Distributed Energy Program

DE Quarterly Progress Report
For the Period
April 1, 2006 to June 30, 2006

Materials

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

DE QUARTERLY PROGRESS REPORT

For the Period
April 1, 2006 to June 30, 2006

Prepared by:

David P. Stinton, Manager, and
Gwen Sims
Distributed Energy Program
Oak Ridge National Laboratory

For:
Department of Energy
Distributed Energy Program
Office of Electricity Delivery and Energy Reliability

Section 1. Advanced Reciprocating Engines

SUBTASK 1.2. SPARK PLUG EROSION AND DEGRADATION INVESTIGATION (PIC 690)

M. P. Brady, H. T. Lin, R. K. Richards, and M. D. Kass
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5153, E-mail: bradymp@ornl.gov

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

SEM examinations of the exposed surface and polished cross section of spark plugs made from ORNL model and developmental electrode alloys after 67h engine test at ORNL in a Caterpillar G3406 industrial natural gas engine were completed during this reporting period. SEM analysis showed that some of the ORNL developmental electrode alloys did not exhibit intergranular crack formation, which was in sharp contrast to those standard electrode alloys currently used in the spark plug industry showing intergranular cracks. The observation of free crack formation suggested excellent corrosion/erosion resistance of ORNL developmental electrode alloy.

Technical Progress

A 500h accelerated bench engine test for some of the ORNL developmental electrode alloys has been completed at Federal Mogul (FM). This is an ongoing collaborative research effort between ORNL and FM to develop more corrosion/erosion resistant electrode alloys to achieve increased engine durability and reliability as compared with current electrode alloys. Although it is a commercial automotive engine, the test data provide a useful feedback on the material degradation mechanisms and a further basis for alloy optimization. Detailed SEM analysis will be carried out and the results will be summarized in the next quarterly report. Results of SEM examinations of ORNL model and developmental electrode alloys after a short term, 67h natural gas engine test on baseline model electrode alloys (without precious metal inserts) indicated that some Cr_2O_3 scale forming alloys do not suffer from intergranular cracks, which was in contrast to standard alloys currently employed. FM is currently completing manufacture of a second iteration of spark plugs utilizing optimized alloys and precious metal insert materials for natural gas engine testing at ORNL during the last quarter of FY06.

Status of Milestones

1. Evaluate developmental spark plugs in an industrial natural gas engine. – it is on schedule.
2. Develop a database for spark plug performance under differing temperature conditions using the newly developed test chamber at NTRC. - modified due to funding and programmatic changes.

Industry Interactions

Conference calls and email communications with Drs. Iryna Levina and Jim Lykowski at Federal Mogul to discuss the second iteration of spark plugs for manufacture by Federal Mogul and engine testing at ORNL as well as the second 500h bench engine test status and initial gap growth results.
Communications with Dr. Luigi Tozzi and other personnel at Woodward at the Advanced Engine System meeting about issues related to spark plugs and potential research collaboration on the spark plug alloy development.

SUBTASK 1.3. ADAPTIVE CONTROLS FOR LEAN BURN ENGINES

K. D. Edwards and R. M. Wagner
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 946-1213, E-mail: edwardskd@ornl.gov

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

Development has begun on a WAVE engine model of the single cylinder representative of the Waukesha APG ARES engine. Waukesha has provided engine specifications, geometry information and operational data needed to complete the model. Once complete, the model will be an invaluable complement to the experimental system. Completion of the model is expected to be on time.

Technical Progress

Work has progressed this month on fabrication of the single cylinder engine at Digital Engines, LLC. Personnel from ORNL visited Digital Engines to review progress. Although the project is behind schedule, sufficient progress is being made on the fabrication of the engine. Engine delivery now depends upon Waukesha receiving and transferring to Digital Engines acceptable APG power cylinder components. The engine will be located in a new engine test cell at the NTRC adjacent to an existing test cells/control room.

Status of Milestones

Develop an analytical model for the single cylinder engine representative of the Waukesha APG ARES engine (Sept. 2006) – on track

Interactions

We have had regular interactions with Waukesha about the single cylinder engine and development of the WAVE engine model of the engine.

SUBTASK 1.6A. NATURAL GAS LEAN NOX TRAP (LNT) EVALUATION

J. E. Parks, S. Ponnusamy, and J. M. Storey
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 926-1283, E-mail: Parksjeii@ornl.gov

Objective

The main objective of this project is to study lean NOx trap catalysis for emissions control from natural gas (NG) engines. Key emission control areas of interest include: NOx reduction efficiency, operational (fuel) penalty, durability, and cost basis of lean NOx traps for ARES applications. Experiments for the study are performed on a Cummins C8.3G NG engine dynamometer platform at ORNL.

- 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.
- In FY05, full characterization of the utilization of NG (fuel efficiency) for catalyst regeneration was performed. Methane oxidation and reforming chemistries were characterized for various conditions.
- In FY06, the focus has shifted to durability issues and, in particular, durability concerns due to sulfur.

Highlights

The primary experiments for FY06 regarding sulfur durability of the oxidation and reformer catalysts have been completed. Results were positive and are summarized in the Technical Progress section below.

Technical Progress

FY06 efforts are focused on Sulfur Durability Studies. Experiments for sulfur durability studies were performed on the Cummins C8.3G+ engine dynamometer platform at ORNL. The study involved exposing the oxidation and reformer catalysts to SO_2 (injected from gas cylinders into the exhaust stream) and characterizing the oxidation and reforming efficiencies of the catalysts before and after sulfur exposure. The goal of the experiments was to determine the effect of sulfur on NG utilization for lean NOx trap regeneration.

It was observed that elevated levels of SO_2 in the exhaust cause degradation of oxidation and reforming processes, but after normal lean-rich cycling without elevated SO_2, the performance of the catalysts recovered to pre-SO_2 levels. Recovery occurred during the rich phase of the cycle where chemisorbed sulfur compounds were reduced and desorbed. ***Thus, for applications with typical levels of sulfur in the natural gas, the durability of oxidation and reformer catalysts should not be significantly affected by sulfur provided normal lean-rich cycling operation is maintained.***

Status of Milestones

Characterize the effect of sulfur on methane oxidation and reforming processes of the lean NOx trap catalyst system. September 2006 – completed.

Industry Interactions

- A presentation on FY06 experimental results was given at the 3rd Annual Advanced Stationary Reciprocating Engines Meeting hosted by ARES and ARICE programs on June 28-30, 2006 at Chicago, IL.
- A draft paper has been written and submitted for review for presentation at the special ARES-ARICE session of the ASME Fall Technical Conference on Internal Combustion Engines in Sacramento, CA on November 7-8, 2006.
- ORNL is communicating with EmeraChem (the catalyst supplier partner on the project) to establish estimates for lean NOx trap catalyst system costs for ARES applications.

Section 2. MATERIALS BASED TECHNOLOGY FOR DISTRIBUTED GENERATION

SUBTASK 2.1.1. ADVANCED ALLOYS FOR HIGH TEMPERATURE RECUPERATORS

P.J. Maziasz, J.P. Shingledecker, and N.D. Evans
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5082; E-mail: maziaszpj@ornl.gov

Objective

The objective is for ORNL to work with commercial foil and sheet suppliers to test, evaluate and enable recuperator manufacturing with alloys that have more temperature capability and performance at reasonable cost. Near term objective is meeting reliability goals (40,000-80,000h) at about 700°C, while the long term objective is pushing performance to 750°C or higher, without sacrificing lifetime. Last year, ORNL completed Phases I and II of a collaborative project with Allegheny-Ludlum to produce and measure properties of a wide range of commercial sheets and foils of AL20-25+Nb stainless alloy. The Phase II creep resistance of sheets was improved by a factor or two, and excellent creep-resistance was also found in a range of foil products, but particularly the 3 mil product. Microstructural analysis of creep-tested specimens is being done to complete this work in FY2006. Relative alloy comparisons include foils of 347 steel, HR120 and alloy 625. ORNL work plans to assess recuperators manufactured from AL20-25+Nb sheets and foils, and to examine behavior of foils exposed in a microturbine environment.

Highlights

Creep-test of Phase II (processing for more creep resistance) AL20-25+Nb stainless alloy foils at 700-750°C consistently shows more rupture strength than HR120 or HR230, and comes closer to the creep-strength of alloy 625 than the Phase I material. This quarter, probes were analyze from the first tests of these Phase I foils in the ORNL Recuperator Test Facility. Creep testing was also completed on foils of alloy 625, showing that they have considerably less creep-resistance than sheet, due to the fine-grain-size effect.

Technical Progress

Recuperators made from 347 steel sheets and foils suffer severe moisture-induce oxidation attack and creep deformation at temperatures above 650°C. While similar sheets and foils of the Ni-based superalloy 625 have excellent oxidation and creep-resistance up to 750°C or more, they cost 3.5-4 times more than 347 stainless steel. Austenitic stainless sheets and foils made from austenitic stainless HR120 and AL20-25+Nb alloys are more cost effective alternatives to 347 stainless steels with higher performance for such recuperator applications.

ORNL completed Phases I and II of a collaborative program with Allegheny-Ludlum in FY2005 to produce a wide range of commercial sheets and foils of the AL20-25+Nb alloy for microturbine recuperator OEM manufacturing trials for prototype air-cells with higher performance. The Phase I effort produced full-scale commercial quantities of a wide range of sheets and foils of AL20-25+Nb with the standard processing. The Phase II effort produced limited quantities of selected sheets and foils with different processing to modify the microstructure for better creep-rupture resistance. ORNL preformed creep-tests at 700-750°C, and completed testing of Phase II material this quarter. Microstructural analysis of Phase I and II were completed this quarter. Study also includes the appropriate comparisons with similar creep-tested sheets and foils of 347 steel, HR120 and 625 alloys. The AL20-25+Nb alloy was provided to make probes for testing in the ORNL Recuperator Test Facility, and those tests are in-progress. The initial creep-tests of Phase II foils and sheets of AL-20-25+Nb alloy at 700-750°C, show significant improvement compared to Phase I, and good relative behavior compared to HR120 and 625 alloys. Creep-testing on foils of alloy 625 were completed this quarter, and microcharacterization will be completed next quarter.

Milestones

Complete creep testing and microcharacterization of Phase II AL20-25+Nb alloy with improved creep resistance, provide commercial sheets and foils (Phase II) to recuperator manufacturers; complete initial characterization of recuperator air cells made from AL20-25+Nb sheets and foils. (June, 2006) Milestone was completed on schedule.

Meetings

1. ORNL communicates periodically with Allegheny-Ludlum Technical Center (Chuck Stinner) on this project. ORNL has worked with Ingersoll Rand Energy Systems to obtain brazed plate-fin aircells manufactured with AL20-25+Nb. ORNL also interacted with Capstone Turbines on their primary surface aircell manufacturing efforts with foils of Phase II AL20-25+Nb alloy.

SUBTASK 2.1.3. RECUPERATOR ALLOYS – COMPOSITION OPTIMIZATION FOR CORROSION RESISTANCE

B. A. Pint
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 576-2897, E-mail: pintba@ornl.gov

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

The oxidation performance of new commercial alloy foils is being assessed in laboratory tests in order to compare to previous commercial and laboratory-made foils. Testing has been completed to 5,000h at 650° and 700°C in humid air for Nb-modified Fe-20Cr-25Ni. Foils of various thicknesses are included to test the hypothesis that water vapor degradation is primary at the alloy surface in this temperature range.

Technical Progress

Laboratory testing is continuing on various model and commercial alloys in order to better understand the effect of water vapor in exhaust gas on oxidation of chromia-forming steels over a range of times and temperatures. Prior work has shown a difference between commercially-rolled and laboratory-rolled foil performance that was attributed to the different surface finish on the foils. In order to confirm prior work on laboratory-rolled Fe-20Cr-25Ni+Nb foils, commercial foils are now being tested with thicknesses of 80-400μm. Prior characterization also indicated that Cr depletion in this and similar alloys were primarily located near the foil surface and therefore should not be affected by foil thickness. The current set of specimens, which have reached ~7,500h, will test that hypothesis. One specimen of each foil thickness was removed at 5,000h for characterization.

Status of Milestones

Submit an open literature publication calculating the rate of Cr loss based on classical gas transport theory with comparison to experimental data. (December 2006, completed)
Complete analysis of chromium depletion data as a function of time and temperature in various commercial and laboratory foil materials. (August 2006, on track)

Industry Interactions

Discussed protective oxide coatings for recuperators with N. Garrett, consultant for C3 International, Alpharetta, GA and sent a sample of commercial 347 foil for trial coatings.

SUBTASK 2.1.4. RECUPERATOR MATERIALS TESTING AND EVALUATION

Edgar Lara-Curzio, Rosa M. Trejo, K. L. More and Sebastien Dryepondt
Oak Ridge National Laboratory
(865) 574-1749; E-mail: laracurzioe@ornl.gov

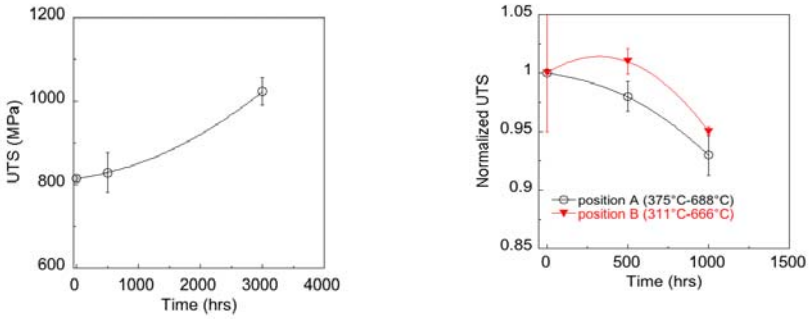
Objective

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. 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

Presented two papers at ASME Turbo Expo 2006.

Technical Progress



(a) (b)

Figure 1. Evolution of UTS for alloy 625 LCF as a function of time of exposure at 750°C. (b) Evolution of UTS for alloy 20/25-Nb as a function of time during intermittent operation. The temperature ranges are indicated.

During the reporting period test campaigns to complete 10,000-hr exposure of foils of HR-120® and 20/25-Nb in ORNL's recuperator testing facility continued. Also the residual mechanical properties of test specimens of alloy 625-LCF that had been exposed for 3000 hrs were determined. It was found that the ultimate tensile strength increases significantly with time of exposure as illustrated in Figure 1a. It was also found that this increase in tensile strength is accompanied by significant reductions in ductility from 50% for the as-processed condition to less than 20% after 3000-hr exposure at 700°C. These results are likely related to the precipitation of the g" phase as suggested by Mathew et al[1].

The effect of intermittent operation on the tensile properties of 20/25-Nb (5 mil) foils was determined after 560 cycles (1000 hrs). In general, it was found that the tensile strength of this alloy decreases with number of cycles for the temperature ranges investigated (Figure 1b). Details about the test conditions have been provided in previous reports. The microstructural characterization of these test specimens is in progress.

1. Mathew M.D., Murty K.L., Rao K.B.S. and Mannan S.L., "Ball indentation studies on the effect of aging on mechanical behavior of alloy 625," *Materials Science and Engineering: A*, **264**, 1, pp. 159-166 (1999)

Staus of Milestones

Complete 10,000-hr exposure on HR-120® and 20/25-Nb foils (September 2006). On track

Industry Interactions
Discussed with Capstone Turbines upgrades to ORNL's microturbine recuperator testing facility.

Problems
The communications board of the microturbine and a power supply of the gas compressor were replaced.

SUBTASK 2.2.2. MICROSTRUCTURAL CHARACTERIZATION OF CFCCS AND PROTECTIVE COATINGS

K.L. More and P.F. Tortorelli
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-7788, E-mail: morekl1@ornl.gov

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-COIC's oxide/oxide ceramic matrix composite, designated A/N720 CMC, has been completed in ORNL's Keiser Rig for 3000 h at 1135°C, 1200°C, and 1250°C, 10 atm total system pressure, and 10% H_2O. These materials were also exposed for ~2000 h at 1250°C, 20 atm total system pressure, 90% H_2O in the Keiser Rig. These laboratory exposures were conducted for comparison with the A/N720 CMC + FGI outer combustor liner currently being exposed (>22,000 h) in a Solar Turbines Centaur 50S engine at the ChevronTexaco engine test site in Bakersfield, CA.

