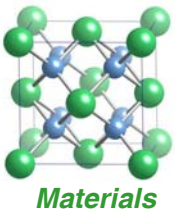
Distributed Energy Program

DE Quarterly Progress Report
For the Period
January 1, 2006 to March 31, 2006



OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

DE QUARTERLY PROGRESS REPORT

For the Period
January 1, 2006 to March 31, 2006

Prepared by:

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For:
Department of Energy
Office of Distributed Energy

Section 1. Advanced Reciprocating Engines

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

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Objective

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

Highlights

A baseline short term (67 h) engine test of spark plugs made from ORNL model and developmental electrode alloys was completed at ORNL in a Caterpillar G3406 industrial natural gas engine. Post test gap measurements, breakdown voltage, and optical spectroscopy have been completed, and microstructural analysis is in progress. These results will be compared with previous studies of field-tested plugs.

Technical Progress

An initial baseline 67 h engine test of spark plugs made from ORNL model and developmental electrode alloys without precious metal electrode insert pads was completed at ORNL using a Caterpillar G3406 industrial natural gas engine. Post test gap measurements, breakdown voltage, and optical spectroscopy were completed. Alloying additions to increase oxidation resistance also are suspected to have lowered alloy thermal and electrical conductivities such that lower gap growth rates did not result because the plugs ran hotter. The total extent of gap growth also did not correlate well with oxidation as the primary material removal process. However, it should be noted that these tests incorporated solid electrodes as this exploratory stage, which artificially increases the importance of alloy thermal and electrical conductivities in the test. In optimized plugs for field use, the electrodes are Cu cored, which significantly improves conductivities. Microstructural analysis of the electrode alloys is in progress, and will be compared with short term field tested plugs studied previously. A test matrix of a second iteration of plugs, utilizing precious metal inserts and electrode alloys selected based on insights gained to date in this program has been agreed upon with Federal Mogul (Champion®) and will be manufactured in Spring of 2006 with engine testing at ORNL anticipated in summer 2006.

Status of Milestones

- Evaluate developmental spark plugs in an industrial natural gas burning reciprocating engine (Sept. 2006) -on track
- Develop a database for spark plug performance under temperature and pressure conditions using the newly developed test chamber at NTRC (Sept 2006) – as funds allow

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.

SUBTASK 1.3. ADAPTIVE CONTROLS FOR LEAN BURN ENGINES

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Objective

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

Highlights

Combustion instabilities under dilute operating conditions are the result of both stochastic effects (such as turbulence and mixing) which produce random variability and deterministic effects (such as cycle-to-cycle feedback via residual gases or EGR) which produce predictable variability that can be controlled. Experiments are being conducted on the Kohler genset to see if the deterministic component of the combustion variability can be made more dominant by increasing back pressure to increase the amount of trapped residual gases.

As recommended in feedback from the DE Peer Review, we are continuing to asses the use of the adaptive control techniques we have developed for dilute combustion to stabilize the mode transition between spark-ignition and HCCI combustion and to extend the practical HCCI operating range. This effort is being leveraged with additional funds from USDOE OFCVT. Papers on this work have been accepted for the SAE World Congress in April 2006, the Spring Technical Meeting of the Central States Section of The Combustion Institute in May 2006, and the 31st International Symposium on Combustion in Heidelberg, Germany in August 2006. The work was presented at the Advanced Engine Combustion Working Group meeting at Sandia National Laboratory in February 2006 and received favorable reviews.

Technical Progress

We have determined that combustion variability during the SI-HCCI mode transition is indeed deterministic in nature and have developed methods which can predict behavior with reasonable accuracy – the first step in developing an adaptive control strategy. We have also identified a large range of operating conditions along the transient pathway where steady-state operation is unstable but NOx-reduction benefits are similar to HCCI. We believe that adaptive control holds promise in stabilizing operation at these intermediate conditions to effectively extend the range of operation over which NOx-reduction benefits are realized.

The single cylinder engine fabrication is still progressing and delivery is expected in the next quarter.

Status of Milestones

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

Industry Interactions

We have had regular interactions with Waukesha about the single cylinder engine.

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

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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

Phase 1 of the sulfur durability experiment has been completed, and preparations for Phase 2 of the study are near completion.

Technical Progress

FY06 efforts are focused on Sulfur Durability Studies. Experiments for sulfur durability studies will be performed on the Cummins C8.3G+ engine dynamometer platform at ORNL. The study will involve 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 is to determine the effect of sulfur on NG utilization for lean NOx trap regeneration. The study will be conducted in three phases:

- Phase 1: Pre-Sulfur Baseline – Characterize the methane partial oxidation and reforming processes of the catalyst before sulfur exposure.
- Phase 2: Sulfur Exposure – Expose the oxidation and reforming catalysts to sulfur with accelerated aging via SO_2 exposure from lab gas cylinders.
- Phase 3: Post-Sulfur Examination – Repeat experiments in Phase 1 and compare performance prior to and after sulfur exposure.

Status of Milestones

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

Industry Interactions

An abstract has been submitted for the annual ARES-ARICE workshop to be held in Chicago, IL.

Section 2. MATERIALS BASED TECHNOLOGY FOR DISTRIBUTED GENERATION

SUBTASK 2.1.1. ADVANCED ALLOYS FOR HIGH TEMPERATURE RECUPERATORS

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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, microanalysis has clearly established that grain size, grain boundary carbides, *and* intragranular nano-NbC dispersions are responsible for the improve creep resistance of the Phase II AL20-25+Nb alloy.

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.

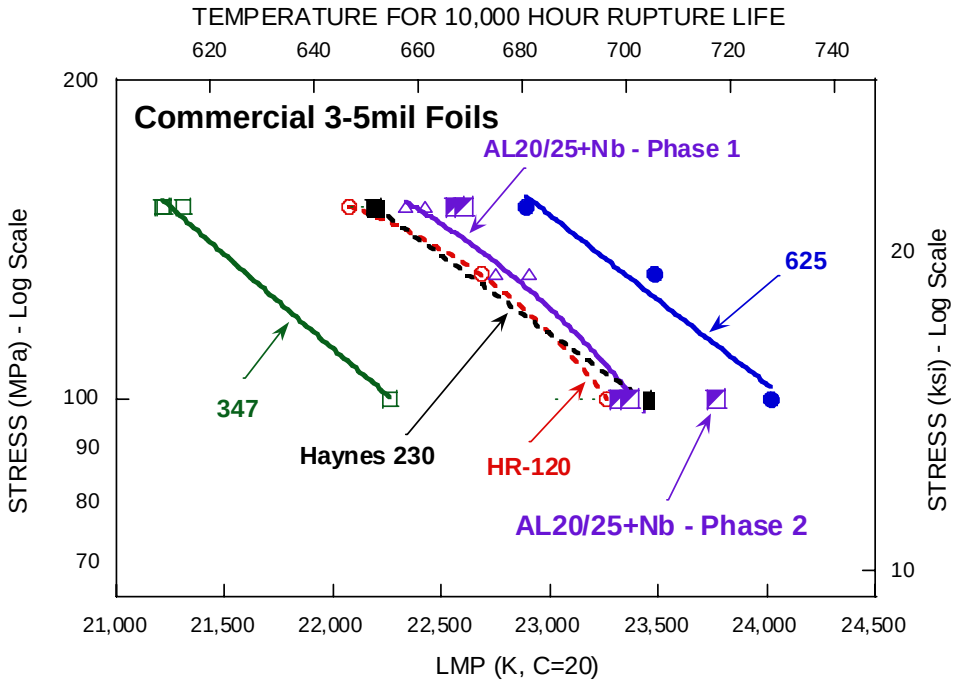
ORNL completed Phases I and II of a collaborative program with Allegheny-Ludlum in FY2005 to produce a wide range of commercial sheets and foils of the AL20-25+Nb alloy for microturbine recuperator OEM manufacturing trials for prototype air-cells with higher performance. The Phase I effort produced full-scale 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 began this quarter and will continue next quarter. This study also includes the appropriate comparisons with similar creep-tested sheets and foils of 347 steel, HR120 and 625 alloys. This study will conclude with analysis of recuperators manufactured from AL20-25+Nb alloy, as well as from the initial in-turbine tests. 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. Relative differences in creep-rupture strength for the various foils of different stainless steels and alloys are shown below in a Larson-Miller plot of rupture stress versus a parameter calculated using test temperature and rupture time.

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 is on track for completion.

Meetings

1. ORNL communicates periodically with Allegheny-Ludlum Technical Center (Chuck Stinner) on this project. ORNL is also working with Ingersoll Rand Energy Systems to obtain brazed plate-fin aircells manufactured with AL20-25+Nb. ORNL also interacts 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

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Objective

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

Highlights

The oxidation performance of model and commercial alloys is being in order to better understand the effect of exhaust gas on the degradation of austenitic steels in recuperators. Chromium depletion rates have been measured in foil specimens after 10,000h in humid air at 650° and 700°C for alloys with Mn contents ranging from 0.04 to 3.8%. Increasing the Mn content had no beneficial effect on the amount of Cr depletion at 650° or700°C.

Technical Progress

The literature on water vapor effects suggest that an alloy addition of Mn reduces Cr volatility in the presence of water vapor by forming an outer Mn-Cr spinel-type oxide layer. In order to test this hypothesis, a range of alloy foils with Mn contents from 0.04wt.% in alloy 625 (Ni-23Cr-9Mo) to 3.8% in a laboratory alloy (Fe-21Cr-21Ni) were exposed for 10,000h in laboratory tests in air + 10vol.%H_2O at 650° and 700°C. While the alloy with the highest Mn content showed the highest mass gain at both temperatures, including alloy 120 (Fe-25Cr-35Ni-0.7Mn) and alloy 709 (Fe-20Cr-25Ni-1Mn), the Cr depletion was similar (~1.7%Cr) for all four alloys after exposure at 650°C. At 700°C, the average Cr depletion for the high Mn alloy (~3.1%) was higher than the other alloys (2.2%-2.6%) but within the standard deviation of the other foil specimens. The lack of benefit for the high Mn content alloy was attributed to an increased scale growth rate which consumed more Cr from the foil.

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

J. Nash and A. Haplau-Colan from Ingersoll-Rand visited ORNL on Feb. 1, 2006

SUBTASK 2.1.4. RECUPERATOR MATERIALS TESTING AND EVALUATION

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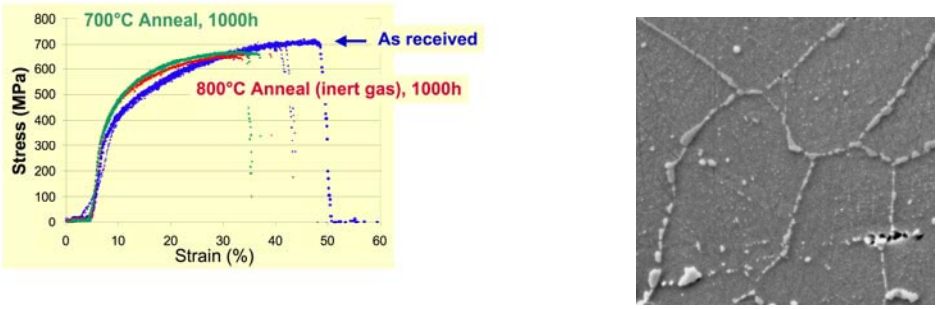
Objective

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

Highlights

Presented a paper at the 2006 TMS Conference.

Technical Progress



(a) (b)

Figure 1. (a) Stress-strain curves for HR-120 foils after various exposure conditions. (b) SEM micrograph revealing he coarsening if grain boundary precipitates in HR-120 foil after 1000-hr annealing at 800°C in argon.

