from research and development laboratories. Operation of these cycles can extract heat energy from a source in the range of 250-800°F and convert it into electricity. Power system efficiency of 8-15% is expected depending on feed heater options and ambient conditions. Lower cost organic Rankine cycle systems could be targeted for combined heat and power bottoming cycles to increase net electrical output or toward low/moderate temperature waste heat streams. Initial field testing of a low-cost Organic Rankine system was funded in FY 2003 and installation and initiation of testing was started in FY 2004. Testing will continue in FY 2005.

Novel combination of liquid desiccant and synthetic membrane separation technologies makes possible a desiccant energy recovery system with separated ventilation air pre-treatment and exhaust air recovery stations. This *enthalpy pump* design which has the energy efficiency advantages of a direct-contact mass and heat exchanger, also allows for combined enthalpy exchange and active-desiccant dehumidification operation, a system that can evaporative cool, summer and winter energy recovery without wheel frosting problems, easy integration with conventional AC, and convenient retrofit to older buildings.

New approaches and applications are needed to address situations in which more thermal energy is available than can be practically used for conventional heating and cooling functions. To capitalize more fully on an otherwise wasted energy resource, for example, thermal energy might be used to treat water or sewage on site; generate hydrogen; generate shaft power for driving pumps or blowers; or generate electricity. Many other approaches are possible as well.

Research, development, and deployment efforts will be directed toward developing novel approaches to make full use of available waste heat.

Highlights

Work was completed on the following 3 tasks: FMEA and Test Plan Review, Recuperator Assembly Design Review, and Test Facility Preparation.

Technical Progress

FMEA and Test Plan Review – As addressed in the Failure Modes and Effects Analysis, the major risks with the steam/hot liquid Organic Rankine Cycle (ORC) system include: impeller high cycle fatigue, oil reclaim methodology and implementation, and control modification. The mitigation plans are in place for the prototype and the test is going to address each major risks as well as the performance of new components such as the evaporator and the recuperator assembly.

Recuperator assembly design review – A recuperator assembly including three brazed-plate heat exchangers in parallel will be incorporated into the ORC system between the power module and the condenser to preheat the working fluid going into the evaporator with the superheated working fluid coming out of the turbine. The recuperators will increase the overall system thermal efficiency. The drawings of the recuperator assembly have been reviewed and were released to manufacturer.

Test facility preparation – The test facility is almost ready except for the installation of the evaporator and recuperator assembly. In order to duplicate typical installation at potential application site, the evaporator

is going to be installed indoors. This decision brought out many site preparation issues due to ES&H concern; therefore the team spent much time to prepare the facility to meet the requirements of indoor ventilation and electrical ratings. In addition, vendors continue to work on piping of the system. The evaporator and recuperator assembly were delivered in May and installed at UTRC testing site. Commissioning of the system is expected to start this month.

Status of Milestones

Demonstrate a steam-driven evaporator design for the Organic Rankine Cycle, applicable to the PureCycle 200 Power System. June 2005: No Report

Industry Interactions

Partners in this project are UTRC.

Section 3.6 Advanced Thermal Recovery Cycles

Section 3.6b Thermochemical Active Working Cycles

Solomon Labinov, Jim Sand
Oak Ridge National Laboratory

Objective

The concept of using a thermochemically active working fluid (AWF) in a closed cycle gas turbine system is theoretically attractive and has been evaluated independently for DOE. It involves the use of a high density working gas which, on heating, breaks into simpler molecules, with an increase in total gas volume. Therefore, the turbine operates with a larger gas volume than the compressor, and generates proportionately more power than the compressor absorbs. This leads to higher net output and significant gain in efficiency. Proof-of-principle experiments have been carried out with an AWF which would not be acceptable for DE applications. The proposed near-term development effort would therefore focus on: (a) a systematic search for candidate working fluids and (b) a thermodynamic model to establish non-equilibrium conditions during the cycle, which includes reversible thermochemical transformations. Once a suitable working fluid is identified and its properties characterized, a design schematic should be developed and modeled in as much detail as is reasonable to address fluids/materials compatibility issues, potential safety issues, and to reassess the technical performance of the cycle in light of the initial findings.

Highlights

A memo report verifying completion of the FY-2005-AOP milestone calling for a complete systematic search of potential active working fluid reaction systems for this cycle was written and sent to the ORNL Program managers and the ORNL Energy & Engineering Sciences Directorate coordinator.

Technical Progress

Eleven eversible reaction systems were considered as alternative active working fluids for the $N_2O_4 \leftrightarrow 2NO_2 \leftrightarrow 2NO + O_2$ reaction system which had been used for most of the previous work and analyses associated with this thermochemical cycle. The Reversible Water Gas Shift recombination Reaction $CO_2 + H_2 \leftrightarrow CO + H_2O$] was chosen as the most promising reversible reaction system for subsequent study because: the reaction provides a 1:2 gas mole ratio between compression and expansion, the reaction occurs in the 300 – 1,200 K temperature range, efficient Fe_2O_3 and Au/Fe_2O_3 catalysts have been found and studied for this reversible reaction, and because reactants and products are less toxic than the N_2O_4 system and leakage will not present an immediate danger. A 3-pager, LDRD proposal application was submitted to construct a bench-top working model of this thermally powered engine as a means of "portable power" generation from low-grade, externally-burned fuels.

Status of Milestones

Complete systematic search of active working fluids for thermochemical cycle and report updated findings to DOE. (COMPLETED).

Section 3.7a Heat & Mass Laboratory Development

Eddie Vineyard, Randy Linkous
Oak Ridge National Laboratory

Objective

Significant advancements in heat and mass transfer have been made in the past two decades that allow for more efficient recycling of thermal energy.

Heat and mass transfer material developed for other industries like automobiles, have brought forth technologies that may significantly impact thermal energy recycling. One such innovation is the micro channel heat exchanger which was initially designed to reduce the size, weight and cost of radiators. Another potential innovation is the use of centrifugal force to significantly increase the rate of heat and mass transfer.

In the field of low temperature energy recovery that is particularly represented by CHP systems, volume, footprint and weight are important indicators of energy efficiency, technical feasibility, application flexibility and economic viability. Therefore, advanced heat and mass transfer innovations will focus upon significantly reducing volume, footprint and/or weight of key thermally activated technology pathways (absorption technologies, desiccant dehumidification and heat transfer, and mass transfer and thermal recovery).

Based on the Thermally Activated Technologies Roadmap (May 2003), work was started in FY 2004 addressing key higher-priority recommendations. Identification, testing and development of advanced heat and mass transfer innovations will continue in FY 2005. This work will be supplemented by the continued acquisition of non-capital equipment upgrades and facility improvements.

Energy recovery systems have taken the form of auxiliary equipment and are generally the purview of installers and not part of a well thought out integration design or strategy. These critical components to integrated energy efficiency have not undergone rigorous research and development. New technologies, like microturbines and fuel cells provide low temperature waste heat (~ 150 - 550°F) which requires a rethinking of heat transfer approaches. “Out-of-the-box” approaches are required to develop low cost systems approaches. New heat recovery heat exchangers (e.g., micro-channel and rotating) must be explored to maximize IES energy efficiency and minimize cost.

Potential benefits:

- Heat recovery devices that have improved efficiency, reduced size, reduced cost, and are better suited to both low grade and high grade heat utilization.

- Proper design and integration of these technologies in IES will likely yield increases greater than 20% in system efficiency and with substantially reduced cost and improved reliability.

Stand-alone heat recovery equipment is vintage technology that has been developed as an auxiliary device without consideration for the proper integration of power generation and TAT equipment. DOE’s role is to partner with industry to accelerate the research and development of higher efficiency and lower cost integrated heat recovery systems based upon IES laboratory, test bed and field experience. In FY05, ORNL will install the heat and mass transfer test loops [procured with FY04 capital funds], and initiate testing.

Highlights

Tom Radcliff from UTRC visited ORNL to discuss the test plan for heat exchanger tests at ORNL. Capabilities of the test rig in Building 3115 were reviewed to determine if ORNL could perform all the testing. It was determined that the test rig would be adequate if a dehumidification loop was added.

ORNL was awarded additional funding for TAT from a proposal submitted for the DOE Lab Call. The Lab Call will fund work on advanced cycles, heat exchanger development, capital equipment, and a study on heat exchanger technology options and metrics.

Ed Vineyard met with Hugh Henderson (CDH Energy), Rich Sweetser (Exergy Partners), Clark Bullard (Consultant), and Pega Hrnjak (University of Illinois) to lay out the plan for a TAT Heat Exchanger Study. The study will evaluate the state-of-the-art for heat exchangers presently used in TAT equipment, determine potential technologies for improvement, and define metrics for energy savings.

Ed Vineyard met with Don Bivens and Thomas Leck (DuPont) to discuss the advanced cycle work that was awarded to ORNL under the DOE Lab Call.

Technical Progress

The wind tunnel heat exchanger test loops were received and all electrical connections have been completed. Chilled water piping connections are underway and instrumentation is being connected to the data acquisition system. A water heater has been ordered which will expand the capabilities of the test loop by enabling hot fluid to be circulated through the heat exchangers. Applications for heat exchangers of this type include generators for absorption chillers, regeneration heat exchangers for desiccant systems, and heat generation for organic rankine cycles.

ORNL is planning to test a microchannel heat exchanger for UTRC. In order to be able to perform some of the tests, it will be necessary to install a desiccant dehumidifier in the test loop in Building 3115. This will enable testing to be performed at extremely low dewpoint conditions. The dehumidifier has been ordered and is scheduled to arrive in August.

We have begun to acquire heat transfer diagnostics to analyze data from the heat exchanger tests. Recently, we received a copy of FEMLAB, which is a software tool for computational fluid dynamic (CFD) analysis of flows and temperature profiles to aid in heat exchanger design improvements. Plans are to also obtain FLUENT software which has different capabilities.

Status of Milestones

Complete installation and initiate shakedown tests of new heat transfer test loop in Building 5800. September 2005
On Schedule

Industry Interactions

DuPont and UTRC

Section 3.7b Micro-Channel Heat Exchanger Development

Eddie Vineyard
Oak Ridge National Laboratory
AMTI and Clark Bullard

Objective

One of the five strategic goals outlined in the TAT technology roadmap was to reduce the footprint, volume, and weight of thermally-activated technologies. A means of achieving that goal is to reduce the size of heat exchangers through advancements in the design, such as micro-channel surfaces and rotating heat exchangers. Plate and frame micro-channel heat exchangers can provide space savings ranging from 50 to 90%, and improved efficiency. For FY 2005, ORNL will develop and test a first generation micro-channel heat exchanger for a 5 to 10 ton refrigeration unit (scalable to 100 tons). Issues that will be addressed in the design of the prototype are pressure drop, size, and cost. The goal will be to achieve a design that gives comparable energy performance with a reduction in size and installed cost.

Highlights

Ed Vineyard met with Kevin Mercer of Modine at ASHRAE to explore the possibility of obtaining a micro channel heat exchanger for a 10 ton heat pump. Kevin indicated that he would fabricate a heat exchanger as close as possible to the specifications provided by Larry Copeland of Southwest Gas.

Technical Progress

After forwarding the design requirements for the Southwest Gas heat exchanger to Bob Linstroth, he was reassigned to another position at Modine which expanded his responsibilities and hindered the time he could devote to working with ORNL on the heat exchanger design. While at the Air-to-Refrigerant Heat Exchanger technical committee meeting at ASHRAE, another contact, Kevin Mercer, was identified. Kevin Mercer is the Product Development Engineer for microchannel heat exchangers and was, most likely, better suited to handle the request initially. Kevin indicated that it should be no problem to obtain some prototype heat exchangers, especially if we can use designs that are within the capabilities of their present manufacturing techniques.

Status of Milestones

Subtask 3.7b Complete initial design, fabrication, and testing of prototype. September 2005
On Schedule

Industry Interactions

Partners in this activity include UTRC, Southwest Gas, AMTI, Clark Bullard, and Modine.