Technical Progress

An update on the status of the current ChevronTexaco engine test (Bakersfield, CA) was recently provided by Mark van Roode of Solar Turbines. To date, 22,132 h (85 starts) have been accumulated on the A/N720 CMC + FGI (hybrid) outer liner in the engine test and 9,550 h (33 starts) have been accumulated on the prepreg MI SiC/SiC + EBC inner liner. The ultimate goal for the hybrid outer liner will be 25,000 h engine exposure, at which point the liner(s) will be removed for microstructural and mechanical characterization. The likely time-frame for stopping the engine test will be November, 2006. Long-term Keiser Rig exposure data (including microstructural observations, weight change data, and mechanical properties data) that has been accumulated at ORNL during the past fiscal year (on the same materials used in the hybrid outer liner) will be compared with observations from the ~25,000 h engine-exposed liner. For example, 3000 h exposure of the A/N720 CMC at 1250°C (10% H_2O) resulted in significant degradation of the Nextel 720 fibers and an ~25% drop in UTS. Also, significant volatilization of both the A/N 720 CMC (~5% weight loss) and FGI (~6-7% weight loss) have been reported after exposures of these materials in the Keiser Rig for 2500 h at 1250°C (90% H_2O), which may explain changes in the gas-path surface of the outer liner observed during recent borescope inspections.

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 – IGTI paper# GT2005-69064 completed.*

Publish report on the exposure of oxide/oxide CMCs at high H_2O pressures and 3 temperatures. *May 2006 – IGTI paper# GT2005-69064 completed.*

Report results from analysis of engine-exposed CMC combustor liners and compare with data for similarly-exposed materials in ORNL's Keiser Rig. *June 2006 – completed. All results to date have been presented to Solar Turbines. Currently waiting for the ATK-COI oxide/oxide+FGI outer liner to be removed from engine test at ChevronTexaco in Bakersfield, CA.*

Industry Interactions

1. Exposure of UTRC EBC/CFCCs completed (Tania Bhatia, UTRC).
2. Correspondence with Solar Turbines continues regarding schedule for A/N 720 CMC liner evaluation.

SUBTASK 2.2.3. HOT SECTION MATERIALS DEVELOPMENT FOR ADVANCED MICROTURBINES

Vimal K. Pujari, Ara M. Vartabedian, William T. Collins, Gregg S. Wayman, Robert H. Licht
Saint-Gobain Ceramics & Plastics, Inc., Northboro R&D Center
Phone: 508-351-7929, Email: Vimal.K.Pujari@saint-gobain.com

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.

Technical Progress

The project is complete.

SUBTASK 2.2.4. OXIDATION/CORROSION CHARACTERIZATION OF MICROTURBINE MATERIALS

K.L. More and P.F. Tortorelli
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-7788, E-mail: morekl1@ornl.gov

Objective

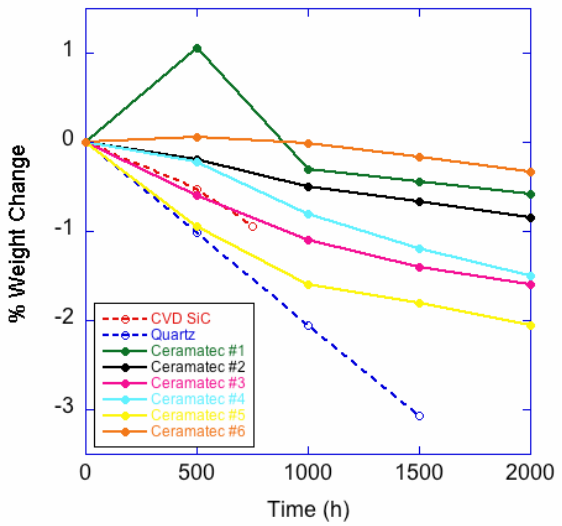
Environmental barrier coatings (EBCs) will be required on surfaces of Si-based ceramic and composite materials exposed to microturbine combustion (high water-vapor pressure) environments. EBC systems are currently being developed for use on Si_3N_4 hot-section microturbine components. The reliability 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 candidate EBC compositions produced by Ceramatec to extremely high water-vapor pressures in ORNL Keiser Rigs was completed during this reporting period and 2000h of exposure time was accumulated. Exposures of Si-based standards and rare-earth-based coupons have validated the use of very high H_2O pressures (18 atm) to evaluate an EBC's volatility, even at the slow-flow gas velocities used in the Keiser Rig. The current exposures are being used to "rank" EBC formulations being developed for Si_3N_4.

Technical Progress

To date, 5 different EBC compositions processed by Ceramatec have been exposed for a total of 2000h at 1250°C, 20 atm total system pressure, and 18 atm H_2O in ORNL's Keiser Rig. A comparison of the weight change data for each of these proprietary EBC compositions are plotted together (right) with weight change data for CVD SiC and Quartz standards. Each exposed stand-alone EBC coupon was carefully weighed after sequential 500 h exposures. These EBCs were then "ranked" in terms of total weight change as a function of exposure time. There are clear differences in stability (volatilization-resistance) between the different Ceramatec EBCs; Ceramatec #6 exhibited the best stability after exposure for 2000 h (less than 1% weight loss) whereas Ceramatec #4 showed the largest weight loss after 2000 h (~2%). Most of the Ceramatec EBCs showed better volatility-resistance than either CVD SiC or Quartz, but were not as good as dense rare-earth based EBCs (such as $Lu_2Si_2O_7$, $Yb_2Si_2O_7$, $Sr_2Al_2O_7$ – see 01-06/03-06 Quarterly Report).



Status of Milestones

Complete exposures of Saint Gobain Si_3N_4 with/without EBCs in high H_2O pressure Keiser Rig and report results. *March 2006 – 4 different St. Gobain EBC compositions have been exposed in the Keiser Rig but this work will not be continued. These data will complete Milestone.*

Prepare a report on compositional effects on EBC stability when exposed to very high H_2O pressures in ORNL's Keiser Rigs. *August 2006 – completed with publication of IGTI paper #GT2005-69064.*

Industry Interactions

1. Completed all exposures of new EBCs in Keiser Rig for St. Gobain, Ceramatec, and UTRC.

SUBTASK 2.2.5. PORTABLE MULTI-FUEL TEST RIG (THE PORTABLE RIG)

Jane Y. Howe
Oak Ridge National Laboratory, Oak Ridge, TN 37831
Phone: (865) 241-9745, E-mail: howej@ornl.gov

Objective

The project is to develop a unique facility at ORNL to evaluate the exhaust emission and assess the degradation of structural materials of turbines, reciprocating engines, and microturbines when conventional and nontraditional fuels are used.

Highlights

The ORNL Fuel-Flexible Turbine Environment Test (FFTET) Rig is designed to perform the following tasks for a given type of fuel:

- Measure the temperature and gas species at selected locations inside the turbine
- Evaluate materials degradation by placing coupons inside the turbine
- Measure the SOx, NOx, CO/CO_2, etc in the exhaust
- Evaluate the degradation of candidate turbine/microturbine structural materials by exposing samples in an exhaust gas stream that is maintained at the desired test temperature and spiked with toxic species or components that make the gas stream characteristic of the exhaust when nontraditional fuels are burned.

Technical Progress

Based upon the design and the current available facilities at ORNL, it was decided to order a custom modified Capstone C65 engine for the Rig. Several meetings with the vendor took place at ORNL and at Capstone offices in California to discuss the details of the modifications of a stock model. Designing of the controlled environment sample exposure chamber is underway, specifically (1) determining the location and amount of gas to draw out of the microturbine; (2) gathering previous computer simulation results by Capstone; (3) discussing the need for carrying out new simulation work at ORNL; and (4) selecting materials for the testing chamber. An order was placed for construction of a roof over the Rig. A poster entitled, "Test Facility to Assess the Effect of Alternative and Opportunity Fuels on the Durability of Microturbine Materials and Components" was presented by Rosa Trejo *et al.* at Women in Science Poster Session on May the 4th.

Status of Milestones

Design the controlled environment test chamber. On time.
Order modified microturbine. It is delayed, due to the slow response of the vendor.

Industry Interactions

Late April: Meetings with Ms. Wendy Matthews of Capstone Turbine Co. at ORNL to discuss the purchase of a new custom-built C65 engine for the Test Rig.
May 4th: Visit Capstone (with Jim Keiser) to finalize the specification of the custom modifications of the C65 engine.
Delivery of the Final Report on the thermal barrier coating failure analysis to Ingersoll-Rand on June 13th. A follow-up phone conference on June 15th. The report is well-received.

SUBTASK 2.2.6. CHARACTERIZATION OF OXIDATION RESISTANT CERAMICS AND SILICON NITRIDES

R. R. Wills and S. Goodrich
The University of Dayton Research Institute, Dayton, Ohio
Phone: (937) 229 4341, Email: roger.wills@udri.udayton.edu

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) Determine the slow crack growth of Saint Gobain's latest NT154 grade silicon nitride and help find the processing conditions that give the material the best high temperature creep and slow crack growth resistance at 1200°C. 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

With all funds expended no further work has been conducted . The problem with the current NT154 was identified earlier this year and solutions proposed to both Saint Gobain and UTRC.

Status Of Milestones

(1) Compare the tensile creep properties of this generation NT154 with that of its predecessor. December 2006 is on track.
(2) Determine the Slow crack growth parameters of NT154 as a function of processing conditions. December 2006 is on track.

Industry Interactions

Discussed technical needs with John Holocwak of UTRC.

SUBTASK 2.2.7. MECHANICAL RELIABILITY EVALUATION OF MICROTURBINE COMPONENTS

H. T. Lin
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 576-8857; E-mail: linh@@ornl.gov

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

Characterization of thermal diffusivity and phase content of thermal barrier coating (TBC) after 40,000 hours engine field service has been completed. Results showed that there was 6-10% phase change (form tetragonal to monoclinic phase) after field service, which was also strongly influenced by the local combustion temperature. Also, results showed that the inside liner exhibited more phase transformation (and thus more degradation) than those obtained from the outside liner mostly due to the exposure temperature difference. In addition, the 40k-hours tested TBC exhibited much higher thermal diffusivity than those as-received samples, indicative of the occurrence of densification during the long-term engine field service.

Technical Progress

The high-temperature steam jet exposure at 1200°C for 500h for a pre-strained FGI oxide-oxide CMC specimen (up to 0.25%) was completed during this reporting period. The exposure tests conducted will provide important insight into the effect of pre-existing damages (i.e., micro cracking) introduced by the pre-mechanical tests on the microstructure stability of FGI layer under a more realistic test condition. Preliminary SEM examinations of FGI surface indicated that more material recession was observed in the region when cracks were present prior to the steam exposure. SEM analysis of the polished cross section will be carried out to provide more details of the material degradation inside the FGI as well as oxide CMC bulk.

The setup of a flexure test system capable of applying stress during the steam exposure has been initiated. The objective of this study is to evaluate the effect of externally applied stress on the material recession and degradation of SiC-SiC CMC with EBC under the simulated combustion environment. Also, it could provide important database for life prediction of the SiC-SiC CMC component.

Status of Milestones

1. Complete high-temperature tensile creep database for ODS alloys and FGI oxide-oxide CMC. Sept 2006 – on schedule.

Industry Interactions

1. Communications and conference calls with Venkata Vendula and David Jarmon on the progress of the setup of steam exposure test system.
2. Communication with Xiaoqun Chen and Mark van Roode at Solar Turbines on the up-to-date status on the characterization of TBC after 40k hour's field service.
3. Visit Solar Turbines to discuss the status and future plans for the TBC as well as ODS project with A. Bhattacharya, X. Q. Chen, M. van Roode, J. Kimmel, and J. Price on May 1, 2006.
4. Communications with Chris Campbell and Jay Morrison at Siemens Power Generation on the updated results of high-temperature steam jet tests on the FGI oxide-oxide CMC.

SUBTASK 2.2.9. ENVIRONMENTAL PROTECTION SYSTEMS FOR CERAMICS IN MICROTURBINES AND INDUSTRIAL GAS TURBINE APPLICATIONS: SLURRY COATINGS

Beth Armstrong
Oak Ridge National Laboratory, Oak Ridge, TN 37831
Phone: 865-241-5862; Email: armstrongbl@ornl.gov

Objective

In 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 collaborators' material systems continue. New additive systems and different sintering approaches are currently being evaluated to improve coated sample densities and adhesion. Formulations and the resulting coatings that meet the collaborator's specifications will be submitted for simulated exposure and characterization.

Technical Progress

Work continues on the collaborators' candidate materials systems. Rheology, dipping, and sintering studies were put on hold due to contamination and equipment issues.

Status of Milestones

Evaluate the corrosion resistance of industrial partner's EBC system in a simulated combustion environment. September 2006 – on track

Industry Interactions

Collaboration with Honeywell continues.

SUBTASK 2.2.10. RELIABILITY ANALYSIS OF MICROTURBINE COMPONENTS

S.F. Duffy, E.H. Baker & J.L. Palko
Connecticut Reserve Technologies, Inc. Strongsville, Ohio 44136
Phone: 330-678-7328 e-mail: sduffy@crtechnologies.com

Objective

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

Technical Progress

The project is complete.

SUBTASK 2.2.11. NDE TECHNOLOGY DEVELOPMENT FOR MICROTURBINES

W. A. Ellingson, C. Deemer, E. R. Koehl, R. Visher, and Z. Metzger
Argonne National Laboratory
9700 South Cass Avenue
Argonne, IL 60439
Phone: (630) 252-5058, E-Mail: Ellingson@anl.gov

Objective

The objective of this project is to develop low-cost, reliable nondestructive evaluation/characterization (NDE/C) technologies for low-cost monolithic ceramics for hot section components of microturbines or industrial gas turbines, environmental barrier coatings (EBCs) for monolithic ceramics and ceramic matrix composites, and evaluating other materials which are part of the overall technology development . The project is directly coupled to other projects focused on materials developments.

Highlights

For some time the issue with high speed 3D image reconstruction from the x-ray computed tomography systems was the slow reconstruction times. In cooperation with Argonne laboratory management, access was provided to the high speed 300 node computer cluster called JAZZ. Using this computer, our reconstruction times have been reduced by over an order of magnitude. Small turbine rotors, eg 12-15 cm tip to tail can be reconstructed in their entire volumes now in less than 120 minutes. This can be faster if the spatial resolution is reduced. The target is less than 15 minutes with higher resolution. A new cross-polarized confocal microscope may show promise for direct cross section images of the EBC coatings in a similar way that the optical coherence tomography (OCT) system can—but the new system may provide better depth spatial resolution.

Technical progress

Work continued on automating the edge detection for the images from the 3D x-ray computed tomographic imaging set up. Work also continued together with the Solar Turbine project for evaluation of the full scale ceramic composite combustor liners. To be noted is that our work scope was greatly reduced caused by the large reduction in budget which was reduced by 2/3.

Status of milestones

1. Complete analytical model for predicting depth of Delaminating from thermal image data for SiC/SiC with EBC June 15/2006 Completed

Industry Interactions

1. Discussions were held with staff of Saint-Gobain Industrial Ceramics and Plastics regarding acoustic emission studies for crack detection.