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. The test campaign had to be interrupted for several days to replace the microturbine igniter and to verify the calibration of the thermocouples and pressure sensors. To further investigate the mechanisms responsible for the change in microstructure and mechanical properties of metallic foils after exposure in ORNL's microturbine test facility, a series of aging tests were performed in inert gas at various temperatures and times of duration. It was found that exposure to high temperature leads to strengthening of the material (increase in yield strength) most likely due to carbide precipitates. It was also found that aging decreases the ductility and ultimate tensile strength and that the magnitude in the reduction is accentuated by oxidation.

Status of Milestones

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

Industry Interactions

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

SUBTASK 2.2.2. MICROSTRUCTURAL CHARACTERIZATION OF CFCCS AND PROTECTIVE COATINGS

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Objective

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

Highlights

The exposure of several candidate EBC compositions on SiC/SiC CFCC substrates was conducted this Quarter to evaluate possible improved EBCs (compared with Si/(Mullite+BSAS)/BSAS) for the next set of combustor liners to be manufactured for engine testing by Solar Turbines at Bakersfield, CA engine test site. The EBCS were exposed to 15% H_2O @ 1200°C for 500h and 1000h and then cross-sectioned to measure the amount of substrate oxidation below the EBC.

Technical Progress

Three different EBC formulations were applied to SiC/SiC CFCC coupons. One set of three coupons was exposed for 500h and another set of three coupons was exposed for 1000h at 1200°C and 15% water-vapor. The layeredEBCs supplied by UTRC for these exposures were:

1. Si/Yttrium silicate(s)
2. Si/Mullite/SAS/HfO2
3. Si/(mullite+BSAS)/BSAS (standard)

Following exposure in ORNL's Keiser Rig, each exposed EBC/CFCC sample was cross-sectioned in order to evaluate the amount of oxidation below the EBC. The microstructural analysis data from these EBCs will not be discussed here, but has been sent to UTRC for future EBC down-selections for CFCC combustor liner applications.

Status of Milestones

Publish report on the exposure of oxide/oxide CMCs at high H_2O pressures and 3 temperatures. *May 2006 – in progress.*

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 – in progress.*

Industry Interactions

Exposed new EBCs in Keiser Rig for UTRC as part of Combustor Liner work.

SUBTASK 2.2.3. HOT SECTION MATERIALS DEVELOPMENT FOR ADVANCED MICROTURBINES

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Objective

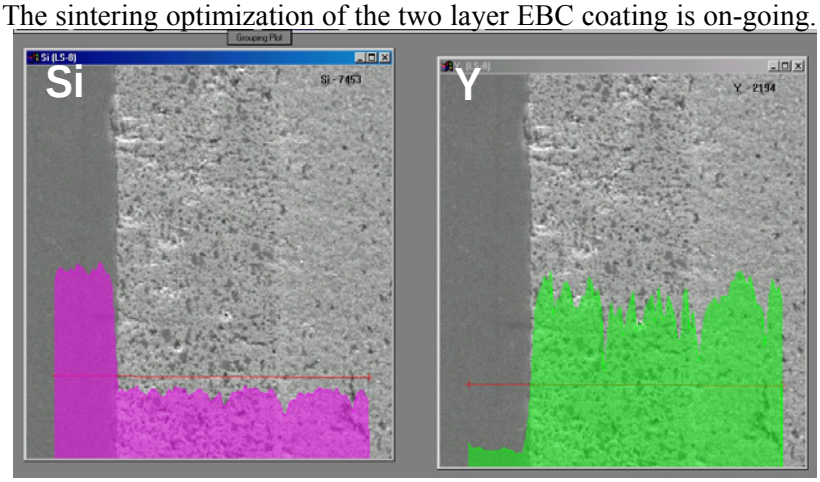
The goal of this program is to develop and optimize a high temperature silicon nitride based ceramic material (NT154) and forming process suitable for microturbine hot section component applications.

Highlights

Bonding between NT154 and our novel EBC compositions has been improved through process modifications.

Technical Progress

The sintering optimization of the two layer EBC coating is on-going. Past work had suggested that better bonding between the NT154 substrate and the EBC bond coat is desired. The sintering study is investigating various temperature, time and environment conditions. The optimized procedure has resulted in improved inter diffusion between the substrate and bond coat (see photo), implying improved adhesion.



Using the established SOP, test samples will be produced for mechanical, thermal shock and recession testing. Efforts continue to be made to reduce the coating defects, improve coating thickness uniformity and sintered density.

Significant effort has been directed towards further improvement in the high temperature slow crack growth (SCG) resistance of NT154. Typical dynamic fatigue (n) values have been in the 30-40 range. Improvements have been made to the material performance by reducing the two grain junction glass film length through grain coarsening. A dynamic fatigue exponent (n) as high as 115, at 1200°C, has been measured on the material. However, we are trying to understand the cause for some variability observed in the 1200ºC dynamic fatigue test data. In addition, efforts are being made to increase the properties of the grain boundary phase at high temperatures (~1000-1300°C).

Status of Milestones

- Improve Slow Crack Growth (SCG) resistance (exponent "n") of NT154 silicon nitride by a factor of two at both room temperature and 1204ºC. – 9/06 (RT done, 1204ºC on-going).
- Develop a non line of sight coating procedure (such as dip coating) for the net shape turbine components (IBR, Vane, etc.) using optimized EBC system proven in the Keiser Rig – 6/06 (EBC material proven, coating procedure development is on-going).

Industry Interactions

- Technical papers were presented by V.K. Pujari and R.H. Licht at the 30th ACerS Cocoa Beach Conference and the 30th USACA ITAR Restricted Conference on Composites, Materials and Structures (January 23-27, 2006) respectively, highlighting our progress towards ceramic

microturbine component and EBC development. Meeting held with technical monitor Terry Tiegs, ORNL, to update development progress.

- Meeting with United Technologies personnel, on February 15th, to discuss material and component fabrication development.
- Communications with John Holowczak and Bill Tredway of UTRC to discuss material and component fabrication development.
- Discussions with HT Lin, ORNL, regarding mechanical testing of NT154 material.

SUBTASK 2.2.4. OXIDATION/CORROSION CHARACTERIZATION OF MICROTURBINE MATERIALS

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Objective

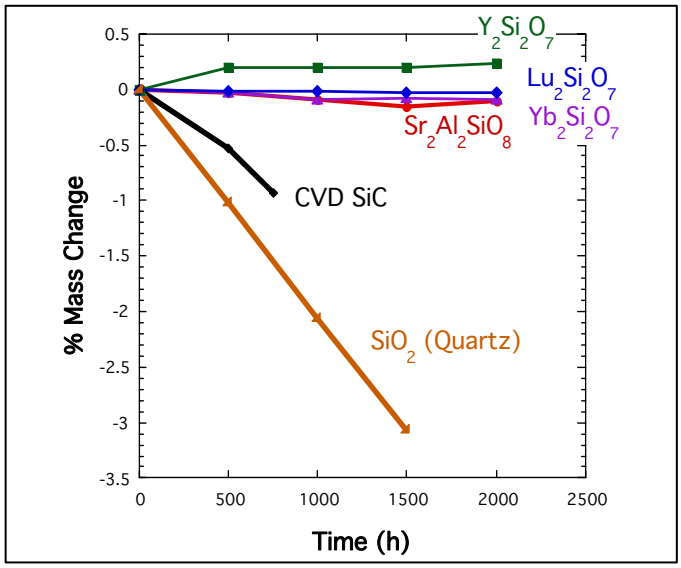
Environmental barrier coatings (EBCs) will be required on surfaces of Si-based ceramic and composite materials exposed to microturbine combustion (high water-vapor pressure) environments. EBC systems are currently being developed for use on Si_3N_4 hot-section microturbine components. The reliability 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 several candidate EBC compositions to extremely high water-vapor pressures in ORNL Keiser Rigs was continued during this reporting period and 2000h of exposure time has been 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, EBC compositions processed by Steve Nunn at ORNL 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. These EBC compositions included $Y_2Si_2O_7$, $Lu_2Si_2O_7$, $Yb_2Si_2O_7$, and $Sr_2Al_2SiO_8$. Each exposed stand-alone 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. The plot (right) shows the weight change for the series of four EBC compositions (compared to standard materials, CVD SiC and SiO_2), all of which exhibited very good volatilization resistance. The weight changes observed for 3 of the exposed EBCs were minimal (especially compared with CVD SiC and SiO_2) and one EBC consistently showed a slight weight gain ($Y_2Si_2O_7$).



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 – on task.*

Industry Interactions

Exposed new EBCs in Keiser Rig for UTRC as part of Combustor Liner project.

SUBTASK 2.25 PORTABLE MULTI-FUEL TEST RIG (THE PORTABLE RIG)

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Objective

The objective of the project is to develop a unique rig at ORNL to evaluate the exhaust emission and assess the degradation of structural materials of turbines, recip 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 various 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 heated to the desired test temperature and spiked with toxic species or components that may accelerate corrosion

Technical Progress

We have finished the conceptual design of the FFTET Rig which consists of three modules: 1) Microturbine specially modified for materials testing; 2) Gas sampling and analysis unit; and 3) Test module for exposure of samples in a controlled temperature stream of spiked exhaust gas. A specially modified microturbine constructed by Capstone is currently being used at ORNL for exposure of test samples in the exhaust stream, and the company has expressed an interest in working with us to modify a microturbine for this new test system. The two remaining modules, ie, the Gas Sampling unit, and the Controlled Environment Module for corrosion studies will be designed and fabricated in-house at ORNL. We are in the process of completing the detailed design and collecting quotes for the Capital Equipment Purchase.

Status of Milestones

Completion of designing the FFTET Rig. On time.

Industry Interactions

Meeting with Dr. Paul Lemar Jr. from Resource Dynamics Co. at NTRC, attending his presentation on "Materials needs for turbines/Recips on alternative fuels."

Telephone meeting with Mr. Jeff Armstrong of Ingsoll-Rand (IR) on the thermal barrier coating (TBC) analysis. IR has experienced TBC coating premature failure from turbines running on landfill gases. We have agreed to carry out an investigation on these TBC coatings.

SUBTASK 2.2.6. CHARACTERIZATION OF OXIDATION RESISTANT CERAMICS AND SILICON NITRIDES

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Objectives

- 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.
- 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 12OO °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 .Last quarter the problem with the current NT154 was identified and solutions proposed to both Saint Gobain and UTRC.

Technical Progress

Status Of Milestones

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

Industry Interactions

Discussed technical needs with John Holocwak of UTRC.

SUBTASK 2.2.7. MECHANICAL RELIABILITY EVALUATION OF MICROTURBINE COMPONENTS

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Objective

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

Highlights

Results of FGI oxide-oxide CMC specimens exposed to high-temperature steam jet at temperatures between 1200°C and 1288°C for 500h showed that there was little material recession on the top surface of FGI coating. However, no material recession and degradation possibly induced by the inward diffusion of oxygen as well as water vapor was observed in the bulk of FGI as well as in the oxide-oxide CMC substrate, suggesting the excellent microstructure stability of FGI at elevated temperatures under steam jet environment.

Technical Progress

Dynamic fatigue tests at 1204°C on NT154 specimens after post heat treatment to improve the secondary phase crystallization have been completed. Mechanical results showed that the heat-treated specimens exhibit similar low fatigue exponent to those in as-sintered condition, indicating the heat treatment employed did not improve the SCG resistance.

The high-temperature steam jet exposure at 1200°C for 500h for the pre-strained FGI oxide-oxide CMC specimens (up to 0.25%) is in progress. 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.

High-temperature tensile creep tests of ODS alloys as well as FGI oxide-oxide CMC have been initiated during this quarterly report period to generate database for probabilistic component design and life prediction of Solar Turbines.