Section 3.7c Heat Exchanger Maldistribution

Eddie Vineyard & Steve Allison & Dennis Earl
Oak Ridge National Laboratory

Objective

Maldistribution of the fluid flowing through the heat exchanger circuit results in capacity losses on the order of 15 to 30%. Efforts to reduce maldistribution are hampered by the ability to effectively measure the temperature in different areas of the heat exchanger. It is proposed to develop a measurement technique based on previous work at ORNL which uses phosphor paint and fiber optics to measure temperatures throughout the heat exchanger. The phosphor method has been applied with a precision of about 0.01 degree. This optical measurement technique would be a significant improvement over present methods. Thermocouples have intrinsic limitations because, being comprised of electrically conducting materials, they alter the resistance of the medium being measured, conduct heat away, and add electrical paths. Calibration and drift also require accommodation. Their accuracies, consequently, at best are only about +/- degree Fahrenheit. The fluorescent method, by contrast, adds no highly conductive component as part of the measurement system (relying on chemically stable and nonconducting oxides and similar structures), no electrical reference, and has no drift in calibration. Fluorescent properties, from which temperature is inferred, have no emissivity dependence and are not subject to moisture problems that may arise with condensation.

For FY05, the work will concentrate on the design of a test apparatus capable of determining the flow maldistribution through means of measuring the temperature distribution throughout the heat exchanger. An air to refrigerant heat exchanger will be installed in the test fixture and measurements will be made to determine the extent of the maldistribution.

Future work will investigate heat exchanger design improvements to correct maldistribution problem and reduce the size of the heat exchanger.

Highlights

We received the FLIR Thermacam S65HS thermal imaging camera and began to use it to evaluate the condenser on the Southwest Gas 10 ton unit. The results have been quite impressive. The resolution was much improved over previous cameras and we were able to identify areas of maldistribution in the heat exchanger under cooling conditions.

Initial proof of concept testing with phosphor paint was completed. Both steady state and transient tests were performed. The results showed excellent agreement with thermocouples placed on the heat exchanger.

Technical Progress

Proof of concept testing with the thermal imaging camera and phosphor paint showed that both approaches are useful for different applications. The thermal imaging camera will be used when the heat exchanger surface is easily accessible. The phosphor paint technique will be employed for areas of the heat exchanger that are not easily accessible, such as when the heat exchanger is several rows wide or for testing rotating heat exchangers that make other forms of instrumentation difficult.

In discussions of the results with Clark Bullard and Pega Hrnjak, they were quite impressed with both measurement techniques. They indicated that ORNL could evolve into a world class laboratory for heat exchanger measurement techniques, especially on the basis of our ability to purchase and develop cutting edge equipment.

Status of Milestones

Subtask 3.7c Complete test apparatus design and initiate measurements for fluid distribution. September 2005

On Schedule

Industry Interactions

University of Illinois

SECTION 4.1.1 Packaged/Modular IES Development

Section 4.1.1.a Burns and McDonnell

Ed Mardiat, Burns and McDonnell
Jan Berry, Oak Ridge National Laboratory

Objective

Burns and McDonnell in Kansas City, Missouri, to partnered with Solar Turbines Inc. and Broad USA, to develop, design and construct a modular integrated energy system (IES) for Austin Energy, a municipal utility. Construction was completed at the Domain Technology Park in Austin, Texas in June 2004. The IES has provided electricity from a Taurus 5,200 kW turbine generator, and up to 2,500 refrigeration tons (RT) of free waste heat driven absorption cooling. The IES is the largest system in the world to use turbine exhaust thermal energy as the only source of fuel for an absorption chiller. Modular construction reduces installation cost and schedule while ensuring that components are fully integrated.

- FY05 work includes:
  1. Collection and analysis of performance and economic data on the Domain Site.
  2. Research and development on a new project with the Burns & McDonnell/Austin Energy team: 4.6-MW Mercury 50 Solar gas turbine integrated with a heat recovery steam generator and 1,000-ton chiller to be installed for Dell Children's Hospital. During FY05, the system will be designed and construction is scheduled to begin. The CHP system is a state of the art facility that is being evaluated by a LEED subcommittee to establish appropriate credit for CHP installations.

Highlights

The Burns & McDonnell design team received an Engineering Excellence Award from the Texas Council of Engineering Companies for the innovative integrated energy system that has been operating at the Domain in Austin, Texas since Fall 2004. A ground breaking ceremony was held in Austin for the Seton Children's Hospital (see photo). The hospital will use energy generated by a second-generation, modular integrated energy system as its primary source of electricity, heating and cooling.

Technical Progress

The following reports were submitted and reviewed by ORNL: (1) Final Report: Field Data Acquisition and Analysis prepared by the University of Texas at Austin; (2) Post Commissioning Test Report prepared by Burns & McDonnell. A project review meeting was held in Kansas City that reviewed project milestones and kicked-off collaboration between ORNL and Burns & McDonnell experts on economic modeling. The project initiated a website with a kick-off meeting and a draft website posted for ORNL review. A paper was presented during the International Sorption Heat Pump Conference entitled, "Advanced Absorption Chiller Converts Turbine Exhaust to Air Conditioning." The paper summarizes the Domain site project economics and field data collected during post commissioning.

Status of Milestones

Draft report on data analysis and operating experience of 5 MW IES system installed at Domain site in Austin, TX - September 2005 - On-schedule

Industry Interactions

Project partners are: Burns and McDonnell, Austin Energy, Solar Turbines, & Broad

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.b Capstone Turbine Corporation

Bob DeVault, Oak Ridge National Laboratory

Objective

Capstone Turbine Corporation in Woodland Hills, California, to design and test packaged IES Systems based on using waste heat from Capstone's 30 kW and 60 kW microturbines coupled with absorption chillers for air-conditioning.

In FY03, Capstone formed a strategic alliance with UTC Power which resulted in the production of the Pure Comfort product line.

Highlights

See Section 4.1.1g – UTRC

Technical Progress

See Section 4.1.1g – UTRC

Status of Milestones

See Section 4.1.1g - UTRC

Industry Interactions

Partners in this project are UTRC and Capstone.

Section 4.1.1 Packaged/Modular IES Development

Section 4.1.1.c Gas Technology Institute

Kevin Olsen and John Kelly, Gas Technology Institute
Tim Theiss, Oak Ridge National Laboratory

Objective

The Phase I technical effort has concentrated on maximizing efficiency and reducing installation costs for the GTI IES system. The Waukesha Model VGF36GLD, lean burn, 615 kW rated output engine-generator was selected as the power plant for the project.

The FY05 work plan is currently under development for resolving remaining R&D gaps.

Highlights

A major accomplishment of the Phase I project is that GTI tested the Waukesha engine according to the newly developed ASERTTI test protocol for laboratory testing of CHP systems. DOE is awaiting a white paper with recommended changes to the ASERTTI protocol.

Technical Progress

ORNL hosted a review meeting with GTI on June 13th at the NTRC. GTI provided a slide presentation on the technical content of their second draft of the project report for the Phase I project. Subsequently, ORNL compiled comments by several in-house technical reviewers and provided the new comments to GTI. The final report is expected this summer. A separate meeting was held with ORNL procurement to discuss contracting issues related to completing a Phase I extension and Phase II for the IES project. In the initial Phase I project, Trane delivered a newly designed absorption chiller that could be coupled with the Waukesha engine being tested at GTI. Both project cost-sharing partners made a business decision to withdraw from the project. GTI has been working with alternate engine manufacturers and absorption chiller manufacturers in an effort to continue the project.

Status of Milestones

Engine-driven Modular CHP System – Complete site location analysis for Phase II and provide recommendations for reviewed selection. August 2005 – Based on difficulty GTI has had in locating a new project partner for Phase II, this milestone will need to be revised to include only Phase I activities.

Industry Interactions

GTI, Waukesha, Trane, Ballard Engineering, Hess Microgen, UTRC, Equity Office Partners, Northern Power Systems, Redwoood Power, Vaporphase, Cummins Power Generation and Charles Equipment.

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.d Honeywell Laboratories

Steve Gabel, Honeywell Laboratories
Jan Berry, Oak Ridge National Laboratory

Objective

- Honeywell Laboratories in Minneapolis, Minnesota, has developed and is field-testing a large (5.2 MW) IES packaged system. The turbine generator was combined with a 1,000 RT absorption chiller and the prototype has been set up and tested at Fort Bragg, North Carolina. This system was installed in FY04.
- FY05 work includes:
- A June 7, 2005 dedication to be held in conjunction with the Army and FEMP.
- Extension of performance monitoring and demonstration of the integrated energy system (IES) throughout FY 2005;
- Use of ASERTTI long-term test protocol to acquire data;
- Incorporation of North Carolina State University faculty and students in system performance monitoring from commissioning through FY 2005;
- Increased number of project review meetings.

Highlights

The dedication event for an Integrated Energy System was held at Ft. Bragg on June 10th. This event was hosted by the Ft. Bragg Directorate of Public Works and was well attended, with representatives from the Army Corps of Engineers in Huntsville, Oak Ridge National Laboratory, the Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy: Distributed Energy Program and Federal Energy Management Program, and the industry team of Honeywell, Broad Air Conditioning, and I.C. Thomasson. The co-chair of the Southeast Combined Heat & Power (CHP) Application Center from North Carolina State University also attended, to further the DOE's objective of providing CHP technology and information to Southern industries and businesses.

The day included remarks from the key participants in the project, and a tour of the central utility plant. All equipment was operational during the tour, and a technical overview of each part of the system was given to the attendees. DOE contractors who are developing the 2005 IES web-cast were also in attendance to gather detailed project information and interview key participants in the project. This event was a great success, and provided opportunities for participants to meet others involved in the project and discuss potential ways to work together on other distributed energy projects in the future.

Technical Progress

A report entitled, Modular Integrated Energy Systems, Field Monitoring Interim Report summarizes data collected for the heating portion of the Cooling Heating and Power system installed at Ft. Bragg. The report was reviewed by several ORNL staff members. A paper was presented during the International Sorption Heat Pump Conference entitled, Exhaust-Driven Absorption Chiller-Heater and Reference Designs Advance the Use of IES Technology."

Status of Milestones

Large-turbine CHP System Mid-Project Report on field testing of Large-turbine and waste heat driven absorption chiller CHP system at Ft. Bragg, NC military base. June 2005 COMPLETE

Industry Interactions

Partners include Honeywell Laboratories, Broad International, Solar Turbines, U.S. Army, FEMP, I.C. Thomason

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.e Ingersoll-Rand

Jay Johnson, Marketing Manager, Ingersoll-Rand
Therese Stovall, Oak Ridge National Laboratory

Objective
Ingersoll-Rand in Portsmouth, New Hampshire will combine a new 70 kW microturbine with an ammonia-water absorption refrigeration system. The absorption system will be used to cool the turbine's inlet air and to produce refrigeration for building space conditioning and for refrigerator-freezer applications.

In FY04, Ingersoll-Rand had a management change and made a decision not to pursue this project further. While awaiting word from Ingersoll-Rand on how to proceed, preferably with on of their subcontractors, Ingersoll-Rand had another change in management and the new Marketing Manager, Jay Johnson, would like to revive the project and get moving.

FY05 objectives and goals are forthcoming.

Highlights
No Report

Technical Progress
No Report

Status of Milestones
There are no milestones because we do not have a contract in place.

Industry Interactions
Ingersoll-Rand, AMTI, Energy Concepts.

Section 4.1.1 (cont.) Packaged/Modular IES Development

4.1.1.f Nisource Energy Technologies *No FY05 funding.*

Bob DeVault, Oak Ridge National Laboratory

Objective

NiSource Energy Technologies in Merrillville, Indiana designed and demonstrated a modular packaged IES system at a Hilton Hotel. The system includes: three microturbines, heat recovery heat exchangers, an absorption chiller, a desiccant unit, and an integrated control system.

Highlights

No report

Technical Progress

No report

Status of Milestones

Hotel/Motel CHP Packaged System – Complete the final report of the Integrated Packaged System at the selected hotel and initiate preparation of the final report. June 2005 No Report

Industry Interactions

Project partners include NiSource and Hilton Hotel.

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.g United Technologies Research Corporation

Tom Rosfjord, UTC Power and Tim Wagner UTRC
Bob DeVault, Oak Ridge National Laboratory

Objective

UTRC in East Hartford, Connecticut developed an IES system based on off-the-shelf components to make a packaged system within the project's first year. Early in FY 2003 (November 2002), United Technologies Power formed a strategic alliance with Capstone. UTRC's Pure Comfort System is based on the use of Capstone's 60kW in multiple-unit IES packages coupled to Carrier absorption chillers. The new 240kW Capstone Microturbine system was launched as a product line by UTC Power in FY2004.

FY2005 work will include a field test verification and demonstration and development of reference designs for systems with varying electrical loads and thermal capacities.