2. Discussions continued with staff of Solar Turbines and ATK/COI relative to NDE tests of oxide/oxide composites for the Solar turbines

SUBTASK 2.3.1. ADVANCED MATERIALS FOR RECIPROCATING ENGINE EXHAUST COMPONENTS

P.J. Maziasz, N.D. Evans, and J.P. Shingledecker
Oak Ridge National Laboratory, Oak Ridge Tennessee
Phone: (865) 574-5082; E-mail: maziaszpj@ornl.gov

Objective

The objective is for ORNL to work with commercial foil and sheet suppliers to test, evaluate and enable recuperator manufacturing with alloys that have more temperature capability and performance at reasonable cost. Near term objective is meeting reliability goals (40,000-80,000h) at about 700°C, while the long term objective is pushing performance to 750°C or higher, without sacrificing lifetime. Last year, ORNL completed Phases I and II of a collaborative project with Allegheny-Ludlum to produce and measure properties of a wide range of commercial sheets and foils of AL20-25+Nb stainless alloy. The Phase II creep resistance of sheets was improved by a factor or two, and excellent creep-resistance was also found in a range of foil products, but particularly the 3 mil product. Microstructural analysis of creep-tested specimens is being done to complete this work in FY2006. Relative alloy comparisons include foils of 347 steel, HR120 and alloy 625. ORNL work plans to assess recuperators manufactured from AL20-25+Nb sheets and foils, and to examine behavior of foils exposed in a microturbine environment.

Highlights

Creep-test of Phase II (processing for more creep resistance) AL20-25+Nb stainless alloy foils at 700-750°C consistently shows more rupture strength than HR120 or HR230, and comes closer to the creep-strength of alloy 625 than the Phase I material. This quarter, probes were analyze from the first tests of these Phase I foils in the ORNL Recuperator Test Facility. Creep testing was also completed on foils of alloy 625, showing that they have considerably less creep-resistance than sheet, due to the fine-grain-size effect.

Technical Progress

Recuperators made from 347 steel sheets and foils suffer severe moisture-induce oxidation attack and creep deformation at temperatures above 650°C. While similar sheets and foils of the Ni-based superalloy 625 have excellent oxidation and creep-resistance up to 750°C or more, they cost 3.5-4 times more than 347 stainless steel. Austenitic stainless sheets and foils made from austenitic stainless HR120 and AL20-25+Nb alloys are more cost effective alternatives to 347 stainless steels with higher performance for such recuperator applications.

ORNL completed Phases I and II of a collaborative program with Allegheny-Ludlum in FY2005 to produce a wide range of commercial sheets and foils of the AL20-25+Nb alloy for microturbine recuperator OEM manufacturing trials for prototype air-cells with higher performance. The Phase I effort produced full-scale commercial quantities of a wide range of sheets and foils of AL20-25+Nb with the standard processing. The Phase II effort produced limited quantities of selected sheets and foils with different processing to modify the microstructure for better creep-rupture resistance. ORNL preformed creep-tests at 700-750°C, and completed testing of Phase II material this quarter. Microstructural analysis of Phase I and II were completed this quarter. Study also includes the appropriate comparisons with similar creep-tested sheets and foils of 347 steel, HR120 and 625 alloys. The AL20-25+Nb alloy was provided to make probes for testing in the ORNL Recuperator Test Facility, and those tests are in-progress. The initial creep-tests of Phase II foils and sheets of AL-20-25+Nb alloy at 700-750°C, show significant improvement compared to Phase I, and good relative behavior compared to HR120 and 625 alloys. Creep-testing on foils of alloy 625 were completed this quarter, and microcharacterization will be completed next quarter.

Milestones

Complete creep testing and microcharacterization of Phase II AL20-25+Nb alloy with improved creep resistance, provide commercial sheets and foils (Phase II) to recuperator manufacturers; complete initial characterization of recuperator air cells made from AL20-25+Nb sheets and foils. (June, 2006) Milestone was completed on schedule.

Meetings

1. ORNL communicates periodically with Allegheny-Ludlum Technical Center (Chuck Stinner) on this project. ORNL has worked with Ingersoll Rand Energy Systems to obtain brazed plate-fin aircells manufactured with AL20-25+Nb. ORNL also interacted with Capstone Turbines on their primary surface aircell manufacturing efforts with foils of Phase II AL20-25+Nb alloy.

SUBTASK 2.3.2. CHARACTERIZATION AND DEVELOPMENT OF SPARK PLUG MATERIALS AND COMPONENTS

M. P. Brady, H. T. Lin, R. K. Richards, and M.D. Kass
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5153, E-mail: bradymp@ornl.gov

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

SEM examinations of the exposed surface and polished cross section of spark plugs made from ORNL model and developmental electrode alloys after 67h engine test at ORNL in a Caterpillar G3406 industrial natural gas engine were completed during this reporting period. SEM analysis showed that some of the ORNL developmental electrode alloys did not exhibit intergranular crack formation, which was in sharp contrast to those standard electrode alloys currently used in the spark plug industry showing intergranular cracks. The observation of free crack formation suggested excellent corrosion/erosion resistance of ORNL developmental electrode alloy.

Technical Progress

A 500h accelerated bench engine test for some of the ORNL developmental electrode alloys has been completed at Federal Mogul (FM). This is an ongoing collaborative research effort between ORNL and FM to develop more corrosion/erosion resistant electrode alloys to achieve increased engine durability and reliability as compared with current electrode alloys. Although it is a commercial automotive engine, the test data provide a useful feedback on the material degradation mechanisms and a further basis for alloy optimization. Detailed SEM analysis will be carried out and the results will be summarized in the next quarterly report.

Results of SEM examinations of ORNL model and developmental electrode alloys after a short term, 67h natural gas engine test on baseline model electrode alloys (without precious metal inserts) indicated that some Cr_2O_3 scale forming alloys do not suffer from intergranular cracks, which was in contrast to standard alloys currently employed. FM is currently completing manufacture of a second iteration of spark plugs utilizing optimized alloys and precious metal insert materials for natural gas engine testing at ORNL during the last quarter of FY06.

Status of Milestones

1. Evaluate developmental spark plugs in an industrial natural gas engine. - on schedule.
2. Develop a database for spark plug performance under differing temperature conditions using the newly developed test chamber at NTRC. - modified due to funding and programmatic changes.

Industry Interactions

Conference calls and email communications with Drs. Iryna Levina and Jim Lykowski at Federal Mogul to discuss the second iteration of spark plugs for manufacture by Federal Mogul and engine testing at ORNL as well as the second 500h bench engine test status and initial gap growth results.
Communications with Dr. Luigi Tozzi and other personnel at Woodward at the Advanced Engine System meeting about issues related to spark plugs and potential research collaboration on the spark plug alloy development.

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

John J. Truhan and Karren L. More
University of Tennessee, Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865)-574-1057, E-mail: truhanjjjr@ornl.gov

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

Because funding for this task ended approximately half way through the quarter, results are limited. However, Waukesha Engine, Dresser is continuing with internal funding the engine testing to determine the effect of lubricating oil filtration on in-cylinder deposit formation with UT and ORNL personal providing consulting support.

Technical Progress

A plan was originally developed with representatives from WED to test the effect of filtration on oil condition and the tendency to form in-cylinder deposits. Further refinements of the plan are necessary after consultation with lab and field serve representatives. Four levels of filtration will be evaluated:

a. Cloth sock full-flow filter as supplied by WED with a standard centrifuge bypass filter
b. Microglass full-flow filter with standard centrifuge bypass filter
c. Stainless steel, cleanable, wire mesh full-flow filter with standard centrifuge bypass filter
d. Fleetguard system consisting of Venturi™ two-stage full-flow filter and a ConeStac™ Centriguard™ bypass filter

Necessary parts for the engine tests have been procured from Fleetguard and other sources. The engines are expected to be modified for the different systems by September, 2006, after which testing will commence.

Status of Milestones

Report on the characterization of current valve materials and deposits as well as used oil.
June 2005 – completed.
The establishment of a new lubricant test to detect the concentration of precursor contaminants.
March 2006 – completed.
Compare friction and wear performance using a rig test of the carbon foam guides with conventional materials. *June 2006 – will not be completed due to termination of funds.*
The fabrication of a prototype carbon foam guide. *August 2006 – will not be completed due to termination of funds*.

Industry Interactions

Planning of the testing of the effect of various filtration levels on the oil condition and in-cylinder deposit formation occurred through numerous phone calls with Roger Rangarajan and Dale Schroeder of Waukesha Engine, Dresser.

The determination of an advanced filtration system for inclusion in the above test plan occurred through conversations with Henry Amirkhanian, Richard Wagner, and Ken Swalls of Fleetguard, Corp.

David Stehouwer of Stehouwer Technical Services and Robert Olnee of General Motors were contacted to determine interest in refining the sludge measurement procedures described in Two STLE papers listed in the last report.

Section 3. Thermally Activated Technologies

SUBTASK 3.2B. TAT LAB PERFORMANCE AND ANALYSIS

Abdi Zaltash
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-4571; Email: zaltasha@ornl.gov

Objective
ORNL will provide technical support and guidance for advanced ammonia-water absorption chillers.

Highlights
ORNL was awarded a work-for-others agreement with the Naval Facilities Engineering Service Center (NFESC). ORNL oversees installation, monitoring, and verification of field performance of advanced ammonia-water absorption chillers at three Federal facilities. Three field sites were selected for evaluation of these pre-commercial ammonia-water absorption chillers: Naval Surface Warfare Center (NSWC) Corona (Norco, California), Naval Amphibious Base (NAB) Little Creek (Norfolk, Virginia), and Oak Ridge National Laboratory (ORNL). Two of the three installations have been completed and under evaluations. Performance data from ORNL site is available using Automated Logic Control (ALC) and Web Control. Based on the remote monitoring of the unit, the control algorithm has already been modified to improve the performance of this unit. This modification will also be used in the units installed at the NAB site.

The installation at the NAB site is near completion. This installation will use two 5-ton ammonia-water absorption chillers linked together to provide 10-ton of cooling. A chiller link controller developed under this project will be evaluated in this field test. This site will also use ALC and Web Control for remote monitoring.

Technical Progress
Installation and evaluation of the advanced ammonia-water absorption unit at three federal facilities are continuing under WFO project for Navy. Data is being reported to the manufacturer.

Status of Milestone(s)
ORNL will provide technical support as requested by industry partner.

Industry Interactions
- Rocky Research.

SUBTASK 3.3. SEMCO, TRANE/FSEC, AND DESICCANT INDUSTRY PARTNERSHIPS

P. W. Garland
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (202) 479-0292; Email: garlandpw@ornl.gov

Objective

Subcontracted desiccant research at ORNL resulted in two commercially successful HVAC products, one with SEMCO and one with Trane, which are undergoing targeted field and verification studies. Market acceptance and widespread application of the energy saving and indoor environmental advantages of this technology are being fostered through demonstrations of advanced thermally activated technologies and activated desiccant systems as called for in the Strategic Goals listed in the DOE Thermally Activated Technologies Roadmap published in 2003.

The work under this subcontract is winding down under carryover funds. Two demonstration sites have been selected and will undergo data collection and analysis: Carnegie-Mellon University's Intelligent Workplace in Pittsburgh, PA, and a Lowes Store in Spartanburg, South Carolina.

Highlights

Work continues on two test and verification projects: 1) Carnegie-Mellon University, and 2) Lowes.

The Subcontract Phase 5 Final Report, "Field Test Performance Verification: Integrated Active Desiccant Rooftop with Heat Pump Capability," was issued as an ORNL TM: ORNL Sub-01-4000031065.

Technical Progress

Lowes – The system has been performing well and the remote monitoring has been installed. This effort was significant since many security concerns raised by Lowe have caused a more expensive approach to be applied. Data is being collected during this cooling season but data thus far has shown that the Revolution technology has the capability of significantly increasing the dehumidification capacity over that possible with the conventional units currently used. As a result, few tons of cooling is required to reach improved comfort for their customers. The system delivers very low dew point air. The Revolution provides 450% of the dehumidification provided by the RTU.

Carnegie-Mellon University - The pilot site at CMU has been performing exceptionally well. Previous to the installation of the system, numerous problems existing during the cooling season, specifically condensation on the radiant cooling panels and discomfort as a result of poor humidity control. The Revolution unit has been operated to deliver very dry, outdoor air throughout this cooling season.

Data has been archived and shows that the space humidity has been controlled as desired, despite a high percentage of outdoor air and the "all glass" structure. It has been reported that for the first time the radiant cooling technology can be utilized effectively without condensation. CMU staff has been closely monitoring the unit as well as the integral energy recovery module.

The unit operates to deliver 2000 cfm of outdoor air at a 40 grain (low dew point) level using only 5 tons of cooling where a conventional system would use more than 15 tons.

Margaret Morrison Building on Carnegie-Mellon Campus

SEMCO Revolution on roof of Margaret Morrison Building

Status of Milestone(s)

Draft reports on subcontractor field installations of SEMCO IADR unit at Carnegie-Mellon University and Lowes (September 2006)
It is on schedule.

Industry Interactions

SEMCO, Incorporated

SUBTASK 3.7B. THERMAL ENERGY PERFORMANCE EVALUATION

E. A. Vineyard, A. Petrov
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5819; Email: vineyardea@ornl.gov

Objective

For FY 2006, ORNL will continue to independently benchmark and measure the relevant performance characteristics of thermally activated equipment regenerated with primary and/or waste heat sources in the laboratory. ORNL data and published results from these newer, commercially available systems will assure the accuracy and availability of important performance results required by the U.S. HVAC and IES/CHP engineering communities.

Highlights

A decision has been made to locate the GOETTL environmental test chamber in the Advanced Heat Exchanger Test Laboratory. Melissa Madgett will assist in planning and working with ORNL's Engineering Division to assemble the chamber and hook up utilities. Patrick Collins, a consultant with experience in assembling environmental chambers, will commission the chamber after it is assembled.

Technical Progress

The glass microspheres to be used in making a superhydrophobic surface for a heat exchanger have arrived and have been etched. Work is underway to find a suitable adhesive for applying them to a heat exchanger surface. John Simpson has located a spray booth suitable for the application of the material. We have contacted Advanced Heat Transfer to send a small heat exchanger to use in the testing of the material. The wind tunnel that will be used in the testing has been disassembled and will be installed in the Advanced Heat Transfer Laboratory.

Status of Milestone(s)

The draft report for the IADR unit is in draft form and will be completed on schedule to satisfy the August 2006 milestone established for this activity.

Industry Interactions

Alcoa

Subtask 3.7C. Micro-Channel Heat Exchanger Development

E. A. Vineyard
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0576; Email: vineyardea@ornl.gov

Objective

Development work on micro-channel heat exchangers for TAT equipment will continue in FY 2006. Additional partners, such as Modine and Advanced Heat Transfer, LLC, have been recruited to assist in development activities.

Highlights

ORNL has discussed the potential for using micro-channel or miniature heat exchangers for military cooling applications. There are presently problems with some types of equipment operating in extreme temperatures that are causing accelerated failures. The Office of Naval Research is interested in collaborative efforts for absorption equipment and micro-channel heat exchangers.

Technical Progress

At the last meeting with Southwest Gas, the decision was made to use one circuit instead of two for the heat exchanger design. This will simplify the overall design of the unit and make it easier to service and improve reliability. We are working with Advanced Heat Transfer on a new design.

Status of Milestone(s)

Test prototype micro-channel heat exchanger and evaluate results. September 2006

The milestone for testing a prototype micro-channel heat exchanger has been delayed due to the disassembly of the test loop which is being moved to 5800. The decision was made to delay the milestone since the loop is being moved with Laboratory Maintenance funds which result in program savings of over $150,000.

Industry Interactions

- Advanced Heat Transfer, LLC
- Southwest Gas
- Office of Naval Research

Subtask 3.7E. Woven Graphite Fiber Heat Exchanger

E. A. Vineyard and R. L. Linkous
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0576, E-mail: vineyardea@ornl.gov

Objective

Development work on woven graphite fiber heat exchangers for TAT equipment was initiated under a DOE Lab Call in FY 2005. Work in FY 2006 will involve testing a heat exchanger to validate heat exchanger models which predict a significant performance improvement for woven graphite fiber heat exchangers.

Highlights

ORNL has initiated tests in one of the new wind tunnels obtained last year. The heat exchanger is shown in Figure 1 installed in the wind tunnel. A test matrix consisting of approximately 90 test points was developed to enable a parametric analysis of the heat exchanger over a wide range of operating conditions.