Characterization tasks of thermal diffusivity, phase content, residual stress, and micro hardness of TBC samples received from Solar Turbines have also been initiated to evaluate the long-term microstructure stability after 40,000h engine field service.

Status of Milestones

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

Industry Interactions

- Communications and conference calls with Vimal Pujari and Ara Vartabedian at Saint-Gobain on the dynamic fatigue mechanical results of NT154 after post heat treatment.
- Communication with John Holowczak and Bill Tredway at UTRC on the updated mechanical results of Saint-Gobain NT154 silicon nitride.
- Communications with Mark van Roode and Arun Bhattacharya at Solar Turbines on the up-to-date status on the tensile creep testing of ODS alloys.
- Communications with Chris Campbell 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

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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 collaborator's material systems continues. New additive systems 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 collaborator's candidate materials systems. Rheology, dipping, and sintering studies continue with new additive systems in order to improve the coated sample densities and adhesion. Iterations of coating, sintering, and characterization to minimize sintering temperatures and maximize coating uniformity, desired thicknesses and densities are in progress. Promising systems will be submitted to collaborators for simulated exposure testing.

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

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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.

Highlights

CARES and WeibPar undergo continuous upgrades this quarter.

Technical Progress

DER Industry Support: Efforts continue to update and add information to the www.CeramicReliability.com website. Background information enhanced. Software download area enhanced. Links to other pertinent web sites have been added.

CARES: The licensing process has been revised. A license validity indicator has been added. Updates to the onlile User Guide have been made. Updates have been made to the online Theory Guide. Current version is now compatible with WeibPar version 4.0. Long file names issue has been addressed.

WeibPar: Licensing process has been revised. Updates to the online User Guide have been made. Current version is compatible with CARES version 7.3. The probability of failure expressed as a percentage has been added to the Weibull plots. Specimen geometry screen has been updated to include an option to process results from a finite element analysis. The pooled data analysis now can process information from a finite element analysis

Status of Milestones

- ANSCARES Update for Compatibility with ANSYS 9.0. ***June 2005 – completed***
- CARES amd WeibPar updates. ***October 2005 – ongoing***
- Support for DER Industry Partners. ***Ongoing***
- Support for the Interfacing of IRASoft with CARES and WeibPar. ***January 2006 – on track***
- Create a brittle materials theory manual. ***December 2005 – completed (CARES help file)***

Industry Interactions

A three day short course on Weibull Analysis was presented at Honeywell in South Bend, Indiana the week of March 13, 2006.

2.3.1. ADVANCED MATERIALS FOR RECIPROCATING ENGINE EXHAUST COMPONENTS

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Objective

Next generation NG reciprocating engines will have higher in-cylinder pressures and temperatures to provide higher power density and efficiency, and lower emissions. Component materials therefore face the paradox of similar or increased life and reliability, while withstanding higher temperatures, which tends to reduce both. A further constraint is maintaining reasonable costs. In FY2005, ORNL extended its collaborative program with Waukesha Engine, Dresser, Inc. (WED) on characterizing the effects of long term engine exposure on exhaust valves, to also include its component supplier, TRW Engine Components (TRW). The mechanical and oxidation properties behavior of current exhaust valves, and the underlying microstructural changes during engine service, all provide the baseline against to measure improved performance. In FY2006, ORNL has characterized current exhaust valves with long-term engine exposure to clearly show microstructural changes responsible for their performance limitations. Such data is now the basis for collaboration with TRW for alloy selection and processing modifications to produce advanced exhaust valves with more temperature capability and performance.

Highlights

Based on direct ORNL microanalysis engine-tested and failed Ni-based superalloy exhaust valves, surface oxidation accelerated by moisture in the exhaust gas appears to initiate fatigue-failure. ORNL, TRW and WED have identified commercial coatings that can be applied to several Ni-based superalloys used for exhaust valves, and are now producing specimens that can be used for lab-testing, as well as coated valves that can be used for engine testing. Both kinds of testing to measure degradation-resistance will begin next quarter.

Progress

Collaborative work between ORNL and Waukesha Engine Dresser, Inc. (WED) expanded in FY2004 to include both intake and exhaust valves, and their seats, and then in FY2005, focused more specifically on the Ni-based superalloy (Pyromet 31V) exhaust valves. Comparison of fresh components with a series of unfailed exhaust valves engine-tested from 750 h to as long as 22,000 h, and a valve with premature failure were completed last quarter. This quarter, ORNL completed detailed microanalysis of a series of Pyromet 31V alloy control specimens aged at 700-800^{o}C for 100, 1000, and 3000h, which showed relative $\gamma'(Ni_3Al)$ stability at 700-750^{o}C, but then rapid coarsening at 800^{o}C. Comparison of the aged specimens to the series of engine-exposed valves and to failed valve with premature failure suggested that accelerated oxidation attack due to moisture-accelerated oxidation rather than over-temperature was the root cause of failure. ORNL and TRW identified commercial coatings rather than alloy compositional modifications as the best approach to enhance such failure resistance, and are getting both specimens for lab-testing and some valves for engine-testing coated. This quarter, microstructural analysis comparing new exhaust valves of several different Ni-based superalloys and with processing modifications were completed. Testing of the coating specimens and valves to evaluate the process and their performance will begin next quarter.

Milestones

Complete testing, aging and evaluation studies of exhaust valve alloys to determine temperature limitations, and the potential of coatings to extend reliable lifetime at those temperatures in collaboration with TRW. (July 2006) Task is on-track for scheduled completion

Meetings

Conference calls and communications with principal investigators at WED and/or TRW occur.

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

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Objective

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

Highlights

A baseline short term (67 h) engine test of spark plugs made from ORNL model and developmental electrode alloys was completed at ORNL in a Caterpillar G3406 industrial natural gas engine. Post test gap measurements, breakdown voltage, and optical spectroscopy have been completed, and microstructural analysis is in progress. These results will be compared with previous studies of field-tested plugs.

Technical Progress

An initial baseline 67 h engine test of spark plugs made from ORNL model and developmental electrode alloys without precious metal electrode insert pads was completed at ORNL using a Caterpillar G3406 industrial natural gas engine. Post test gap measurements, breakdown voltage, and optical spectroscopy were completed. Alloying additions to increase oxidation resistance also are suspected to have lowered alloy thermal and electrical conductivities such that lower gap growth rates did not result because the plugs ran hotter. The total extent of gap growth also did not correlate well with oxidation as the primary material removal process. However, it should be noted that these tests incorporated solid electrodes as this exploratory stage, which artificially increases the importance of alloy thermal and electrical conductivities in the test. In optimized plugs for field use, the electrodes are Cu cored, which significantly improves conductivities. Microstructural analysis of the electrode alloys is in progress, and will be compared with short term field tested plugs studied previously. A test matrix of a second iteration of plugs, utilizing precious metal inserts and electrode alloys selected based on insights gained to date in this program has been agreed upon with Federal Mogul (Champion®) and will be manufactured in Spring of 2006 with engine testing at ORNL anticipated in summer 2006.

Status of Milestones

- Evaluate developmental spark plugs in an industrial natural gas burning reciprocating engine (Sept. 2006) -on track
- Develop a database for spark plug performance under temperature and pressure conditions using the newly developed test chamber at NTRC (Sept 2006) – as funds allow

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.

SUBTASK2.3.3. Optimization of In-Cylinder Materials for Reciprocating Natural Gas Engines

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Objectives

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

Highlights

Testing for the friction and wear behavior of valve stems and guides has started. Testing of current valve stem and guide materials are being carried out as a baseline from which alternate materials can be compared. A test plan has been developed with Waukesha Engine, Dresser (WED) to test for the effects of filtration level on oil condition and in-cylinder deposit formation.

Technical Progress

Initial testing of current conventional valve stem and guide materials has started but no data is yet available since the testing conditions are being varied to determine the final test protocol. Used oil is being used as the lubricant in varying quantities to simulate oil-starved conditions.

A plan was developed with representatives from WED to test the effect of filtration on oil condition and the tendency to form in-cylinder deposits. 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

The tests will be run for 500 hours each in pre-aged oil to accelerate oil degradation. Oil condition will be tracked by a combination of conventional analysis to determine wear metals, decomposition products, viscosity, and TBN along with the measurement of sludge contamination using the method described in previous reports. A post-test examination will be made in-cylinder to determine the extent of sludge formation on valves and piston rings. Filters will be examined for the amount of contaminant removed. The hardware necessary to conduct the tests has been assembled at WED.

Status of Milestones

- Report on the characterization of current valve materials and deposits as well as used oil. *June 2005 – completed.*
- Establishment of a new lubricant test to detect the concentration of precursor contaminants. *March 2006 – completed (see below).*
- Compare friction and wear performance using a rig test of the carbon foam guides with conventional materials. *June 2006 – on task.*
- Fabrication of prototype carbon foam guide. *August 2006 – on task.*

  Although the last two milestones are currently on task, funding reductions could threaten their on-time completion unless additional sources of funding can be secured.

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 of Waukesha Engine, Dresser.

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

The sludge measurement procedure, along with a characterization of the higher molecular weight contaminants were documented in two papers which were submitted and reviewed for the Proceedings of the 2006 annual meeting of the Society of Tribologists and Lubrication Engineers to be held in Calgary in May. The titles are:

"Development of a Procedure to Measure Oil Sludge Content using Thermogravimetric Analysis" by G. A. Mullins and J. J. Truhan

"Characterization of Semi-volatile Species in Used Natural Gas Engine Lubricating Oils" by G. A. Mullins and J. J. Truhan

Section 3. Thermally Activated Technologies

SUBTASK 3.2B. TAT LAB PERFORMANCE AND ANALYSIS

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Objective

ORNL will provide technical support, minimal testing, and guidance for the NETL managed subcontracts during the transition period for the subcontracted activity.

Highlights

ORNL completed the evaluation of "Heating-Only" advanced ammonia-water absorption heat pump unit in the environmental chambers at various outdoor conditions.

Technical Progress

Evaluation of the advanced ammonia-water absorption heat pump (Heating-Only) unit was completed in the environmental chambers. These tests included the performance and emissions of this unit at various outdoor conditions. These tests were reported to Rocky Research.

Status of Milestone(s)

Provided NETL with a copy of the technical evaluation report on in-house testing performed on advanced ammonia-water heat pump (Heating-Only) unit. ORNL will provide technical support as requested by NETL.

Industry Interactions

Partners include: Rocky Research.

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

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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.

Technical Progress

Carnegie-Mellon University - CMU has had a very successful heating season and we are beginning to get to cooling season days, but still no humidity. One of the CMU PHD candidates is using the Revolution as the basis of her thesis.

Lowes – The installation at the Lowes Store is complete. The Revolution unit brings in a high percentage of outdoor air and delivers it at a low dewpoint. The unit also includes the high efficiency heat pump option. The unit will be jointly monitored by Lowes and SEMCO for the next 9 months or so. SEMCO is working with Lowes to get access to their high speed network to monitor the unit. Downloadable performance data should be available within the next few weeks. Performance data is being archived now.

Status of Milestone(s)

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

Industry

SEMCO, Incorporated

SUBTASK 3.7B. THERMAL ENERGY PERFORMANCE EVALUATION

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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

The GOETTL environmental test chamber has arrived and is in storage at ORNL. We are evaluating several locations for placing the chamber so that we can begin tests early in FY 2007. In addition, we are negotiating a contract with Patrick Collins, a consultant with experience in assembling environmental chambers, to aid in installation.

Contact was initiated with Patrick Atkins regarding waste heat recovery from aluminum smelting operations. He seemed quite interested in the work that ORNL was involved with and we discussed the potential for collaboration in the future.