Highlights

A dedication ceremony of the CHP System installed at an A&P Fresh Market in Mt. Kisco, New York, was held on May 17, 2005. This local supermarket is the first U.S. customer to take delivery of the UTC Power's new PureComfort 240M solution that was developed under this joint DOE/ORNL/UTRC program. This new on-site generation system will significantly reduce the store's dependency on the electric grid, while providing: power for the building's electrical needs, sub-cooling for its refrigeration system, cooling in the summer and heating in the winter, and desiccant regeneration. Each installed PureComfort IES system produces about 40% less CO_2 per megawatt-hour than the average fossil-fueled utility power plant and about 10,000 lbs per year less NO_x, the equivalent of taking more than 250 average passenger cars off the road. This system, which was commissioned in December, comprises four microturbines with a Carrier double-effect absorption chiller. The system is sized to meet approximately 50% of the store's load, providing 150 RT cooling, 950 MBH thermal, and 230 kW at 59°F.

At the dedication, UTC Power President Jan von Dokkum said, "The store is brightly lit, shelves are stocked with quality products, an overabundance of fresh produce, a clean and well organized meat and fish counter and a beautiful deli. That's what a customer sees. Behind the scenes it is equally impressive. This is without a doubt a very technically advanced store and energy efficiency is a big part of it." Also speaking at the event was Douglas L. Faulkner, Principal Deputy Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy, who said: "This event recognizes the value of partnerships dedicated to technological innovation between government and business," "The use of technology to improve efficiency is a key objective of President Bush's energy plan and public-private partnerships like this one can be the model for others as we work together to secure America's energy future."

Technical Progress

No Report

Status of Milestones

UTRC Phase II – Demonstrate technology readiness of enhancements including electric load following control capability for installations of multiple microturbines, applicable to PureComfort CHP Systems, April 2005 No Report

Industry Interactions

Project partners include UTC Power, UTRC, Carrier, Capstone, and A&P.

Section 4.1.2a/b University of Maryland Collaboration

Reinhard Radermacher and Dennis Moran, U of M
Patti Garland, Oak Ridge National Laboratory

Objective

The Chesapeake Office Building on the University of Maryland Campus is a 52,000 square foot office building housing over 150 office personnel. Once an all electric building with 2 separate heating and air conditioning zones, the building has been upgraded with gas-driven equipment for electric generation coupled with thermally driven absorption and desiccant dehumidification [both liquid and solid] equipment. This building is known in the DOE Program as the CHP Integration Test Center. Work scheduled for FY05 consists of:

- Mining existing data collected over the last few years
- Operating the newly installed DTE engine
- Operating the newly installed Broad absorption chiller with internal cooling tower
- Investigate low-temperature regeneration of desiccant systems
- Assessing opportunities to improve system integration [such as combining engine generator with liquid desiccant]

Highlights

The Capstone turbine was operated throughout the month of May. However, the diaphragm/coupling in the Capstone turbine failed on June 1. The failed core has been returned to Capstone and U of M is waiting on a replacement. The turbine core must be replaced before system operation can resume and Broad chiller can be commissioned.

Installation of the intelligent software developed by Darrell Massie is complete. The computer is accessible using pcAnywhere and work has begun on the models and model maps for optimization of the systems. The software will initially examine, separately, the energy efficiency and cost effectiveness of operating the liquid and solid desiccants versus doing dehumidification with only the cooling coils in the rooftop units.

Technical Progress

System 1: The engine generator was run at a range of loads from 40-75 kW as much as possible during May and June. Operating temperature varied and it was necessary to add coolant periodically during the month. A serious problem was encountered with the starter which failed completely at the end of June. DTE was contacted and a new starter motor and wiring harness have since been installed. On May16th, the engine generator did not start due to a failure of the air fuel mixer valve. It was determined that the valve seat broke due to a casting defect. DTE provided a new air-fuel mixer which was installed on the engine. Some of the PVC and copper pipes to the cooling tower ruptured during the winter and were repaired in mid-May. During the third week of May, the cooling tower for the liquid desiccant system was charged with makeup water. A new magnetic capsule and rear casing parts were purchased from Kathabar Spare Parts and the regenerator pump was disassembled completely, the new parts were installed and the pump assembled back into the system. Operation of the Kathabar desiccant was limited by ongoing problems with the regenerator pump that persisted all of June and by problems with the circulator pump which began near the end of June. The regenerator pump subsequently was replaced and repair parts for the circulator pump were ordered (both in July).

The new liquid desiccant conditioner [designed by NREL] will arrive in mid-August and it will be installed immediately. Current plans are to accumulate as many operating hours as possible on the existing system before the new unit arrives. After installation of the new conditioner, a series of tests will be conducted to compare performance of the two units. This work is being done in conjunction with

Steve Slayzak at NREL.
System 2: The microturbine was run at various power levels throughout May as shown in the attached work log. At the end of the month, the diaphragm/coupling broke (see photo) hence the unit is deemed inoperational. The new Broad chiller can not be commissioned until the microturbine is operational.

Status of Milestones

Complete draft report on lessons learned and initial data collection of new Broad absorption chiller and Capstone turbine IES at the Chesapeake Office Building. September 2005

The Capstone Microturbine has been out of service during much of the summer months. The Broad chiller cannot be commissioned until the microturbine is up and running.

Section 4.1.2c/d DE Integration Lab Test and Evaluation

Abdi Zaltash and Andrei Petrov
Oak Ridge National Laboratory

Objective

It is essential to industrial partners that we understand technical issues related to optimal integration of components as well as optimal operating conditions for DE and HVAC equipment and systems. ORNL offers the unique capability of benchmarking equipment throughout the full range of operating conditions in a closely controlled laboratory environment or in precisely controlled environmental test chambers. Equipment from manufacturers can be operated and tested in precisely controlled environmental conditions to assist those manufacturers in optimizing equipment and component matching and operational control of the equipment. This work can also be used to help develop or test rating/certification test procedures and standards.

In addition, ORNL assists the University of Maryland by providing hands on training and experience to students in-house at ORNL.

Highlights

Testing of the industry confidential prototype gas-fired heat pump with the interim alternate refrigerant (R407C) is near completion. Report on performance test results of R22 and R407C will be completed by the industry partners.

The article entitled “Laboratory R&D on Integrated Energy Systems (IES)” was published in the peer reviewed Applied Thermal Engineering Journal, available on line, June 15, 2005.

Technical Progress

The refrigerant R22 of the industry confidential gas-fired heat pump prototype was replaced by the interim alternate refrigerant R407C. Tests were conducted at various ambient conditions (standard rating conditions, ARI Standard 210/240-94). These tests included the performance, emissions, and thermal imaging of the outdoor coil. These tests are being reported to the manufacturer.

Arrival of the new liquid desiccant DRYKOR TAC-10 has been postponed due to the manufacturer problems with their heat exchanger.

The supply and return hot water lines of the microturbine-based CHP system were connected to the IADR SEMCO heat pump unit. These lines were also instrumented in preparation of performance evaluation of SEMCO unit as part of the CHP system. The hot water will be used in the hot water coil supplied with the SEMCO unit for regeneration of desiccant materials in lieu of the gas burner.

The paper entitled “Integration of the Indirect-Fired Absorption Chiller in the Microturbine-Based CHP System” was presented on June 22, 2005, and published in the Proceedings of the 2005 International Sorption Heat Pump Conference (ISHPC), Denver, Colorado.

Status of Milestones

Completed baseline testing of industry confidential prototype gas-fired heat pump with R22 - April 2005. COMPLETE

Industry Interaction

Partners include: SEMCO, Southwest Gas, and Team Consulting.

Quarterly meetings are held with the CHP Laboratory Advisory Council, which includes the following industry partners: Solar Turbines, UTRC, GE Power Systems, Georgia Tech, Caterpillar, Munters, and Austin Energy

Section 4.1.3 Integrated Energy Systems Design Tool

Steve Fischer
Oak Ridge National Laboratory

Objective

The IES Design Tool is a computer program that is evolving from the BCHP Screening Tool developed by GARD Analytics for simulation of CHP systems in commercial buildings. In FY05, ORNL will upgrade the BCHP Screening tool as delivered by GARD Analytic in 2004. Previously, accurate results for annual energy use and cost and life cycle performance were inadequate to explain counter-intuitive results as users refined CHP component selections to improve overall system design.

FYO5 work will focus on in-house modifications to the user interface, databases, and miscellaneous changes such as: 1. clean up (delete or optionally delete) temporary files 2. incorporate check(s) on equipment compatibility (e.g. recip-engine / double-effect chiller), and 3. correct "internal" error.

a. currently the user can specify different electric tariff schedules as needed for each scenario in a calculation

b. the simulations & economic calculations can be run and the input data file saved for future use

c. reading the saved file for subsequent "re-use" causes an "internal" error and all data following the rate schedule selection is lost.

ORNL will also evaluate the potential to have the BCHP Screening Tool to interface with Energy Plus.

Highlights

The BCHP Screening Tool was presented at the RAC bi-annual face-to-face meeting in Washington DC in May.

Technical Progress

A brief overview and demonstration of the BCHP Screening Tool was presented at the RAC meeting in Washington, DC on May 3. The crowded agenda did not allow for significant discussion of the model capabilities or how the RAC's can use it to evaluate the economic viability of IES equipment or CHP systems at sites in their geographic areas. Each RAC was given a CD containing a copy of the BCHP Screening Tool and full documentation.

Copies of the program were also give to Ed Pierce and Evelyn Baskin of ORNL, Jerry Jackson of the University of Central Florida, Joel Bluestein of EEA, and Dan Hamblin of Dan Hamblin Associates. Pierce and Baskin are using the BCHP Screening Tool in their analyses of CHP potential at federal sites for FEMP.

FY06 work plans are being developed. A planning meeting with Drew Crawley of DOE OBT is being planned in an effort to coordinate with the Energy Plus software package.

Status of Milestones

Complete BCHP Screening Tool Beta Version 2. November 2004
COMPLETE.

Section 4.1.5 Regional Outreach on IES Applications and RAC Coordination

John Cuttica and Leslie Farrar, University of Illinois, Chicago
Jim Sand, Oak Ridge National Laboratory

Objective

There has been a 3 GW increase in installed CHP capacity in the Midwest region since the base year of 1998. This represents an estimated 0.283 Quads of energy savings, $1.5 billion in cost savings, and 2.2 metric tons of carbon equivalent in global warming avoided. The Midwest CHP Application Center (MAC) activities have had a direct influence on approximately 1 GW of the increased capacity.

In FY2005, the University of Illinois at Chicago will continue subcontracted work in support of the and resources until future resources are secured. The MAC will continue to focus its activities on providing targeted education, information, and technical assistance in the area of CHP applications in the eight state Midwest Region.

Highlights

The most significant highlights for the MAC during the third quarter (April, May and June) were the two workshops hosted by the MAC. "Evaluating and Marketing CHP Options in a Volatile Energy Marketplace" was held for Engineers and Architects on May 18th in Willowbrook, IL. The workshop was sponsored by the Illinois Department of Commerce and Economic Opportunity, Bureau of Energy and Recycling, DOE Midwest Regional Office and the Midwest Cogeration Association. "Effect of CHP Regulations on State Jobs and Consumer Benefits." Was the 3rd DG/CHP Regulatory Workshop held on June 8th at Wayne State University in Detroit, MI. Representatives from 7 of the 8 Midwest states participated in the workshop.

Technical Progress

During this quarter, the MAC was active in the area of technical assistance for potential CHP sites. Analysis work was underway on Pharmaceutical Plant – Illinois; High School - Illinois; University – Illinois; Prison – Indiana; University – Minnesota; and Hospital – Ohio. The MAC met with facility representatives to investigate CHP at facilities including University – Illinois; Hospital (landfill gas); and Women's Shelter – Illinois. With initial meetings held during the 2nd Quarter, the Municipal Utility Industry has been identified as a potential CHP targeted market in Iowa, Ohio, Minnesota and Wisconsin. The state associations have been assisting in developing a plan to outreach to the Municipal Electric Utilities. A number of project profiles are underway with the completion of these expected in August - total number completed to date is 28 and 34 by August. In April, the MAC met with NiSource Energy Technologies (NET) and toured three CHP site installations in Indiana. The MAC will be working with NET to analyze the operating data and system efficiencies of two CHP installations with a deliverable of two site reports. Progress has been made on the Iowa and Indiana CHP Baseline Studies with the expected completion of these studies by the end of August. Also, the MAC met with a technology developing firm to discuss software modeling of the firm's new technology to compare to baseline technologies and developing a market study.

