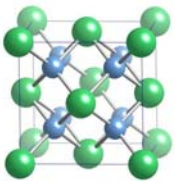
Distributed Energy Program

DE Quarterly Progress Report
For the Period
October 1, 2005 to December 31, 2005



OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

DE QUARTERLY PROGRESS REPORT

For the Period
October 1, 2005 to December 31, 2005

Prepared by:

David P. Stinton, Manager, and
Jennifer Fusaro
DE Materials Research
Oak Ridge National Laboratory

For:
Department of Energy
Office of Distributed Energy

Section 1. Advanced Reciprocating Engines

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

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

Objective

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

Highlights

Testing of spark plugs made from ORNL model and developmental electrode alloys has been initiated at ORNL in a Caterpillar G3406 industrial natural gas engine. Ongoing results of laboratory engine tests at Federal Mogul (Champion®) indicate a stronger than expected impact of alloy thermal/electrical conductivity on electrode wear.

Technical Progress

Laboratory engine tests at Federal Mogul of a series of spark plugs incorporating optimized model Cr_2O_3-forming alloys based on ferritic, austenitic, and Ni-base microstructures indicated a strong link between alloy thermal/electrical conductivity and the rate of electrode wear. These results suggest co-optimization of these properties with oxidation resistance to enhance electrode alloy durability, as the addition of Cr and Al to improve oxidation resistance can also significantly degrade conductivity. Based on these insights, engine testing of electrodes based on developmental ORNL Cr-base and Ni/NiO forming base alloys was accelerated, with rods of these materials manufactured and delivered to Federal Mogul for spark plug manufacture. Oxidation study of a series of high conductivity commercial, model, and developmental alloys was also initiated. Instrumentation and setup of a Caterpillar G3406 industrial natural gas engine was completed at ORNL in the first quarter of FY06. Testing of model and developmental spark plugs in this engine was initiated in January 2006.

Spectroscopic arc measurements were also performed on standard new and used plugs to determine the temperature and vibrational energy distribution in the arc components (ions, neutrals and electrons). This information was incorporated into the erosion model to better estimate the differential heating rate on the spark plug tip, thus predicting a different erosion rate for the anode and cathode.

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) – on track

Industry Interactions

- Conference calls and email communications with Drs. Iryna Levina and Jim Lykowski at Federal Mogul to discuss the engine testing of the spark plugs using ORNL developmental alloys.
- Manufacture and delivery of alloys for spark plug manufacture.

SUBTASK 1.3. ADAPTIVE CONTROLS FOR LEAN BURN ENGINES

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

Objective

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

Highlights

In November 2005, we were invited by Southern California Gas Company (SoCal) to participate in field testing of a large, lean-burn, NG gas-compression engine to evaluate the potential of adaptive nonlinear control to stabilize combustion and reduce emissions in pipeline applications.

To address industry requests, we have developed a technique to estimate the fuel efficiency and emissions reduction benefits that may be achieved with application of adaptive control to a specific engine platform. Two papers detailing the hybrid model used in the estimation technique were presented at the 2005 SAE Powertrain & Fluid Systems Conference and Exhibition (24-27 Oct 2005 in San Antonio, TX).

Technical Progress

At the request of SoCal Gas, Dean Edwards and Robert Wagner were present during field testing of a lean-burn, gas-compression engine operating on one of the SoCal pipelines on 14-17 Nov 2005. We were able to learn much about the operation of these engines and the challenges they face. We have identified several areas in which we feel we could provide assistance to SoCal Gas and are attempting to obtain additional data.

ORNL personnel visit Digital Engines, LLC, , to discuss the fabrication and delivery of the single cylinder engine. Several issues regarding timing and functionality of the engine were discussed and agreed upon. Delivery is now expected in March-April 2006. Discussions were also held with Waukesha Engine Dresser (WED) about this engine which will be modeled after the WED ARES engine (APG) about the installation and safety of this engine.

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 are pursuing collaborations with SoCal Gas and Colorado State University to apply adaptive nonlinear controls to the lean-burn NG gas-compression engines operated by SoCal Gas on their pipeline system.

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

SUBTASK 1.6A. NATURAL GAS LEAN AFTERTREATMENT (PIC 687)

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

Objective

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

- In FY04, NOx reduction in engine exhaust was demonstrated. **ARES program target emission levels of <0.1 g/bhp-hr NOx were demonstrated**, and NOx reduction efficiencies of >90% were obtained with the lean NOx trap catalyst.
- In FY05, full characterization of the utilization of NG (fuel efficiency) for catalyst regeneration was performed. Methane oxidation and reforming chemistries were characterized for various conditions.
- In FY06, the focus has shifted to durability issues and, in particular, durability concerns due to sulfur.

Highlights

- Recently completed system integration studies with an exhaust heat exchanger and the lean NOx trap catalyst system show the potential for the combined optimization of system efficiency and emissions when heat recovery and aftertreatment systems are integrated carefully.
- An abstract has been submitted for the annual ARES-ARICE workshop to be held in Chicago, IL.
- A new team member Senthil Ponnusamy, who recently completed his Masters at the University of Alberta in Canada, has been added to the project; his background is in NG combustion.

Technical Progress

- System Integration Studies - A preliminary set of experiments studying system integration were completed on the engine platform. Results showed that system efficiency and emissions can be collectively optimized with careful design during integration of heat recovery and aftertreatment devices.
- Setup for Sulfur Durability Studies - Experimental setup for sulfur durability studies has been completed on the engine platform. The initial studies (to start in Q2) 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.

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

A teleconference between all active catalysis researchers in the ARES program was held by ORNL on November 17, 2005 to discuss as a group issues related to catalysis in ARES applications. Participants included representatives from ORNL, Univ. of Maryland-College Park, PNNL, ANL, Ohio State Univ., Univ. of Tennessee, and West Virginia Univ. In addition, for this call, catalyst

industry representatives were also invited to attend to discuss “real-world” catalysis experience and market issues related to ARES catalyst technologies being researched. This effort was in part due to a call from the engine manufacturers to get more interaction from the catalyst industry in ARES activities (expressed at the ARES Catalysis Workshop in April of 2005 at ORNL). During this call, catalyst industry representatives from Miratech, DCL Inc., and Engelhard participated. An excellent discussion was held on the current NG engine market and emissions control options and how that information relates to current ARES activities.

Section 2. MATERIALS BASED TECHNOLOGY FOR DISTRIBUTED GENERATION

SUBTASK 2.1.1. ADVANCED ALLOYS FOR HIGH TEMPERATURE RECUPERATORS

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

Objective

The objective is for ORNL to work with commercial foil and sheet suppliers to test, evaluate and enable recuperator manufacturing with alloys that have more temperature capability and performance at reasonable cost. Near term objective is meeting reliability goals (40,000-80,000h) at about 700°C, while the long term objective is pushing performance to 750°C or higher, without sacrificing lifetime. Last year, ORNL completed Phases I and II of a collaborative project with Allegheny-Ludlum to produce and measure properties of a wide range of commercial sheets and foils of AL20-25+Nb stainless alloy. The Phase II creep resistance of sheets was improved by a factor or two, and excellent creep-resistance was also found in the 3.2 mil foil product. Microstructural analysis of creep-tested specimens will be done to complete this work in FY2006. Relative alloy comparisons include foils of 347 steel, HR120 and alloy 625. ORNL work will also assess recuperators manufactured from AL20-25+Nb sheets and foils, and examine behavior of foils exposed in a microturbine environment.

Highlights

The initial creep-test of Phase II AL20-25+Nb stainless alloy foil (3.2 mils) at 750°C/100 MPa gave a rupture life of about 1800h. This is about 20-40 X better than similar 347 stainless steel foil, over 3 X better than HR120 or Phase I AL20-25+Nb foils, and approaches the creep resistance of alloy 625 foil.

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 3.5-4X more than 347 stainless steel. Austenitic stainless sheets and foils of alloys HR120 and AL20-25+Nb are more cost effective, higher performance alternatives to 347 stainless steels 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 to produce prototype higher performance air-cells. Phase I produced full-scale commercial quantities of a wide range of sheets and foils of AL20-25+Nb with standard processing, and Phase II produced limited quantities of selected sheets and foils with processing to modify the microstructure for better creep-rupture resistance. ORNL preformed creep-testing at 700-750°C, and will complete testing of Phase II material, and microstructural analysis of Phase I and II in FY2006. This study also includes appropriate comparisons with similar sheets and foils of 347 steel, HR120 and 625 alloys. This study will include analysis of recuperators manufactured from AL20-25+Nb alloy, as well as from initial in-turbine tests. The initial creep-testing of Phase II foils and sheets of AL-20-25+Nb alloy at 750°C/100 MPa, shows significant improvement compared to Phase I, and good relative behavior compared to HR120 and 625 alloys. Testing will continue at 700°C next quarter, and microcharacterization of creep-tested specimens will continue.