Technical Progress

Greg Walker, a professor from Vanderbilt University has been developing a model of the woven graphite heat exchanger to analyze the theoretical performance. The model is an equivalent resistance model that incorporates lateral conduction to describe the heat transfer between tubes in the fiber. Results suggest that high conductivity fibers can significantly improve the heat transfer. However, for extremely large conductivities, performance will degrade due to parasitic heat losses. Furthermore, contact resistance between the fiber and tube govern the performance more than the fiber conductivity.

Status of Milestone(s)

The milestone for testing a prototype woven graphite fiber heat exchanger and evaluating the results is on schedule to be completed in July 2006.

Industry Interactions

- 3-TEX
- Office of Naval Research
- Foam Application Technologies

Fig. 1. Woven Graphite Fiber Heat Exchanger installed in wind tunnel.

SUBTASK 3.7G. CFD MODELING ANALYSIS

E. A. Vineyard and P. J. Geoghegan
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0576; Email: vineyardea@ornl.gov

Objective

To employ CFD to provide an insight into the fluid mechanics and heat transfer mechanisms within complex heat exchange systems, with particular emphasis on the GEDAC unit.

Highlights

Good collaboration with the engineers at Southwest Gas has resulted in a prototype GEDAC unit that has been heavily influenced by the CFD findings.

A presentation from the CHP group was made to the project sponsors. The presentation included images from the CFD modeling and resulted in very positive feedback. The trip also highlighted the need for a commercial gas-engine-driven air-conditioning unit in the utility area.

Technical Progress

CFD modeling of the GEDAC unit focused on both the outdoor and indoor sections. Preliminary studies on the outdoor section highlighted the critical importance of heat exchanger selection and positioning in terms of balancing pressure losses. A low pressure loss coefficient in one heat exchanger results in a high flow bias that has adverse effects on the performance of the other heat exchangers making up the system.

CFD modeling also made it possible to investigate the performance of the outdoor section driven by two 24" axial fans as compared to a single 36" axial fan arrangement. It was found that the single fan approach yielded heat exchanger capacities that were approximately 5% lower than the two-fan approach. Temperature contours are shown below in figures 1a and 1b. The single fan did have the positive effect of pulling air through the centre of the unit and would provide significant cost savings. For these reasons the GEDAC prototype was constructed to allow easy fan arrangement substitution.

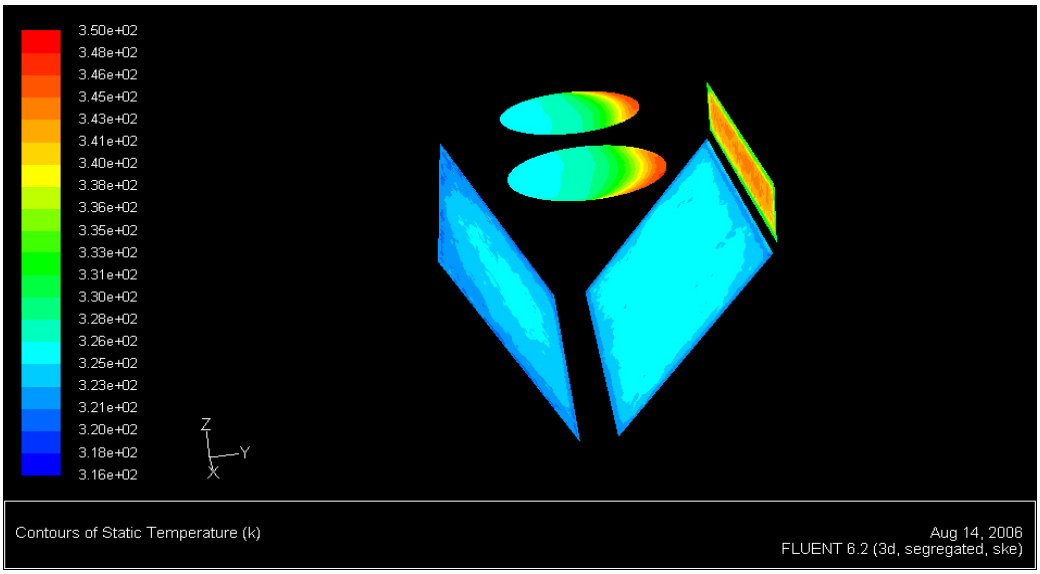


Fig. 1a. Outdoor section heat exchanger temperature contours resulting from twin 24" axial fans.

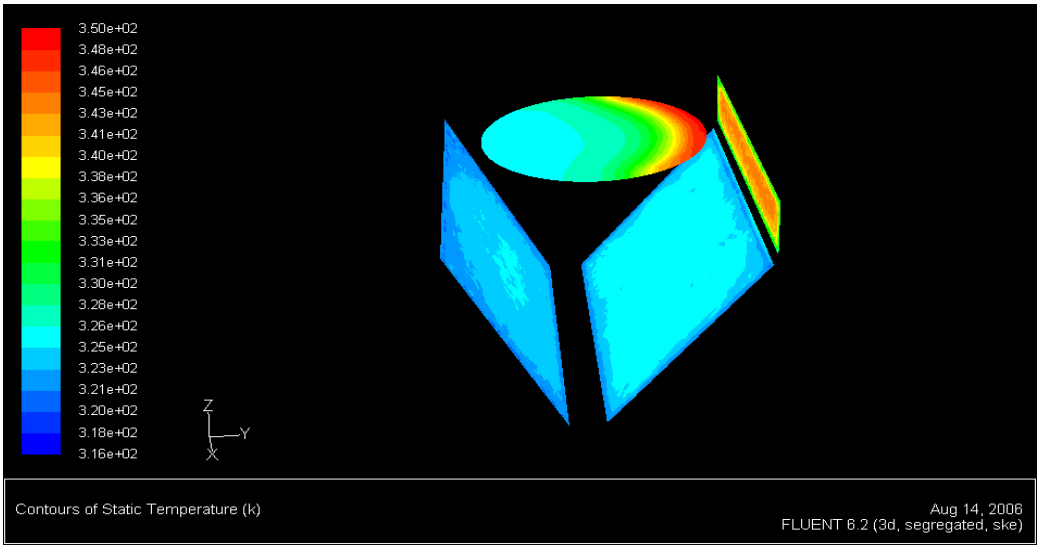


Fig. 1b. Outdoor section heat exchanger temperature contours resulting from a single 36" axial fan.

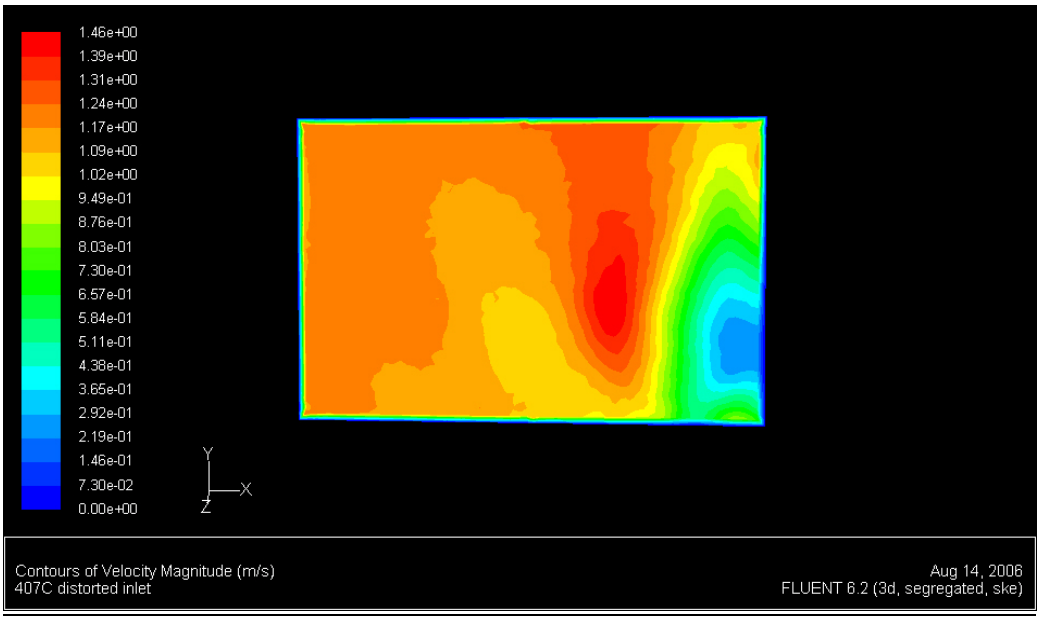


Fig. 2. Flow through the indoor evaporator when air is introduced from one side.

The indoor section of the GEDAC unit was also modeled using CFD. The position of the centrifugal fan relative to the evaporator was varied to achieve maximum exchanger performance. Again, the angular position of the exchanger was found to be critically important. Figure 2 shows the effect of the duct inlet position on the flow through the condenser. The inlet runs below the evaporator from the right-hand-side and creates a dead-space on that side. Such a set-up can significantly reduce the overall unit performance.

Status of Milestone(s)

CFD laboratory is completed and initial analysis results have been obtained for GEDAC unit. April 2006 milestone was completed as scheduled.

Section 4. End Use Systems Integration and Interface

Subtask 4.1.1a. Packaged/Modular IES Development

R. C. DeVault, J. B. Berry, T. K. Stovall, T. J. Theiss
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-2020; Email: devaultrc@ornl.gov

The industry teams selected for developing packaged/modular IES are:

- Burns and McDonnell in Kansas City, Missouri, partnered with Solar Turbines Inc. and Broad USA, to design and construct IES systems at the Domain Site [2004] and at Dell Children's Hospital [2005] in Austin, Texas. (PIC #504) [Jan Berry & Patti Garland]

- 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. This project was combined with the UTRC project upon the development of a partnership between UTRC and Capstone in FY2003. NO FY06 FUNDING. (PIC #505) [Bob DeVault]

- Gas Technology Institute (GTI) in Des Plaines (Chicago), Illinois, partnered with Waukesha and Trane, to combine Waukesha engine generators with Trane absorption chillers. Test and verification of the Phase I packaged system will occur in 2006. This project will be completed in 2006 with 2005 carryover funding. (PIC #506) [Tim Theiss]

- Honeywell Laboratories in Minneapolis, Minnesota, developed, constructed and is field-testing a large (5.2 MW) IES packaged system at Fort Bragg, North Carolina. Testing and verification of the packaged system will continue into 2006. This project will be completed in 2006 with 2005 carryover funding. (PIC #507) [Jan Berry & Patti Garland]

- Ingersoll-Rand in Portsmouth, New Hampshire, planned to combine a new 70 kW microturbine with an ammonia-water absorption refrigeration system. Ingersoll-Rand stopped work in FY05 without completing Phase I for internal business reasons. No 2006 funding. (PIC #508) [Therese Stovall]

    - NiSource Energy Technologies in Merrillville, Indiana, worked with a Hilton Hotel developer to demonstrate a modular packaged IES system. The system, three microturbines, heat recovery heat exchangers, an absorption chiller, a desiccant unit, and an integrated control system is targeted at hotel/motel chains with the goal of becoming the standardized model for hotels/motels. The data collection was completed in 2003. ORNL is awaiting completion of the final report. This project will be completed in 2006 with 2004 carryover funding. (PIC #509) [Bob DeVault]

    - UTRC in East Hartford, Connecticut for an accelerated IES system based on off-the-shelf components to make a packaged system within the project's first year; an additional optimized IES system also will be developed. In FY 2005, test and verification of the UTRC PureComfort 240 was started at an A&P Supermarket. Data collection and analysis will continue in 2006. Additionally, in FY 2006, UTRC will focus on CHP technologies for improved value PureComfort systems. Such improvements are expected to come from greater capacity, more efficient C200-based microturbine/chiller systems, reciprocating engine/hybrid chiller systems, or trigeneration chillers that simultaneously provide chilling and heating with any prime mover. The technology efforts will identify and evaluate high-value pathways, reduce their technology risks, and integrate/assess the technology readiness of systems. (PIC #510) [Bob DeVault]

Highlights

- **UTRC**

- **Burns and McDonnell**
- The 3rd Quarter Joule Milestone status report was provided to DOE as complete: Install packaged CHP system on site. [Dell Children's Hospital]
- Burns & McDonnell is working with Austin Energy to plan a ribbon-cutting at Dell Childrens Hospital during September or October of this year. DOE DE personnel have been notified of the potential ribbon-cutting.
- ORNL technical staff held a teleconference with Burns and McDonnell to discuss the final version of the data acquisition report on the Domain Site in Austin Texas, "Data Mining Algorithms for Modeling Efficiency of a CHP System." The report will be revised and resubmitted to ORNL.
- A Domain Turbine System Efficiency Optimization Tool in Excel Spreadsheet format and a User's Manual have been provided to ORNL.
- The IES System at the Domain Site is operational. Austin Energy plans on operating the system for approximately 9 hours per day between May and October.
- Burns & McDonnell participated in the Gulf Coast CHP RAC's seminar held April 20th; approximately 40 persons toured the Domain and Dell Sites in conjunction with the seminar.
- Burns & McDonnell presented at Energy 2006, held in Atlanta in May, at the request of DOE.
- The following documents have been completed on the Dell Site: Equipment Anchoring Design Package, Mechanical Piping and HVAC Design Package, and Draft Testing Plan.

- **Honeywell**
- The draft final subcontract report was submitted to ORNL. Abdi Zaltash, Andrei Petrov and Patti Garland reviewed the report and provided technical comments. We are awaiting delivery of the revised final report. Honeywell states the report will be issued prior to the end of July 2006, one month behind schedule. ORNL is preparing a no-cost extension to allow time for delivery of the final report.

Technical Progress

- **UTRC**
- **Burns & McDonnell**

DELL Children's Hospital Site:

The following project design milestones are complete:

a. Equipment Layout Development – **Complete**
b. Major Mechanical Procurement Specifications – **Complete**
c. Electrical and Miscellaneous Equipment Specifications – **Complete**
d. Final Mechanical Shop Drawings – **Complete**
e. Equipment Anchoring Design Package – **Complete**
f. Mechanical Piping and HVAC Design Package – **Complete**
g. Final Electrical Shop Drawings – **Complete**
h. Final Controls Design Package – **In progress**
i. As-built Design Package – **In progress**

Construction of the system is complete as follows. Acceptance testing will start this summer.

j. Cooling tower fabrication is complete and it has been leak tested.
k. Chill water system has been tested.
l. The electric chiller / electric controls module has been installed.
m. Piping has been installed between the electric chiller skid and the cooling tower.
n. TES tank installation is complete.
o. Transformers are set in place and have been tested.
p. Switchgear is set in place and is being tested.

q. Absorption chiller is set in place with piping interconnections made on the cooling water and chill water side.
r. Packaged boiler is set in place.
s. Natural gas compressor is set in place. Natural gas piping has been installed and passivity. Natural gas is available at the site.
t. HRSG has been set in place and all piping and equipment is installed on the boiler.
u. Diverter valve assembly installation is complete.
v. The two exhaust stacks are installed.
w. Emergency generator is set in place and wiring has commenced.
x. The combustion turbine installation is complete.

The following is the status of acceptance testing:

1. Inspection and hydro of chilled water and steam piping is complete.
2. Acceptance testing on electric chiller skid and cooling towers is complete.
3. Acceptance testing on the turbine is continuing. They synched the turbine with the grid in June as part of this testing.
4. Acceptance testing on the HRSG started June 26th.
5. Acceptance testing on the absorption chiller will commence the week of July 10th.