Status of Milestones

Update CHP Regional Application Center Guide. August 2005 - On Schedule

Meetings

Presented at Electric Power 2005 Conference – April, Chicago
Presented at NCEMBT Workshop on Healthcare Industry – April, Las Vegas
Attended Landfill Gas Energy Workshop – May, Toledo

Attended USCHPA Policy Days – May, Washington D.C
Attend Michigan Clean Cluster Technology Workshop – June, Lansing
Presented MWCHPI meeting – June, Chicago

Next Quarter:

Presenting at Energy 2005 – August, Long Beach
Presenting at Ohio Industrial Conference – September, Ohio
Presenting at MiSHE (hospitals) Annual Conference – September, Gaylord, MI

SECTION 4.2 IES End-Use Systems Integration

Section 4.2.1 DG Improvements in Industrial Applications

Rich Biljetina, Patti Garland
Energy Solutions Center, Oak Ridge National Laboratory

Objective

This project addresses CHP systems and how to integrate DG equipment within manufacturing processes with the greatest opportunity to use waste heat. This program focuses on innovative packaged CHP systems for specific applications that are highly replicable and can be integrated with industrial process energy needs. Two of four test and verification projects are complete: Faith Plating (Los Angeles, CA) and C&F Packing (Lake Villa, IL). At a third project at Higgins Brick in Chino Hills, CA, three Bowman 80 kW microturbine generators provide electricity and process heat for a kiln. The microturbine exhaust is ducted through a heat exchanger to preheat the combustion air for numerous burners in the brick drying process. A 4th project, added in FY05, evaluates a CHP system at Arrow Linen in Brooklyn, NY. The project, in coordination with Keyspan and NYSERDA will also evaluate the ASERTTI long term testing protocol. Equipment of interest is a Coast Intelligen system that uses two 150 kW MAN engines. Two plate heat exchangers recover heat from both the engine exhaust and cooling jackets to provide: 1) hot process water for washing, and 2) boiler feed-water preheat for process steam that is used in the laundry operation .

Highlights

Completed case study report on Faith Plating. Met ORNL control milestone due June 2005 on schedule.

Technical Progress

At the *Higgins Brick project site*, Simmax, the energy service provider for the Higgins plant is operating two of three microturbines. In April, an isolation damper failed in the open position causing damage to the MTG-3 microturbine. Simmax modified the dampers and was able to restart the system within a week using two microturbines to provide power and combustion air preheat for the kiln operation. Simmax plans to replace the MTG-3 microturbine and plans to have all three turbines in operation later this summer. Connected Energy completed the necessary instrument tie-ins and activated a website that allows the project team to remotely monitor and collect data on the CHP operation. Data collection started on May 1. The instrument installation report for this project was completed.

At the *Arrow Linen project site*, the Energy Solutions Center completed and signed a host site agreement with Arrow Linen on May 18, 2005 and subsequently provided a subcontract to EEA for data collection and analysis services. A project kick-off meeting was held at the site on June 22. The necessary data to complete a full site assessment of the Coast Intelligen/MAN engine CHP system was collected and any additional instrumentation needs required to satisfy the ASERTTI long term testing protocol were identified. Long lead-time instrumentation has been ordered and it is expected that installation and shake-down of the additional instrumentation will be completed later this summer and that the data evaluation effort will begin in September of 2005.

Status of Milestones

Complete case study on a CHP Installation that uses heat from a microturbine to provide plate tank heating and sludge drying at an industrial facility, contributing to the PART long-term measure of developing a 70% efficient CHP Integrated System. September 2005 JOULE Milestone] ORNL Control Milestone June 2005 COMPLETE Case Study Document provided to Division and EERE Program Management on June 29, 2005.

Industry Interactions

Partners are the members of the Energy Solutions Center DG Consortium comprised of: Atmos Energy – TXU Gas, Dominion Energy, DTE Energy/MichCon Gas, Enbridge Gas, Exelon Corporation – PECO Energy, GTI, Keyspan, National Fuel Gas, NICOR, NiSource, NW Natural, Southern California Gas Co, Southern Natural, Wisconsin Gas Company, and Yankee Gas Services – Northeast Utilities.

Section 4.2.2 National Accounts DE Projects

Rich Sweetser, ExergyPartners/AGF

John Kelly, NAEA, GTI
Patti Garland, ORNL

Objective

The American Gas Foundation (AGF), a non-profit arm of the American Gas Association, and the Gas Technology Institute has developed the National Accounts Energy Alliance (NAEA), a national DE-based deployment, testing and verification, marketing, and education program. NAEA is focusing directly on Fortune 1000 national chain end-users across the retail, supermarket, food service, hotel, and healthcare industries, along with other national chain industries. The NAEA program is the first "post-deregulation" partnership where energy managers from these important end-users have offered their facilities as test sites, are requesting DOE's assistance in developing this important body of knowledge, and are willing to share this knowledge with their competitors and the nation at large. The NAEA program partners have thousands of facilities across the nation, are actively engaged in new constructions and retrofits, and typically utilize a "central box" design for most, if not all, of their facilities. NAEA program participants believe that the central box principle is the largest barrier to widespread DE use. NAEA's unique approach will be working with national chains to redesign and reengineer their central boxes, incorporating highly efficient DE systems, thereby creating a paradigm shift in the marketplace.

Specific activities include: (1) Russell Development Inc. Project which involves the application of a microturbine/hot water activated absorption chiller to air conditioning of an office building in Portland, Oregon [complete]; (2) HEB Grocery Co. Project which will test a CHP system consisting of a Bowman 80 kW microturbine and a Broad single-effect absorption chiller; (3) Walgreens site in Pinelles Park, FL which involves a DOE/ORNL/SEMCO developed desiccant dehumidifier with a PowerCold 40 kW rotary engine-driven generator; and (4) Cinemark Movie Theater which involves two DOE/ORNL/SEMCO developed desiccant dehumidifier in Plano, Texas. [complete] (5) A&P Supermarket in Long Island, NY with a 20,000 cfm munters air handling unit that provides cooling and heating to the main sales areas of the store. The unit also includes a desiccant section to provide dehumidification. A unifin heat exchanger is a part of this system [complete].

Highlights

Task 7.3 Walgreen's Initial Data Acquisition Report was completed and invoiced.

Technical Progress

HEB in Texas: Monitoring of the system operation is continuing. After repair on the TXVs on Racks 3L and 3M in early-April, the chilled water output started oscillating every 3 hours and not following load properly. Several reasons include that there are size and controls problems; the chiller is actually a 66 ton absorber de-rated to 15 tons. However, the pumps and cooling tower are sized to handle the full 66 tons. The chiller is working on 510°F air from the microturbine. A visit to the site occurred on April 26th at which time, the controls were modified and the system has been operating since; however the capacity of the chiller appears to be low. Lessons Learned include an analysis include an assessment of parasitic power and looking further at better matching of components. Data will be collected through December 2005.

Walgreens in Florida: Data collection on the desiccant unit continues since last December. Due to security reasons, Walgreeens would not let the ORNL data loggers transmit data off-site. Therefore, data loggers have been installed that require data down-loading on-site. The first set of data is scheduled to be

downloaded next week. Data will be collected through December 2005. Because of the failure to execute an agreeable operating agreement between Progress Energy and Walgreens, the engine generator will not be run at this site. Although the engine generator was commissioned on-site, it will be move to an alternate test site. Various options are being considered, including movement to the ORNL Integration Test Lab or to a university in Florida.

Status of Milestones

Complete Cinemark final test and verification report. February 2005
COMPLETE

Industry Interactions

GTI National Accounts Energy Alliance, AGF, HEB, City Public Service of San Antonio, Bowman, Broad, CDH, Exergy Partners Cinemark/Tinseltown Theater, DTE Energy Technologies, Oncor, Russell Development, NW Natural, Capstone, Yazaki, AGF, Waldbaums/A&P, Keyspan, NYSERDA, DTE, Munters

Section 4.2.3 DE in Telecommunications Switching Center

Verizon
Randy Hudson, Oak Ridge National Laboratory

Objective

This project will place DE at Verizon's Zeckendorf Central Office (CO) on Long Island. The project consists of placing seven 200-kW IFC fuel cells at the facility to generate 1.4 MW of power and capture waste heat for CHP systems. The work includes (1) preparation of a detailed design and engineering; (2) review of the options for contracting the construction, operation and/or maintenance of not only the primary hybrid power plant but also the existing building heating, cooling, and emergency power systems; (3) preparation of a detailed commissioning and startup plan; and (4) overall project integration and technology transfer. Construction began in FY04 and will be completed in FY05.

Highlights

Equipment is on-site for the Zeckendorf Central Office (CO) on Long Island. Commissioning process is in-progress.

Technical Progress

The commissioning process is still in progress.

Status of Milestones

Complete and document two DER/CHP demonstration projects within the high tech industry, contributing to the PART long-term measure of developing a 70% efficient CHP integrated system. September 2005 [This milestone is shared with the Domain Site under Section 4.1.1a].
On-schedule.

Industry Interactions

Project partners Verizon

Section 4.2.4a – Ritz Carlton

John Kelly, Gas Technology Institute, Director, Distributed Energy Group
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Therese Stovall, Oak Ridge National Laboratory

Objective

Gas Technology Institute (GTI), of Des Plaines, Illinois, is collaborating with a UTC Power project to install a PureComfort 240M system at a Ritz Carlton Hotel in San Francisco, California. The PureComfort system is pre-engineered to include four Capstone microturbines integrated with a double-effect absorption chiller with a rated capacity of 229 kW net electricity and 161 tons of chilled water. Partners on this project are UTC Power, Carrier Commercial Systems, and Host Marriott. Knowledge gained from this hotel installation will document first cost and energy cost savings, and create critical lessons-learned that can enable widespread replication throughout the lodging sector of the economy.

Benefits:-Document reductions in hotel operating costs through use of combined cooling, heating, and power.
-Provide high visibility demonstration of CHP benefits in the hotel sector.
-Reduce peak electric demand through "free" waste heat generated chilled water.

Objectives
-Establish confidence in the traditionally risk adverse hotel building design community that integrated CHP systems are technically and commercially viable alternatives to traditional power and HVAC products.
-Validate building power and HVAC load integration and cost benefits of integrated systems.
-Demonstrate an integrated energy system that can be replicated throughout the Host Marriot system, as well as other hotel chains.

Highlights

During this quarter, the system components were delivered to the site and will soon be lifted into position on the roof.

Technical Progress

Gas Technology Institute (GTI), of Des Plaines, Illinois, is collaborating with a UTC Power project to install a PureComfort 240M system at a Ritz Carlton Hotel in San Francisco, California. System engineering, including extensive interconnection designs, is complete and the system has been delivered to the hotel site.

Status of Milestones

Delver PC240 System to the Ritz Carlton. September 2005
On schedule.

Industry Interactions

Partners include Gas Technology Institute, The Ritz-Carlton, and UTC Power

Section 4.2.4b Ramapo College

John Kelly, Gas Technology Institute, Director, Distributed Energy Group
Therese Stovall/Oak Ridge National Laboratory

Objective

Gas Technology Institute (GTI) will utilize two gas-fired reciprocating engines to generate 1600 kilowatts of electricity and low pressure steam to operate an absorption chiller, at Ramapo College in Mahwah, New Jersey. This project seeks to demonstrate the cost and energy savings of a packaged integrated energy system that can be easily replicated throughout the small college sector of the economy. Benefits include:

- Demonstration of cost and energy savings of low pressure steam reciprocating engine generators will accelerate acceptance of CHP system installations.
- Provide steam for summer loads very efficiently in place of a large boiler, which is very inefficient because it operates at a turn down ratio of nearly 10 to 1.
- Efficiency of the engine generator system is estimated to be 30% -- adding in summer or winter heat recovery will take the maximum CHP efficiency to 67.7% HHV.

Objectives:

- Develop a pre-engineered package providing cooling and power that can be easily applied at small colleges.
- Develop clear, concise results that establish the benefits of this technology that can be communicated to the larger audience of college and universities.
- Design a more cost-effective CHP system with lower emission levels and higher fuel efficiency.

Highlights

None

Technical Progress

Negotiations with the engine manufacturer are on-going.

Status of Milestones

Deliver engine/generator sets to the college. July 2005
Schedule on hold while alternate site is considered. Milestone will likely be revised.