Technical Progress

ORNL has initiated work on developing a superhydrophobic surface coating that can be applied to a finned heat exchanger. Glass micro spheres were ordered and will undergo a process to yield a superhydrophobic surface. They will then be combined with an adhesive and applied to the heat exchanger surface.

Status of Milestone(s)

Progress is consistent with the August 2006 milestone established for this activity.

Industry Interactions

Alcoa

Subtask 3.7c. Micro-Channel Heat Exchanger Development

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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

ORNL is working with AHT to supply a prototype heat exchanger for the next generation Southwest Gas unit. We have obtained working drawings from Southwest Gas that describes the capacity, airflow, and dimensions of the existing heat exchanger. The challenge will be to design two refrigerant circuits intertwined in a single heat exchanger as the present design uses two separate circuits.

Status of Milestone(s)

Milestone is on schedule for testing in September 2006.

Industry Interactions

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

SUBTASK 3.7G. CFD MODELING ANALYSIS

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Objective

In addition to flow visualization resources, ORNL will develop computational fluid dynamic modeling capabilities to determine flow characteristics of the air passing through the heat exchanger for both experimental tests in a tunnel and for a heat exchanger installed in a system.

Highlights

Patrick Geoghegan, a research engineer at the Wellcome Trust-Sanger Institute in Cambridge, was hired to conduct design studies on heat and mass transfer for heat exchangers using computational fluid dynamics modeling techniques. Dr. Geoghegan will begin work on May 8th. The start date was delayed due to the length of time required to obtain his visa.

Technical Progress

See "Status of Milestone(s)" below.

Status of Milestone(s)

CFD laboratory is completed. However, initial modeling efforts will be delayed till June as the result of the length of time required to obtain a Post-Doc and satisfy visa requirements to begin employment.

Section 4. End Use Systems Integration and Interface

Subtask 4.1.1a. Packaged/Modular IES Development

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Objective

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]

- 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]

- 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

PureComfortTM 330R CCHP System was released. UTC Power proudly introduced the PureComfort™ 330R cooling, heating and power solution; a reliable energy source with low emissions. This innovative system features a proven absorption chiller/heater that provides space cooling in the summer, space heating in the winter and continuous year-round thermal capacity, while a lean-burn reciprocating engine provides 334 kW of reliable power year-round. This results in a simultaneous heating and cooling system.

The thermal capacity can be used for domestic hot water, supplemental heating, reheat for HVAC systems and/or preheating for facilities systems. As a result, overall grid power consumption is significantly reduced throughout the year.

The PureComfort™ 330R solution includes a double-effect absorption chiller/heater from Carrier Corporation, a world leader in building, heating, cooling and control networks. The chiller/heater is driven by the exhaust from the lean-burn engine. With the double-effect absorption chiller/heater, the PureComfort™ 330R solution can achieve an overall energy utilization of more than 80% which is far greater than the 33% typical of a central power plant.

The remote monitoring feature enables our service organization to monitor system performance round-the-clock, which means we can respond quickly if there's ever a need, minimizing downtime.

Features

- High energy efficiency
- Low emissions
- Indoor/outdoor capable
- Scalable configuration
- Proven technology
- Operates both grid connect/independent

Benefits

- Lower electric bills
- Environmentally friendly
- Increased flexibility
- Maximizes energy savings
- High availability
- Continuous business operation

Burns and McDonnell

Domain System Date acquisition and performance reports have been reviewed by ORNL. Burns & McDonnell is incorporating comments.

Schedule Dell CHP Project: As of this report, it is anticipated that the IES fabrication will be completed by late spring 2006 with commissioning occurring in the summer of 2006.

Tours of the Domain and the Dell sites are planned for April 20th in conjunction with the Gulf Coast CHP Application Center, CHP Seminar, with over 130 participants expected.

Honeywell

The Integrated Energy System operated throughout the quarter, providing electricity and heating (steam and hot water) to the buildings on the post. The absorption chiller (and other cooling equipment) will remain offline until the cooling season begins in the spring of 2006.

A report entitled, “Modular Integrated Energy Systems, Task 6 Field Monitoring Interim Report Period covered: May 2005-August 2005. ORNL is reviewing and providing final comments on this document.

ORNL reviewed and provided final comments on the Honeywell/IC Thomasson document entitled, "Modular Integrated Energy systems, Task 5 Prototype Development Reference Design Document."

Performance Data indicate that the Integrated Energy System fuel use efficiency is:

- >70% year-round
- Frequently >75% even in cooling-only operating mode

Technical Progress

UTRC

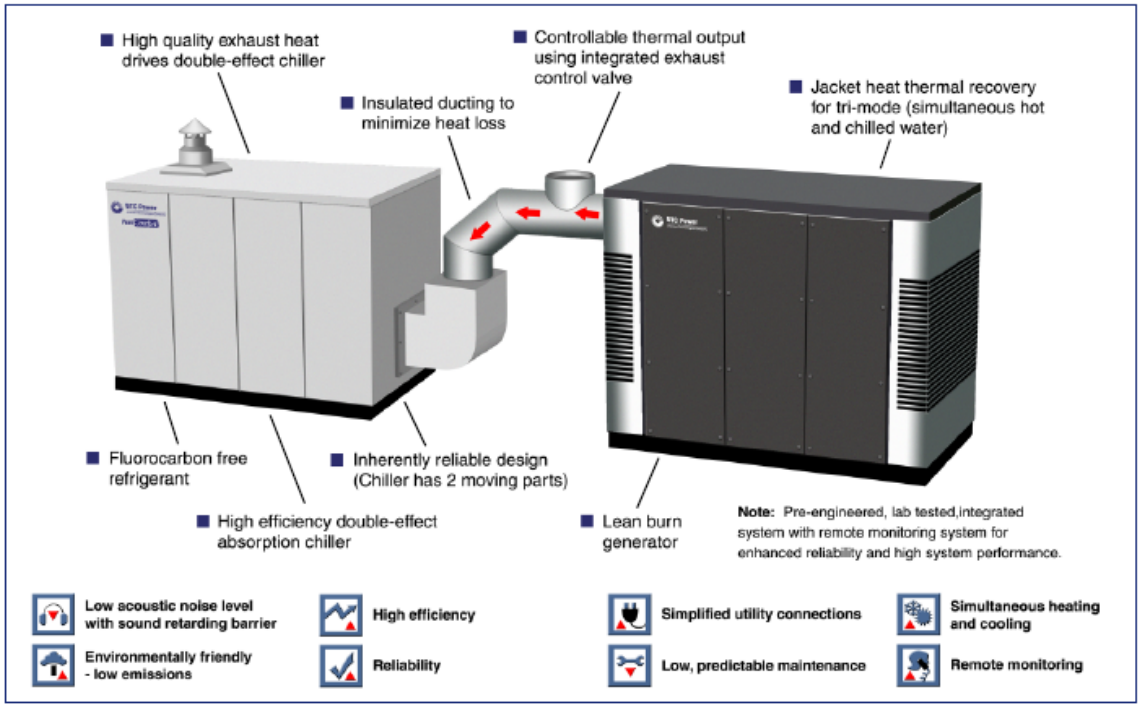
Work during this period focused upon Tasks 11.6 and 13.3 of the Program Plan.

The objective of Task 11.6 (ID and Evaluation) is the identification, analysis and selection of system modifications to enable simultaneous generation of electricity, cooling and heating from a microturbine/chiller CHP system. This "Trigeneration" capability would be advantageous for buildings with multiple zones having independent thermal loads, e.g., buildings where some zones have constant cooling loads while other zones of the building have seasonally-varying thermal loads. Another application benefiting from this technology would be buildings that are located in climates requiring daytime cooling and nighttime heating.

In Task 13.3 (System Technology Readiness), a system level feasibility demonstration to characterize and quantify performance and reliability of the integrated reciprocating engine and hybrid absorption chiller CHP system selected for development in Task 12 was performed. The chiller has been received, the facility was commissioned in January 2006, the complete reciprocating engine driven system was assembled and tested, and new products were announced.

As a result of the Task 11 and 13 activities, new products were announced, i.e., PureComfort^{TM} 330R CCHP System.

The PureComfort^{TM} 330R CCHP has a lean-burn reciprocating engine prime mover. This system utilizes a 334 kWe reciprocating engine's exhaust to drive an absorption chiller. Additional thermal heat is available for simultaneous tri-generation capabilities. This system is available through out the U.S. but doesn't meet California CARB 2007 emissions levels.



Burns & McDonnell

ORNL and Burns & McDonnell continued to facilitate the implementation of an engineered solution to correct the chiller capacity degradation. A conference call was held on January 6, 2006 with Broad and Austin Energy to discuss results of chiller gas sampling and the path forward to a final solution. Broad submitted a work plan to Austin Energy to install an upgraded purge system allowing the chiller to operate at capacity under intermittent operating conditions. The work plan and drawings are being reviewed by Austin Energy. It is anticipated that this solution will be implemented prior to the beginning of the 2006 cooling season (May 2006), so that the work can be accomplished while the system is idle.

The FY 05 data collection effort was completed October 31, 2005. Performance assessment reports for the months of May, June, August and September were reviewed ORNL. B&McD continues the effort to incorporate ORNL comments into the final versions of these reports. It is anticipated the final version of these reports, along with the October 2005 Performance Assessment Report, will be submitted in early April 2006. The performance assessment task for the Domain project will then be complete.

Burns & McDonnell and the University of Texas at Austin are revising UT's final performance assessment report to incorporate ORNL comments.

Burns & McDonnell, the University of Iowa (UOI) and Milster Engineering, LLC continued to collaborate on the data mining task in support of the Domain CHP system performance assessment. UOI, ORNL and Burns & McDonnell held a conference call on January 13, 2006 to discuss further UOI's methodology. A revised report was submitted to ORNL on February 15, 2006 for review and comment.

Burns & McDonnell prepared a Dell IES project flyer, with ORNL input, to be used at industry conferences, peer review meetings, website postings etc. This flyer will be updated periodically to include project progress and system performance information. The following deliverables are being produced:

- Equipment Anchoring Design Package.
- Mechanical Piping and HVAC Design Package.
- Economic Modeling Task, including a review of ORNL CHP modeling tools and development of recommendations to improve both the ORNL and Burns & McDonnell modeling tools.

Progress on the project design milestones is summarized below. The items in bold are updates from the previous progress report:
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

The following summarizes of installation progress to-date:

- Cooling tower fabrication is complete and it has been leak tested.
- Chill water system has been tested.
- The electric chiller / electric controls module has been installed.
- Piping has been installed between the electric chiller skid and the cooling tower.
- TES tank installation is complete.
- Transformers are set in place and have been tested.
- Switchgear is set in place and is being tested.
- Absorption chiller is set in place with piping interconnections made on the cooling water and chilled water side. Chiller start-up for acceptance testing is scheduled for early to mid-May 2006.
- Packaged boiler is set in place.
- Natural gas compressor is set in place.
- HRSG has been set in place and all piping and equipment is installed on the boiler.
- Diverter valve assembly installation is complete.
- The two exhaust stacks are installed.
- Emergency generator is set in place and wiring has commenced.
- The combustion turbine installation is complete. Turbine start-up for acceptance testing is scheduled for early to mid-May 2006.

Schedule Dell CHP Project: As of this report, it is anticipated that the IES fabrication will be completed by late spring 2006 with commissioning occurring in the summer of 2006.

Honeywell
The "Modular Integrated Energy systems, Task 5 Prototype Development Reference Design Document." presents a set of Reference Designs for Modular Integrated Energy Systems (IES). These designs were prepared under a research and development project funded by the U.S. Department of Energy (DOE). This work was administered by Oak Ridge National Laboratory (ORNL) under subcontract number 4000011476 entitled "Research, Development and Demonstration of Packaged Cooling, Heating, and Power Systems for Buildings".