- **Honeywell**

The draft final report was reviewed by ORNL staff. The report contains the following sections:

- Introduction
- Technology Development
  - IES Reference Designs
  - Exhaust-Driven Absorption Cooling Technology
  - IES Controls Optimization
- IES Technology Field Demonstration
  - System Description
  - Site Description
  - Overview of Results
- Performance Monitoring
  - Field Monitoring Overview
  - Summary Performance Results
- Conclusions
  - Development of Reference Designs
  - Development of Exhaust-Driven Absorption Cooling Technology
  - Development of On-line Control Optimization Technology
  - IES Plant Operations
  - IES System Measured Performance

SUBTASK 4.1.2. DG THERMAL RECOVERY AND INTEGRATION RESEARCH/COLLABORATION WITH UNIVERSITY OF MARYLAND

P. W. Garland
Oak Ridge National Laboratory, ONRL/DC Office, Washington, DC
Phone: (202) 479-0292; Email: garlandpw@ornl.gov

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. This facility has consistently scored among the top rated projects within the DE peer review process. Work scheduled for FY06 consists of:

- Testing of the newly designed low-flow conditioner components for liquid desiccant dehumidifier [work to be done in partnership with NREL]
- System optimization and beta-testing of the neural network "smart" controllers [work to done in partnership with Darryl Massie and NETL]
- Commissioning of the newly installed Broad absorption chiller with internal cooling tower
- Continuation of data mining started in FY05
- Analysis of potential for new prime mover to replace Capstone 60 micro-turbine
- Development of course material on absorption chiller systems operation and integration into CHP Systems for Buildings

Highlights

- Program efforts in June were focused on commissioning the Kathabar liquid desiccant system, trouble shooting the DTE engine and Capstone microturbine and completing repairs of sensors for CHP System 1. Initial test results have been obtained.
- ORNL is working with the University of Maryland on a close-out plan for this project.
- Dennis Moran, the principle investigator at the University of Maryland, has left the university. His replacement, Dr. Joe Orlando started on July 1st. A meeting has been scheduled between ORNL and Dr. Orlando and DOE.

Technical Progress

System 1 - The overheating problem of the DTE engine was solved by replacing the defective radiator cap. It also solved the overflow problem, which happened when the flow to the liquid desiccant system was closed off and glycol solution went to the dump radiator directly. The spark plugs and air filter were replaced for the engine. This effort could not solve engine periodic shutdown problem completely.

The Kathabar system commissioning was completed in early June. A desiccant foaming problem happened both for AIL conditioner and Kathabar conditioner. When it occurred, there will be desiccant overflow and carry over from the AIL conditioner. Also the PH value for desiccant is much lower than natural. The desiccant filter with active carbon filters was changed twice to purify the desiccant solution. An active carbon filter bag was also installed inside the Kathabar conditioner. Anti foaming solution was added to the desiccant solution. The foaming phenomena is less, but still cannot be ignored. There are also some black 'hairlines" produced inside AIL conditioner when flushing it with high desiccant flow. [AS the LiCl solution emerges from the air processor, it contains some kind of black "paint" that looks like streamlines that are marked or visualized in black ink. Very unusual, and the source is unknown. A sample of desiccant and black hairlines were taken for testing by AIL Research. The suspicion is that due to the acidity of the LiCl solution, which should be basic, perhaps a component is dissolving or losing its coloring. Replacement of desiccant solution and flushing the system is scheduled for July.

System 2 - An overheating problem of the microturbine occurred in May. The microturbine could not run because of this. A replacement fan inverter board and LCM fan were ordered from Capstone and installed. The problem was partly resolved. Now the microturbine can operate. However, the temperature for ECM board is still higher than LCM board on hot days. Capstone specifies the temperature difference between these two boards to be less than 10^{o}F. Capstone engineers are helping to determine the cause of the problem. Capstone updated the control software, and U of M purchased new control boards and new fans to control the boards.

There has been much difficulty in commissioning the Broad chiller this summer. There is "A/C WATER OFF" fault all the time. The chilled water pump runs for only 10 seconds before the fault happens. It is because the sensor for chilled water flow rate could not sense flow, so that the system will turn off the pump. We drained air out of the chilled water loop several times. Ultrasonic flow meter measurement results show there is flow inside chilled water pipes when the pump is starting for the first 10 seconds. We contacted Broad engineers repeatedly, but they had schedule conflicts that required deferring completion of commissioning.

Status of Milestone(s)

Complete draft report on lessons learned and initial data collection of new low-flow conditioner for Kathabar Liquid Desiccant Dehumidification Unit. August 2006.

Subtask 4.1.2c. DE Integration Lab Test and Evaluation

Abdi Zaltash
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-4571; Email: zaltasha@ornl.gov

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. [The equipment at the University of Maryland is incorporated into an occupied building, which limits the test conditions that can be exercised.] 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

Evaluation of the "next generation" 10-ton packaged heat pump unit (GEDAC #13 unit) with R407C was completed at various speeds, indoor and outdoor conditions in cooling and heating modes. Fifty five cooling and heating tests were conducted. The first halves of the tests were conducted using 1.5hp blower motor and the rest with 2hp motor for the indoor section of the unit. Two air to fuel ratios (stoichiometry <1% oxygen and lean with ~6% oxygen in the flue) were also investigated. Cooling and heating tests were conducted at ARI Standard 210/240 rating conditions. These include cooling tests up to 125ºF and heating tests down to 17ºF. Heating run is conducted at high engine speed of ~2550 rpm. Cooling runs include both high (~2550 rpm) and intermediate (~1900rpm) engine speeds.

Change of air to fuel ratio from stoichiometry to lean improved the Coefficient of Performance (COP) by ~15% and lowered CO concentration by ~65% at 95ºF outdoor condition. This showed the importance of having an active fuel management for optimum performance with reduced emissions.

Results showed ~38,000 Btu/h in total heat recovery from engine coolant and exhaust. Diverting coolant to the indoor coil significantly improved performance in heating mode. Results showed the inadequacy of the defrost scheme used in GEDAC #13 and need of modification in future designs for optimum utilization of recovered heat. A draft report has been prepared by the manufacturer and is currently under review.

After completion of these evaluations, the GEDAC unit was disconnected and shipped to the manufacturer in preparation for the next 10-ton packaged heat pump unit (GEDAC #16) with optimized control scheme and re-designed indoor and outdoor coils.

In addition, the hot water-fired Rotartica lithium bromide/water air-cooled absorption unit (1.3-ton or 4.5 kW chiller) with rotating heat exchanger is currently being evaluated at various ambient temperatures, hot water flow rates and temperatures, chilled water flow rates, and air flow rates of the air handling unit (Figures 1-2). Evaluations were initially conducted at nominal flow rates of chilled and hot water (2,375 lb/h or 18 kg/min and 4,250 lb/h or 32 kg/min respectively); the hot water temperature was kept constant at 194°F (90°C). The chilled water temperature was varied by changing the air flow rate through AHU and the cooling water temperature was controlled by changing the air temperature inside the environmental chamber where the Rotartica unit is located. Automated Logic Control and Web Control have been used successfully for sharing performance evaluations with the manufacturer. The plans are to

document performance improvement for rotating heat (and heat/mass) exchangers based on the Rotartica unit and then assess the technical potential for using rotating heat exchangers in other applications.

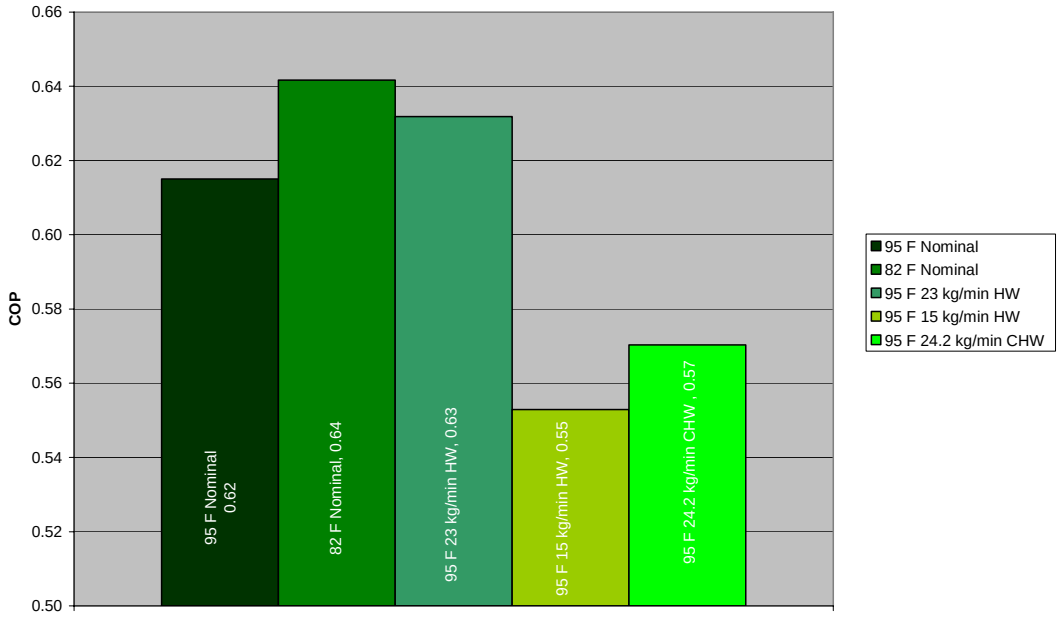


Fig. 1. COP of Rotartica unit at various ambient temperatures, hot water and chilled water flow rates and air handler air flow rate of ~2200 scfm

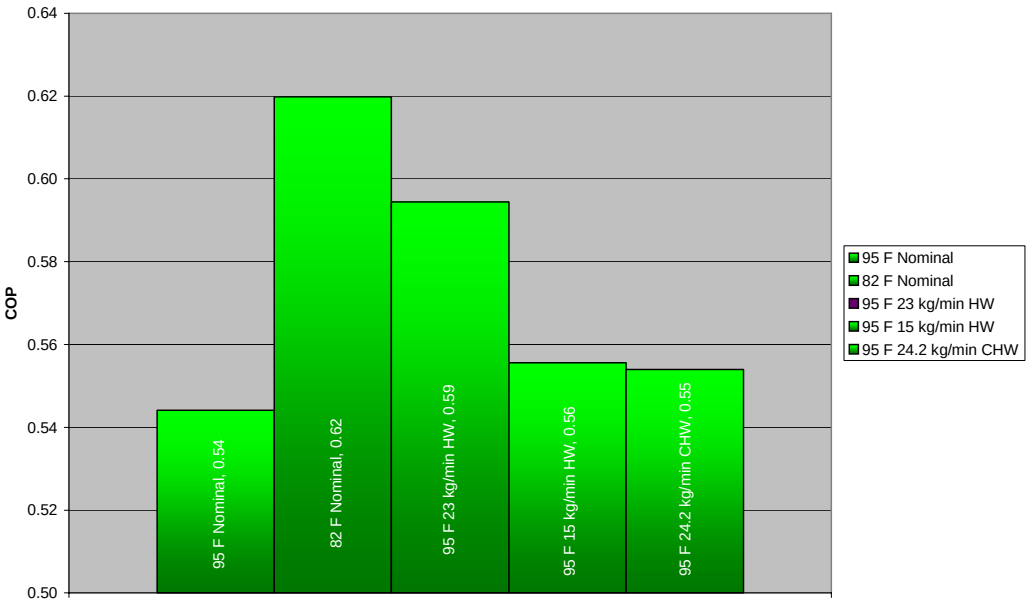


Fig. 2. COP of Rotartica unit at various ambient temperatures, hot water and chilled water flow rates and air handler air flow rate of ~650 scfm

Technical Progress

Evaluation tests of the 10-ton packaged heat pump unit at various ambient conditions including ARI Standard 210/240-94 rating conditions were completed. These tests included the performance and emissions of this unit at these conditions. A draft report has been prepared by the manufacturer and is currently under review.

Status of Milestone(s)

Results showed the importance of having an active fuel management for optimum performance with reduced emissions. In addition, the inadequacy of the defrost scheme used in GEDAC #13 was observed. Modifications have been made in future designs for optimum utilization of recovered heat.

Industry Interactions

- Partners include: Southwest Gas, Team Consulting, and Rotartica.

Subtask 4.1.2e. Integrated Energy Systems Technology Update

R. S. Sweetser
Exergy Partners Corporation, Herndon, Virginia
Phone: (703) 707-0293, E-mail: rsweetser@exergypartners.com

Objective

First generation IES modular and packaged systems are currently being field tested and verified. Important systems and application integration lessons learned are captured by the various project teams.

Onsite power and thermally activated technology equipment are constantly evolving as discreet equipment to serve the marketplace. These improvements need to be captured to provide next generation designs and models with state-of-the-art information.

Compiling targeted discreet equipment improvements, assessing strategic lessons learned for a wide variety of field sites and studying and assimilating current trends is critical to going forward efforts for next generation IES projects.

Strategic focus on key meetings like PowerGen, ASHRAE, Electric Power and groups like the USCHPA, IDEA and ASERTTI will provide a fertile source of data, lessons learned and consensus of strategic technical direction.

ORNL will collaborate with industry and update IES component improvement, lessons learned and key integration issues. A series of assessment reports on the findings will be prepared.

Highlights

The final report on the IEA Heat Pump Conference was revised to include information regarding the CHP session and lessons learned.

Technical Progress

No Report.

Status of Milestone(s)

Subtask 4.1.2e – IES Technology Update
Complete review of new equipment and provide a letter report to Steve Fischer for inclusion in BCHP equipment database. January 2006
No Report.

SUBTASK 4.1.3. CHP ECONOMICS/MODELING

S. K. Fischer
Oak Ride National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-2017; Email: fischersk@ornl.gov

Objective

Performance data from the field tests of the Honeywell Integrated Energy Systems at Fort Bragg, North Carolina and Burns and McDonnell at Austin, Texas is a tremendous resource that can be used both to ascertain that the systems are performing as designed and to evaluate their economic potential under different energy costs and equipment loads. Initial analysis will focus on whether the systems are achieving the design efficiencies and to characterize their operation over broad ranges of conditions (akin to a compressor map for conventional heat pumps and air conditioners). Further analyses will be performed to simulate the annual cost savings possible using the equipment characterizations with simulated power and thermal loads and utility rate tariffs at different locations in the U.S. The results of these evaluations will be summarized in high visibility case studies of the IES systems (as opposed to the field tests of systems at specific sites) to assist in determining the economic viability of CHP throughout the country.

IES operators (and engineers) frequently lack information or even guidelines necessary to operate combined cooling, heating, and power systems most economically. "Gut instinct" and operational biases compete with and frequently dominate poorly understood analytical information when making decisions about when and how to operate a CHP system to maximize economic return. The BCHP Screening Tool will be used with different equipment control schemes, energy costs, and priorities for use of recovered heat to develop the qualitative information and knowledge needed by system operators. The results of these studies will be published in technical journals and presented at national and regional conferences.

The BCHP Screening Tool was developed to estimate the annual performance of combined cooling, heating, and power systems in commercial buildings. It employs a "data template" that incorporates default parameters for 14 types of proto-typical commercial buildings identified for DOE by LBL. Application of the BCHP Screening Tool can be expanded to residential buildings with minor modifications to the program and adding default values to the template for building occupancy levels and schedules, hot water usage, lighting and plug loads and schedules, etc. Residential utility rates will be added to the utility rates database for up to 16 major metropolitan areas in the U.S. and performance data for micro-CHP systems and residential air conditioners will be added to the equipment databases. This activity is jointly funded by HUD and DOE.

Presently there is no known tool for simulating the thermal and electrical loads and CHP performance in multi-use facilities (there is some disagreement about whether or not CHP Heatmap is capable of doing this or if it simulates the operation of a district energy system to meet user prescribed loads). Such facilities include enclosed retail shopping malls and entertainment complexes, business or medical complexes, high school and university campuses, and military bases. Limited effort is needed to determine if there are computer models for economic screenings of CHP in multi-use facilities, and if so to outline a general approach and data requirements to adapt an existing computer model (BCHP Screening Tool or another program) to fulfill this need.

Highlights

Steve Fischer assisted Bob Groberg in presenting the HUD update at the RAC face-to-face meeting in May:

- The CHP Guidebooks and the ORNL-developed software are up on the website. The Challenge now is to get data on buildings and see how the software works. HUD is making a special effort to find buildings in large cities, emphasizing regions where the economics work, such as the Northeast. HUD's target is to do 6 buildings in the

next 6 months. The RACs may be contacted for support in identifying buildings, helping put together the data and analyzing the results.

- HUD is updating their CHP software with ORNL's Steve Fischer. The software now can be downloaded focusing on potable hot water, with cooling modules to be provided in the near future. Entering simple information from past electric bills is used to determine loads.

Technical Progress

See Highlights above.