Industry Interactions

Partners on this project are: unknown at this time.

Section 4.2.4c - Basin Electric

John Kelly, Gas Technology Institute, Director, Distributed Energy Group
Therese Stovall, Oak Ridge National Laboratory

Objective

Gas Technology Institute (GTI), of Des Plaines, Illinois, will partner with Basin Electric to utilize waste heat from an existing pipeline compressor station's gas turbine to generate electricity via an organic Rankine cycle. This project seeks to improve the economics by developing a standardized approach to integrate components of known reliable technologies into a comprehensive configuration that can be replicated and meet market concerns.

Benefits: -Provide the pipelines with a steady, long-term revenue stream, exploiting what is now only a waste product.
-Provide voltage support to the distribution system that serves a local hospital.
-Allow designers to modularize the components, reducing field installation costs and risks, while shortening construction periods.
-Concept could be used at other pipelines and compressor stations, as well as many other locations where waste heat is available

Objectives
-Provide a demonstration of the combined technologies into a prototype, with a real-time, web-based monitoring and control system, which can be replicated at numerous, similar compressor sites.
-Partnering of critical stakeholders-the partnership of the local utility with the pipeline to produce electricity-which would then be integrated into the overall system to produce firm power at a competitive rate.
-Leverage economy of scale by standardizing the modularization and increasing production volumes to reduce unit price.

Highlights

The transmission line connecting the site to the Basin Electric grid was completed. All system equipment has been fabricated except the oil cooler. The equipment should be delivered and installed within the next quarter.

Technical Progress

Gas Technology Institute (GTI), of Des Plaines, Illinois, will partner with Basin Electric to utilize waste heat from an existing pipeline compressor station's gas turbine to generate electricity via an organic Rankine cycle. The utility has completed the transmissions line installation necessary to connect the new remote generation to the grid. The organic Rankine cycle equipment has all been ordered and delivery at the site is expected before the end of the summer.

Status of Milestones

Deliver organic Rankine cycle equipment to the compressor station. July 2005
The foundations and condenser should be delivered on schedule. The turbine-generator may be delivered a few months later, and system operation is now projected for summer 2006 rather than November 2005.

Industry Interactions

Partners include the Gas Technology Institute, the Basin Electric Power Cooperative, and OREG1 (a new corporate entity formed to construct, own, and operate the project).

Section 4.2.5 -Butler Hospital

Jim Chambers, Butler Hospital, Phone: 401-455-6285, E-mail: Jchambers@Butler.org
Jan Berry, Oak Ridge National Laboratory

Objective

Butler Hospital, located in Providence, Rhode Island, will use a United Technology Corporation (UTC) PureComfort System, that packages four Capstone microturbines, to generate 240 kilowatts of electricity, and 110 tons of chilled water, using a Carrier exhaust fired absorption chiller. The project seeks to demonstrate the cost and energy savings of a pre-engineered, packaged integrated energy system that can be easily replicated throughout the healthcare sector of the economy while profiling the system in this high-profile setting.

Benefits: -Reliable microturbine technology, packaged with double-effect absorption technology, should be easily installed, and highly replicable.

-By producing both hot and chilled water, the thermal energy from the microturbines is captured year-round, resulting in high system efficiency.
-Because free waste heat drives the 110 ton double-effect absorption chiller/heater, energy costs are reduced.
-The system's two major components, the microturbine and the chiller/heater, both have relatively few moving parts, leading to high system reliability and low maintenance.
-The PureComfort System is quiet and does not require sound attenuation.
-The chiller/heater control system allows stable, continuous part-load operation down to 25% of full load at cooling water temperatures as low as 64.4 F (18 C), without the need for a cooling tower bypass.

Objectives: -Demonstrate cost and energy savings achieved by a PureComfort System in a mid-sized hospital.
-Collect year-round field data, evaluating use of CHP to support revenue-generating equipment, such as MRI and x-ray.
-Prepare project profile to promote the energy, economic and environmental benefits and system commercialization.
-Identify locations and applications suited to PureComfort System based on performance, weather and utility rates.

Highlights

The project is on schedule with construction scheduled for completion in mid-July. A project review meeting is scheduled for July 22nd in Providence, Rhode Island.

Technical Progress

Butler Hospital, located in Providence, Rhode Island, will use a United Technology Corporation (UTC) PureComfort System, that packages four Capstone microturbines, to generate 240 kilowatts of electricity, and 110 tons of chilled water, using a Carrier exhaust fired absorption chiller. Butler Hospital submitted milestone deliverables which incorporated ORNL's comments on an earlier draft. Milestones included: Task 1.1 CHP system conceptual design, Task 1.2 Develop Lay Layout Design to Incorporate CHP System, Task 1.3 Finalize CHP System Design, Task 1.4 Develop Monitoring Plan, and Task 2.1 Procure PureComfort System and BOP Equipment.

Status of Milestones

Integrate and install CHP packaged system PC240 and heating, cooling BOP equipment.
September 2005. On schedule.

Industry Interactions

Partners on this project are UTC Power, Carrier Corporation, Witham & Associates, New England Gas, and CDH Energy Corp.

Section 4.2.6 – Eastern Maine Medical Center

Eastern Maine Medical Center
Jeff Mylen, Project Manager, Eastern Maine Medical Center
Phone: (207) 973-7786, E-mail: jmylen@emh.org
Jan Berry, Oak Ridge National Laboratory

Objective

Eastern Maine Medical Center (EMMC), in Bangor, Maine, will use a Solar Turbines gas turbine to generate 4.4 MW of electricity, 24,000 lb/hour of steam, and drive a 500 ton absorption chiller. The new CHP system will respond to the following concerns: high energy costs, fuel use diversity, the need for additional chilled water capacity, the need to deliver services under any climatic condition, utility reliability, diverse thermal heating load profile, and emissions compliance.

Benefits: -Power availability during adverse weather conditions
-Reduced emissions.
-Increased thermal and heating capacity and enhanced emergency backup power.
-Savings will directly reduce healthcare costs.

Objectives: - Design a system responsive to specific concern for healthcare: energy reliability.
-Use an integrated, modular "power island" design concept to reduce field labor costs and installation time, while increasing the opportunity for replication.
-Design a system that could be replicated for similar applications with a minimal amount of balance of plant and integration costs.
-Structure the CHP system using advanced information technology to aid in information dissemination.

Highlights

The turbine has been ordered from Solar Turbines and the final air permit has been approved by the State of Maine.

Technical Progress

Eastern Maine Medical Center (EMMC), in Bangor, Maine, will use a gas turbine to generate 4.4 MW of electricity, 24,000 lb/hour of steam, and drive a 500 ton absorption chiller. The project is on schedule with an expected commissioning in the Fall of 2006.

Status of Milestones

Obtain approval of Certificate of Need. March 31, 2005 COMPLETE.

Industry Interactions

Partners are Solar Turbines, Cianbro Corporation, Vanderweil Engineers, University of Maine, and International District Energy Association.

Section 4.2.7 – Sheraton Hotel

Donald C. Erickson, Principal Investigator, Energy Concepts Co.
Phone: (410) 266-6521, E-mail: enerconcep@aol.com
Randy Hudson, Oak Ridge National Laboratory

Objective

Energy Concepts Co., of Annapolis, Maryland, will utilize a 200 kW reciprocating engine, a 250 kW microturbine, and 100 tons of absorption chillers, in a new 150 room Sheraton hotel complex in Rancho Mirage, California. The system will also supply utility service to an adjoining medical clinic. One additional feature will further add to the reliability and system stability: a 500 kWh zinc bromide battery powering a 250 kW inverter. This mix of three types of electric generators will make it possible to maintain high electrical efficiency at all times.

Benefits: Low emissions, noise, and maintenance; low energy cost; high-energy utilization; desirable exhaust characteristics; extremely fast and very low cost black start capability; very good turndown to quite low part loads; excellent ability to absorb load transients; high electrical efficiency.

Objectives

Demonstrate a CHP system that will:
-Be replicated in other hotels and larger buildings and businesses.
-Be grid-independent with overall efficiency and environmental benefits.
-Provide service to areas beyond the grid, and locations within the grid where capacity is constrained.

Highlights

The search for a new site, using the same technologies, is underway.

Technical Progress

A reciprocating engine has been selected: The Guascor SF 240 GLD which generates 410 kW at 1800 rpm. This engine has two highly desirable characteristics: 38% efficiency (LHV), and high temperature jacket water (235°F). Work is continuing on the heat exchanger and chiller designs.

Status of Milestones

None defined at this time.

Industry Interactions

Partners are now to be determined.

Section 4.2.8 Metropolitan Hospital

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Jan Berry, Oak Ridge National Laboratory

Objective

NOVI Energy, of Novi, Michigan, will use two reciprocating engines to generate 2 megawatts of electricity, as well as steam. Steam will be used to fuel an absorption chiller and meet process heating loads. The CHP package will part of the new Metropolitan Hospital (Metro), in Grand Rapids, Michigan, Central Utility Plant which will deliver electricity, steam, chilled water, and hot and cold domestic water to the hospital complex. NOVI will widely disseminate information about the design, construction, operational and financial issues and benefits of using an integrated CHP package in a hospital complex.

Benefits:

-Load profiles of many small and mid-sized hospitals could be met with the system, as power, steam and chilled water are produced.

-Engineering and installation cost savings associated with this packaged CHP system will be determined by comparing project costs with a hypothetical design-build system.

-Fuel flexibility will give Metro the option to run on biogas (after minor modifications) as well as natural gas.

-Will result in a replicable model, with a highly accessible demonstration site, that can be used to promote CHP in general, and packaged CHP systems for hospitals in particular.

Objectives

To facilitate the widespread adoption and implementation of integrated reciprocating engine CHP packages to hospitals through:

-Demonstrating the use of an innovative integrated CHP package that suits a hospital integrated in a multi-use site (e.g., ambulatory care center, doctors' offices).

-Conducting research on improving technical and economic viability of integrated CHP packages.

-Accelerating CHP commercialization by preparing and disseminating information on system performance through multiple channels to other hospitals, business leaders, government officials, and the general public.

Highlights

Metropolitan Hospital has decided to cancel their project with NOVI. ORNL is working with NOVI to identify an alternate test site.

Technical Progress

None

Status of Milestones

Complete analysis of how packaged system compares in complexity and cost to equivalent on a custom basis. August 2005

On hold until mid-April.

Industry Interactions

Partners are Inland Detroit Diesel, GE Jenbacher, Stanley Consultants, Workstage, and NTH Consultants.

Section 4.9a/b Real Energy

Kevin Best, Real Energy
Randy Hudson, Oak Ridge National Laboratory

Objective
Demonstration of two end-use package systems in a hotel and healthcare application

Highlights
RealEnergy is continuing to seek two new projects.

Technical Progress
Real Energy LLC is in the process of trying to develop two projects in California. They are in negotiations with several hotels and hospitals. A proposal for at least one of the two projects is expected soon.

Status of Milestones
Milestones will be defined after acceptance of project proposals.

Industry Interactions

Section 4.2.10 – Floyd County, Georgia, Pepperell High School

John Fischer, Director of Research and Development, SEMCO, Inc.
Phone: (770) 850-1030, E-mail: johnfischer@bellsouth.net
Jim Sand, Oak Ridge National Laboratory

Objective

SEMCO, Inc., of Columbia, Missouri will package a reciprocating engine generator, coupled with an integrated active desiccant (IADR) system, at the new Pepperell High School, in Floyd County Georgia. This project work will encourage further widespread adoption and implementation of integrated distributed energy systems consisting of electrical generators combined with desiccant dehumidifiers regenerated by engine heat to provide power and dry air. This hybrid HVAC system allows integration with building exhaust air energy recovery exchangers for exceptionally efficient performance and convenient integration with waste heat recovery applications.

Objectives

-Develop an integrated CHP System to optimize performance for a variety of energy customers in the most popular air conditioning package.
-Define prototype system(s) in one of the most demanding applications.
-Demonstrate energy-saving and enhanced comfort/IAQ features.

Highlights

The first four SEMCO, Revolution hybrid desiccant units that will be served by the Deutz, IC genset are in production and final testing. The Deutz IC engine genset package is in production and will be shipped in July or August to the school construction site. SEMCO, the local school board, DOE, and ORNL are still in a good position to have a "ribbon cutting" event at this jobsite in August or September when the major components for this CHP packaged system are on site.