The technical work in developing the Reference Designs was led by I.C. Thomasson, with support from Broad USA and Honeywell. The technical description of the Reference Designs is presented. Development of standardized packaged IES modular systems will provide lower life-cycle costs, and will also speed the acceptance of this technology in the marketplace. Streamlining the upfront design process is needed to produce the greatest benefit from IES technology. The project team's focus is on IES modular systems in the 1- to 5-MW size range, with 900 to 3000 tons of cooling. These systems are typically intended for central plant and district energy applications serving multiple buildings.

Because large IES systems' (1 to 5MW in size) installation scenarios vary widely, packaging is dependent on modularity, namely, the ability to construct a system by choosing from a selection of compatible components with standardized interfaces. This is especially important for larger IES systems, where the physical size of the equipment prohibits the manufacture and shipment of the entire system in one enclosure. Designing these systems as a number of component modules with each corresponding to a

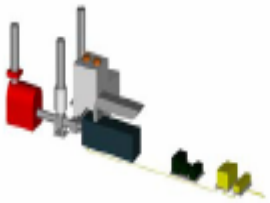
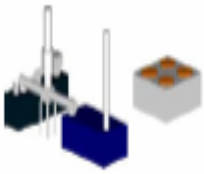
piece of major equipment (i.e. gas turbine-generator, heat recovery steam generator, and absorption chiller or chiller-heater) simplify the design and installation process by reducing the amount of site-specific engineering and site preparation required. The benefits of applying a "reference" package design are:

- The amount of custom design work for a given site application is greatly reduced. These modular Reference Designs provide IES systems that are more cost-competitive through a reduction in installed cost and optimal matching of equipment to the energy loads.

- These improved economics can serve to validate applications that may have otherwise been difficult to justify (from a purely economic standpoint). For these applications, the other benefits provided by IES technology (e.g., reduced emissions, improved IAQ, and increased energy efficiency) are thus made available to the central plant/building owner and occupants.
- Readily available reference designs can serve to shorten the time required to perform the upfront analysis needed to quantify the economic and other benefits offered in each individual application. This will help speed the process of evaluating candidate IES applications.

- The Reference Designs are built around a gas turbine as the prime mover, and an exhaust-driven absorption chiller (or chiller-heater). An overview of the designs is shown in the following table.

Reference Design Overview

Title	Arrangement	Description
R-1		5.7-MW Turbine, 1,000-Ton Chiller, Outdoor Installation with HRSG and Inlet Air Cooler, New Chiller Building, Existing Plant Expansion
R-2		5.3-MW Turbine, 3,300-Ton Chiller-Heater, New Standalone Plant Building
R-4		4.6-MW Turbine, 1,300-Ton Chiller-Heater, Complete Outdoor Installation, Auxiliaries Installed in Existing Space
R-6		3.5-MW Turbine, 2,000-Ton Chiller-Heater, New Standalone Plant Building, Dual Chiller-Heaters
R-8		1[illegible]W Turbine, 900-Ton Chiller-Heater, Existing Plant Expansion, All Contained in Existing Space

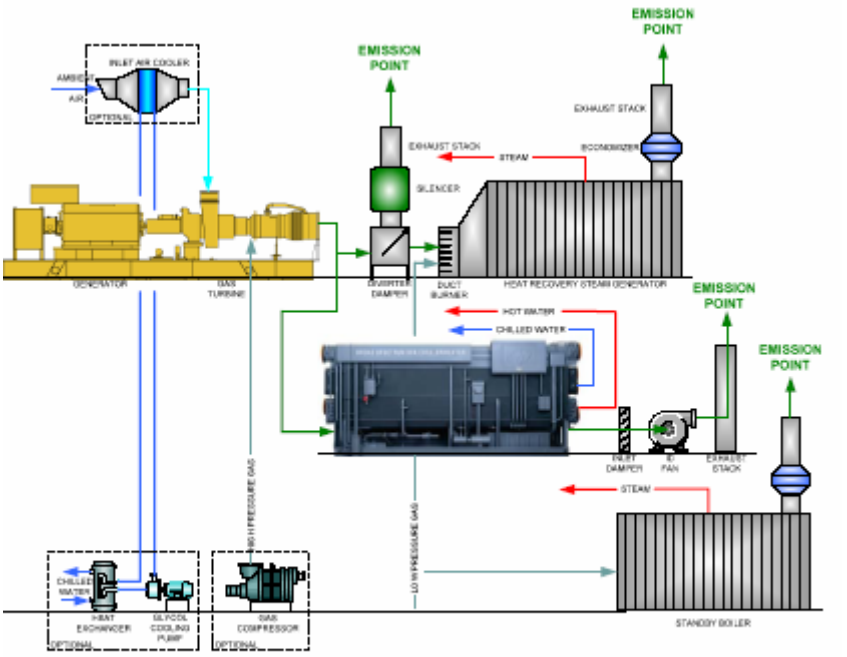


Figure 2-1. System Arrangement: Reference Design R-1

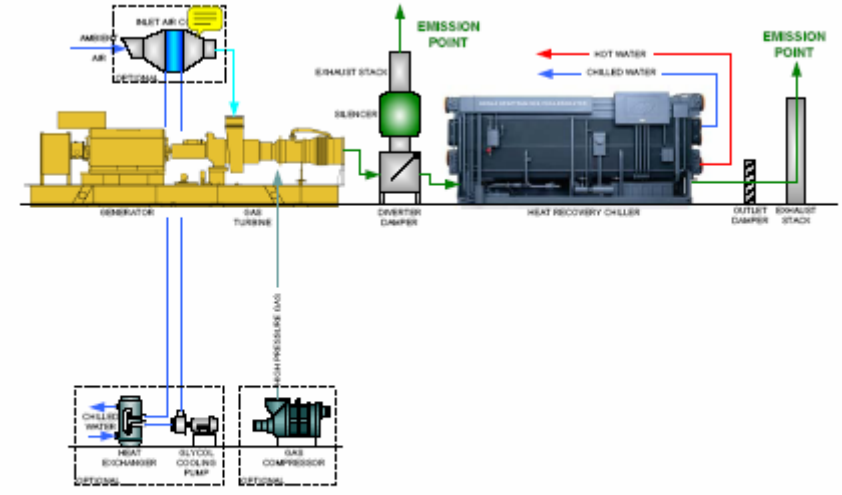


Figure 2-2. System Arrangement: Reference Design R-2, R-4, and R-8

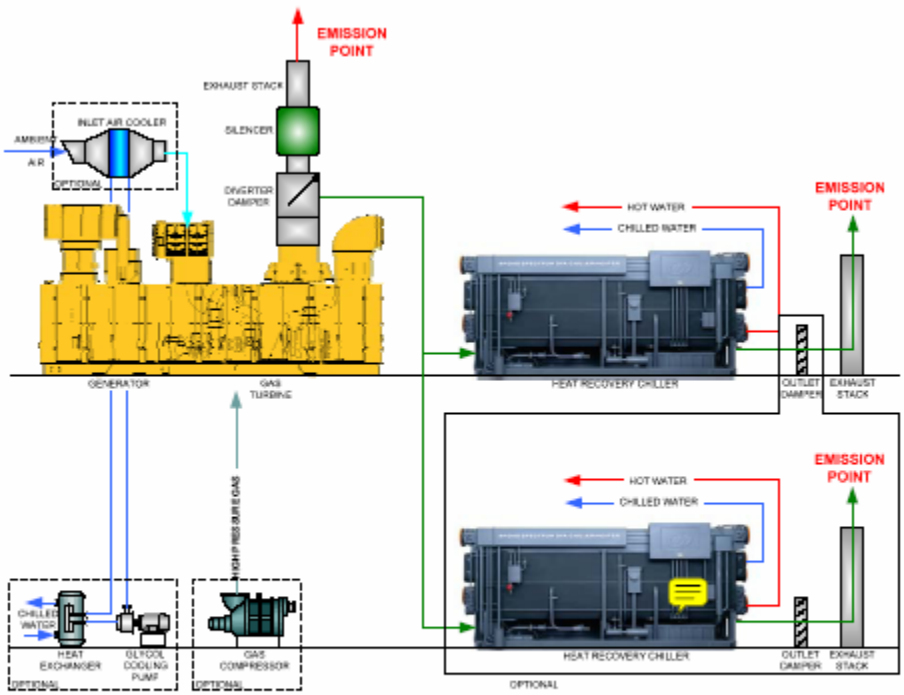


Figure 2-3. System Arrangement: Reference Design R-6

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

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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

- Both CHP systems have been winterized. The microturbine has been operated on a periodic basis.
- Shirley Luo attended the 1-week microturbine training class.
- ORNL is working with the University of Maryland on a close-out plan for this project.

Technical Progress

System 1 - The liquid desiccant cooling tower has been drained and the LDU will not be operated until spring. Work on System 1 this month focused on testing to identify the cause of cooling water flow and overheating problems. The problem has been narrowed down to a defective control valve and/or contamination in the system that is periodically plugging the valve. Next steps are to drain the coolant system, install a filter, and refill it with cleaned glycol/water solution.

System 2 - The chilled water system was drained for the winter in October, hence the absorption chiller did not operate. The microturbine was operated at power levels ranging from 50 – 60 kW for several days in February to collect data for investigating system performance to determine if core replacement in 2005 has affected operating characteristics. Shirley Luo attended a 1 week training class to learn basic operation and maintenance for the Capstone microturbine. In addition, the microturbine was operated at power levels ranging from 50 – 60 kW for 12 days in January. The work focused collecting data to characterize performance over a range of operating conditions.

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
On schedule.

Subtask 4.1.2c. DE Integration Lab Test and Evaluation

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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 unit) with R407C (interim alternate refrigerant) was initiated. The performance and emissions of this unit is currently being evaluated at various indoor and outdoor conditions in cooling and heating modes. These tests are being conducted ARI Standard 210/240 rating conditions and at temperatures greater than 110ºF. These tests are being reported to the manufacturer.

In addition, the installation of the hot water-fired Rotartica lithium bromide/water air-cooled absorption unit (1.3-ton or 4.5 kW chiller) with rotating heat exchanger was completed. Rotartica personnel visited ORNL the week of February 27, 2006 during which they commissioned the unit. The data is currently available on the web at https://buildingstech.ornl.gov. In addition, a webcam is available to view the inside of the Rotartica unit. This has been a very useful tool for remote monitoring of the unit by the manufacturer.

Technical Progress

Initiate evaluations of the 10-ton packaged heat pump unit at various ambient conditions including ARI Standard 210/240-94 rating conditions. These tests include the performance and emissions of this unit at these conditions. These tests are being reported to the manufacturer.

Status of Milestone(s)

The 10-ton packaged heat pump was received and installed. Currently, the performance and emissions data collected on this unit are being reported to the manufacturer.

Industry Interactions

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

SUBTASK 4.1.2E. INTEGRATED ENERGY SYSTEMS TECHNOLOGY UPDATE

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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

forthcoming

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

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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

None

Technical Progress

S. 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.

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

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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.

Highlights

Thermax (an absorption chiller manufacturer headquartered in India, with sales offices in the U.S.) visited ORNL to discuss advanced absorption technology.

Bob. DeVault visited Blue Mountain Energy in Februarry to assist them in developing and coordinating technical project plans as part of Blue Mountain Energy's negotiations with NETL on the Gas Engine Driven A/C project.

Technical Progress

(See individual project reports.)

Status of Milestone(s)

(See individual project reports.)

Industry Interactions

In addition to numerous e-mails and telephone calls, meetings were held with a number of industry organizations. Meetings with industry included:

- Thermax visit to ORNL on advanced absorption technology.
- Review meetings with Blue Mountain Energy and Southwest Gas Company in Las Vegas, NV (GEDAC coordination).