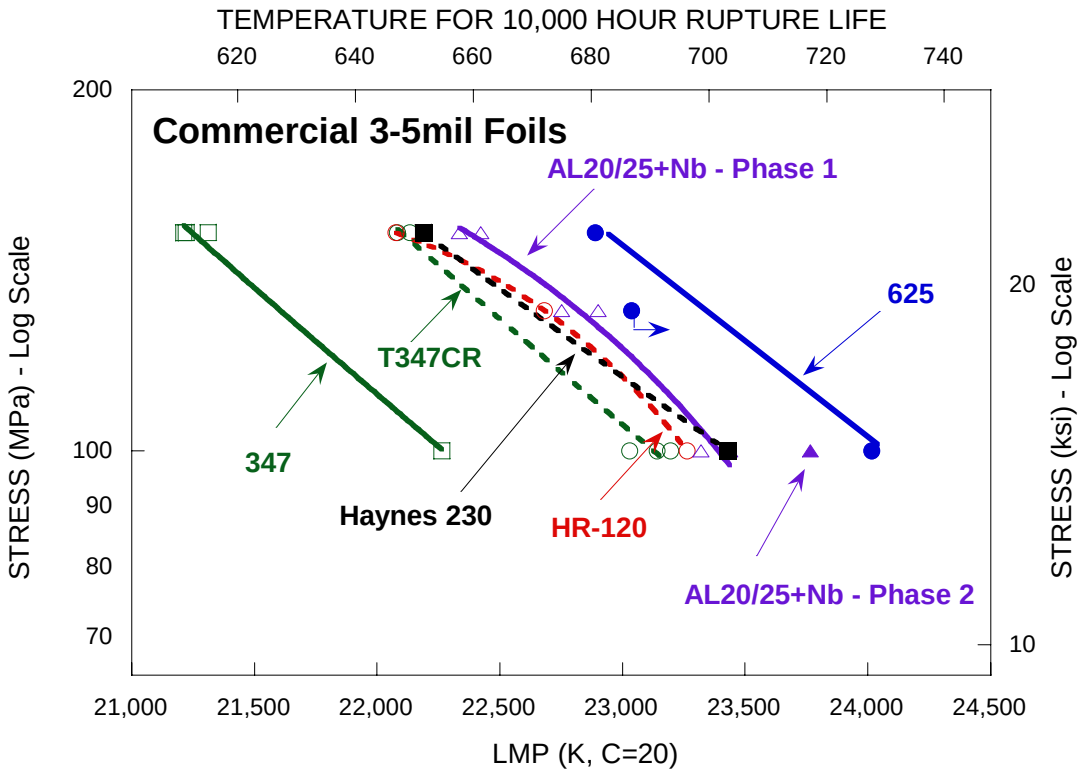
Milestones

Complete mechanical testing and microstructural characterization of various foils and sheets of new AL20-25+Nb alloy and evaluate the effects of modified processing on creep resistance. Characterize trial air cells manufactured from AL20-25+Nb for engine testing. *March 2005 – completed*

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 – on track.*

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 air cells manufactured with AL20-25+Nb.



SUBTASK 2.1.2. OXIDATION/CORROSION CHARACTERIZATION OF HIGH-TEMPERATURE RECUPERATOR ALLOYS AND FIELD EXPOSED RECUPERATORS

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

Objective

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

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

Highlights

As part of an ongoing ORNL/industry collaborative recuperator project, Wendy Matthews from Capstone Turbines visited ORNL November 14-18, 2005 to conduct additional microstructural characterization of field-aged 347SS and alloy 120 recuperator foils. This work was a continuation of work initiated in June 2005. Wendy Matthews also worked on acquiring data and preparing a paper for 2006 Turbo Expo.

Technical Progress

During the reporting period, additional microstructural characterization was conducted in collaboration with Capstone Turbines to evaluate and quantify the amount of degradation (oxidation) of recuperators, which were field-tested in a Capstone C60 microturbine. This study was conducted to compare the oxidation-performance of recuperators fabricated from 347 stainless steel and alloy 120. This work has been extremely beneficial to ORNL's research on the oxidation and creep behavior of the same commercial alloys for recuperators, which have been exposed to laboratory conditions (high temperature and H_2O) and in ORNL's MRTF.

Status of Milestones

Report on the microstructural characterization of commercial alloys, which have been laboratory-exposed (elevated H_2O) and engine-tested (in ORNL Microturbine Recuperator Test Facility) at Temp. > 600°C. *June 2005 – completed.*

Publish summary report of microstructural evaluation of exposed AL20-25+Nb alloy at 650°C and 700°C. *January 2006 – in progress.*

Report on characterization of recuperator exposed in a landfill gas application. *August 2006 – on task.*

Industry Interactions

1. Conducted microstructural characterization of Capstone engine-tested recuperators November 14-18, 2005. Wendy Matthews of Capstone Turbines visited ORNL during evaluation of alloys.

SUBTASK 2.1.3. RECUPERATOR ALLOYS – COMPOSITION OPTIMIZATION FOR CORROSION RESISTANCE

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

Objective

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

Highlights

Commercial alloy foil specimens have been exposed in both laboratory and engine testing in order to compare the two tests. After 1,000h exposures, specimens have been characterized to determine the extent of Cr depletion. The amount of Cr depletion at 720°C in the engine test was similar to the depletion at 800°C in the laboratory test.

Technical Progress

The Cr depletion rates for various commercial and experimental alloy foils has been measured as a function of temperature at 650°-800°C for times up to 10,000h in laboratory tests in humid and dry air. A model has been developed to calculate and predict these rates based on classical gas transport theory. The last step in quantifying the behavior of these materials is to quantify the Cr loss in the recuperator exhaust gas environment. The first comparison was made after 1,000h exposures of alloy 120 in laboratory and engine tests. The laboratory exposures were at 650°, 700° and 800°C and the engine tests were at 600°, 670°, 690° and 720°C. At the lower temperatures, the Cr loss was low and difficult to quantify. At the temperatures over 700°C, significant depletion levels could be measured. Microstructurally, both tests showed oxide penetrations and enhanced Cr depletion on alloy grain boundaries. Longer term experiments are being conducted to complete this comparison.

Status of Milestones

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

Submitted paper to 2006 IGTI meeting comparing Cr depletion in engine and laboratory testing.

SUBTASK 2.1.4. RECUPERATOR MATERIALS TESTING AND EVALUATION

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

Objective

The objective of this sub-task is to screen and evaluate candidate materials for the next generation of advanced microturbine recuperators. To attain this objective a microturbine was modified to operate at recuperator inlet temperatures as high as 850°C. The durability of candidate recuperator materials is determined by placing metallic foil test specimens at a location upstream of the recuperator, followed by determination of their physical and mechanical properties as a function of time of exposure. 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

Foils of 20/25-Nb were subjected to 250 cycles to simulate intermittent microturbine operation.

Technical Progress

During the reporting period test campaigns continued to evaluate alloys Haynes 120, 20/25-Nb and LCF-625 in ORNL's microturbine recuperator testing facility (MRTF). Foils of 20/25-Nb were evaluated under intermittent conditions for 250 cycles and the residual properties were determined at ambient temperature. The maximum and minimum temperatures experienced by the foils during the intermittent tests were: Position 1: 680°C-380°C; Position 2: 659°C-334°C; Position 3: 587°C-248°C.

It was found that after 250 cycles the foils in positions 1 and 2 experienced a 25% loss of ductility and a loss of tensile strength of 6% and 4%, respectively.

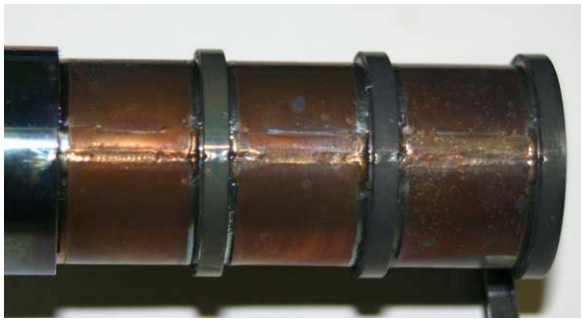


Figure 1. Photograph of sample holder with 20/25-Nb foils after 250 2-hr cycles of simulated intermittent microturbine operation.