SUBTASK 4.1.8. INDUSTRY COLLABORATION, CROSSCUTTING ACTIVITIES, AND GROUP MANAGEMENT

B. DeVault
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-2020; Email: devaultrc@ornl.gov

Objective

ORNL will monitor the progress of the various CHP projects and provide technical direction to the subcontractors. As the tasks progress, lessons learned and technical results will be compiled and disseminated to the stakeholder community. In addition, ORNL will facilitate dialogue with industry stakeholders to encourage the consideration and use of DE in high-tech applications. Barriers to application of DE/CHP will be identified with the intent of reducing or removing them. ORNL will continue working with existing CHP design and evaluation software tools and will work with stakeholders to ensure their awareness of the tools and to assist in their use in studying potential DER/CHP applications. ORNL will continue to assist DOE with participation at crosscutting conferences and events such as PowerGen, ASHRAE, ASHE, etc. This work activity supports the technical guidance and analysis provided by the CHP Group Leader.

Technical Progress

(See individual project reports.)

Status of Milestone(s)

(See individual project reports.)

SUBTASK 4.1.11. RESEARCH SURVEY, HISTORY OF DOE PROGRAMS

S. K. Fischer, P. F. Fairchild, subcontractor
Oak Ride National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-2017; Email: fischersk@ornl.gov

Objective

This task continued from FY05. Over the last few decades, DOE has provided considerable funding in support of development of technologies for improving energy efficiency. There have been several technical analyses completed on potential for energy savings in a variety of technology applications. Although documentation on previous work activities has been completed, it is often difficult to find the relevant work because of passing time or lack of a centralized reference list. This task will survey previous work activities completed under DOE or industry funding and provide a reference bibliography that could be integrated into the DOE DE website. The reviewer will also provide a technical review of where the historical information could be of benefit to the current work or in development of future work plans for the DE program. An example of previous work to be reviewed is: 1978-79 Study by Arthur D. Little on best places to save energy in building related equipment [ex. Heat pumps, water heaters, refrigerator motors, heaters, dryers, heat pump water heaters, ground source heat pumps, etc.]. This review could provide key technical information in where recycled heat could be used in building related equipment.

Highlights

Web pages have been created for close to 300 individual publications. These can be viewed at http://www.ornl.gov/~fis/. Additional publications available only in hard copy are being scanned and added to the on-line reports database as time allows. Phil Fairchild has been working to anticipate and sidestep any copyright issues that may arise in making PDF files available for papers published in technical journals and conference proceedings. He also identified approximately 60 papers and reports published between 1993 and 2000 that need to be included in the database. Although this is a DOE DE-funded project, this work has been of interest to DOE BTP personnel.

Technical Progress

See “Highlights” above.

SUBTASK 4.1.12. GROUND-COUPLED/GEOTHERMAL ABSORPTION SYSTEMS CALCULATION

V. C. Mei
Oak Ride National Laboratory, Oak Ridge, Tennessee
Phone: (865) 576-4945; Email: meivc@ornl.gov

Objective

This activity is to evaluate the engineering and economic potential for ground-coupled absorption systems as an alternative to using cooling towers. Using existing ground-coupling engineering models (developed previously in DOE's electric ground-coupled heat pump program), ground-coupling potential will be evaluated for replacing cooling towers for absorption chiller applications (both stand-alone absorption chillers and absorption chillers incorporated in Integrated Energy Systems (cooling, heating and power).

Highlights

The project has been completed. A letter report, "Cost Comparison of Ground Coupled and Cooling Tower Absorption Systems," was sent to the DOE sponsor in January, 2006.

Technical Progress

Project completed.

SUBTASK 4.1.13. ORNL DISTRICT SYSTEM EVALUATION

J. B. Berry
Oak Ride National Laboratory, Oak Ridge, Tennessee
Phone: (865) 241-1939; Email: berryjb@ornl.gov

Objective

ORNL is upgrading the site infrastructure and adding capacity for the on-site chilled water system. ORNL management is interested in evaluating whether an advanced CHP packaged system could be installed to upgrade the chilled water system while also improving on-site energy security and will provide staff to provide information for this assessment. Three projects are planned as follows:

1. Multiple Research Facility: to be constructed by September 2005 including gas-fired boilers and electric centrifugal chillers.
2. Central Utility Plant, Bldg. 5800: additional chiller(s) required immediately to cool new advanced computer center.
3. 4509 Central Chilled Water Plant: System could be expanded to include and connected to new facilities.

These extensive system modifications offer an opportunity to install advanced, energy efficient technology in an ORNL District CHP System.

ORNL staff will evaluate whether Integrated Energy Systems (IES) fit ORNL's need for chilled water including economic return on investment, offsetting planned procurement of capital equipment, value of benefits such as additional on-site power generation and increased chilled water capacity, and research and development projects that could be conducted using an on-site IES. This evaluation will be performed in collaboration with the Federal Energy Management Program (FEMP).

Highlights

None

Technical Progress

No report.

Status of Milestone(s)

Waiting for final negotiation of electric contract between DOE and TVA.

Section 4.2. Distributed Energy Systems Applications Integration

SUBTASK 4.2.1 – DG IMPROVEMENTS IN INDUSTRIAL APPLICATIONS

P. W. Garland
Oak Ridge National Laboratory, ONRL/DC Office, Washington, DC
Phone: (202) 479-0292; Email: garlandpw@ornl.gov

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). A secretarial level milestone of posting on the DOE DE website a case study of the Faith Plating project was met in FY05. At the 3rd project at Higgins Brick in Chiao Hills, California, Bowman 80 kW microturbine generators are providing electricity to process for peak shaving and redundancy. The microturbines exhaust streams are ducted through two heat exchangers into combustion air for the brick drying process. A 4th and final project was added in FY05. It is Arrow Linen in Brooklyn, NY. The project is being done in coordination with Keyspan and NYSERDA, who is paying for equipment. The ASERTTI long term test protocol will be beta-tested on this facility. Hardware of interest is two Coast Intelligen 150 kW MAN engines. There are two plate heat exchangers that provide: (1) process water for washing, and 2) make up thermal for a boiler that provides steam for processing linens. The CHP system will provide 300 kW of electricity and 2 MBTUs of thermal. This project is a great example of overcoming space and neighbor obstacles to design a unique solution that provides electric and thermal energy savings in an industrial application.

This project will be completed in FY06.

Highlights

- Higgins Brick – Startup of the kilns after the winter season was delayed due to increasing operational costs associated with higher gas prices.
- Arrow Linen – Data collection continues since October 2005.
- Due to difficulties in operation of Higgins Brick and resource restrictions associated with both sites, a no-cost extension through March 2007.

Technical Progress

The following are outstanding milestones under the contract:

Complete monthly reporting for both projects	End of September, 2006
Deliver Arrow Linen Summary Protocol Report	End of October, 2006
Arrow Linen Draft Case History	End of November, 2006
Arrow Linen Final Case History	End of January, 2007
Higgins Draft Case History	End of January, 2007
Higgins Final Case History	End of March, 2007

Higgins Brick: Operation of the microturbine CHP system was resumed on May 4 after the winter break. Prior to this date, a strategy meeting was held between Higgins, the owner of the brick plant, and Simmax Energy, the energy service provider, that set the terms of the energy service contract for the year. In addition, given the current power requirements at the plant it was decided to operate two turbines, keeping one turbine on standby as a back-up unit.

Operation for the month has been intermittent. The turbines are tripping on occasion on over-speed. This is an event that would normally call for a routine restart of the machines; however, in this case the residual heat in the turbine enclosure is damaging the start-up igniters. Other components may also be

affected by the high cabinet temperatures. Simmax Energy is working with Bowman to design and implement a solution.

Arrow Linen: Data acquisition was initiated at the Arrow Linen site in Brooklyn on October 1, 2005. During the month of June 2006, the two Coast Intelligen engine-generator sets using MAN engines continued to provide remarkably reliable power service and process heat to the laundry facility for the two-shift, six days per week operation.

The figure below provides a snapshot of the daily and weekly typical power production of the CHP system. The engines are automatically started up each day and run six days a week providing most of the power consumed in the plant. Table 1 provides the CHP plant statistics for the month. For June the CHP efficiency averaged 66.4 %, a slight increase over the 66.2 % average reported for May. Preliminary data analysis continues to indicate that Arrow Linen could avoid paying high electric demand charges, thus potentially saving well over $4,000 in some months on their utility bills.

CHP Power Production during June 2006

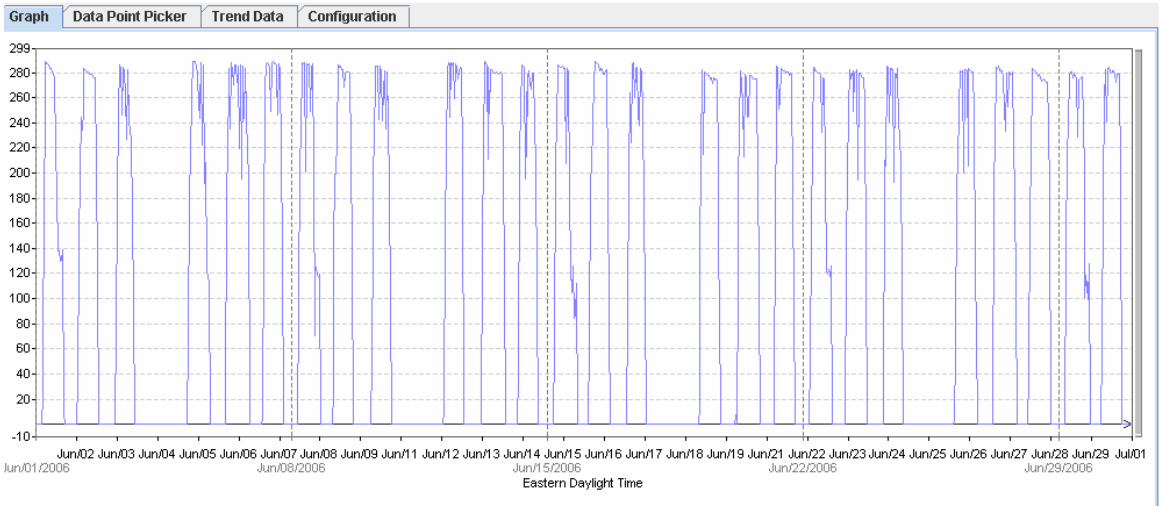


Table 1. June Operating Results

Total Power Consumed on Site (kWh):	116,942
Gross Power Generated (kWh):	84,885
Estimate Parasitic Load (KWh):	6,153
Net Power Generated (kWh):	**78,732**
Fuel Consumed (MBtu):	**1,199,483**
Useful Thermal Energy (MBtu):	527,205
Boiler Fuel Avoided (MBtu):	**659,006**
System Efficiency:	**66.4%**

Status of Milestone(s)

Draft project profile for Higgins Brick. August 2006. Delayed until January 2007.
Draft project profile for Arrow Linen. September 2006. Delayed until November 2006.

Industry Interactions

This program is coordinated with and complements the activities of ESC's Distributed Generation Consortium. Fifteen key US and Canadian energy utilities comprise the consortium. ESC conducted its Technology and Market Assessment Forum (TMAF) in Montreal from June 6-8. Climate Energy provided an update on their 1kW residential generator package to the ESC membership. The ESC DG Consortium held its meeting on Wednesday, June 7. For that meeting we asked UTC to provide an update on their PureComfort and fuel cell marketing effort, and SEMCO Inc. to provide information on the Pepperell High School, Rome, Georgia demonstration plans. Also, ESC appraised the membership on the current status regarding the introduction of the new 6.3 MW Solar Taurus 65 turbine set, the two new engines from Jenbacher, the 900 kW J412 and the 1.2 MW J416, and the current status of the evaluation efforts at Arrow Linen in New York and Higgins in California.

In a separate effort, ESC continues to inform plant operators of the merits of CHP through its publication of Gas Technology Inserts, a regular feature in Plant Engineering Magazine.

SUBTASK 4.2.2. NATIONAL ACCOUNTS DE PROJECTS

P. W. Garland
Oak Ridge National Laboratory, ONRL/DC Office, Washington, DC
Phone: (202) 479-0292; Email: garlandpw@ornl.gov

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 which 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.

Three projects are complete: (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 [completed in FY04]; (2) 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 [completed in FY05]. (3) Cinemark Movie Theater which involves a DTE engine and a DOE/ORNL/SEMCO developed desiccant dehumidifier in Plano, Texas [completed in FY05].

Two projects are continuing into FY06. The equipment was installed and commissioned in FY05. Data monitoring and analysis will continue until December, 2005. (4) HEB Grocery Co. Project which will test onsite power, CHP and liquid refrigerant subcooling at a 71,000 sq. ft. supermarket in San Antonio, Texas; (5) Walgreen's site in Pinellas Park, FL which involves a DOE/ORNL/SEMCO developed desiccant dehumidifier.

This project will be completed in FY06.

Highlights

This project is complete as reported last quarter. **The contract has gone into contract close-out at ORNL.**

Technical Progress

NA

Status of Milestone(s)

Complete Walgreen's final report. April 2006 COMPLETE
Complete HEB final report. April 2006 COMPLETE

SUBTASK 4.2.3. VERIZON CENTRAL OFFICE SWITCHING CENTER

C. R. Hudson
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0578; Email: hudsoncrii@ornl.gov

Objective

This project installs DE at Verizon's Zeckendorf Central Office (CO) on Long Island. The project consists of placing seven 200-kW International Fuel Cells (IFC) fuel cells at the facility to generate 1.4 MW of power and capture waste heat for CHP systems. The work includes (1) detailed design and engineering; (2) construction and installation of the DE/CHP system; (3) commissioning and startup; and (4) initial operations and monitoring. Construction began in FY04 and was completed in FY05.

The project will complete initial operations and monitoring, as well as final project documentation in FY06.

Highlights

The fuel cells are now fully operational.

Technical Progress

Operation continues using the fuel cells to provide building electricity with reject heat being used for building heating.

Status of Milestone(s)

A draft report on documenting the project is being prepared by Verizon.

SUBTASK 4.2.4. GAS TECHNOLOGY INSTITUTE

T. K. Stovall
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0329; Email: stovalltk@ornl.gov

Objective

The FY04 solicitation sought proposals for projects that utilized pre-engineered, packaged IES systems that both generate electricity and make effective use of the thermal energy produced. Target applications for this procurement were healthcare and education facilities, hotels, and supermarkets. Four of these projects, under subcontract to GTI, are included in this subtask and two of these projects were active in the reporting period: (1) The Ritz Carlton Hotel, San Francisco, California has installed a UTC Pure Comfort System (with four Capstone microturbines) to generate 240 kilowatts and operate a 110 ton absorption chiller. Partners on this project are UTC Power, Pacific Gas & Electric, Carrier Commercial Systems, and Ritz Carlton. (2) Utica College, New York was investigating the use of a gas-fired reciprocating engine equipped with a novel emissions control system to generate 334 kilowatts and to generate steam. However, due to a change in DOE priorities, this project has been cancelled. (3) Basin Electric, North Dakota will utilize waste heat from an existing pipeline compressor station's gas turbine to generate electricity via an organic Rankine cycle. (4) Wingate Hotels, Nevada was going to utilize a 150 kW gas-fired reciprocating engine with heat recovery, an innovative emissions control system, hot water regenerated desiccant system and ventilation air energy recovery system. The partners on this project were PowerCold, Southwest Gas, Wingate, Nevada Power, and Preventative Maintenance. However, due to a change in DOE priorities, this project has been cancelled.

Highlights

The Ritz Carlton system continued to operate this quarter and data collection and analysis activities were underway. At the Basin Electric site, all of the major equipment has been installed and the electrical interconnections are being completed.

Technical Progress

Due to reductions in expected FY07 funds, both the Utica and Wingate Hotel system projects were cancelled and their remaining FY06 funds reprogrammed. Design documents for both projects are being prepared to serve as guidance for future projects.

Status of Milestone(s)

The subcontract, including all remaining milestones, was substantially rewritten this quarter to reflect the reduced budget. The revisions were accepted by all parties late in the quarter. Milestone status based on the revised subcontract will be reported next quarter.