SUBTASK 4.1.11. RESEARCH SURVEY, HISTORY OF DOE PROGRAMS

S. Fischer, P. Fairchild, subcontractor
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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

Space was obtained for the historical "database" of publications on one of the public internet servers at ORNL and work was initiated on creating web pages for viewing or downloading PDF files for publications. Significant effort was directed toward creating an organization or "structure" for the database. There are three computer files associated with each of the reports in the database; one containing HTML instructions that tell internet browsers (e.g. Internet Explorer, Netscape) how to display the web page, one containing a JPG image of the report cover, and a third with the PDF file itself.

Initial attention was given to the nearly 300 reports and publications that trace back to ORNL or subcontracts managed by ORNL. Web pages and "index" pages have been created for 158 of these reports; they can be viewed at http://www.ornl.gov/~fis/. Report covers and publication cover pages were "cleaned up" to remove evidence of wear and tear from 20 to 30 years of use by covering over undesired creases, stamps, and handwritten notes with clean patches. Abstracts from the publications were copied into the HTML code to be displayed alongside the picture of the cover, and links were created to other useful pages. Work continues on the remaining reports.

The URL listed above is a temporary "home" for the database. Once work is nearly completed the web pages will be moved to a server that is more accessible to outside users and entries will be made to various browser indexes for key-word searches (until that time it is unlikely that entries in the database will appear in random key-word searches of the internet).

Technical Progress

See "Highlights" above.

SUBTASK 4.1.12. GROUND-COUPLED/GEOTHERMAL ABSORPTION SYSTEMS CALCULATION

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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
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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

A report entitled, "CHP at ORNL" documented evaluation of a Mercury turbine installation at ORNL to meet electric and cooling loads. The economic evaluation concluded that annual operating costs would break even if electricity energy prices nearly doubled to $0.046/kWh while gas prices stayed constant at $7.50/MMBtu. A contract between DOE-Oak Ridge Operations (ORO) and Tennessee Valley Authority (TVA) has not been negotiated, but it is expected that this contract will not result in a large enough increase in electricity demand charges to justify an on-site CHP system.

Technical Progress

U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy through the Federal Energy Management and Distributed Energy Programs directed an evaluation of the Oak Ridge National Laboratory (ORNL) site for opportunities to deploy advanced Integrated Energy Systems (IES) which have recently been developed through ORNL/industry partnerships. DOE indicated the importance of improving the efficiency of energy supply at federal facilities. The evaluation is timely since ORNL infrastructure is being improved.

ORNL site infrastructure needs and facilities were matched with IES system designs to determine the best candidate for further evaluation. The IES reference design that was selected is the Solar Mercury 50 (4.6 MW) gas combustion turbine/generator integrated with Broad BE-400 (2600 ton) two-stage absorption chiller. Turbine exhaust would be used to produce 25 MBtu/hr of chilled and hot water simultaneously. ORNL's Central Chilled Water Plant would provide space for a stand-alone building to house the turbine, chillers, balance of plant equipment, and switchgear. The Mercury-based IES also offers ORNL research opportunities in advanced IES application, control, and power electronics.

Both quantitative economic factors and qualitative benefits were evaluated. The economic evaluation concluded that annual operating costs would break even if electricity energy prices nearly doubled to $0.046/kWh while gas prices stayed constant at $7.50/MMBtu. Therefore, a decision was made not to pursue system installation with current operating cost.

Reconsideration of an ORNL IES is recommended when the DOE-Oak Ridge-Tennessee Valley Authority (TVA) electric contract is renegotiated. Contract negotiations are scheduled for completion in early in FY06.

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

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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 – The kilns are shut down, which is a normal occurrence during the winter season.
- Arrow Linen – Data collection continues since October 2005.

Technical Progress

Higgins Brick: During the month of February, the CHP system was not in operation and the brick kiln was shut down for the winter break. The kiln is normally shut down in the winter months to avoid the high winter natural gas rates, allow any necessary repairs to the plant equipment, and to build up orders for the coming year. Currently, the kiln is expected to resume operation in the spring of 2006.

Arrow Linen: Data acquisition was initiated at the Arrow Linen site in Brooklyn on October 1. During the month of February the two Coast Intelligen engine-generator sets using MAN engines continued to provide power and process heat to the laundry facility for the two-shift, six days per week operation. For February the CHP efficiency averages increased to a level of 64.1%. We also completed some preliminary data analyses that seem to indicate that Arrow Linen could avoid paying high electric demand charges, thus potentially saving up to $5,000 in some months.

Status of Milestone(s)

Draft project profile for Higgins Brick. August 2006. On Schedule.
Draft project profile for Arrow Linen. September 2006. On Schedule

Industry Interactions

ESC conducted a Technology and Market Assessment Forum (TMAF), February 14 -16 in San Antonio. A number of DG Technology providers provided presentations at this Forum. Burns & McDonnell talked about their showcase installation with Austin Energies, Northern Power Systems presented on their installations throughout the US, Generac presented on standby and bi-fuel generators, GTI-Altronics on bi-fuel conversions, and SwRI on their new microturbine concept. In addition, we invited Capstone to provide a presentation on their new C65 at the Distributed Generation Consortium meeting which was held in conjunction with the TMAF meeting. Rich Biljetina provided an overview of both the Arrow Linen and Higgins project at this same consortium meeting.

SUBTASK 4.2.2. NATIONAL ACCOUNTS DE PROJECTS

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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

The final two projects: HEB and Walgreens were completed this quarter:

- The Walgreens Final Report was submitted to ORNL and DOE in February 2006.
- The HEB Final Report was submitted to ORNL and DOE in December 2005.

Technical Progress

The Gulf Coast RAC is preparing a project profile on the HEB test and verification project. Sentech is preparing a project profile on the Walgreens test and verification project.

Status of Milestone(s)

Complete Walgreens 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: (202) 479-0292; Email: garlandpw@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 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 is investigating the use of a gas-fired reciprocating engine equipped with a novel emissions control system to generate 334 kilowatts and to generate steam. (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 will 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 are PowerCold, Southwest Gas, Wingate, Nevada Power, and Preventative Maintenance.

Highlights

The remaining equipment was delivered to the Basin Electric site and installation began in late March.

Technical Progress

The Ritz Carlton system operated and data was collected and evaluated. Progress has been made toward improving the compatibility between the data acquisition and reporting systems.

At the Basin Electric site, all equipment, including turbines, switchgear, diverter valve, pumps and fans, have been delivered and the construction cranes are on site. Given the North Dakota climate, this in itself is no mean accomplishment. Mechanical construction should be complete by the end of May and electrical and communications installation should be complete by the end of June.

Status of Milestone(s)

The subcontract is under revision to reflect future funding reductions. Milestones for the Utica and Wingate systems in particular have been revised to allow us to record and share the lessons learned regarding system design even though the hardware portion of these two projects was cancelled.

SUBTASK 4.2.5. BUTLER HOSPITAL IN PROVIDENCE, RHODE ISLAND

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

Objective

Provide field data on and analyze use of a UTC PureComfort 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

Milestone reports were submitted regarding system startup and training of operators.

Technical Progress

See following letter

March 6, 2006

Oak Ridge National Laboratory
Cooling, Heating and Power Group
P.O. Box 2008
Oak Ridge, TN 37831-6070

Attention: Ms. Jan Berry R&D Program Manager

Subject: Butler Hospital Combined Heat and Power Project
Task 2.3.2 Memo Regarding Start Up of the CHP

Dear Ms. Berry,

This memo is for the purpose of comparing the ways in which the testing, start up, and commissioning of this facility was easier or harder and more or less costly than testing, start up, and commissioning comparable equipment on a custom basis.

The field start up was conducted during November and December of 2006. The testing, start up, and commissioning was easier and less costly at the Butler Hospital CHP facility for the following reasons:

- Integrated factory components on the absorber - the absorber was factory supplied with many hardware components that would typical field purchased in a custom CHP job. An example is the final stage heat exchanger with its associated pump and drive that was factory installed on the absorber. In a typical custom application, the electrical starter or drive, the heat exchanger, and the piping would be engineered, purchased, installed, and tested in the field. In the Butler application this final stage heat exchanger came factory installed and tested as part of the absorber.
- Another example is the factory supplied exhaust diverter valve that regulates the exhaust flow from the turbines to the absorber. This valve, actuator, and blower are manufactured and engineered at the factory. The control of the diverter valve is by the integrated control routine within the absorber microprocessor. This eliminates the need for field engineering or purchasing of this component.
- Communication protocol for the absorber and the turbines communicated on a RS4585 bus utilizing the Carrier CCN protocol. This factory written and tested sequence for integrating and operating the absorber and turbines is used as part of this package and is utilized at many installations. This eliminates the need to write a custom sequencing program in the field.

The above examples illustrate some of the ways that the start up was easier and less costly than custom applications.

Sincerely,

Russell Mack
Project Manager- Carrier Corp

Cc: Jim Chambers, Butler Hospital
Robert Fitzpatrick, Carrier Corp
Mike Guyder, Carrier Corp
Bill Deschennes, Carrier Corp
Dan Perry, Carrier Corp

March 6, 2006

Oak Ridge National Laboratory
Cooling, Heating and Power Group
P.O. Box 2008
Oak Ridge, TN 37831-6070

Attention: Ms. Jan Berry R&D Program Manager

Subject: Butler Hospital- Providence, Rhode Island
Combined Heat and Power Project
Task 3.1- Memo Regarding Training of the CHP

Dear Ms. Berry,

This memo is for the purpose of documenting that the training has been completed for this project. The personnel training session was completed in December of 2005. This memo also compares the ways in which the testing, start up, and commissioning of this facility was easier or harder and more or less costly than testing, start up, and commissioning comparable equipment on a custom basis.

The field training was conducted on December 15, 2005.
The following Carrier personnel conducted the training:
Chris Parnaby, Carrier Start Up Technician
Bill Deschennes, Carrier Service Engineer
Russ Mack, Carrier Project Manager

The training was held at Butler Hospital. The project SOP manuals (3 copies) were issued to Butler Hospital. In addition, a training specific handout package was issued to personnel for the data displays panel located on the turbines. Hand held quick index cards were distributed to assist with navigating the display panels. Laminated copies of flow schematics were issued at the training. These were mounted locally at the CHP to aid in troubleshooting.

The training covered:
- Component identification of the system and nomenclature
- Location of electrical switches, and location of other utilities including natural gas, electrical, and water flow.
- Review of system auxiliaries including water pumps, heat exchangers, valves, fuel gas boosters, air intake, and exhaust.
- Start up of system and sequencing for a start up
- Shut down of system and sequencing for shutdown

- Navigation and understanding of the turbine display panel
- Navigation and understanding of the absorber display panel
- Flow cycle of the absorber
- Flow cycle for the turbines
- Review of the CCN front end computer controlling the plant
- Review of the building system pump stations throughout the campus

The testing, start up, and commissioning was easier and less costly at the Butler Hospital CHP facility for the following reasons:
- The display of information from the turbines and the absorbers can be displayed locally at the turbines. This information can also be read at the absorber and also at the front end of the computer. This is convenient for operating and for the training session.
- CHP system operates on the CCN communication protocol. The Carrier CHP system is controlled by the Carrier control system that Butler Hospital has been operating for 15+ years. Butler personnel are familiar with operation of the Carrier CCN front-end computer. This includes logging on, modifying set points and schedules, and responding to alarms. This alleviated the need to provide additional training on the operation of the computer interface.
- The computer graphical displays of the system that are installed on the Butler front-end computer were used for training. This offered a graphical real time display of the CHP. These displays are viewed daily by Butler Hospital personnel.