Status of Milestones

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

Industry Interactions

None during this period

SUBTASK 2.2.2. MICROSTRUCTURAL CHARACTERIZATION OF CFCCS AND PROTECTIVE COATINGS

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

Objective

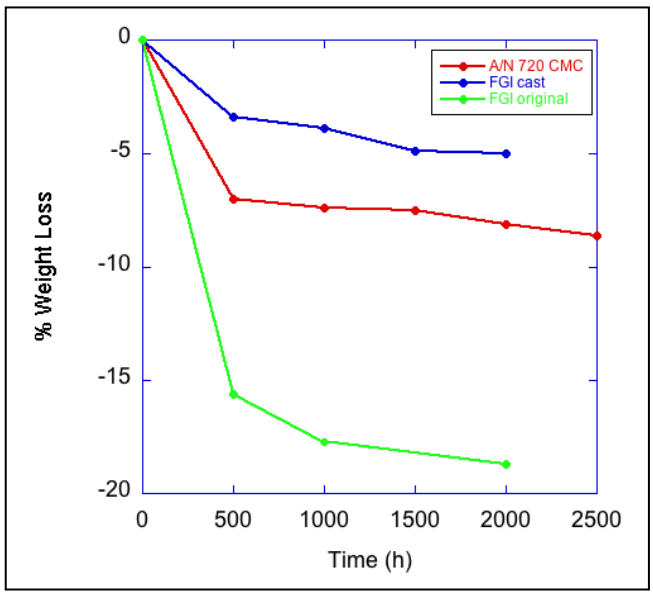
SiC/SiC continuous-fiber ceramic composite (CFCC) combustor liners with a BSAS-based environmental barrier coating (EBC) have been exposed in several Solar Turbines engine tests for >10,000 h. The engine-exposed combustor liners have been characterized microstructurally and mechanically at ORNL to evaluate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

Highlights

The exposure of ATK-COI Ceramic's oxide/oxide ceramic matrix composite, designated A/N 720 CMC, and two stand-alone differently-processed FGI (friable graded interface) coupons has been conducted in ORNL's Keiser Rig at 1250°C, 20 atm total system pressure, and 18 atm H_2O. These materials were exposed for ~2000 h in the Keiser Rig for comparison with the A/N720 CMC + FGI combustor liner currently being exposed (>18,000 h) in a Solar Turbines Centaur 50S engine at the ChevronTexaco engine test site in Bakersfield, CA.

Technical Progress

A comparison of the weight losses experienced by the two different FGI materials and the A/N 720 CMC is shown to the right. The FGI "original" composition exhibited significant weight losses after exposure for 2000 h at 18 atm H_2O – this composition is the same as that currently coating the gas-path surface of the engine-exposed oxide/oxide outer liner. The FGI "cast" material, prepared since the engine test began, is an improved version of the FGI "original" composition and shows greater stability (less weight loss) at very high H_2O pressures used in the Keiser Rig exposures.



Status of Milestones

Prepare a report and present results on the expanded use of ORNL's Keiser Rig to evaluate the volatility resistance of EBCs. *August 2005 – IGTI paper completed.*

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

1. Attended DOE's EBC Workshop, Nashville, TN, November 16-17, 2005.
2. Results of recent Keiser Rig exposures discussed with ATK-COI Ceramics, November 16-17, 2005.

SUBTASK 2.2.3. HOT SECTION MATERIALS DEVELOPMENT FOR ADVANCED MICROTURBINES

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

Objective

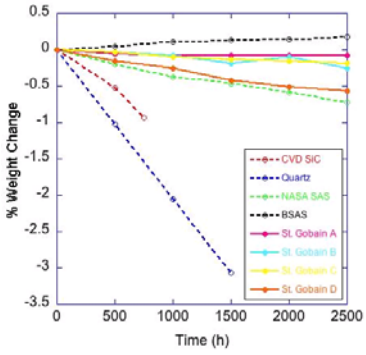
The goal of this program is to develop and optimize a high temperature silicon nitride based ceramic material (NT154) and forming process suitable for microturbine hot section component applications.

Highlights

Monoliths of novel EBC compositions completed 2500 hours of testing in the high pressure Keiser Rig at ORNL with promising results comparable to BSAS.

Technical Progress

Hot pressed, monolithic, EBC samples of the novel bond coat and top coat compositions, previously defined, completed 2500 hours of testing in the high pressure Keiser Rig at ORNL. The test conditions were 1250°C, 18 atm water vapor pressure and 20 atm total pressure. The results appear to be promising as three of the four compositions were very stable for the life of the test (see graph).



Dip coating and densification development is on-going using the novel bond coat and top coat EBC compositions. Internal testing of EBC coated NT154 coupons revealed an issue with delamination at the silicon nitride interface, likely due to interface porosity. Effort is now focused on improving the adherence of bond coat of the EBC to the NT154 substrate.

Significant effort has been directed towards further improvement in the high temperature slow crack growth (SCG) resistance of NT154. The main focus has been on the proper crystallization of the grain boundary phase, through process modifications. A review of the data to date indicates that an overall strength improvement of 10-25% has been realized at both fast and slow loading rates. However, the result is only modest changes in the dynamic fatigue exponent with a value up to ~40.

A radial NT154 rotor, manufactured during 2004, successfully survived spin testing to 143,330 RPM without failure. The testing was stopped due to equipment limitations. Based on FEA calculations, the rotor experienced a maximum stress of 490 MPa on as-processed surfaces.

Status of Milestones

1) 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).
2) 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 (as well as possibly the NASA high velocity Rig) – 6/06 (EBC material proven, coating procedure development is on-going).

Industry Interactions

1) Communications with Terry Tiegs, H.T. Lin, Karren More and Beth Armstrong of ORNL regarding NT154 and EBC development work.
2) Discussions with Bill Tredway and John Holowczak of UTRC on Si_3N_4 turbine components.

3) Communications with Roger Wills of UDRI regarding the SCG performance of NT154.
4) RHLicht attended the DE Peer Review Meeting, Arlington, VA, December 13-15 to review and discuss Microturbine programs with ORNL, DOE and industry.
5) Vimal Pujari and Ara Vartabedian attended and presented at the Fourth Annual EBC Workshop, Nashville, TN, November 15-16.

SUBTASK 2.2.4. OXIDATION/CORROSION CHARACTERIZATION OF MICROTURBINE MATERIALS

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

Objective

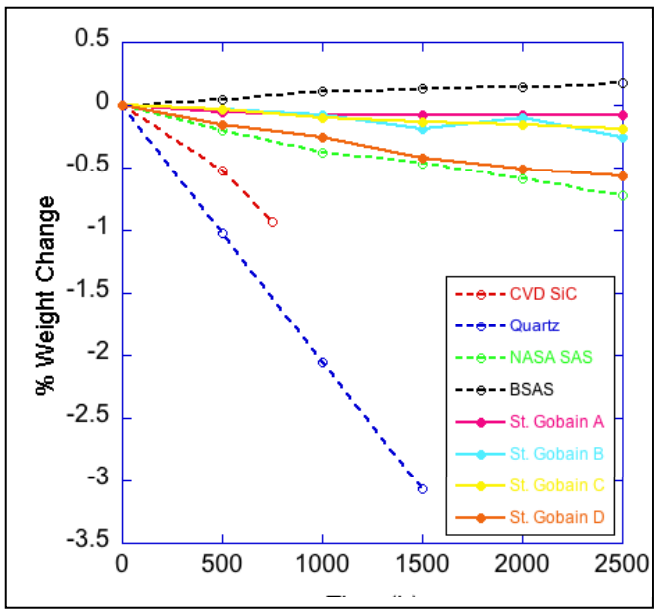
Environmental barrier coatings (EBCs) will be required on surfaces of Si-based ceramic and composite materials exposed to microturbine combustion (high water-vapor pressure) environments. EBC systems are currently being developed for use on Si_3N_4 hot-section microturbine components. The reliability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

Highlights

The exposure of several candidate EBC compositions (produced by Saint Gobain and Ceramatec) to extremely high water-vapor pressures in ORNL Keiser Rigs was continued during this reporting period. 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 produced by Saint Gobain Ceramics and Ceramatec have been exposed for a total of 2000 h at 1250°C, 20 atm total system pressure, and 18 atm H_2O in ORNL's Keiser Rig. Each exposed stand-alone coupon is carefully weighed after sequential 500 h exposures. The EBCs provided by each manufacturer are then "ranked" in terms of total weight change as a function of exposure time. For example, this plot shows the weight change for a series of 4 different EBC compositions prepared by Saint Gobain compared to standard materials (CVD SiC, SiO_2, SAS, BSAS). The weight changes observed for the 4 Saint Gobain EBCs were minimal.



Status of Milestones

Report the volatilization results from the exposure of 3 different Si_3N_4 compositions to very high H_2O pressures in ORNL's Keiser Rig. *June 2005 – 1000 h exposures of NT-154 and CVD Si_3N_4 completed.*

Complete exposures of Saint Gobain Si_3N_4 with/without EBCs in high H_2O pressure Keiser Rig and report results. *March 2006 – in progress.*

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

1. Attended DOE's EBC Workshop, Nashville, TN, November 16-17, 2005.
2. Results of recent Keiser Rig exposures discussed with Saint Gobain and Ceramatec, November 16-17, 2005.

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

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

Objective

The objective is to set up a Portable, Multi-Fuel Test Rig (the Portable Rig) to support the turbine and engine community in their development of gas turbines and engines that are multi-fuel capable. The use of the alternate fuels such as landfill gas, bio-diesels, poses a number of materials stability challenges for a variety of components including the combustor liner, combustor injector, and recuperator. The Portable Rig can either conduct the test on-site, or simulate a controlled environment off-site. It is capable of assessing materials degradation and air pollution issues simultaneously.

Highlights

The original stationary multi-fuel combustor project was deferred because the supplier in incapable of delivering a combustor that meets the agreed the specification. Instead, we will develop a Portable Multi-Fuel Test Rig in-house at ORNL. The Portable Rig is mobile, which can be transported to the end user's sites for testing. Mobility is a unique advantage to engines or turbines running on land-fill gas because that the gas composition may vary significantly from day to day as the humidity and temperature changes. Such portable rig is equally useful in engine development: we propose to use fluorescent nanosized particles as marker to monitor the combustion around the fuel injector. The Portable Rig is much less-expensive to maintain.