SUBTASK 4.2.5. BUTLER HOSPITAL IN PROVIDENCE, RHODE ISLAND

C. R. Hudson
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0578; Email: hudsoncrii@ornl.gov

Objective

Provide field data on and analyze use of a UTC Pure Comfort System (with four Capstone microturbines) to generate 240 kilowatts and operate a 110 ton absorption chiller. Partners on this project are UTC Power, Carrier Corporation, Witham & Associates, New England Gas, and CDH Energy Corp.

Highlights

No input provided by subcontractor.

Status of Milestone(s)

Task 3, Field Operations, System Testing and Verification, and Research Reporting, and Task 4, Dissemination of Project Information and Results, are all that remains to complete the project.

SUBTASK 4.2.6. EASTERN MAINE MEDICAL CENTER IN BANGOR, MAINE

C. R. Hudson
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0578; Email: hudsoncrii@ornl.gov

Objective

Complete construction and begin testing of a Solar gas turbine to generate 4.4 MW, generate 24,000 lb/hour of steam and drive a 500 ton absorption chiller. Partners are Solar Turbines, Cianbro Corporation, Vanderweil Engineers, University of Maine, and International District Energy Association.

Highlights

Construction of the Integrated Energy System is proceeding on schedule.

Technical Progress

Currently, the siding and roofing is being installed on the cogen building. All major equipment is in place, and control, electrical, and mechanical systems are being installed. Bangor Gas has completed the piping on campus for the new high pressure gas line. In addition, work continues on the gas pipeline external to the campus with gas expected around the middle of July.

Status of Milestone(s)

It is on schedule.

SUBTASK 4.2.7. EAST HARTFORD HIGH SCHOOL

C. R. Hudson
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0578; Email: hudsoncrii@ornl.gov

Objective

Install a UTC Pure Comfort system in the East Hartford (Connecticut) High School that will have black-start capability. United Technologies Research Center is the subcontract partner.

Highlights

Construction work is complete.

Technical Progress

Commissioning is completed and signed off by the customer. The efficiency monitoring will not be on line until late July. Training will most likely occur in mid to late July, no date scheduled.
UTC Power has received a CO (Certificate of Occupancy) from the Town of East Hartford Building Dept. which basically means all inspection criteria have been met and the system can be operated.

Status of Milestone(s)

System startup is underway.

SUBTASK 4.2.8. REAL ENERGY

C. R. Hudson
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0578; Email: hudsoncrii@ornl.gov

Objective

Install an integrated reciprocating engine and absorption chiller system at the Madera Community Hospital in Madera, California. The system will have capacities of 600 kW and 115 RT. The subcontract partner is RealEnergy, LLC.

Highlights

Skid design has been provided to the skid packager, BluePoint Energy.

Status of Milestone(s)

Completing negotiations with subcontractors for site construction and skid assembly.

SUBTASK 4.2.9. SEMCO INCORPORATED

C. R. Hudson
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5819; Email: sandjr@ornl.gov

Objective

Utilize a 200 kilowatt reciprocating engine generator coupled with an integrated active desiccant system in a high school in Floyd County, Georgia. Partners are C&M Engineering, Floyd County Schools, Deutz Engines, and WW Williams electrical generation equipment. Develop an islanded Integrated Energy System (IES) design that will function independently of the grid to provide adequate building air conditioning and ventilation in the event of a local disaster, blackout, or terrorist attack.

Highlights

Construction activities nearly complete.

Technical Progress

Final work on engine controls is being done. All of the systems have been tested and started.

Status of Milestone(s)

System will be operational and building occupied in mid-August. A DOE site visit has been suggested for September.

Industry Interaction

- SEMCO Corporation
- CM Engineering
- WW Williams Company
- Deutz Corporation
- Automated Logic Corporation.

SUBTASK 4.2.10. NORTH CAROLINA STATE UNIVERSITY

P. W. Garland
Oak Ridge National Laboratory, ONRL/DC Office, Washington, DC
Phone: (202) 479-0292; Email: garlandpw@ornl.gov

Objective

The Connecting to the Grid Project, a program of the Interstate Renewable Energy Council (IREC) administered by the NC Solar Center at NC State University, provides technical assistance to federal, regional, state, utility and other stakeholders in the process of developing interconnection and/or net metering rules for distributed energy resources (DER). The Project also serves as the leading national information clearinghouse on net metering and Interconnection issues. The goal of the IREC Connecting to the Grid Project has been to develop a speedy, transparent and economically improved landscape within the electric utility sector for distributed energy projects. The general thrust of the work is twofold: to monitor and report on interconnection and net metering activities around the country; and to report out the good and bad "lessons learned" from these processes in both news and policy model formats to help guide new states beginning the process.

Highlights

- The final progress report was submitted to ORNL. All milestones have been completed and all invoices have been paid in full. **This contract is complete.**

- This reporting period has seen the publication of three issues of the *Connecting to the Grid* newsletter, as well as continued updates to and maintenance of the project web site. The project staff continues to work with state regulators, federal regulators, utilities, and local and national nonprofit organizations to develop appropriate interconnection rules for distributed energy resources (DER), including combined-heat-and-power (CHP) systems.

- The June 2006 edition of the newsletter – the current newsletter at the time of this report – is available at www.irecusa.org/connect/enewsletter.html. The April May and June 2006 editions of the newsletter are available in the "Newsletter Archives" section of the project web site, available at www.irecusa.org/connect. (All newsletters are available in HTML and PDF format.) In addition, a catalog of recently featured articles appears in chronological order on the project web site.

Technical Progress

Publication of the *Connecting to the Grid* newsletter continued with April 2006, May 2006 and June 2006 issues. Prior to the publication of each monthly newsletter, project staff researched relevant information available at more than 60 individual web sites; reviewed information provided by approximately two dozen newsletters and publications; and collected information from government officials, businesses and solar advocates.

The three newsletters published during this reporting period included 29 state articles covering developments in 16 different states (California, Colorado, Connecticut, Florida, Kentucky, Maryland, Minnesota, New Jersey, New Mexico, Oregon, Pennsylvania, Vermont, Virginia, Washington, West Virginia and Wisconsin) and the District of Columbia. The newsletters also included 17 articles covering developments in three foreign countries (Canada, India and the United Kingdom) and the European Union. Furthermore, the three newsletters covered national developments, including those involving the Federal Energy Regulatory Commission (FERC) and the U.S. Department of Energy (DOE), as well as publications, industry news, conferences, events, people and other news relevant to interconnection issues.

At the state level, the Washington Utilities and Transportation Commission adopted interconnection standards for DER up to 25 kilowatts (kW) in capacity. Prompted by Sections 1251 and 1254 of the federal Energy Policy Act of 2005 (EPAct 2005), the regulatory commissions of Kentucky, Maryland, Virginia and West Virginia initiated proceedings to investigate interconnection standards based on IEEE 1547. These proceedings are currently ongoing. The regulatory commissions of Minnesota and the District of Columbia continue to iron out inconsistencies in interconnection tariffs filed by investor-owned utilities, and the regulatory commissions of Arizona and Pennsylvania are still in the process of developing interconnection standards for DER.

The New Jersey Board of Public Utilities is revising its universal interconnection application and agreement, while California is considering allowing interconnection to networks. The Vermont Public Service Board is developing interconnection standards for DER with no maximum limit, with the assumption that larger DER systems will be subject to FERC's interconnection rules. In addition, the Oregon Public Utilities Commission has begun holding workshops to discuss interconnection standards for DER.

Existing net-metering laws were expanded -- and enhanced -- in Maryland, Virginia and Washington. Washington's revised law extends net metering to combined-heart-and-power (CHP) systems up to 100 kW in capacity. In West Virginia, the Public Service Commission launched an investigation into net metering. (West Virginia is one of only 10 U.S. states with no net-metering options.) PG&E, an investor-owned utility in California, announced that net metering in its service territory is approaching the current legal limit of 0.5% of PG&E's peak load. Interestingly, We Energies, an investor-owned utility in Wisconsin, voluntarily expanded its existing net-metering program and production incentives for renewables.

At the national level, FERC rejected proposed exemptions filed by the Midwest Independent System Operator (MISO) and the New York Independent System Operator (NYISO) from the commission's standard interconnection rule for wind generators. FERC also proposed amendments to regulations adopted in Order Nos. 888 and 889 to ensure transmission services are provided in a nondiscriminatory and just and reasonable basis.

DOE issued a request for information (RFI) regarding technology acceptance activities -- including interconnection standards and net metering -- that address marketplace barriers to solar-electric technologies and offer the opportunity for market expansion. On a related note, DOE concluded in a report that the number of net-metered energy systems in 2004 reflects a 132% increase over the number of net-metered systems in 2003.

Update and Maintain the "Connecting to the Grid" Project Web Site. During this reporting period, the project staff continued maintenance of the "Connecting to the Grid" site. This site includes featured individual news articles, information about the project, relevant interconnection documents, and the aforementioned archive of past *Connecting to the Grid* newsletters. Updated versions of IREC's state-by-state interconnection and net-metering tables were completed and added to the project web site in June 2006.[1] Project staff continued the process of restructuring the state-by-state library of legal documents related to interconnection. In May 2006, project staff also conducted a reader evaluation of the *Connecting to the* Grid newsletter. The results of this evaluation were provided to the ORNL technical monitor.

During the reporting period, approximately 60 new subscribers signed up to receive the *Connecting to the Grid* newsletter, showing continued strong growth in total newsletter subscriptions. Only approximately five people unsubscribed during the reporting period. The total number now subscribed to the newsletter was approximately 1,015 as of June 8, 2006.

Status of Milestone(s)

Provide Quarterly Reports to ORNL. COMPLETE.

Industry Interaction

During this reporting period, net metering and interconnection activities continued at a rapid pace in numerous states around the country, reflected by the high number of state-related articles (29) during this three-month reporting period. Activities related to net metering and/or interconnection regulations, rules and procedures continue in about 20 states. Regional efforts remain active as well. The N.C. Solar Center and IREC anticipate that developments will continue to unfold quickly and accelerate, due to: (1) the passage of the EPAct of 2005, (2) extremely volatile energy prices, and (3) increased public interest and awareness concerning energy use and energy resources. Significantly, proceedings still in progress Arizona and Pennsylvania may yield interconnection standards extremely favorable to the DER and CHP communities in those states and beyond. The U.S. Combined Heat and Power Association (USCHPA) continue to work with the IREC National Interconnection Project to facilitate the creation of favorable state-level, regional-level and federal-level interconnection standards.

---

[1]IREC's state-by-state interconnection and net metering tables are available to the public at www.irecusa.org/connect/statebystate.html

SUBTASK 4.2.11. SENTECH

P. W. Garland
Oak Ridge National Laboratory, ONRL/DC Office, Washington, DC
Phone: (202) 479-0292; Email: garlandpw@ornl.gov

Objective

Sentech will provide technical upgrades to the DOE DE Website. ORNL will work with to Sentech to develop DOE DE case studies for each of the IES packaged systems projects as the data becomes available. In addition, SENTECH will collect new DE case studies and update an Internet-based, searchable database of completed case studies--currently posted at http://www.eere.energy.gov/de/casestudies--on a quarterly basis.

Highlights

- SENTECH submitted updated html files, for DE website, on all requested DE Projects.
- SENTECH is drafting a DE Program Project Profile for the Fort Bragg Site in North Carolina.
- The final increment of FY06 funding was provided to the contract.

Technical Progress

In this quarter, Sentech focused on technical activities under their separate DE contract with Dave Stinton. The following final draft reports were submitted

- *"Societal Benefits of DE White Paper"*
- *"A Compendium of Case Studies of Distributed Energy Systems Providing Value to Utilities"*
- *"Downtime Costs in Select DE Markets Report"*

Status of Milestone(s)

- Provide Quarterly Reports to ORNL. Ongoing.

SUBTASK 4.2.13. TECHNICAL ANALYSIS AND SUPPORT

C. R. Hudson
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5819; Email: sandjr@ornl.gov

Objective

ORNL will continue to review and develop tools that can be used by the DE community in evaluating the technical and economic viability of distributed energy systems. Having a means to accurately evaluate the potential of a DE project is critical to sound decision making and project success. In many instances, DE systems are very close in economic parity to traditional sources of electricity and thermal supply. Determining the economic viability of a DE/CHP system goes beyond knowing just the prices of electricity and fuel at a given location. Due to the non-coincident behavior of electrical and thermal loads, one must evaluate the interaction of the DE system to the loads on an hourly basis in order to obtain an accurate determination of the DE system utilization. Furthermore, work in this area last FY demonstrated that the proper sizing of electrical and thermal installed capacity is critical to achieving a positive economic result for a project.

Work will continue on development and refinement of tools that can provide guidance on proper size selection of DE systems. Various operational modes of CHP systems, (e.g., thermal following, thermal storage) will be modeled. Work products produced in this area, such as the CHP Capacity Optimization Tool, will be documented and made available to the end-user community and to the regional application centers. Training and support for evaluation tools will be provided.

Highlights

The initial version of the CHP Capacity Optimizer has been completed and is available on the DOE and ORNL web sites.

Technical Progress

The initial release of the CHP Capacity Optimizer and associated documentation is complete.

Status of Milestone(s)

It is on target.

Section 4.3. Cooling, Heating, and Power

Most of the projects in this area were completed in FY05. Only projects receiving FY06 funding are being reported on in separate headers below. As final reports are completed on the remaining projects [funded in FY05], information will be reported in *Section 4.3.17, Project Direction and Technical support.*

SUBTASK 4.3.5 COORDINATION OF CHP MEETINGS AND STAKEHOLDER OUTREACH

P. W. Garland with Energetics, Inc.
Columbia, Maryland
Phone: (410) 953-6215; Email: jbrinch@energetics.com

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

- CHP Team Meetings Continue on a bi-monthly basis
- The FY06 CHP Roadmap Meeting has been scheduled for September 13-15, 2006 in Seattle, Washington.
- The results of the CHP Café held in New York in September 2005 are complete and have been distributed to the CHP Team.

Status of Milestone(s)

Subtask 4.3.5 Facilitate the CHP Roadmap Meeting. October 2005. COMPLETE.

SUBTASK 4.3.6. EMISSIONS, PERMITTING, DG RELIABILITY DATABASE, COST AND FINANCING OF DG/CHP, INVENTORY OF COMMERCIAL/INDUSTRIAL BOILERS

P. W. Garland with Energy & Environmental Analysis Corporation
Arlington, Virginia
Phone: (703) 528-1900, E-mail: bhedman@eea-inc.com, jbluestein@eea-inc.com

Objective

Project 1: This project consisted of multiple tasks including emissions, permitting, DG reliability database, cost and financing of DG/CHP, and inventory of commercial/industrial boilers. One task remains for FY06, to update and maintain the DG reliability database.

Project 2: This project consists of multiple tasks: CHP Installation Database, Applications Integration and Installed Costs Analysis for Small CHP Systems, DG/CHP Financing, and Electric Rate Primer. One task remains for FY06, to update and maintain the CHP installation database.

Highlights

- The DG Installation Database updates continue. The database indicates over 83,000 MW of installed capacity. Preliminary data on the 2005 updates were provided to ORNL and Discovery Insights for use in the CHP Action Agenda.
- Maintenance of the regulatory database continues.
- An update of the installed costs of CHP systems, previously contained in the Technology Characterization reports of October 2003, is being completed.

Technical Progress

- EEA continues to work with the RACs to verify and update the CHP Installed Database. Anne Hampson has provided an updated listing to each of the 8 RACs asking for additions and corrections.
- The following reports are undergoing internal review at EEA:
  DG Financing Options and Industry Feedback on Financing Issues
  Impact of Electric Rate Structures on CHP Economics
  The market trends of last five years are undergoing review.
- A draft template to use for the updating of the installed costs estimates for CHP was provided to ORNL for comment. It builds upon the data collected to-date through this project. The intent is to get as many "real world" estimates as we can to develop the range of values we might see for each line item in the template. The sense is that the equipment estimates will be relatively consistent, but we'll see wide variations in the installation costs. Hopefully we'll be able to get a range of expected costs and what drives them. Our intent is to gather as much data as we can over the next 4 to 5 weeks in this format. Then we'll analyze and develop ranges by technology and size, and see if we can get feedback from developers and EPA CHP Partners on the aggregate numbers and relative ranges of each.