Technical Progress

IC engine jacket water regeneration of the active desiccant component in these hybrid rooftop units is being thoroughly tested at SEMCO's corporate engineering laboratory in Columbia, MO, and will be studied by ORNL on their laboratory test unit. Higher regeneration air flow rates will be required for this lower quality heat source, but they are easily obtained with the inverter driven blowers provided on the Revolution product. Additional diagnostic sensors are being installed on the ORNL laboratory unit to research this hot water mode of regeneration and the circuit is being checked for refrigerant leaks and proper refrigerant charging before these tests are initiated.

Status of Milestones

Define control and monitoring strategies, develop software and monitoring package. February 2005. Completed.

Industry Interactions

Third quarter meetings with C&M Engineering-Columbia MO, Southern Engineering mechanical contractors, and Deutz Corporation-North American Operations in Norcross GA.

Section 4.2.11 TIAX LLC

Howard Mason, TIAX, Phone: 408-517-1570, E-mail: mason.howard@tiaxllc.com
Peter Palmer, Hess Microgen, Phone: (775) 844-1000, E-mail: ppalmer@hess.com
Randy Hudson, Oak Ridge National Laboratory

Objective

TIAX, LLC, of Cupertino, California, had teamed with Hess Microgen to utilize two reciprocating engines to generate approximately 280 kilowatts of electricity, and provide cooling with two 30-ton capacity absorption chiller units, in a Raley's supermarket in Loomis, California. Due to a major reorganization by Hess Microgen, the project was cancelled.

Highlights

The project has been cancelled. A final report has been received, and final payments have been made.

Technical Progress

None

Status of Milestones

None

Section 4.2.13 Technical Direction Analysis and Support

Randy Hudson
Oak Ridge National Laboratory

Objective

ORNL will assess the electrical and thermal energy needs of specific market applications and develop analytical tools to assist in providing an optimum fit of vendor-independent DE/CHP technologies to end-use needs.

The price of electricity and primary fuels (in particular, natural gas) varies widely across the United States. This variability has a strong influence on the economic viability of Integrated Energy Systems (IES) in the commercial sector. This study evaluates a matrix of 6 IES applications in 13 locations within the U.S. The overall figure of merit is the net present value (NPV) of the IES relative to the use of grid-based electricity and heat from an on-site natural gas boiler. For the IES, both operating and capital costs are included in the assessment. This study also provides the results of an optimization analysis in which the most optimal installed electrical generation capacity has been determined for the given IES application and location.

Highlights

Work has continued on development and testing of the simulation/optimization model.

Technical Progress

The model development is essentially complete and is undergoing testing. Due to the high cost of natural gas, the current economic viability of IES is limited to a few areas of the country. As a result, the report will serve to document the model and use selected areas as examples of the model's operation.

Status of Milestones

Draft report on Economic Evaluation of IES in the Commercial Sector by Application and Location. August 2005
on schedule (as modified above)

Section 4.2.14 Ancillary Services Offered by Distributed Energy Resources

John Kueck & Tom Rizy
Oak Ridge National Laboratory

Objective

Reactive power, which is measured in volt ampere reactive (vars), is produced when current is out of phase with voltage due to inductive or capacitive loads. Inductive loads produce current that lags voltage or a lagging power factor and capacitive loads produce current that leads voltage or leading power factor. Only real power is produced when there are only resistive loads which produce voltage and current that is in phase at unity power factor. Reactive power consumption results in lagging power factor and can cause increased losses and excessive voltage sags and it doesn't travel far very well. Distributed Energy Resources could be controlled to correct the current phase angle and eliminate reactive power flow by producing/absorbing reactive power. They can also be controlled to regulate local voltage by the production/consumption of reactive power. The objectives of the reactive power lab are to:

- Demonstrate that DER can provide reactive power locally for power factor correction and voltage regulation.
- Demonstrate that DER with low-cost controls can provide reactive power locally for voltage regulation and power factor correction using either inverters or synchronous machines.
- Demonstrate that DER can be an economical, cost-effective (produces value both to the user and system and receives associated return based on var prices), and practical method of supplying reactive power to the distribution network.
- Demonstrate the strengths/weaknesses of rotor machine-based DER versus inverter-based DER. For example inverters can correct for all inactive power components (reactive power, harmonics, and flicker) while rotating machines can only correct for reactive power needs.
- Demonstrate the parallel operation of the different DER technologies. We plan to simultaneously operate the synchronous condenser and inverters at 3114 on two ORNL circuits.

Highlights

Synchronous condenser portion of the Reactive Power Laboratory was completed in May.

Construction of the inverter portion of the Reactive Power Laboratory will begin again this month with completion in September.

Our milestone to inject vars into the ORNL network was met ahead of schedule.

Technical Progress

The milestone of having the Synchronous Condenser (SC) portion of the Reactive Power Laboratory operational by May was met two weeks ahead of schedule. The milestone achieved injection of reactive power into power panel B at the Reactive Power Laboratory (building 3114) interface with circuit #4 of substation 3000 at ORNL's distribution system. Testing of the 250hp synchronous condenser has continued with full characterization of the unit over its full excitation and reactive power (kVar) output range. The test data has been used in conjunction with SKM modeling (a commercial power system analysis package) to confirm the possible voltage regulation, power factor correction and loss minimization benefits of a rotating based reactive power producing DER. Additional testing scenarios for the SC are being planned (such as reconfiguration of the circuit to change impedance and loading) as well feedback control strategies for the SC. The goal of the control systems is to using off-the-shelf instrumentation and hardware to provide a proof of principle system for local control. To date the SC has been operated manually using turn dials and keyboard entry of the programmable DC power supply that controls the motor's excitation and the SC's kVar output. The next stage is the remote control of the SC

via the remote control of the DC power supply. We plan to be testing this feature shortly.

Preliminary work on the control and operation of the programmable DC to AC inverters has started over at the NTRC. The focus is on using dSpace Real-time hardware and software to control and operate the inverters. The inverter portion of the Reactive Power is scheduled to be completed in the August to September time frame at which time the dSpace system will be set up over at the laboratory. The three-phase inverters (three sizes; 75, 150 and 300A) will be tested using a large 150kW DC power supply. The inverters will interface to a second power panel at the laboratory via line inductors (2/4/6 mH).

An interim report on the Reactive Power Laboratory is underway and will give background and discuss status and progress to-date including the testing and modeling that has been performed. We plan to complete the interim report by the end of July/early August for distribution to our industry partners and DOE for review. Energetics is working on the economic valuation of reactive power producing DER and has developed a draft report which is currently under review and will be discussed shortly.

Status of Milestones

Milestone #1 was met two weeks ahead of schedule with injection of reactive power from the Synchronous Condenser (at 3114) into circuit #4, substation 3000 of ORNL's distribution system.

Meetings

During this quarter, we have had email communication and teleconference calls with our partners. Also, we have had several teleconference calls with Energetics regarding the economic evaluation study to provide input and guidance on this important work. We are planning on having a review (our second) meeting at ORNL in September to discuss the laboratory progress, plans and to give a tour of the laboratory along with some demonstrations.

Industry Interactions

Project partners are: Bowman Power, Capstone, General Electric, Lenoir Cities Utilities Board, PJM, Southern California Edison, Tennessee Valley Authority, EPRI-PEAC.

SECTION 4.3 CHP

Subtask 4.3.1 Utility, Regulatory and Environmental CHP Analysis
American Council for an Energy-Efficient Economy

Neal Elliott, Anna Shipley

Objective

A utility survey task will focus on interconnection and tariff practices for major utilities, with results compiled into a database that will be added to state by state information on state legislation, environmental office, and public utility commission's regulations that apply to CHP.

Conduct a detailed review of existing CHP models to produce some basic rules of thumb for regulators and CHP system developers to estimate the general local environmental impact of a CHP system in a simple and timely manner.

In 1996, DOE, EPA, and ACEEE organized an ad hoc group of analysts to support the assessment of CHP as part of a national global climate strategy. This task will provide for continued development and facilitation of Analysis Working Group Meetings.

Highlights

All 3 tasks are ongoing. All work is scheduled to be complete February 2006, with no FY06 funding being requested.

Technical Progress

Progress has been underway to complete the utility survey. Telephone interviews as well as other research have been conducted. The preliminary results of this research will be presented at the upcoming CHP/WADE Conference in New York City on October 25-27, 2005.

The model review will be used to estimate some rules of thumb for estimating displaced emissions. A review of IPM and AMIGA has been conducted. Further research will be necessary to complete the emissions estimates.

The plan is for up to three meetings. The next meeting will discuss the implications of the newly approved Energy Bill and what it will mean for the CHP marketplace.

Status of Milestones

Facilitate CHP Analysis Working Group Meeting. January 2005
Vendor did not hold meeting in January. Topics for the next meeting were solicited from other CHP subcontractors attending the CHP Subcontractor Coordination Review Meeting held on April 14th. Next meeting will be scheduled in coordination with DOE.

Subtask 4.3.4 CHP and DG Topical Issue Analysis

Susan Horgan
Distributed Utility Associates [DUA]

Objective

In this project, the vendor will use current contacts and leverage other ongoing efforts to complete data analysis and deliver periodic briefings on CHP and DER strategies. The primary topic of year one has been chosen: natural gas infrastructure issues for the market penetration of CHP and DG. Year two work included technical synergies between the U.S. and the European Union.

Highlights

An outline of the Resource Planning and Procurement Guide was provided to ORNL.

In an effort to confirm the end-of-year cash history of the project, the new owner of DUA continues to sort through the accounting books left by the previous owner. Some progress is being made, but it is taking much time on the part of the ORNL technical monitor.

Technical Progress

The Resource Planning and Procurement Guidebook is designed to help utility resource planners and power procurement specialists consider CHP/DG projects as viable alternatives to traditional, centralized resources. The guidebook provides cost, performance, reliability and operating characteristics, typical sizes and project locations, potential advantages and disadvantages relative to conventional resources for CHP/DG options. Advice on development issues, including bidding and procurement terms to assure timely, reliable, cost effective resource delivery will also be provided. This document addresses the reasons why utilities should consider DG/CHP projects, the issues associated with developing CHP/DG projects and how utility resource planners and power procurement specialist can strategically plan for those issues when implementing or contracting for power from DER projects.

The primary audience for this document is utility resource planning, development and purchasing staff. A secondary audience is third-party power generation developers, energy service companies and engineering firms that intend to provide power to utilities via DG/CHP projects.

Status of Milestones

Write a summary paper on IEA/EU international collaborative efforts. December 2004.
This task will not be completed due to the death of Joe Iannucci. A new milestone is being negotiated.

Subtask 4.3.5 National and Regional CHP Roadmapping Activities

Jan Brinch
Energetics

Objective

One element of this project consists of technical analysis and planning of various technical workshops and roadmaps with the goal of coordinating technical information development and dissemination regarding high potential CHP scenarios nationally, regionally and internationally.

Another activity is to coordinate Regional CHP Roadmapping efforts. Energetics has assisted and coordinated Roadmapping workshops held in the Pacific, Northwest, Northeast, and Mid-Atlantic.

Energetics is also facilitating and coordinating activities and information between multiple agencies, regional entities, trade associations, and non-profit groups.

Highlights

The technical content of the CHP Roadmap meeting is being developed.

The CHP Action Plan is being revised.

Technical Progress

The CHP Roadmap meeting is scheduled for October 27 at the Park Central Hotel, in New York City. It is being held in conjunction with the 6th Annual Meeting on Decentralized Energy co-sponsored by WADE, USCHPA and DOE.

Meeting information can be found on the following webite. http://www.internationalchp-de.net/

A Combined Heat and Power (CHP) Action Plan is being developed in advance of the October 2006 CHP Roadmap Meeting. The objective of the Action Plan is to document accomplishments and progress to date by the CHP community in achieving the goals set in the CHP road-mapping process.

Status of Milestones

Facilitate the CHP Roadmap Meeting. September 2005
Roadmap meeting has been scheduled for October 25-27, 2005 in New York, New York

Subtask 4.3.6a Emissions, permitting, DG reliability database, cost and financing of DG/CHP, inventory of commercial/industrial boilers

Joel Bluestein
Energy and Environmental Analysis

Objective

This project consists of four distinct and separate tasks, including:

Task 1: Inventory of Existing Commercial/Industrial Boiler Population - The goal of this task is to create a current inventory of commercial/industrial boilers by age, size, type, end use sector, region and fuel. This will provide CHP developers with a focus on the best opportunities and encourage the replacement of the least efficient, highest emitting boilers in the existing mix as well as providing a better basis for estimating future CHP retrofit potential.