Technical Progress

The Purchase Order of the original Multi-fuel Laboratory Combustor was placed in September 2005, at the end of FY05. A tentative installation site was selected and evaluated in December 05 to January 06. From October 2005 to January 2006, after three months of close interaction with the supplier, Becon Inc., it is evident that the supplier is not capable of deliver the rig that meets the specification. A stop working order was issued in January 2006.

Design of the Portable Multi-Fuel Evaluation Rig has initiated at the end of January 2006.

Industry Interactions

Interacting with Mr. Dave Winicki at Becon Inc. in a weekly basis.

Phone conference and on-site meeting with Solar Inc. to discuss the starting of the Portable Rig and, how ORNL can help the industry to solve the issues related to the usage of land-fill gas.

Meeting with Ingersoll Rand to learn the industry's concerns of the materials degradation caused by using alternative fuels.

SUBTASK 2.2.6. CHARACTERIZATION OF OXIDATION RESISTANT CERAMICS AND SILICON NITRIDES

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

Objectives

1) Determine the tensile creep properties of Saint Gobain's latest NT154 grade silicon nitride to ensure that this batch of material has at least equivalent creep properties to the previous material made in the mid 1990s.
2) Determine the slow crack growth of Saint Gobain's latest NT154 grade silicon nitride and help find the processing conditions that give the material the best high temperature creep and slow crack growth resistance at 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

Stressing rate experiments on NT154 at 1200 °C did not show any significant difference in the slow crack growth rate exponent(n value) for NT154 samples processed using either the standard HIP and heat treatment cycle or an extended HIP and heat treatment cycle. The observed n value of 22 is due to the presence of Y_2SiO_5 , as a secondary phase in the microstructure of both sets of NT154 silicon nitride.

Technical Progress

Two sets of silicon nitride tiles were received. Sample set#1 contained material that had gone through the standard HIP and crystallization processes whereas the second set of tiles had gone through an extended HIP and crystallization conditions with the hope of obtaining complete crystallization of the grain boundary glassy phase. Since the tiles are about 2 inch in length the standard buttonhead tensile creep specimen geometry cannot be used so that new fixturing and flags had to be designed. This task is complete and quotations have been requested for making the new flags. Saint Gobain is currently having the creep samples machined from appropriate silicon nitride tiles. Bend bars were machined out of the other tiles for the slow crack growth experiments.

The slow crack growth rate exponent was determined by measuring the flexural strength at 1200 °C at two different stressing rates, 30MPA/s and 0.003MPa/s. Both sets of samples showed a similar values(approx 22) for the slow crack growth exponent. This similarity is due to the same second phase, monoclinic Y_2SiO_5 , being present in both sets of samples. Thus the extended heat treatment did not effect either the phase chemistry or slow crack growth exponent. The thermal expansion characteristics(1) of Y_2SiO_5 are deleterious to the stability of the silicon nitride under high temperature load.

Status Of Milestones

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

With funding almost exhausted neither of these tasks will be completed. Work on the project will cease in January unless other sources of funding are found.

Industry Interactions

Discussed delivery of specimens and results to date with Vimal Pujari of Saint Gobain. Made recommendations to improve the material.

Reference

1) J.W.Nowak, J.P.Kay and R.J.Kulas, "Thermal Expansion and high temperature phase transformation of the yttrium silicate Y_2SiO_5 " , J.Mater.Res. Vol 16,[8],2251-2255, 2001

SUBTASK 2.2.7. RELIABILITY EVALUATION OF MICROTURBINE COMPONENTS

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

Objective

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

Highlights

High-resolution transmission electron microscopy analysis showed that there are substantial residual glassy phase present in NT154 silicon nitride microturbine rotor airfoil regions, which did not completely crystallize during the sintering process. The presence of the glassy phase could cause degradation in mechanical performance and reliability of components.

Technical Progress

Studies of flexure strength for bend bars machined from NT154 rotor hub region are completed. Results show that the rotor hub bend bars exhibit characteristic strength that is ~32% lower than that obtained for the bend bars from production billets, but with similar high Weibull modulus values. The difference in mechanical response could possibly result from difference in microstructure and chemical composition based on preliminary SEM analysis. On the other hand, the conversion of biaxial strength yields consistent strength value to that obtained for bend bars machined from the same rotor, suggesting that the biaxial test technique could quantitatively estimate the flexure strength of the same components and billets.

Post heat treatment conditions have been carried out by Saint-Gobain to completely crystallize the glassy phase present after the sintering step. Tensile dog-bone type creep specimens prepared under proprietary post heat treatment condition are in preparation, and will be evaluated at ORNL under specified application conditions.

Status of Milestones

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

Industry Interactions

1. Communications and conference calls with Vimal Pujari and Ara Vartabedian at Saint-Gobain on the mechanical results (both biaxial and flexural strength) of NT154 microturbine rotors.
2. Communications with Vimal Pujari and Ara Vartabedian at Saint-Gobain on the X-ray results of NT154 with various post heat treatment conditions.
3. Communication with John Holowczak and Bill Tredway at UTRC on the updated mechanical results of Saint-Gobain NT154 silicon nitride rotors.
4. Communications with Tania Bhatia and John Holowczak at UTRC on the steam jet tests for barium-strontium-aluminum-silicate (BASA) and strontium-aluminum-silicate (SAS) EBC bulk specimens under specified test temperatures.
5. Communications with Charles Lewinsohn at Ceramatec on the steam jet tests for EBC systems developed using geomimetic approach.

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

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

Objective

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

Highlights

Slurry development of 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 and dipping 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 process. 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. Collaboration with Saint-Gobain has begun.

SUBTASK 2.2.10. RELIABILITY ANALYSIS OF MICROTURBINE COMPONENTS

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

Objective

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

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 papers and web sites have been added.

ANSCARES: Has been modified so that the warning regarding membrane stiffness has been removed.

CARES: The "Eigen" subroutine was updated. The *User Guide* was updated. A *Theory Guide* has been added. Results (rri, pf, rel) are now reported according to the symmetry segment setting. Other minor updates have also been performed.

WeibPar: Now compatible with CARES 7.2. A test for the Weibull modulus > 250 was added. This case occurred for a censored data set. The graphical output was adjusted to plot a vertical line. The CMP file now includes three-parameter Weibull distribution output. The WPR output file now includes information regarding skewness and kurtosis of the data set. The software now distinguishes between user-entered Effective Volumes and Effective Areas. The graphical output was modified to allow the user to change the Y-axis title, and turn on and off the grid lines.

Status of Milestones

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

Industry Interactions

Attended the Environmental Barrier Coatings for Microturbines and Industrial Gas Turbine Ceramics Workshop November 18-19, 2005 Gaylord Opryland Resort & Convention Center Nashville, Tennessee, USA.

2.3.1. ADVANCED MATERIALS FOR RECIPROCATING ENGINE EXHAUST COMPONENTS

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

Objective

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

ORNL microanalysis of long-term engine tested Ni-based superalloy exhaust valves show significant coarsening of the gamma-prime structure, which reduces high-temperature strength, and surface oxidation effects related to moisture-enhanced oxidation, which can initiate fatigue-failure. ORNL, TRW and WED have defined alloy/processing/coating modifications which may mitigate such properties degredation, and are proceeding to test them.

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 this quarter. Detailed microstructural analysis showed that Pyromet 31V exhaust valves had significant aging effects after only a few thousand hours of engine service. Grain boundary $M_{23}C_6$ carbide precipitation increased, while the $\gamma'(Ni_3Al)$ precipitates which strengthen the alloy at high temperatures coarsened significantly with some dissolution. This quarter, ORNL also provided detailed microanalysis of a new 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 rapid coarsening at 800^{o}C. Joint experiments by TRW and ORNL to examine new exhaust valves of several different Ni-based superalloys and processing modifications are currently underway, and examination should 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 – in progress.*

Meetings

Conference calls and communications with principal investigators at WED and/or TRW occur periodically to guide this project.

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

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

Objective

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

Highlights

Testing of spark plugs made from ORNL model and developmental electrode alloys has been initiated at ORNL in a Caterpillar G3406 industrial natural gas engine. Ongoing results of laboratory engine tests at Federal Mogul (Champion®) indicate a stronger than expected impact of alloy thermal/electrical conductivity on electrode wear.

Technical Progress

Laboratory engine tests at Federal Mogul of a series of spark plugs incorporating optimized model Cr_2O_3-forming alloys based on ferritic, austenitic, and Ni-base microstructures indicated a strong link between alloy thermal/electrical conductivity and the rate of electrode wear. These results suggest co-optimization of these properties with oxidation resistance to enhance electrode alloy durability, as the addition of Cr and Al to improve oxidation resistance can also significantly degrade conductivity. Based on these insights, engine testing of electrodes based on developmental ORNL Cr-base and Ni/NiO forming base alloys was accelerated, with rods of these materials manufactured and delivered to Federal Mogul for spark plug manufacture. Oxidation study of a series of high conductivity commercial, model, and developmental alloys was also initiated. Instrumentation and setup of a Caterpillar G3406 industrial natural gas engine was completed at ORNL in the first quarter of FY06. Testing of model and developmental spark plugs in this engine was initiated in January 2006.