Sincerely,

Russell Mack
Project Manager- Carrier Corp

Cc: Jim Chambers, Butler Hospital
Robert Fitzpatrick, Carrier Corp
Mike Guyder, Carrier Corp
Bill Deschennes, Carrier Corp
Dan Perry, Carrier Corp

Status of Milestone(s)

Milestone reports were submitted regarding system startup and training of operators.

SUBTASK 4.2.6. EASTERN MAINE MEDICAL CENTER IN BANGOR, MAINE

J. B. Berry
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 241-1939; Email: berryjb@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. The gas turbine has been received on site. Over 85% of site work, 88% of concrete and 74% of structural work have been completed.

Technical Progress

Construction of the Integrated Energy System is proceeding on schedule. The gas turbine has been received on site. Balance of plant equipment is being received. The photograph shows the Heat Recovery Steam Generator. The true size of the building structural steel is misleading because the picture was taken from the top of the slope versus the bottom of the slope.

Status of Milestone(s)

Details regarding percent completion of construction are shown on AIA Document G702 below.

B	C	D	E	F	G		H
DESCRIPTION OF WORK	SCHEDULED VALUE	WORK COMPLETED		MATERIALS PRESENTLY STORED (NOT IN D OR E)	TOTAL COMPLETED AND STORED TO DATE (D+E+F)	% (G ÷ C)	BALANCE TO FINISH (C - G)
		FROM PREVIOUS APPLICATION (D + E)	THIS PERIOD				
Overal Scheduled Value	**$1,034,461.00**						
Division 01 (OH & General Cond.)	$206,892.00	$93,685.10	$23,581.00		$117,266.10	56.68%	$89,625.90
Division 02 (Sitework)	$153,446.00	$120,335.90	$10,293.00		$130,628.90	85.13%	$22,817.10
Division 3 Concrete	$41,378.00	806.00	$35,981.00		$36,787.00	88.90%	$4,591.00
Division 5 Structural	$41,378.00		$30,672.00		$30,672.00	74.13%	$10,706.00
Division 7 Insulation	$31,034.00				$0.00	0.00%	$31,034.00
Division 8 Doors	$10,345.00				$0.00	0.00%	$10,345.00
Divison 9 Finishes	$10,345.00				$0.00	0.00%	$10,345.00
Division 11 Equip.	$177,581.00		$26,263.00		$26,263.00	14.79%	$151,318.00
Division 12 Furnishings	$10,345.00				$0.00	0.00%	$10,345.00
Division 13 Special Construction	$31,034.00	$5,454.00	$6,684.00		$12,138.00	39.11%	$18,896.00
Division 15 Mechanical	$124,135.00	$13,788.00	$17,528.00		$31,316.00	25.23%	$92,819.00
Division 16 Electrical	$196,548.00		$20,191.00		$20,191.00	10.27%	$176,357.00
GRAND TOTALS	**$1,034,461.00**	**$234,069.00**	**$171,193.00**	**$0.00**	**$405,262.00**	**39.18%**	**$629,199.00**

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 nearing completion.

Technical Progress

- Project approved and permitted
- Planning and Zoning approved
- Demolition completed
- Carrier absorption chiller foundation work completed and chiller installed in building
- New piping work 75% completed. (Gas, chilled water, cooling water, hot water)
- New electrical work in chiller building 50% complete.
- New power wiring from building switch gear installed
- UTC Power visited microturbine skid vendor in Illinois on 3/23 for inspection at 75% interval
- Micro-Turbine skids completed and shipping 4/5 & 4/6

Status of Milestone(s)

Installation is expected to be completed in late April, with commissioning to start in May.

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

Design of the system is continuing. Currently reviewing site contractor qualifications in the Madera area, selection will be made after completion of engineering.

Technical Progress

Initial modular design layout and equipment sizing has been completed. Performing material take-offs for bill of materials.

Status of Milestone(s)

Working toward completion of 100% engineering design.

SUBTASK 4.2.9. SEMCO INCORPORATED

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

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

External building structure essentially completed.

Customized active desiccant HVAC equipment and IC engine generator set have been delivered to site for installation and initial start-up.

Technical Progress

Piping and equipment are being installed.

Status of Milestone(s)

Progress to date is consistent with the system start-up, trouble-shooting, and initial monitoring milestone set for late spring 2006.

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 IREC Newsletter was published in January, February and March 2006. These newsletters can be found at the following website:
http://www.irecusa.org/connect/newsletterarchives.html

Technical Progress

The three newsletters published during this reporting period included 34 state articles covering developments in 17 states (California, Colorado, Connecticut, Florida, Iowa, Idaho, Massachusetts, Michigan, Minnesota, Missouri, New York, Ohio, South Carolina, Texas, Virginia, Washington and West Virginia) and the District of Columbia. The newsletters also included 23 articles covering developments in six foreign countries (Canada, China, Cuba, India, Japan 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, Colorado officially adopted interconnection and net-metering rules for the state's investor-owned utilities and certain larger municipal utilities. Significantly, Colorado is the first state to adopt interconnection standards based closely on the standards adopted by the FERC in May 2005 (Order 2006). Colorado's new net-metering rules, which apply to systems up to two megawatts (MW) in capacity, rival New Jersey's net-metering rules as the best in the country.[1]

The New York Public Service Commission began an investigation of the potential extension of standby rates and procedures for certain types of DER. In addition, the New York Independent Service Operator (NYISO) agreed to take steps to ease the bottleneck of wind-energy projects seeking to interconnect at the transmission level in the state. In California, the "Rule 21" Working Group continued to address issues related to the evolution of the state's interconnection standards, including network interconnection and the interconnection of combined technologies.

The federal Energy Policy Act of 2005 (EPAct 2005) has inspired several states to examine or re-examine interconnection standards and/or net-metering rules. The public utilities commissions of Ohio, South Carolina, Virginia, Washington and West Virginia have either begun proceedings or soon will begin proceedings to address these issues. In March 2006, Washington adopted interconnection standards for

[1] IREC co-organized and made presentations at an interconnection and net-metering workshop in Denver in February 2006. The workshop was designed to help the state's municipal utilities and electric cooperatives understand the details of the state's new rules, initially adopted in December 2005.

generators up to 25 kilowatts (kW) and currently is developing standards for larger systems. In addition, Massachusetts adopted a revised model tariff for the interconnection of DER, and that the Iowa Department of Natural Resources Energy and Waste Management Bureau abandoned management of the state's interconnection and net-metering program.

At the federal level, the FERC issued an order finalizing revised regulations for CHP and small power-production facilities. The rule, issued in February 2006, eliminates ownership restrictions for both new and existing facilities and ensures that the thermal output of cogeneration facilities is used in a "productive and beneficial" manner. The FERC also proposed changes to its mandatory power-purchase obligation rules under the Public Utility Regulatory Policies Act (PURPA) to implement new provisions under EPAct 2005. Furthermore, the FERC issued an order establishing interconnection standards for wind-energy systems with a capacity of 20 MW and above.

DOE invited public input for a study (required by Section 1817 of EPAct 2005) of the potential benefits of DER. DOE invited stakeholders -- including utilities, CHP developers, small power producers, original equipment manufacturers, local and state regulatory bodies and trade associations -- to relate experiences, convey data, communicate results of case studies or analyses, or provide other information pertaining to the planning, installation, commissioning and operation of CHP or small power production systems. DOE also issued a Notice of Inquiry (NOI) to obtain public comments on a national transmission-congestion study (also required by EPAct 2005) that the department must complete by August 2006.

Updated versions of IREC's state-by-state interconnection and net-metering tables were completed and added to the project web site in March 2006, and an updated version (IREC MR-I2005) of IREC's model interconnection standards also was added to the site. In addition, project staff continued the process of restructuring the state-by-state library of legal documents related to interconnection.

During the reporting period, approximately 67 new subscribers signed up to receive the *Connecting to the Grid* newsletter, showing continued strong growth in total newsletter subscriptions. Approximately eight people unsubscribed during the reporting period, and about 49 obsolete email addresses were culled from the subscription list. The total number now subscribed to the newsletter was approximately 979 as of March 14, 2006.

Status of Milestone(s)

Provide Quarterly Reports to ORNL. Ongoing

Industry Interaction

This IREC activity was noted as positive during the National CHP Initiatives monthly call held on March 17th. John Jimison, Executive Director of the USCHPA, was assigned the task to follow up with Steve Kalland to see if NC State had the resources to take on the Initiative interconnection resource needs, i.e. keeping a site up-to-date and easily accessible to the regional work.

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 Walgreen's Project in Pinellas Park, Florida.
- SENTECH updated the DE Case Study Database for Q1, 2006, with a current case study tally of 419 case studies.

Technical Progress

- SENTECH submitted updated html files on all requested DE Projects (Technologies, Applications, and TAT) for the DE Program Website, to NREL; this included meeting EERE Communications Standards, suggesting to NREL webmaster where the files should be placed, the logic behind those placements, etc.
  - Attached is zip file of html files sent to NREL.
- SENTECH is drafting a DE Program Project Profile for the Walgreen's Project in Pinellas Park, Florida. SENTECH conducted research on project using published reports and met with *Exergy Partners* to go over project details.
- SENTECH spent considerable effort updating the DE Case Study Database, housed at http://www.eere.energy.gov/de/casestudies/. As of end of Q1 2006, there are 419 case studies.
  - Attached is Resource List document of Federal, State, Nonprofit, Association, Regional CHP Application Centers, Project Developers, Utility, and Manufacturer organizations whose websites we've searched for new case studies and new case study additions.
- SENTECH is in the process of adding covers and abstracts to approximately 20 DE Reports for posting on DE website.

Status of Milestone(s)

- All milestones will be met.
- **Provide Quarterly Reports to ORNL.**
  - Ongoing; submitting Q2 2006 Quarterly Report in mid-April.

Industry Interactions

- SENTECH conducted research on project using published reports and met with *Exergy Partners* to go over details of Walgreen's Project in Pinellas Park, Florida.
- SENTECH may opt, with ORNL's guidance, to interview end-users at Walgreen's, its energy service provider, related manufacturers, or other DG/CHP industry representatives.

SUBTASK 4.2.13. TECHNICAL ANALYSIS AND SUPPORT

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

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.
- Meetings continue to distill the information from the CHP Café held at the October 2005 CHP Roadmap meeting held in New York City.

Status of Milestone(s)

- Subtask 4.3.5 Facilitate the CHP Roadmap Meeting. October 2005. COMPLETE.
- Dissemination of roadmap results is forthcoming.
- Subtask 4.3.6. DG Reliability Database, Cost and Financing of DG/CHP, Inventory Of Commercial/Industrial Boilers & CHP Installation Database

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.
- 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.
- A meeting with ABMA was held to discuss comments and suggestions on the Boiler Summary Report.

Technical Progress

- EEA continues to work with the RACs to verify and update the CHP Installed Database. Tim Lip man of the Pacific RAC has expressed a renewed interest in this activity.
- 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 is 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. EVAULATION OF CHP MARKET POTENTIAL

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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.