Task 2: Evolution in the Demand for Steam - The goal of this task is to evaluate changes in the use of steam in the industrial (and possibly commercial) sectors and the potential impact on markets for CHP. As noted above, there are indications of decline in the use of steam in the commercial and industrial sectors. The key topics of this task will be:

- Determine if there is, in fact, a decline in the use of steam.
- If so, identify the reasons for this change.
- Evaluate the possible impacts on markets for CHP and the changes in policy or technology needed to address them.

Task 3: Changing Applications for Steam - The goal of this task is to identify new applications for CHP, especially new non-steam applications.
There are several potential changes in CHP markets that this task must address:

- Changing uses of steam due to process and technology change in industrial and commercial markets.
- Different sources of thermal energy from new prime movers available for CHP.

Task 4 – Revised Forecast of Industrial CHP
This task will develop a new forecast of industrial CHP based on the changing market dynamics and technology options analyzed in Tasks 2 and 3.

Highlights

Completed the final report: "Characterization of the U.S. Industrial/Commercial Boiler Population." It is posted on the EEA website at: www.eea-inc.com/natgas_reports/BoilersFinal.pdf

Technical Progress

The final report has been provided to Doug Hinrichs for inclusion on the DOE DE website.

Status of Milestones

Complete inventory of industrial boilers and provide final report. May 2005
on-schedule

Subtask 4.3.6c CHP Installation Data, Cost Analyses, and Financing

Bruce Hedman
Energy and Environmental Analysis

Objective

This project consists of multiple tasks:

Task 1: CHP Installation Database - Identify and collect basic information on existing CHP facilities and track the installation of new facilities over time. This data measures progress toward the goal to double CHP capacity from 46 GW in 1998 to 92 GW by 2010, and tracks the progress of specific technologies and markets.

Task 2: Applications Integration and Installed Costs Analysis for Small CHP Systems - Quantify the range of small CHP installation costs experienced in the field, document the driving factors for those costs, and identify areas for cost improvements to develop a consistent and complete understanding of total installed costs CHP projects based on various generation technologies with information from actual installations that have been completed within the last three years.

Task 3: DG/CHP Financing - Document available financing options for customer-sited DG/CHP projects through interviews, analysis and case studies and to evaluate the effectiveness of these financing options to the implementation of DG/CHP in the U.S. Alternative financing, ownership and risk sharing arrangements that may accelerate customer acceptance will be explored. The focus of the effort will be on customer-sited DG and CHP systems less than 5 MW in size.

Task 4: Electric Rate Primer - The objective of this task is to review the primary types of electric rate structures that exist throughout the country, categorize and measure the impact of these rate structures on the economic viability of on-site generation. Illustrative examples of the economic performance of representative distributed power projects within each type of rate structure will be presented. Rate structures designs that best encourage energy conservation and CHP will be highlighted. A limited number of rates from top electric utilities will be categorized and evaluated as to whether they are favorable or not toward energy efficiency and CHP.

Highlights

The CHP installation database went live to public in June 2005. It can be found at: http://www.eea-inc.com/chpdata/index.html. It can be accessed from the EEA homepage.

Technical Progress

ORNL will work with NREL to get the CHP installed database posted to the DOE website at: http://www.eere.energy.gov/de/databases.html

The initial 2005 update of the CHP installation database is complete. A draft report is forthcoming.

The preliminary tariff results under the electric rate primer task were provided to ORNL in May. The final report including updates and a presentation will be completed by end-of-September.

The preliminary survey results for DG financing were completed in May. The final report, including example case summaries, is scheduled to be complete before the end-of-September.

The preliminary survey results and the initial cost characterizations for the Integration and Installed Costs Analysis for Small CHP Systems Task are complete. Additional cost characterizations are scheduled to be completed by mid-September this year.

Status of Milestones

Maintain and update the installed CHP database. Ongoing

Subtask 4.3.7

Rick Tidball
Energy and Environmental Analysis

Objective

This project focuses on the 4-state region comprising the Pacific Northwest: Washington, Oregon, Idaho, and Alaska and includes an assessment of technical and market potential for the region and case studies.

- Development of a market penetration model, evaluation of regional energy pricing and economic trends, and incorporation of current and advanced technology cost and performance parameters.

- Development of CHP Screening Calculator and development of four analysis scenarios related to Northwest region.

The project is divided into three tasks:

- Market Assessment
- Resource Development
- Western States Analysis

Highlights

The vendor completed the Task 4 Report on the Arizona and Nevade CHP Market Assessment.

The vendor completed the technical brochure for regulators and policy makers regarding the benefits of DG in the Pacific Northwest.

Technical Progress

Work continues on the Western States Summary Evaluation

Work continues on the 4 additional case study reports.

The following work was necessary on the 4 original case study reports: insert correct EERE graphics, make corrections requested by site respondents, and provide to WSU for incorporation on the Northwest CHP RAC website.

The technical brochure will be updated to reflect comments made by ORNL and PEA.

Status of Milestones

Subtask 4.3.7 An educational technical brochure will be developed for regulators and policy makers regarding the benefits of CHP in the Pacific Northwest. April 2005
Comments on the brochure were provided by ORNL to EEA.

Industry Interactions

This work is being done in close cooperation with the Northwest CHP Regional Application Center and with the DOE Seattle Regional Office.

Subtask 4.3.9 Development of a Preliminary Environmental Permitting Screening Tool

Jay Dyer
I.C. Thomasson

Objective

Develop an environmental permitting screening tool, useful in each state of Environmental Protection Agency (EPA) Region 4: Southeast, serving Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.

A computerized screening tool will be developed to assist users with permitting of any small gas turbine (1 MW to 5 MW) in any area of Region 4 with enough depth to cover the majority of permitting conditions. Users will be able to identify applicable regulations and standards, as well as supplemental analyses required by the respective regulatory agency.

Highlights

The draft Environmental Permitting Screening Tool Task Report was completed in second quarter, 2005. The tool is applicable to facilities interested in installing a gas turbine between one and five megawatts and located in the Environmental Protection Agency's region for the Southeastern United States, i.e. Region IV. The tool provides a brief overview of gas turbines, emissions produced by a cogeneration plant and how gas turbines are regulated, the applicable Code of Federal Regulations (CFR), and how to determine the type of permit required.

Technical Progress

The draft report contains the following Sections: 1. Project Summary, 2. Equipment and Technology, 3. Air Permitting, 4. Air Permit Types, 5. National Regulatory Standards, 6. Federal Facility Example, 7. Flow Diagrams, 8. Region IV Contacts, 9. Tennessee, 10. Florida, 11. Alabama, 12. Georgia, 13. North Carolina, 14. South Carolina, 15. Mississippi, and 16. Emission Factors form EPA Document AP-42. Sections 10-15 are not complete.

Status of Milestones

Subtask 4.3.9 Provide draft final report on environmental screening tool in Southeastern States. June 2005 COMPLETE The draft report is complete. The final report is due at a date to be determined due to the uncertainty related to a return date [from maternity leave] of one of the principal investigators.

Subtask 4.3.10 CHP Awareness and Barrier-Busting Technical Assistance to Facilitate Implementation of CHP in the District Energy Sector

Patti Garland, Jan Berry
Rob Thornton
International District Energy Association

Objective

Phase I of this project consisted of multiple tasks funded in FY03-04:

- Identify potential CHP/District Energy candidates
- Initial screening and ranking based on an overall project assessment.
- Assess other market factors affecting the likelihood of project success, such as endorsement or level of project support in the organization; permitting status and timing; funding capability or credit-worthiness; project visibility; project support or opposition; timing on capital replacement needs; load growth timing. .

Second-level analysis and ranking of high probability candidates from the following sectors: institutions, hospitals, airports and utility systems. FY05 work includes the following activities:
Task 1: Disseminate Technical Industry Information

Create searchable archive of technical conference proceedings on website for dissemination of valuable industry information including thermal network optimization and renewals, case studies of successful system developments; integration of thermal energy distribution networks with combined heat and power; district cooling and electric reliability, maintenance for thermal distribution systems, etc.*Task 2.Continue Barrier-Busting Activities – Technical Support*

To follow up on 24 high-probability, near- term potential CHP projects representing nearly 450 MW capacity, previously identified by IDEA in ORNL Phase III Census survey. Rather than abandon this valuable market intelligence, objective of task is to identify, evaluate and recommend strategies to provide direct (1:1) project support to known, viable CHP projects with industry sponsors; and to provide executive level support to campus leaders to assist with overcoming institutional barriers, including lack of urgency, perception of risk, and confirmation of market acceptance by institutions.

Task 3. Continue Barrier-Busting Activities – Educate and Promote CHP

Task 4. LEED

In coordination with other district energy and CHP stakeholders, provide review, comment and recommendations relative to LEED standards as they impact buildings served by district energy systems and/or CHP.

Highlights

The 18th Annual Campus Energy Conference was completed. A campus energy track was planned and implemented. Technical tours at the University of Maryland Central Power Plant were coordinated and completed. A tour of the CHP Integration Test Center at the Chesapeake Office Building was coordinated and completed.

All LEED Analysis work is complete with the exception of the development of case studies of campus LEED.

Technical Progress

A white paper commenting on the draft LEED Application Guide for Campus settings was completed. The white paper is an attempt to systematically review the issues that must be addressed in developing an Exceptional Calculation Method to incorporate CHP systems into LEED EA Credit 1 calculations. The paper is organized into four sections: 1) To provide a framework for later reference, the Energy Cost Budget (ECB) method in ASHRAE 90.1 is summarized in equation form. 2) Major structural issues associated with applying the ECB method to district energy, CHP and renewable thermal energy are discussed, and an alternative set of cases for testing the ECM are suggested. 3) An Exceptional Calculation Method (ECM) is recommended for crediting CHP and renewable energy within the current version of LEED-NC and the upcoming version 2.2. and 4) The conceptual basis for the ECM is summarized based on LEED-NC 2.1, the associated Reference Guide, rulings on Credit Interpretation Requests (CIRs) and ASHRAE 90.1.

Status of Milestones

Subtask 4.3.10 Review and comment on the draft LEED Application Guide for Campus. February 2005 COMPLETE. A white paper titled: LEED New-Construction Structural Issues Relative to District Energy, CHP and Renewable Energy

Subtask 4.3.11 Coordinating National and Regional Policy Activities and Promoting CHP in Light Industrial Markets

Diane DuVaul, Suzanne Watson
Northeast-Midwest Institute, NESCAUM

Objective

Phase I of this work consists of several tasks:

Build and Support Regional & State CHP/DER Initiatives

Create a National CHP/DER Coalition Board, host/facilitate regular meetings among all regional groups and attend individual regional CHP meetings, monitor and analyze regional CHP materials, create and organize an annual meeting of regional CHP groups, create/organize regional efforts for CHP Roadmap and Policy Conferences, coordinate state level efforts to remove barriers through coordination of formal comment preparation and meetings with state PUCs, environmental regulators, state legislators, industry, etc.

Manufacturing Sector Initiatives

(Note that "manufacturing sector" does not mean CHP equipment manufacturers, but rather the US manufacturing sector). Utilize the existing Northeast-Midwest Manufacturing Task Force to reach potential end-users by holding two targeted DER/CHP workshops in Chicago and Boston regions working with the DOE Regional Offices to specifically highlight the benefits of CHP/DER to manufacturers; and by working to include representation from the manufacturing industry and the DOE Industries of the Future (IOF) program in the MW and NE CHP Initiatives.

Phase II activities for FY05 include continued work with Regional Initiatives and development of technical content for hill meetings.

Highlights

The draft of the 2005 final report [in powerpoint format] was provided to ORNL for comments.

A meeting was held between DOE, NEMW and ORNL to discuss topics and scheduling of the 2 subcontracted hill briefings.

Technical Progress

Monthly calls with the Regional Initiatives continue. At the request of ORNL/DOE, minutes of the calls are being taken and distributed to participants in the calls, DOE and the CHP RAC coordinators, Ted Bronson and Patti Garland.

ORNL provided comments back to NEMW on the draft final report. The final 2005 report should be forthcoming next month.

Three topics were chosen for the FY05 hill briefings: Multi-Family Housing and DER CHP Application Centers.

Status of Milestones

Write a summary paper on status and lessons learned among CHP Regional Initiatives. March 2005. Draft completed and comments made.