Spectroscopic arc measurements were also performed on standard new and used plugs to determine the temperature and vibrational energy distribution in the arc components (ions, neutrals and electrons). This information was incorporated into the erosion model to better estimate the differential heating rate on the spark plug tip, thus predicting a different erosion rate for the anode and cathode.

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) – on track

Industry Interactions

- Conference calls and email communications with Drs. Iryna Levina and Jim Lykowski at Federal Mogul to discuss the engine testing of the spark plugs using ORNL developmental alloys.
- Manufacture and delivery of alloys for spark plug manufacture.

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

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

Objectives

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

Highlights

Testing for the friction and wear behavior of valve stems and guides is set to begin. This quarter, profilometry has been completed on all rubbing surfaces to allow for the evaluation of the extent of wear after the testing. Testing current materials will be carried out as a baseline from which alternate materials can be compared.

Technical Progress

In order to prevent oil deposit formation on intake valve sealing surfaces, excessive oil migration through the valve stem/guide interface must be avoided. Manufacturing tolerances are a compromise between freedom of motion and excessive clearances and are exacerbated by wear allowing for oil to flow and coke onto hot valve surfaces. Alternate guide materials such as ORNL-developed carbon foam may allow for tighter clearances with a material that is somewhat self-lubricating reducing the probability of deposit formation.

Testing for the friction and wear behavior of valve stems and guides is set to begin. Fixturing was constructed earlier to allow the use of segments of currently used valve stems and guides. This quarter, profilometry has been completed on all rubbing surfaces to allow for the evaluation of the extent of wear after the testing. Testing current materials will be carried out as a baseline from which alternate materials can be compared. We have not yet received carbon foam blocks for the machining of alternate valve guide sections.

A procedure to determine the amount of higher molecular weight organic contaminants (sludge), which build up in lubricating oil, was developed and described previously. This type of contaminant is a precursor to deposit formation and, if removed by high efficiency filtration, can prevent or delay deposits from occurring. The procedure is an adaptation of the method for determining soot concentration in diesel lubricating oil using thermogravimetric analysis. Fleetguard, a business unit of Cummins, Inc. provided a list of filters and filter heads which will be used by Waukesha Engine, Dresser for engine tests to compare different levels of sludge removal with the tendency to form in-cylinder deposits. It is anticipated that these engine tests will be carried out this spring.

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 – in progress.
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*.

Industry Interactions

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

"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

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

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

J. Sand, A. Petrov
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5819; Email: sandjr@ornl.gov

Objective

Subcontracted desiccant research at ORNL resulted in two commercially successful HVAC products which are undergoing targeted field and laboratory 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.

ORNL will support this strategic program goal in 2006 through in-house laboratory research and research reports on system performance in these targeted demonstration/verification sites.

Highlights

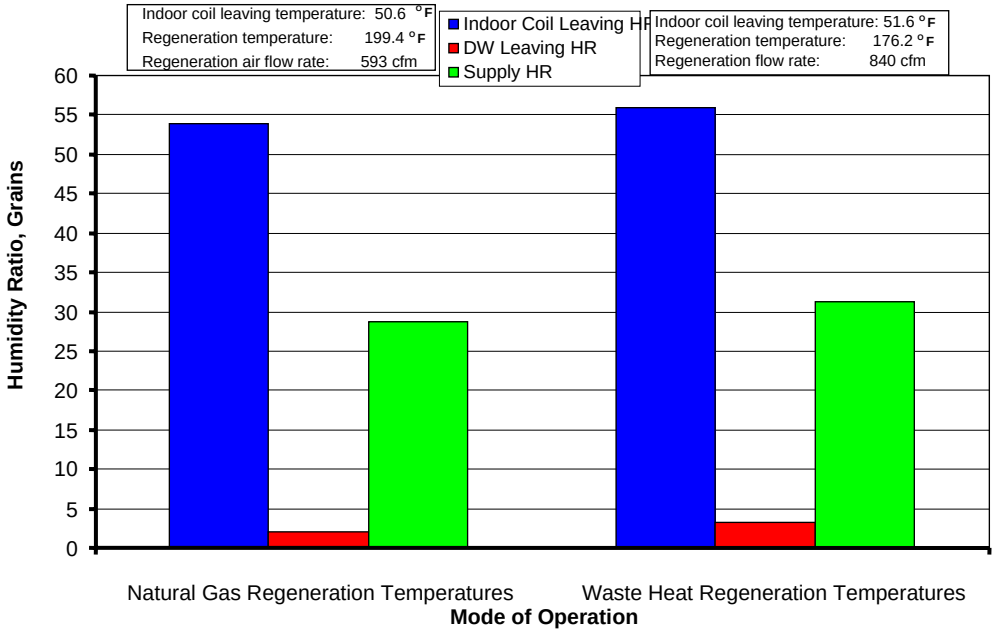
ORNL subcontract research report on hybrid desiccant installation and IAQ improvement in Timber Ridge elementary school – **ORNL/Sub-01-4000025209**.

Installation and start-up of ERV supported, hybrid active desiccant HVAC system in Carnegie Mellon University Intelligent Workplace where it complements other energy saving building technologies being demonstrated.

Web-based, real-time data displays of Trane CDQ™ desiccant system installations at St. Vincent's and Franklin Memorial Hospitals can be found at: http://sitepower.org/thumbs.php?category=5&equip_type=4

Technical Progress

ORNL recently completed a series of test in the Cooling, Heating, and Power (CHP) Integration Laboratory, Building 3114, in which waste heat captured from the exhaust of a turbine generator was used for desiccant regeneration in an integrated heating, ventilating, and air conditioning (HVAC) system. Effective utilization of low grade waste heat generated as a by-product of thermally driven equipment is a key component for full exploitation of all of the energy from fossil fuel consumed in the U.S. and efficient resource energy use. Comparisons were made of the dehumidification capacity of the desiccant module in this unit when waste heat was substituted for natural gas combustion as the thermal source for desiccant regeneration. The figure shown below clearly indicates that equivalent desiccant dehumidification capacities can be obtained when lower temperature waste heat is used in this application. These results from ORNL's CHP Integration Laboratory are significant because they confirm that heat like that recovered from a gas-powered, internal-combustion engine cooling jacket can effectively be used with newer hybrid desiccant HVAC products useful for a broadened range of market applications to achieve optimal performance.



Status of Milestone(s)

Progress is consistent with stated 2006 milestones proposed for this activity.

Industry Interactions

SEMCO, Incorporated, Trane Company

SUBTASK 3.6A. ORGANIC RANKINE CYCLE

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

Objective

This work builds upon previous research to characterize reversible chemical reaction systems that can be used as new, safer active working fluids in this thermo-mechanical converter.

For FY 2006, ORNL will concentrate on designing the recuperator, heat input, and heat rejection heat exchangers, for a bench scale working system.

Highlights

The Cooling, Heating and Power (CHP) group at ORNL completed an interim report on selection of optimal working fluids or use in Organic Rankine Cycles (ORCs The report indicates that the dismal thermal conversion efficiencies of 8 – 15% currently being obtained with conventional ORCs be improved to 20 -30% by using zeotropic mixtures as working fluids in these systems.

Technical Progress

As shown below in the Temperature (T) vs. Entropy (S) plots for pure and mixed Rankine cycle working fluids, essentially all of the opportunity to improve the efficiency of ORCs operating with low grade waste heat comes from internal recuperation of thermal energy from the working fluid after turbine expansion. Sharper focus on enhanced heat recovery and improved heat exchangers for ORCs and thermally activated technologies in general fits well with ORNL's current strategic program plans.

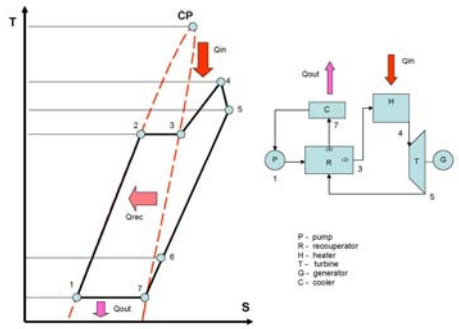


Fig.2a Organic Rankine Cycle for pure substances

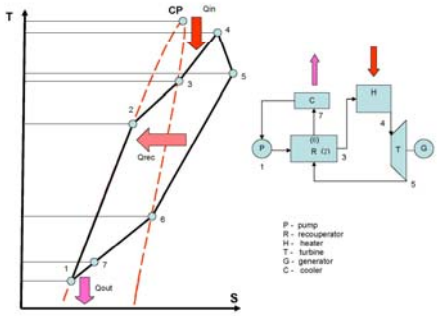


Fig.2b Organic Rankine Cycle for mixtures

Status of Milestone(s)

Progress is consistent with the September 2006 milestone proposed for this activity.