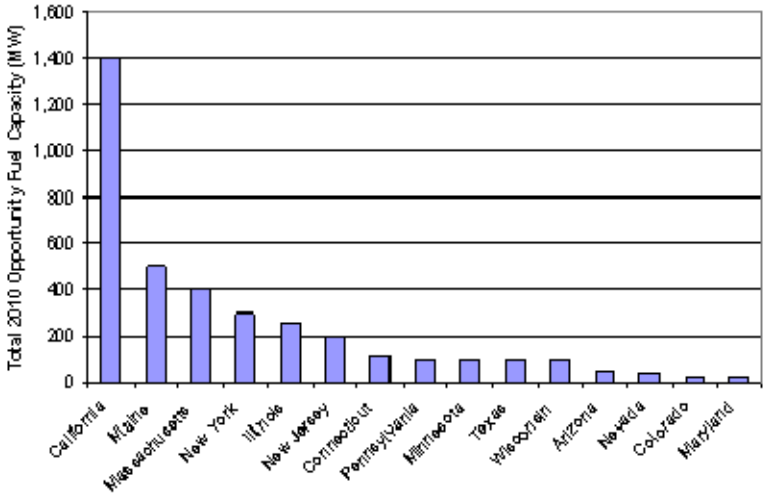
In FY06, one task was added to the contract: *Satisfying of Renewable Portfolio Standards with Opportunity Fuels and CHP*. In this effort, a state-by-state analysis of the impact of state level renewable portfolio standards will be performed, using state target dates and impacts as well as emerging values 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 review meeting was held with DOE, Exergy Partners, ORNL, and Resource Dynamics on March 8, 2006.
- A review meeting was held with ORNL ESTD and M&C personnel and Resource Dynamics on March 21, 2006.

Technical Progress

The states with active renewable portfolio standards include: **Arizona, California, Colorado, Connecticut,** Delaware, Hawaii, **Illinois,** Iowa, **Maine, Maryland, Massachusetts, Minnesota,** Montana, **Nevada, New Jersey,** New Mexico, **New York, Pennsylvania,** Rhode Island, **Texas,** Vermont, **Wisconsin,** and The District of Columbia. The 15 states in **bold** appear to be the most promising for future digester gas, landfill gas, and biomass development. The figure below shows state ADG/LFG/Biomass Capacity: 2010 Projections.



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
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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

- The RAC end-of-year report [in presentation format] was completed on December 31, 2005 and submitted to ORNL.
- The quarter working group conference calls continue.
- The next RAC face-to-face meeting has been scheduled in the ORNL DC offices on May 2nd, 2006.

Technical Progress

- The following focus areas have been established by the RACs:
  - Midwest – Hospitals, Ethanol, Farms, A/Es, Municipal Utilities, Regulatory
  - Intermountain – Waste Water Treatment and Landfills, Regulatory
  - Mid-Atlantic – Government facilities, opportunity fuels
  - Northeast – Commercial Office Buildings, HUD, Grid Congestion Relief, Wood Products, Hospitals, A/Es
  - Northwest – Farms, Waste Heat to Power, District Energy
  - Pacific – Ultra Clean Technologies, Waste Heat to Power
  - Gulf Coast – Hurricane Recovery Efforts, Cooling and Dehumidification Technologies, Hospitals
  - Southeast - Hurricane Recovery Efforts, Cooling and Dehumidification Technologies, Agriculture
- A list of potential new tasks for the upcoming RAC task order solicitation has been developed and discussed with each of the RACs.
- The state energy partnerships solicitations for DOE buildings and DOE ITP have been provided to the RACs.
- The agenda for the May 2nd RAC face-to-face meeting includes the following items:
  - RAC Task Order
  - Coordination Efforts: EPA, HUD, VA, and FEMP
  - New Tools for CHP: CHP Toolkit, CHP Capacity Optimizer, BCHP Screening Took, ASERTTI DG Database, Website Effectiveness, EPA Emissions Calculator
  - *What's Working and What's Not?* Policy Issues, Targeted Market Workshops Results and Plans, Project Support, How Should We Measure Success

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
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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 results of the DE Peer Review indicate that this project presentation, entitled: CHP Outreach, Education and Markets scored highest of all 17 projects scored by the End-Use Integration Panel #1. The reviewers suggested increasing out-year funding to this project.
- A summary of all project accomplishments from this 3-year program is being compiled.
- Continued interaction is occurring with HUD, EPA, the VA and FEMP.
- A hill technical briefing on the **perfect power system** -- what is it and why is it important? will be held at 1:00 pm in 1539 Longworth House Office Building on April 26th. This is the final deliverable under the NEMW contract.

Technical Progress

- In an effort to provide the most benefit for the DOE support to the RACs, several meetings and teleconferences have been held to discuss coordination of end-user workshops and case study reports. SENTECH is providing some support in preparing case studies.
- The CHP Toolkit is undergoing review and comment by the RACs.

Status of Milestone(s)

Subtask 4.3.1 Facilitate CHP Analysis Working Group Meeting (ACEEE), April 2006
Meeting is scheduled for April 6, 2006 on the topic of "changing gas prices."

Subtask 4.3.4 Complete Resource Planning and Procurement Guide (DUA), December 2005
A draft report titled: "The Value of Distributed Generation and Combined Heat and Power Resources in Wholesale Power Markets," was provided for comments. Comments are being incorporated into the final report.

Subtask 4.3.9 Complete final report on environmental screening tool in Southeastern States (IC Thomasson), June 2006
The draft report was provided to USCHPA and EPA for comment. On-Schedule.

Subtask 4.3.11 Write a summary paper on status and lessons learned among CHP Regional Initiatives (NEMW) March 2006
In-progress.

SUBTASK 4.3.18. CHP REGIONAL APPLICATIONS CENTER SUPPORT

S. K. Fischer
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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

There has been scant technical progress in addressing problems with desiccant calculations identified by the Gulf States RAC. The BCHP Screening Tool will calculate annual electrical power consumption, annual latent cooling provided, and annual increase to the building sensible cooling load and for all practical purposes appears to work when viewed as a "black box" without regard for technical details. Unfortunately it does not readily produce hourly data for checking results or any values for annual fuel consumption, steam or hot water use, or use of recovered engine heat. Examination of the FORTRAN source code for DOE2 appears to indicate that GARD analytics did not implement the desired DOE2 instructions for performing desiccant calculations; built in correlations for desiccant performance seem to be used and the database parameters developed by GARD totally ignored. Late in March the DOE2 instructions for saving desiccant hourly operating data were deciphered (inadequate documentation in DOE2 manuals) and positive progress was made toward resolving problems with the desiccant calculations.

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
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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

None

Technical Progress

There were no requests for assistance from HUD during the January to March period.

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
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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

Markets must be transformed for advanced technology to be adopted. Engineering Science and Technology Division staff worked with a U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) committee to foster market transformation for cooling heating and power (CHP) technology. This advanced technology supplies on-site electricity and recycles thermal energy to increase fuel use efficiency from 33% to over 75%. LEED is transforming the market for energy-efficient technology by recognizing the use of advanced technology in a formalized certification process--building owners proudly displace their LEED certification status.

ORNL staff tenaciously worked with the LEED committee through a year-long process to develop LEED guidance so that the efficiency gains of CHP technology are recognized. ORNL technical excellence and leadership emerged as the committee co-chairs (who were appointed by LEED) repeatedly turned to ORNL for guidance on how to proceed. ORNL staff used the BCHP model, that was developed by ORNL, to analyze technically-based options for establish LEED credit including use of ASHRAE standards. An ORNL staff member was selected to represent the technical aspects of the guidance to the LEED oversight committee and to assist in reporting progress to committee members. This effort culminated in the US Green Building Council's acknowledgement of the energy benefits of CHP is a significant achievement for the Office of Energy Efficiency, Distributed Energy Program.

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

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Objective

This task will develop needed methods for local voltage regulation that are not currently available utilizing programmable inverters in several different sizes (62, 129, 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 150kW 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% of the load's reactive power demand by providing about 12kVars. The inverter was able to correct the power factor from 0.857 to 0.943 and raise the power panel's voltage by 0.8% by using a current control logic developed by ORNL for the dSpace Real-Time Control System.

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. Testing of the inverter has continued and on March 29th, the inverter was operated at three different operating levels of 30A, 45A and 60A peak. Data was collected for each of these operating levels and is being analyzed. As the testing was coming to an end, the inverter failed with what appears to be a failure of its phase C terminal. The fault caused irreparable damage to the inverter, and the root cause of the failure, which occurred with the inverter operating at less than 58% of its rating, is being pursued with the inverter manufacturer. The inverter failure caused no personnel injury because the inverter is operated in a Lexan isolation cabinet. Also, there was no damage to the contactor that interfaces the AC output of the inverter to the AC system (electrical panel) or the 150kW DC power supply that supplies the DC side of the inverter. In addition to following up with the manufacturer as to the possible cause of the inverter failure, we are planning/implementing additional safety measures for the next testing which include (1) adding more fan cooling that is more directed at the inverter's heat sink, and (2) placing external thermocouples or thermistor to monitor the inverter/heat sink temperature as the inverter's current is increased.

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 have 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 synchronous condenser.

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 which we have responded to. We have assigned responsibilities to the ORNL team for addressing these items which relate directly to the project tasks.

SUBTASK 4.4.1B. ANCILLARY SERVICES OFFERED BY DISTRIBUTED ENERGY RESOURCES

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Objective

The inverter will be operated in parallel with the synchronous condenser. ORNL will evaluate how well existing control schemes can handle this problem.

Highlights

Work has continued on the development of a feedback control for the 300kVar synchronous condenser and integration with the earlier developed inverter feedback control. The initial thrust is to use the two reactive power producing devices to control line voltage locally on circuits #2 and #4 at the Laboratory. The Matlab/Simulink and Real-Time Workshop platform is being used to design the feedback control and the control is implemented via the Real-Time interface with the dSpace Real-time Control System.

Technical Progress

The two areas of the Reactive Power Laboratory, synchronous condenser and inverter testing have both been operational this quarter. In the synchronous condenser portion of the laboratory, we are operating a three-phase 480V/250hp overexcited/unloaded synchronous motor to produce a 300kVar synchronous condenser. The synchronous condenser, which is interfaced with circuit #4 (out of Substation 3000) of the ORNL distribution system, has been operated to regulate local voltage by injecting reactive power in its 480V/1000A panel. We have completed a significant amount of testing to characterize the synchronous condenser, and recently the focus has been more on controls. In the inverter portion of the laboratory, we are currently testing a three-phase 480V/75A/62kVA inverter with RMS (root-mean-squared) and Instantaneous current control developed by the Power Electronics Group.

The focus for each device is now on testing and development of feedback control software for each individually and how to integrate them for parallel operation. The significant achievement this quarter was the installation/operation of the 75A inverter with the 480V/600A panel at the Reactive Power Laboratory and the injection of reactive power from the inverter into circuit #2 (out of Substation 3000) of the ORNL distribution system which has met a project milestone several months ahead of schedule. The milestone was due by June 2006, and we met this milestone the end of February. Some details on various aspects for this quarter follow. We did have a setback with the failure of the 75A inverter on March 29th. Although we expect it to only cause a short delay for the inverter testing, we are still on track to meet the milestone of controlling the paralleled synchronous condenser and inverter by September.

For the time being, the SC and the inverter testing will be conducted independently and their controls will be independent. Our experience from the independent testing will be used to developed integrated controls for the SC and inverter so that they can be operated in parallel.

Status of Milestone(s)

Our milestone to operate the synchronous condenser (SC) and inverter in parallel to produce reactive power locally to regulate voltage and control power factor is on target. After each of the devices under go independent testing and control development, we will start on an integrated control scheme. We plan to meet the September 30th milestone of achieving parallel operation of the SC and inverter.

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 which we have responded to. 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

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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

A draft chapter describing the technical aspect of DG-grid interactions was completed and posted on the working group web site. An overall organization for the report was presented to integrate the task group contributions into a cohesive and understandable whole. Comments submitted by the public to support this project were reviewed.

Technical Progress

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

In the MADRI project, multiple business cases have been developed and presented to the working group, including an ambitious effort to develop a CHP demonstration model.

Status of Milestone(s)

The work supporting the CPS/Control milestone regarding the EP Act Benefits Study is on track to meet the schedule. However, the milestone calling for a report on the MADRI program progress may not be met due to a delayed budget for that effort.

Industry Interactions