Status of Milestone(s)

Complete and post regulatory database. September 2006 COMPLETE
See URL: http://www.eea-inc.com/rrdb/DGRegProject/

SUBTASK 4.3.12. DEVELOPING CHP MARKETS WITH OPPORTUNITY FUELS

P. W. Garland with Resource Dynamics Corporation
Vienna, Virginia
Phone: (703) 356-1300, E-mail: pll@recnet.com

Objective

This project consisted of several tasks: Collect and summarize opportunity fuels information for fuels that already are or could be used in CHP applications, Evaluate CHP Technology Options, and Analyze Potential Market Impacts and Develop Recommendations. This work was completed in FY05 with publication of the final task report, which can be found on the DOE DE website.

In FY06, one 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.

Highlights

- A contract modification is being negotiated with Resource Dynamics to add an additional increment of FY06 funding to complete 3 tasks.

Technical Progress

The following tasks are being added to the current contract:

- Barriers to Installing CHP Associated with Renewable Portfolio Standards
  In this effort, state-by-state research and analysis will be conducted to determine what the barriers are to using biomass, landfill gas and other opportunity fuels for CHP. Specifically, we will explore the projects that are proposed or have been installed that are using renewable fuels for straight power generation and not using the associated waste heat. In addition, this effort will explore potential options for enhancing CHP prospects, including measures developers could adopt, revisions that RPS programs could consider, or other policy options.
- Conduct Opportunity Fuel Presentations. This effort would entail preparing presentations that combine existing opportunity fuel information on the fuels, costs, technologies, and markets along with any state or regional activities that are relevant to expanding use of opportunity fueled CHP, and conducting two presentations at the request of DOE.
- Collect CHP Cost Data for Use With Opportunity Fuels. This effort would entail collecting data on the installed cost of opportunity fueled CHP units and organizing this data in the DOE framework prepared for the publication entitled Gas Fired Distributed Energy Resource Technology Characterizations. Tables will be prepared for insertion in an updated document, along with limited explanatory text and notes.

Status of Milestone(s)

Complete presentation summarizing the results of the state-by-state analysis of the impact of state level renewable portfolio standards. February 2006 COMPLETE.

SUBTASK 4.3.16. COORDINATION OF REGIONAL APPLICATION CENTERS

P. W. Garland with Power Equipment Associates, Ltd.,
Carol Steam, IL 60188
Phone: (630) 248-8778; Email: tlbronsonpea@aol.com

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 face-to-face coordination meeting of the DOE CHP Regional Application Centers (RAC) was held on May 2nd, 2006.
- The quarter working group conference calls continue.

Technical Progress

- The purpose of the May RAC face-to-face meeting is to (1) share information on emerging issues and actions among the regions that can help each RAC and Initiative optimize its performance through leveraging other actions of the group, (2) Learn about emerging US DOE DER projects, and those of other government partners that can have a regional impact, and
  (3) Provide a feedback mechanism to US DOE as to what is working and what's not with respect to CHP Installations.
- The next RAC face-to-face meeting is scheduled to be held in conjunction with the CHP Roadmap Workshop, September 15th.
- A meeting has been scheduled for August 2, 2006, with Dr. Orlando, the new Director of the Mid-Atlantic CHP Application Center.
- A list of potential new tasks for the upcoming RAC task order solicitation has been developed and discussed with each of the RACs.
- A task is being added to the ORNL/Resource Dynamics contract to allow for presentations in support of the Regional Application Centers.

Status of Milestone(s)

Subtask 4.3.16. Complete report on 2005 RAC accomplishments and lessons learned. January 2006 COMPLETE.

SUBTASK 4.3.17. PROJECT DIRECTION AND TECHNICAL SUPPORT

P. W. Garland
Oak Ridge National Laboratory, ONRL/DC Office, Washington, DC
Phone: (202) 479-0292; Email: garlandpw@ornl.gov

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.

Highlights

- The Annual CHP Roadmap meeting has been scheduled for September 13-15, 2006 in Seattle, Washington.
- A CHP Analysis Team Meeting, hosted by ACEEE, was held on April 6, 2006. The topic was "changing gas prices."

Technical Progress

- Planning meetings continue in support of the CHP Roadmap Meeting being held in September. Representatives from DOE, EPA, USCHPA, and ORNL are on the Steering Committee. This year's meeting is being co-located with the NASEO organization annual meeting. Exergy Partners will support the CHP Café Process.
- ORNL is working with Discovery Insights and EEA to develop the CHP Action Agenda, which they will present at the September Roadmap Meeting.
- ORNL is working with Sentech to develop a case study for Fort Bragg.
- ORNL is working with EEA, Discovery Insights and Resource Dynamics to update the CHP-installed costs reports.

Status of Milestone(s)

Subtask 4.3.1 Facilitate CHP Analysis Working Group Meeting (ACEEE), April 2006
COMPLETE.

Subtask 4.3.4 Complete Resource Planning and Procurement Guide (DUA), December 2005
COMPLETE. The final report, "The Value of Distributed Generation and Combined Heat and Power Resources in Wholesale Power Markets," is dated March 1, 2006.

Subtask 4.3.9 Complete the final report on environmental screening tool in Southeastern States (IC Thomasson), June 2006. It is in-Progress.
The vendor states the report is complete; however has not delivered the final version to ORNL.

Subtask 4.3.11 Write a summary paper on status and lessons learned among CHP Regional Initiatives (NEMW) March 2006 COMPLETE.
The final task report and a power point presentation on the 2005-2006 Regional Initiative Accomplishments were provided to ORNL on May 21, 20006.

SUBTASK 4.3.18. CHP REGIONAL APPLICATIONS CENTER SUPPORT

S. K. Fischer
Oak Ride National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-2017; Email: fischersk@ornl.gov

Objective

ORNL will provide technical assistance in performing screening and optimization calculations on an as-needed basis to the CHP Regional Application Centers. ORNL will train CHP Regional Application Center staff on the use of the BCHP screening tool and the capacity optimizer.

Highlights

- None, see notes below

Technical Progress

Steve Fischer worked with staff at the Gulf States Regional Application Center and the ORNL FEMP program to resolve problems with the BCHP Screening Tool and with the RateScriptEditor used to compute monthly energy costs in the BCHP Screening Tool calculations. Utility rate data files were produced for landfill gas for a proposed project selling heat and power to the U.S. Army installation at Fort Campbell, Kentucky and for "simulated" energy costs in Hawaii (artificially priced natural gas was used as a surrogate for diesel fuel and propane). Technical problems concerning transfer of data between the BCHP Screening Tool and the RateScriptEditor were corrected. Problems persist with performing desiccant calculations using the BCHP Screening Tool. There have been serious difficulties in obtaining detailed energy results for desiccant operation from the DOE2 "kernel" of the BCHP Screening Tool and also deep-rooted problems (or even errors) in the desiccant implementation performed by the initial subcontract developer for the BCHP Screening Tool.

Work is continuing on improving desiccant system calculations in the BCHP Screening Tool. While the model currently allows the simulation of desiccant systems, it is not clear if the original contracted implemented this option correctly so that recovered engine heat can be used for desiccant regeneration. Efforts to view hourly performance data for the DOE2 simulations have been stymied by the somewhat obtuse manner of DOE2 itself.

Status of Milestone(s)

Hold at least one training session for RACs on use of BCHP Screening Tool May 2006
COMPLETE.

SUBTASK 4.3.19. HUD SUPPORT

S. K. Fischer and Patti Garland
Oak Ride National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-2017; Email: fischersk@ornl.gov

Objective

In this cost-shared work-for-others project, ORNL will provide technical support to Bob Groberg at Housing and Urban Development (HUD) on an as-needed basis. Current work includes recommendations on the accuracy of the CHP calculator based on for the Cogen Manual for Multi-Family Housing, Appendix A. Additional work will include collaboration with HUD, and HUD "partners", in identifying and applying the best tools for evaluating CHP in multi-family housing. Among others, these partners include Sebesta Blomberg & Associates of Arlington, Virginia and Dougherty and Associates of Alexandria, Virginia who are under contract to HUD to evaluate combined heat and power for multifamily housing. A data template and utility data files will be produced for use with the BCHP Screening Tool to assess its potential for use in studying combined cooling, heating, and power in multifamily housing.

Highlights

- Steve Fischer assisted Bob Groberg in presenting the HUD update at the RAC face-to-face meeting in May.

Technical Progress:

- The CHP Guidebooks and the ORNL-developed software are up on the website. The Challenge now is to get data on buildings and see how the software works. HUD is making a special effort to find buildings in large cities, emphasizing regions where the economics work, such as the Northeast. HUD's target is to do 6 buildings in the next 6 months. The RACs may be contacted for support in identifying buildings, helping put together the data and analyzing the results.
- HUD is updating their CHP software with ORNL's Steve Fischer. The software now can be downloaded focusing on potable hot water, with cooling modules to be provided in the near future. Entering simple information from past electric bills is used to determine loads.
- HUD is speaking in PA on June 20th, comparing incentives from NJ and NY, and again on June 28th in New York on multi-family housing.

Status of Milestone(s)

Provide support to HUD on an as-needed basis. Ongoing

SUBTASK 4.3.20. TECHNICAL ANALYSIS AND SUPPORT TO LEED

J. B. Berry
Oak Ride National Laboratory, Oak Ridge, Tennessee
Phone: (865) 241-1939; Email: berryjb@ornl.gov

Objective

Participate on and contribute to the U.S. Green Building Council, Leadership in Energy and Environmental Design CHP subcommittee, which was formed to ensure that appropriate LEED credit is awarded for on-site power generation CHP. Evaluate and validate proposed revisions to the methodology used to calculate Leadership in Energy and Environmental Design (LEED) credit by modeling installations of advanced, packaged on-site power systems such as the Integrated Energy System at Dell Children's Hospital in Austin, Texas and the packaged CHP system at Metropolitan Hospital in Grand Rapids, MI. Use and modify the BCHP Model to accommodate interests of the subcommittee. Model and evaluate CHP applications to encourage development of LEED 3.0 to incorporate benefits of CHP such as reduced air emissions and improved efficiency of fossil fuels.

Highlights

The CHP Calculation Methodology for LEED-NC v2.2.EA Credit 1, *Guidance on Combined Heat and Power Systems Supplying Electricity or Recovered Thermal Energy to LEED Applicant Buildings*, was issued by the U.S. Green Buildings Council on March 28, 2006.

Technical Progress

Project is complete.

Status of Milestone(s)

Subtask 4.3.20 - Complete LEED analysis for Dell Children's Medical Center using the revised LEED EA1 credit interpretation that includes CHP. *Due date changed from April 2006 to June 2006 due to the fact that the LEED EA1 credit for CHP was issued by the Green Buildings Council on March 28, 2006.*

Dell Children's Medical Center staff has started evaluating the newly released LEED guidance for CHP as it applies to their facility operation.

Section 4.4. Power Electronics

SUBTASK 4.4.1A ANCILLARY SERVICES OFFERED BY DISTRIBUTED ENERGY RESOURCES

J. Kueck, L. Tolbert
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5178; Email: kueckjd@ornl.gov

Objective

This task will develop needed methods for local voltage regulation that are not currently available utilizing programmable inverters in several different sizes (62, 125, and 250 kW).

Highlights

On Tuesday, February 23rd 2006, a milestone was met with the operation of the 75A (62kVA) PowerEx three-phase Inverter at the ORNL Reactive Power Laboratory. The inverter was operated at a voltage of 780Vdc by setting the 144W power supply at this voltage. The inverter output was successfully connected to Circuit #2 of the 13.8kV/2.4kV ORNL Distribution System by closing the AC contactor between the 480V/600A power panel and the three-phase inverter. The inverter was able to provide approximately 40% (about 12kVar) of the load's reactive power demand. The inverter was able to correct the power factor from 0.857 to 0.943 lagging and raise the power panel's voltage by 0.8% by using a current control logic developed by ORNL for the space Real-Time Control System. The inverter has since been operated up to 58% of its rating.

Technical Progress

On February 23, the milestone of injecting reactive power from the three-phase 75A (62kVA) inverter was achieved and a highlights prepared; the inverter was operated to ~10A peak. In March 29th, the inverter was operated at three higher levels (30A, 45A and 60A peak). Data was collected for each of these operating levels and analyzed. Unfortunately, as the testing was coming to an end, the phase C terminal of the inverter failed. The fault caused irreparable damage to the inverter, and the root cause of the failure is being pursued with the inverter manufacturer. The inverter failure caused no personnel injury and there was no damage to the contactor that interfaces the AC output of the inverter to the AC system (electrical panel). We did find out in later testing, that there was damage to the 150kW DC power supply that supplies the DC side of the inverter. The power supply has since been repaired and reinstalled. Also we have implemented additional safety measures for continued inverter testing which include (1) adding more fan cooling that are directed at the inverter's heat sink, and (2) placing external thermocouples to monitor the inverter/heat sink temperature as the inverter's current is increased, and (3) installing a stop switch to open the AC contactor to separate the inverter from the AC interface if any inverter problems appear during testing. A 150A (125kVA) inverter has been outfitted with heat sink fans and thermocouples and has been placed in the inverter test chamber. The inverter has been checked out and testing will resume soon now that the power supply is back from repairs.

Status of Milestone(s)

The inverter has been demonstrated to be able to compensate for fundamental reactive power, harmonics, and unbalanced load conditions for loads up to 45Arms (60A peak). We met the milestone of injecting reactive power for several power levels. We will continue to focus on higher power levels and enhancing our controls both for individual inverter operation and paralleling with the 300kVar synchronous condenser. The inverter control system has been developed to provide voltage regulation based on one variable, local voltage. The inverter controls have been programmed in Matlab/Simulink and dspace and are ready for testing.

Industry Interactions

On September 29th, we had a project review meeting to go over the status of activities for the Reactive Power Project in FY05 and plans for FY06. As a result of this meeting, the industry participants came up with a list of feedback items to which we have responded. We have assigned responsibilities to the ORNL team for addressing these items which relate directly to the project tasks.

Section 6. DE Crosscutting, Systems Integration, and Analysis

SUBTASKS 6.1 AND 6.2. DE ASSESSMENTS AND BENEFITS, AND MARKET STUDIES AND TECHNICAL DIRECTION

T. K. Stovall
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0329; Email: stovalltk@ornl.gov

Objective

Perform DE benefit analyses to: (1) provide the foundation for informed program management decisions, (2) facilitate the deployment of advanced technologies developed under the program mantle by conveying the full extent of potential benefits and the role of DE in the energy market, and (3) support cooperation and partnership with other DOE offices and other government agencies.

Highlights

Material describing the technical aspect of DG-grid interactions was prepared for an integrated version of the Energy Policy Act 1817 report. Close coordination with coauthors continued.

In the MADRI project, significant accomplishments this quarter included the adoption of a DER policy statement and an agreement among the regional PUC's to consider and act upon a MADRI developed DER Action Plan.

Technical Progress

In addition to providing the revised draft chapters for the Energy Policy Act DG Benefits Study, contributions were made to the authors of other sections of that report.

In the MADRI project, an ambitious DER action plan was finalized and has received favorable attention from all of the Mid-Atlantic States as well as at least one major multi-state utility. This plan includes: (1) Consideration of a 3% DER goal, (2) Consideration of a model revenue stability tariff to minimize the impact of changes in throughput, (3) Coordination of pricing pilots, (4) Development of cost/effectiveness criteria for evaluating potential DER investments, (5) Development of regional standards for AMI systems, and (6) Development of regional criteria for evaluating the AMI business case.

Status of Milestone(s)

The work supporting the CPS/Control milestone regarding the EP Act Benefits Study is on track to meet the schedule. The MADRI program progress is also on track and multiple reports describing that project's products have been received.