Industry Interactions

United Technologies Research Center (UTRC), E. I. DuPont DeNemours Company – Fluorochemicals Division

SUBTASK 3.7B. THERMAL ENERGY PERFORMANCE EVALUATION

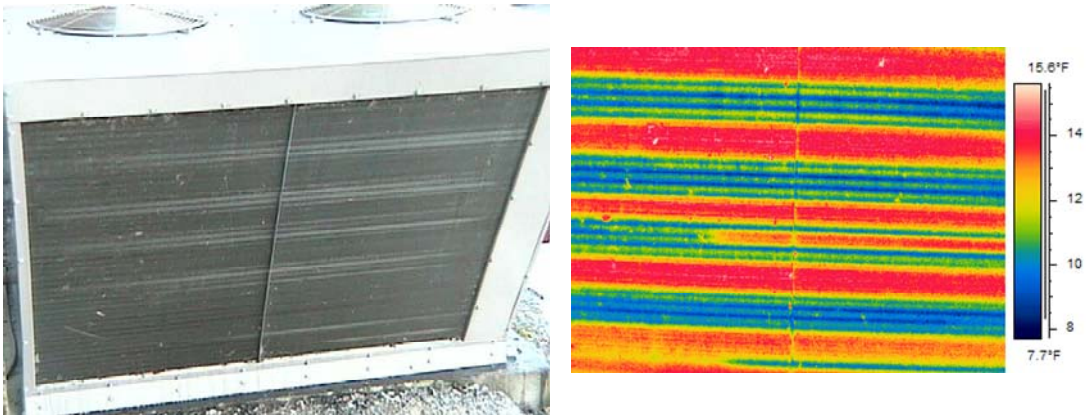
J. Sand, R. Linkous
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-5819; Email: sandjr@ornl.gov

Objective

For FY 2006, ORNL will install flow visualization equipment to augment basic heat exchanger testing. The flow visualization capabilities, together with computational fluid dynamic analysis will enable advanced heat exchanger designs to be tested and analyzed to aid in determining areas for improvement, such as eliminating maldistribution and advanced materials. Miscellaneous instrumentation and P&E support is needed to complete this task.

Highlights

ORNL has taken simultaneous visual and thermal imaging videos of outside coil defrost cycles on the heat pump serving Building 3114 on the Oak Ridge campus. These synchronized videos show how effectively frost is cleared off the coil surface and fins as a result of hot refrigerant circulation and distribution through the tubing circuits.



Simultaneous visual and thermal images of coil defrost

Research plans and a Maturation Funding Proposal were developed to test the "superhydrophobic" surface concept patented by ORNL as a means of improving the frost free and defrosting performance of heat pump equipment.

Technical Progress

These experiments help develop expertise and procedures for effective application of the thermal imaging camera equipment used by ORNL for their heat exchanger/heat transfer work and the results indicate heat exchanger design modifications that result in more efficient operations, such as improved refrigerant distribution patterns, changes in fin spacing, and air circulation nodes.

Discussions with the ORNL/ESTD Advanced Lasers, Optics, and Diagnostic Technology group that originally developed and is promoting application of this "superhydrophobic" technology resulted in a proposal and an experimental plan in which this concept could be tested as a means to prevent or control the frost formation on the outdoor coil of vapor-compression heat pump equipment. Improved defrosting performance would have significant energy saving and owner comfort implications for this commercial technology.

Status of Milestone(s)

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

Industry Interactions

SEMCO, Incorporated, Heatcraft USA LLC, and Lennox, Advanced Heat Transfer.

Subtask 3.7c. Micro-Channel Heat Exchanger Development

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

Objective

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

Highlights

Contact was made with Mike Heidenreich of Advanced Heat Transfer, LLC (AHT) to discuss a partnering effort with ORNL on developing heat exchangers for a gas heat pump rooftop unit.

Technical Progress

A meeting was held with Southwest Gas to discuss plans for developing a microchannel heat exchanger in their next-generation rooftop unit. The development effort will most likely focus on the condenser since that is the heat exchanger with the greatest potential for reducing the size and weight of the unit. The condenser is the largest of the two heat exchangers and reducing its overall height could also help with reducing the overall height of the unit which is one of the goals to aid in meeting local code requirements.

We discussed the possibility of AHT supplying a prototype heat exchanger to test for the Southwest Gas unit. AHT agreed in principle to furnish a heat exchanger and to aid in the design.

Status of Milestone(s)

Milestone is on schedule for testing in September 2006.

Industry Interactions

Advanced Heat Transfer, LLC
Southwest Gas

SUBTASK 3.7G. CFD MODELING ANALYSIS

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

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

Issued job description for Post Doc position with emphasis on experience with CFD modeling and laboratory testing of heat exchangers. Several resumes have been received. Expected hire date is February 2006.

Status of Milestone(s)

CFD laboratory is completed and initial modeling efforts are on schedule for completion in April 2006.

Section 4. End Use Systems Integration and Interface

Subtask 4.1.1a. Packaged/Modular IES Development

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

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

- **Completion of GTI IES Report**

The Gas Technology Institute (GTI) recently submitted their final report on the Waukesha engine-based Integrated Energy Systems (IES) project. Other project partners include: Trane, Ballard, and University of Illinois-Chicago. The team developed, built and tested an advanced 600-kW IES package that has an efficiency of over 70%. The two-module system requires only seven connections in the field, lowering installation costs and reducing total installed cost (including the absorption chiller) from nearly $2,500 to less than $2,000 per kW – a 25% reduction. The system included a Waukesha 615 kW engine-generator, GE switchgear, a Trane absorption chiller, and Cain heat recovery equipment. Ballard Engineering developed the control system. The IES design provides controls to vary engine jacket water outlet temperature. This feature provides for a 40% increase in the production of chilled water when called for. The report included design details at the component and system level, laboratory test results, an economic assessment of different markets (locations) and applications. Lesson learned from the project and additional recommendations are also detailed.

- **UTRC**

Tom Rosfjord made a presentation at the DOE Distributed Energy PEER Review meeting titled: **Research, Development, and Demonstration of Packaging and Cooling, and Power Systems for Buildings** on Thursday, December 15th, 2005 in Crystal City, Virginia. The DOE PEER review presentations are available at the following web site:
http://www.energetics.com/depeerreview05/agenda.html

Technical Progress

Burns & McDonnell

Burns & McDonnell submitted performance reports on the Domain IES for May and August. ORNL review and comment will strengthen the technical report and clarify results.
Honeywell submitted performance reports and Reference Design. That are posted to ORNL's website: http://www.ornl.gov/sci/engineering_science_technology/cooling_heating_power/

ORNL met with Austin Energy and Burns & McDonnell staff resulting in a decision to operate the IES 24-hr per day during the cooling season to obtain data on reported degradation of chiller performance. Several conference calls were held to discuss the results of the extended testing resulting in a determination that performance degradation is influenced by the starting and stopping of the turbine each day. However, tests were not conclusive, so Austin Energy and Broad are negotiating to determine how to pay for the recommended system repair (i.e., increasing air flow of the chiller purge).

Gas Technology Institute

Details of the design and evaluation of the GTI reciprocating engine IES system can be found in the report, which will be posted on the Web soon.

UTRC

Work during this period focused upon Tasks 11.5, and 13.2 of the program plan. These tasks were to identify options and evaluating performance, economics and CVP (customer value proposition) for adsorption refrigeration, and investigate integration of a reciprocating engine with a novel absorption chiller, respectively.

Task 11.5 involves identifying options and evaluating performance, economics and CVP (customer value proposition) for adsorption refrigeration. Alternative coupling of adsorption and absorption units to generate either refrigeration only or both cooling and refrigeration have been

analyzed. A hybrid adsorption-absorption system with better thermodynamic performance than coupled configurations has been proposed. A life cycle cost analysis shows very short paybacks for an adsorption refrigeration system using waste heat from micro-turbines, reciprocating engines or fuel cells.

In Task 13.2 (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 will be performed. The chiller has been received, and facility construction, including electrical work, painting, thermal load stand, and room preparation, is underway. During the quarter, all drawings were completed and reviewed. The facility is expected to be commissioned in January 2006.