Subtask 4.3.12a Developing CHP Market Potential with Opportunity Fuels

Paul Lemar
Resource Dynamics

Objective

This project consists of several tasks:

Collect and summarize opportunity fuels information for fuels that already are or could be used in CHP applications. Description of quality characteristics of the available opportunity fuel sources, their potential suitability as a CHP or DG fuel and their potential environmental implications. Rough supply availability and cost estimates for each reasonably suitable and available opportunity fuel will be developed.

Evaluate CHP Technology Options – Analyze the set of CHP and DG technologies and applications that might benefit from use of opportunity fuels will be analyzed. From these, a set of cost, performance, efficiency and emissions data will be developed for each generator type consuming a particular opportunity fuel.

Analyze Potential Market Impacts and Develop Recommendations - Scenario analyses will be performed with the DISPERSE model to examine in detail the influence of various opportunity fuel's use in its partnered generator set technology.

Recommendations and conclusions will be drawn addressing barriers that are presently impeding expanded use of these technologies and opportunity fuels, and discussing potential solutions for barrier removal.

Highlights

Phase I of this work was completed with the issuance of the final report: "CHP Market Potential for Opportunity Fuels." It has been provided to Doug Hinrichs for posting to the DOE DE website.

Technical Progress

A task was added to the contract: Satisfying of Renewable Portfolio Standards With Opportunity Fuels and CHP. In this effort, a state-by-state analysis of the impact of state level renewable portfolio standards will be performed, using state target dates and impacts as well as emerging values of renewable energy certificates (RECs). This analysis will build off of the Phase I work. It will analyze the potential capacity from opportunity fuels that would satisfy the state renewable portfolio standards, based on availability of fuel, economics of opportunity fueled CHP, and prospects for wind and solar renewables.

Status of Milestones

Complete final report on Opportunity Fuels Market Analysis. May 2005
COMPLETE.

Subtask 4.3.12b A Review of DG Siting Procedures

Paul Lemar
Resource Dynamics

Objective

This project consists of several tasks:

Task 1: Collect Siting Data – including financial case study information from and about a wide selection of DG and CHP installations. The focus will be on what steps the developer needed to take to complete the installation, how long each step took, and the cost to conduct each task. Barriers faced and actions taken to successfully mitigate these barriers will be identified.

Task 2: Perform Siting Trends Analysis - Trends in each of the following 3 tracks will be analyzed to determine what impact they have on siting costs:
1. Site analysis including engineering feasibility and financing,
2. Permitting including an environmental analysis, air permit, zoning permit, building and construction permits, and 3. Interconnection including engineering, inspection and coordination with the local distribution utility.

Task 3: Analyze Siting Procedures and Recommendations –Prepare recommendations of ways regulators might help improve the siting process, and ways end-users and ISPs might minimize costs when installing DG and CHP units.

Highlights

The final report: "A Review of Distributed Generating Siting Procedures" was completed and provided to ORNL in June.

A final presentation summarizing the report was provided to ORNL and DOE. A project close-out meeting is being planned for September.

Technical Progress

The final report and presentation were complete this quarter. These items will be posted on the DOE website after completion of the final project review meeting scheduled for September.

This contract will be closed out in FY05. No FY06 work is expected.

Status of Milestones

No milestones scheduled for this project

Subtask 4.3.14 Conveying Targeted CHP Messages through Industries Associations

John Jimison, Executive Director
United States Combined Heat and Power Association

Objective

FY05 work builds upon Phase I. Specifically, USCHPA will complete a *two-step information task:* (a) Assembly and organization of existing information concerning the potential use of CHP, primarily using opportunity gas fuels that are produced by the facilities themselves, and (b) preparation of both hard-copy brochures and a set of web-pages that are designed for access by municipalities and their waste-water treatment managers to attract them to consider use of CHP, and an *Association outreach task.* Contact and outreach by USCHPA leaders and members to Associations representing municipal wastewater treatment facilities to encourage them to consider CHP, and to advocate that municipal electric utilities incorporate CHP into their own resources, helping to open opportunities for 3rd party CHP to be interconnected on municipal utility systems, as well as to use municipal wastewater treatment CHP systems as a leading edge participant on non-municipal (IOU) electric utility systems.

Basis: Municipal electric utilities represent both a leading potential market for distributed generation, one which has many potential ways of using the related thermal energy in CHP mode including wastewater treatment, and also a key segment of the electric utility industry that is reluctant to embrace the procedural and regulatory changes that are necessary to allow CHP easier access to the market. Outreach to this sector could therefore have both market and policy benefits to the CHP community.

Highlights

No report

Technical Progress

No report

Status of Milestones

Finalize CHP in food processing web site and go live. November 2004
COMPLETE. http://www.sentech.org/CHP4foodprocessing/index.html

Subtask 4.3.16 Coordination of Regional CHP Application Centers

Ted Bronson
Power Equipment Associates

Objective

Based on the consistent technical success by the Midwest CHP Application Center to promote the implementation of CHP in the Midwest, DOE has launched through its SEP Process an additional 7 CHP Regional Application Centers. To date these centers have garnered support of over 100 companies to promote the development of CHP markets on a regional basis. By effectively integrating with the Initiatives, and coordinating amongst themselves, Regional Application Centers can be a highly effective tool in meeting DOE's current and future goals with CHP. This task provides technical assistance for the launching of the new application centers and for coordination and evaluation of RAC activities on an annual basis.

Highlights

A CHP RAC face-to-face meeting was held on May 3rd in Washington DC.

A meeting was held with DOE to discuss the next RAC face-to-face meeting being held in conjunction with the October Roadmap meeting.

The Gulf Coast held their first CHP RAC roadmap workshop. Proceedings of the workshop were posted to the following website in June: http://www.gulfcoastchp.org/chp/News/Roadmap/ActionPlan.pdf

The Southeast is planning their first CHP RAC roadmap workshop.

Technical Progress

The Gulf Coast held their first Roadmap workshop on April 26-27, in the Woodlands, Texas. The objectives of the workshop were to: review the status of national and state CHP initiatives and programs, develop an action plan to be implemented by the Gulf Coast CHP Applications Center, set the stage for the creation of a Regional Strategic Plan, and discuss creation of a CHP Initiative to further the regional market for CHP. The agenda consisted of the following topics: Setting the Stage- The National CHP Status, DOE's CHP RAC Program, EPS's CHP Partnership, CHP Market Status: National and Regional Perspectives, Regional Market Drivers, Regulatory Landscape in the Gulf Coast Region, Sate of Louisiana and Texas, Industrial CHP, Green Buildings and CHP, Strategic Goals for Gulf Coast RAC, Establishing 4 priority market sectors, specific RAC actions, and the RAC roadmap.

Status of Milestones

Subtask 4.3.16 Write a summary paper on status and lessons learned among CHP Regional Application Centers March 2005
COMPLETED early. This paper [in presentation format] was delivered to ORNL and DOE on February 7, 2005.

Section 4.3.17 Project Direction and Technical Support

Patti Garland and Jan Draine
ORNL

Objective

The objective of this activity is to promote CHP installations into the public and private sectors by focusing on the issues of CHP awareness, regulatory and institutional barriers, and CHP economic feasibility. ORNL issued a solicitation at the end of FY 2002 for CHP-related projects. The objective of the solicitation was to support activities that facilitate and encourage the use of CHP technology in the U.S. This activity was developed in response to the "Consensus Action Items from the CHP Roadmap Process" issued in June 2001, which supports the National Energy Plan. ORNL is synthesizing the data and tools developed under the contracts. As the tasks progress, lessons learned and technical results will be compiled and disseminated to the stakeholder community. Results of these projects will be disseminated through the DOE DE Website, the DOE CHP Regional Application Centers; the U.S.CHP team meetings, which includes industry partners, utilities, associations, and other federal agencies, such as EPA, HUD and the Veterans Administration. ORNL works with DOE for coordination of CHP Application Center activities. ORNL provides technical resources to the Regional Application Centers.

As part of the CHP Roadmap activities, ORNL supports development and updates of the CHP action plan in response to the Roadmap. ORNL participates on the CHP in LEED conference calls and provides a critical technical review of the draft guidance for CHP in LEED. ORNL has supported the IEA Heat Pump Center's Annex Activity related to District Heating and Cooling Systems with CHP. In FY05, Annex VII will be completed with a final project review in June, 2005, in Berlin. Annex VIII will kick-off in June 2005. ORNL will provide technical review and recommendations on the projects that are part of the Annex Activities.

Highlights

ORNL is continuing technical development of the IES webcast, in conjunction with Energetics and Exergy Partners. Announcements of the webcast, which will take place on September 21st, from 12 noon til 4 pm EST, have been provided to subcontractors and to the CHP Regional Application Centers. The official announcement for the webcast can be found at: http://www.ornl.gov/sci/engineering_science_technology/cooling_heating_power/

Work is continuing on the final version of the RAC toolkit. PEA and Avalon Consulting are helping to put a user interface on the toolkit CD.

The CHP Subcontractor Coordination Review meeting was held on April 14, 2005 in Washington DC. Copies of the presentations were provided to Energetics for posting on the DOE DE website.

Much time is being spent with the subcontractors in an effort to decrease un-costed balances. .

Technical Progress

Much time is being spent with the subcontractors in an effort to decrease un-costed balances.

ORNL is working with Doug Hinrichs of Sentech to post the following reports to the DOE DE website.

1.) DE Technology Characterization--EEA
2.) Guide to Developing Air-Cooled LiBr Absorption for CHP Applications--Zogg et. al., TIAX
3.) Review of TAT--TIAX

4) CHP Market Potential for Opportunity Fuels—RDC
5) Heat Activated Solid-Gas Sorption Commercial Refrigeration – Rocky Research

Status of Milestones

Subtask 4.3.17 Facilitate and publish the results of the 3rd Annual CHP Subcontractor Coordination Review Meeting. May 2005 COMPLETE

Subtask 4.3.19 Subtask Consolidate tools in "tool box" for use by CHP Application Centers. February 2005. Draft tool-kit COMPLETED on December 23, 2004.

Subtask 4.3.19 Subtask Consolidate tools in "tool box" for use by CHP Application Centers. DOE milestone in CPS due September 30, 2005

Subtask 4.3.15 Plan and implement the November NOVEM IEA Annex meeting to be held in New Orleans, LA. November 2004. COMPLETE

Task 4.3.18 Application Integration Analysis

Randy Hudson
ORNL

Objective

ORNL will continue to identify the most appropriate evaluation tools for assessing DE/CHP viability. ORNL will evaluate existing software tools and will work with stakeholders to ensure development of the appropriate tools and to assist in their use in studying potential DE/CHP applications. ORNL will continue development of the IES optimization tool.

Highlights

Cost-shared effort. See Task 4.2.13.

Technical Progress

See Task 4.2.13.

Status of Milestones

Develop a 2nd generation model for IES optimization June 2005
COMPLETED

Section 4.3.20 Cogen Manual (HUD Support)
No FY05 funding…work-for-others project carried over from FY04

Steve Fischer
Oak Ridge National Laboratory

Objective

In this cost-shared work-for-others project, ORNL will use carryover HUD funds to provide technical support to Bob Groberg HUD on an as-needed basis. Current work includes writing an Excel spreadsheet calculator for the Cogen Manual for Multi-Family Housing, Appendix A worksheets for facility owners. A technical review of the worksheets will be provided, as well as providing recommendations on the accuracy of the worksheets.

Highlights

In coordination with Bob Groberg the first version of the CHP Guide for Multifamily Housing was completed.

Bob Groberg was so pleased with the level of effort provided by ORNL in the 2004-2005 timeframe under the cost-shared work-for-others project between ORNL and HUD that he has proposed extending the agreement into 2006.

Technical Progress

Steve Fischer provided a copy of the BCHP Screeng tool to Bob Groberg, who was impressed by the graphical interface. Bob is reviewing the data on multi-family housing.

Steve continues to provide answers to questions and reviews of technical materials requested by Bob Groberg.

HUD has requested extending the work-for-others project into FY2006 with the following tasks for ORNL: ORNL Tasks
-Continue to develop and refine the CHP feasibility software developed during 2004-5:
-Provide technical advice to Regional CHP Application Centers and others using the software
-Adjust the software to reflect experience in using it
-Consider expanding the scope to deal with space heating and cooling.

Status of Milestones

Provide ongoing support to Bob Groberg at HUD on development of the revised Cogen Manual for Multi-Family Housing. Ongoing