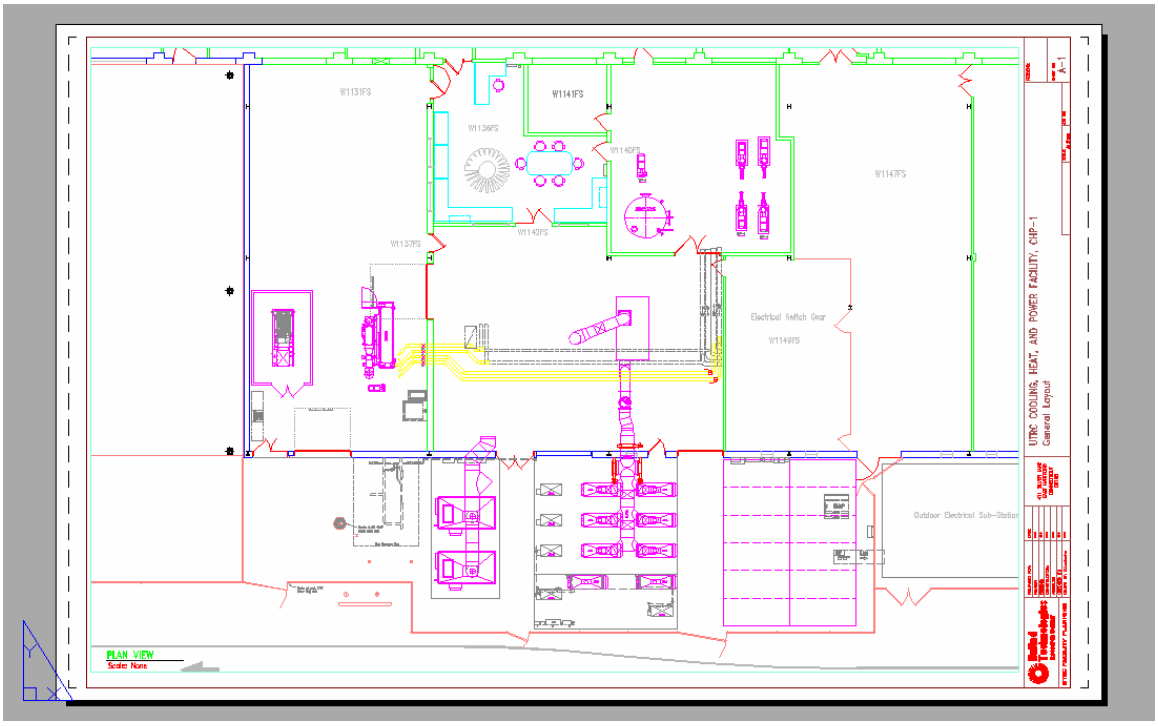


Figure: UTRC CHP Test Facility Layout, Including New Reciprocating Engine and Hybrid Chiller System

Status of Milestone(s)

Burns & McDonnell

Joule Metric: Burns & McDonnell continued developing a packaged CHP system which operates at 70+ % efficiency by meeting the Q1 milestone: Complete the design of the packaged CHP system as documented in the following:

Equipment Layout Development
Major Mechanical Procurement Specifications
Electrical and Miscellaneous Equipment Specifications

Final Mechanical Shop Drawings
Equipment Anchoring Design Package
Mechanical Piping and HVAC Design Package
Final Electrical Shop Drawings
Final Electrical and Miscellaneous Design Package

Gas Technology Institute
The completion of the final report completes Phase I of this project. GTI will receive no FY 2006 funds for future follow-on Phases of this work.

Industry Interactions
Burns & McDonnell
Honeywell and Burns & McDonnell presented the results and success of their IES during DOE Peer Review.

Gas Technology Institute
GTI and their partners (primarily Ballard) are installing the IES system at a new school in New Lenox, IL (near Chicago). The installation is proceeding without DOE funds. GTI is continuing to work directly with various industry partners on incorporating lessons learned from this Phase of the project into future systems.

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

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

Objective

The Chesapeake Office Building on the University of Maryland Campus is a 52,000 square foot office building housing over 150 office personnel. Once an all electric building with 2 separate heating and air conditioning zones, the building has been upgraded with gas-driven equipment for electric generation coupled with thermally driven absorption and desiccant dehumidification [both liquid and solid] equipment. This building is known in the DOE Program as the CHP Integration Test Center. This facility has consistently scored among the top rated projects within the DE peer review process. Work scheduled for FY06 consists of:

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

Highlights

Two graduate students, Joy Bian and Sandeep Nayak, graduated in December with a Master of Science and PhD degrees in Mechanical Engineering respectively. Both went to work in industry. A new student, Shirley Luo, has been training under the leadership of Sandeep and Joy, in anticipation of their graduation.

Technical Progress

CHP System 1 – The Liquid Desiccant Cooling Tower was drained for the winter months. Modifications to the system to include the low-flow absorber were completed. Characterization tests will be completed in the spring-summer of 2006. This work is important to our DOE sponsor in that it is an opportunity for ORNL to work in partnership with NREL, who co-developed the low-flow absorber with AIL Research. DTE Technologies, the manufacturer of the system generator, announced they are terminating operations and selling off assets. They do not want the generator on-site returned, as it is a beta unit, however they will no longer maintain the unit.

CHP System 2 – The Capstone microturbine was operated at power levels ranging from 50 – 60 kW. Minor problems were experienced with one of the circuit breakers connecting the unit to the building power lines. It is suspected that the breaker or control panel has a defect as it is tripping occasionally when the microturbine is not operating. This problem is being reviewed with the interconnect system designer to confirm there is no design problem. The new absorption chiller was winterized and will not be operational until spring.

ORNL assisted with development of the following 3 project-related presentations made at the DE Peer Review: Integrated Energy Systems/Cooling, Heating, and Power Systems for Buildings – Dennis Moran, University of Maryland; Neural Net Optimizing – Darrell Massie, US Army; Commercial Liquid Desiccant Technology – Andy Lowenstein, AIL Research.

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

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

Objective

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

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

Highlights

The "next generation" 10-ton packaged heat pump unit (GEDAC unit) with R407C (interim alternate refrigerant) was received and installed for evaluation in the ORNL Environmental Chambers. The performance and emissions of this unit will be evaluated at various indoor and outdoor conditions.

In addition, the Rotartica air-cooled lithium bromide/water absorption unit (1.3-ton chiller) with rotating heat exchanger was received. The installation of this unit in the environmental chamber is near completion. Rotartica personnel are currently planning to visit ORNL in February 2006 for commissioning and start of our collaborative efforts.

Technical Progress

Initiate evaluations of the 10-ton packaged heat pump unit at various ambient conditions in cooling mode 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.

Completed evaluations of the SEMCO unit in the CHP Integration Laboratory in which waste heat recovery from the exhaust of the microturbine-based CHP system was used for desiccant regeneration. Effective use of low grade waste heat generated is a key component for optimum utilization of fuel consumption and improved source efficiencies. This integrated system was then compared with the performance of the SEMCO unit when natural gas combustion was used as the thermal source for desiccant regeneration.

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: SEMCO, Southwest Gas, Team Consulting, and Rotartica.

SUBTASK 4.1.2E. INTEGRATED ENERGY SYSTEMS TECHNOLOGY UPDATE

R. Sweetser
Exergy Partners, Herndon, Virginia
Phone: (703) 707-0293; Email: rsweetser@exergypartners.com

Objective

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

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

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

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

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

Highlights

Several key first generation packaged systems of engines, CTs and microturbines and thermal devices have been installed and commissioned during 2005 and significant lessons learned have been recorded that will lead to more effective and cost competitive second generation solutions. For example, adaptation of thermal components to recycle wasted energy to cool, heat, and dehumidify is achieving first order success. Projects like A&P Mt. Kisco is showing the need to better match the thermal cooling load to increase the chiller utilization. A similar situation is emerging at the Ritz Carlton (to a lesser extent). Austin Energy's district cooling facility has seen the need to cycle their 2,500 RT absorber due to slower than projected load growth. This latter site caused operating problems with the chiller as it was not designed to cycle and thus could not initially remove internally generated non-condensable. Getting to the right amount of packaging from a single lift module to an erector set have been employed with varying success. These lessons have been documented and presented to the industry in several venues. Finally, during the rising cost of natural gas in 2005, it became clear that a near term strategy for CHP is two fold: 1) migrate to opportunity fuels, 2) work where electric constraints are severe (New York, parts of New England and California, of 3) replace low efficient boilers with CHP where you are displacing natural gas in the boiler and displacing "gas on the margin" electricity as a byproduct of boiler heating.

Technical Progress

Status of Milestone(s)

Industry Interactions

SUBTASK 4.1.3. CHP ECONOMICS/MODELING

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

Objective

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

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

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

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

Highlights

S. Fischer provided one-on-one training on use of the BCHP Screening Tool to staff at the Gulf States Regional Application Center in December. This interaction with end-users identified several program modifications that would aid individuals using the BCHP Screening Tool without requiring significant effort in modifying the source code. These included (1) incorporation of alternative equipment depreciation schedules (GARD had "hard-wired" factors for 7 year declining balance depreciation into the code), (2) user specification of escalation factors for energy and labor

costs, and (3) cash flow calculations for the duration of a proposed project. Effort was also directed toward a significant update of program documentation to aid end users.

Technical Progress

Status of Milestone(s)

Industry Interactions

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

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

Objective

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

Highlights

Bob DeVault made a presentation at the DOE Distributed Energy PEER Review meeting titled: **Integrated Energy Systems - Distributed Energy Systems Overview** on Wednesday, December 14th, 2005 in Crystal City, Virginia. The DOE Peer Review presentations are available at the following web site:

http://www.energetics.com/depeerreview05/agenda.html

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:

- Gas Engine Driven Air-Conditioner (GEDAC) review meeting in Washington, D.C.
- XDX technology review meeting & laboratory tour in Chicago. IL.
- Participation in the 6th Annual World CHP/Decentralized Energy Conference and the CHP Roadmap Workshop in New York, NY.
- Participation in the National DG/CHP Protocols and Database Program Stakeholder Advisory Committee Meeting (ASERTTI) in New York, NY.
- Annual PowerGen Conference & Exposition held in Las Vegas, NV.
- Review meetings with Blue Mountain Energy and Southwest Gas Company in Las Vegas, NV (Mega Development study and GEDAC updates).
- Participation in the DOE Distributed Energy PEER Review meeting held in Crystal City, VA.

SUBTASK 4.1.11. RESEARCH SURVEY, HISTORY OF DOE PROGRAMS

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

Objective

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

Highlights

Material was accumulated on approximately 500 publications from the EERE Program and the organizations that preceded it at the Department of Energy. Publications that were received in "hard copy" were categorized and filed; those that were received in an electronic format were "processed" for later use. Publications were received on CD's in both "PDF" and "TIFF" formats; in every case the files were not sorted as to subject area and "cryptic" file names were employed (e.g. "ANASSE~1.PDF" "CALOR~1.TIF" "PRD1A2~1.PDF"). The PDF files were (1) copied, (2) renamed to reflect the sponsoring national laboratory and the publication name, and (3) a Microsoft Access database was created to keep track of all of the electronic files associated with putting the reports on-line (approximately three separate files will be required for each publication placed on-line). Subsequent effort will be directed toward dividing the publications into meaningful categories and constructing the HTML instructions associated with the web-pages for each publication.

Technical Progress

Hard copies of reports from John Ryan were shipped to ORNL. Scanned copies of the reports were provided to ORNL on 3 CDs.

Status of Milestone(s)

Industry Interactions

SUBTASK 4.1.12. GROUND-COUPLED/GEOTHERMAL ABSORPTION SYSTEMS CALCULATION

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

Objective

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

Highlights

A technical report, "Cost Comparison of Ground Coupled and Cooling Tower Absorption Systems," was prepared for the DOE sponsor. In the report, the cost to own and operate a ground coil coupled and a cooling tower system were analyzed. The study reported that the initial ground coil is much higher than a cooling tower system with the same cooling tonnage. However, after adding the operating and maintenance costs, the life cycle costs for both systems are actually quite close.

Technical Progress

Status of Milestone(s)

Industry Interactions

SUBTASK 4.1.13. ORNL DISTRICT SYSTEM EVALUATION

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

Objective

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

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

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

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

Highlights

DOE-ORO included a performance measure in their contract with ORNL requiring an assessment of on-site power generation.(reference conversation with Marilyn Brown, Ph.D.)

Technical Progress

A report entitled, "Combined Heat and Power at Oak Ridge National Laboratory" was completed. The executive summary follows:

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 MMBtu/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.

Section 4.2. Distributed Energy Systems Applications Integration

SUBTASK 4.2.1 – DG IMPROVEMENTS IN INDUSTRIAL APPLICATIONS

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

Objective

This project addresses CHP systems and how to integrate DG equipment within manufacturing processes with the greatest opportunity to use waste heat. This program focuses on innovative packaged CHP systems for specific applications that are highly replicable and can be integrated with industrial process energy needs. Two of four test and verification projects are complete: Faith Plating (Los Angeles, CA) and C&F Packing (Lake Villa, IL). A secretarial level milestone of posting on the DOE DE website a case study of the Faith Plating project was met in FY05. At the 3rd project at Higgins Brick in Chiao Hills, California, Bowman 80 kW microturbine generators are providing electricity to process for peak shaving and redundancy. The microturbines exhaust streams are ducted through two heat exchangers into combustion air for the brick drying process. A 4th and final project was added in FY05. It is Arrow Linen in Brooklyn, NY. The project is being done in coordination with Keyspan and NYSERDA, who is paying for equipment. The ASERTTI long term test protocol will be beta-tested on this facility. Hardware of interest is two Coast Intelligen 150 kW MAN engines. There are two plate heat exchangers that provide: 1) process water for washing, and 2) make up thermal for a boiler that provides steam for processing linens. The CHP system will provide 300 kW of electricity and 2 MBTUs of thermal. This project is a great example of overcoming space and neighbor obstacles to design a unique solution that provides electric and thermal energy savings in an industrial application.

This project will be completed in FY06.

Highlights

Faith Plating:

Although this project was completed in FY05, the CHP system has undergone technical difficulties with one of the microturbines. ESC, ORNL, and EEA are working with Capstone's Steve Gillette to revive interest in the project. Capstone is hopeful that they can replace the microturbine, under grant money, as Faith Plating is located in a SCAQMD area.

Higgins Brick:

During the month of December 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 Mid-March of 2006. The project team will use this time to analyze the data collected in June, July, August, and September of this year. We have determined that the CHP system has a very positive impact on the efficiency of the kiln as currently configured. We are projecting that for next year the CHP system may deliver power to the owner at a cost that averages 7.5 c/kWh. This is expected to be several cents below the summer rates by the local electric utility. This calculated CHP power cost is based on $7 million Btu gas and an allowance for kiln efficiency increases.

Arrow Linen:

Data acquisition was initiated at the Arrow Linen site in Brooklyn on October 1. During the month of December the two Coast Intelligen engine-generator sets using MAN engines continued to provide power and process heat to the laundry facility for the two shifts, six days per week operation. For December the CHP efficiency averaged 65.5%

Market Transformation:

The project team is preparing a poster report on the Higgins project for the DOE microturbine workshop scheduled for January 17-19 in San Francisco. ESC is also preparing for its Technology and Market Assessment Forum, February 14 -16 in San Antonio. A number of DG Technology providers have been invited to speak at this Forum.

Technical Progress

Status of Milestone(s)

Industry Interactions

SUBTASK 4.2.2. NATIONAL ACCOUNTS DE PROJECTS

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

Objective

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

Three projects are complete: (1) Russell Development Inc. Project which involves the application of a microturbine/hot water activated absorption chiller to air conditioning of an office building in Portland, Oregon [completed in FY04]; (2) A&P Supermarket in Long Island, NY with a 20,000 cfm Munters air handling unit that provides cooling and heating to the main sales areas of the store. The unit also includes a desiccant section to provide dehumidification [completed in FY05]. (3) Cinemark Movie Theater which involves a DTE engine and a DOE/ORNL/SEMCO developed desiccant dehumidifier in Plano, Texas [completed in FY05].

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

This project will be completed in FY06.

Highlights

The Walgreen's data acquisition report was submitted and invoice paid. Data acquisition and monitoring is complete on the Walgreen's and HEB Sites, each over a 9-month period. ORNL is waiting submittal of the final reports for those projects.

Technical Progress

Status of Milestone(s)

Industry Interactions

SUBTASK 4.2.3. VERIZON CENTRAL OFFICE SWITCHING CENTER

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.

Industry Interaction

SUBTASK 4.2.4. GAS TECHNOLOGY INSTITUTE

T. 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 Ritz Carlton system was commissioned this quarter and data collection activities were initiated.

Technical Progress

During this quarter, the Utica College system was designed and equipment specifications prepared. However, due to reductions in expected FY07 funds, this project has been cancelled and it's remaining FY06 funds reprogrammed.

The Wingate Hotel system was designed and equipment specifications prepared. The continuation of this project is under review due to increases in labor costs and reductions in expected FY07 funds needed to complete the project.

Status of Milestone(s)

Four subcontract milestones were met this quarter. A number of future milestones will likely be altered in the subcontract to reflect the reduced scope of the work in FY07.

Industry Interactions

SUBTASK 4.2.5. BUTLER HOSPITAL IN PROVIDENCE, RHODE ISLAND

J. 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

Construction was completed and operation began on the Butler Hospital PureComfort system.

Technical Progress

Installation and operation of this Combined Heat and Power system eliminates the need for steam production allowing the use of No. 6 fuel oil boiler fuel to be eliminated.

Status of Milestone(s)

Industry Interaction

SUBTASK 4.2.6. EASTERN MAINE MEDICAL CENTER IN BANGOR, MAINE

J. 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

Because of project delays caused by the utility's public objections to the project, the project costs escalated above the original budget. EMMC Board of Directors approved additional expenditures to ensure that the project remains on schedule including scheduling construction during winter months. Issues have been resolved and the project remains on schedule. Plans continue to include use of the Honeywell CHP Optimization software developed during ORNL's IES project with Honeywell at Ft. Bragg.

Technical Progress

Documentation on delivery of the gas turbine at Eastern Maine Medical Center (EMMC) was completed including a testing and performance report. The Solar Centaur 50 is 4 MW gas turbine package configured with a 23,000 lb/hr Deltak Boiler that provides steam for heating or driving an absorption chiller. This integrated energy system is a modular combined heating, cooling and power system that matches EMMC's load profiles at their 500+ bed hospital in Bangor, Maine. The only issue that required resolution during the testing process was replacement of a starter motor. The system can be replicated at other projects that have similar heating, cooling and power needs.

Status of Milestone(s)

Industry Interactions

SUBTASK 4.2.7. EAST HARTFORD HIGH SCHOOL

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 has started at the site.

Technical Progress

Concrete pads have been poured at the site. Skids consisting of microturbines, a flue gas boiler, and some ductwork are being assembled at a packager. The absorption chiller is in storage near the high school.

Status of Milestone(s)

Installation is expected to start mid-February, with commissioning to start in April.

Industry Interactions

SUBTASK 4.2.8. REAL ENERGY

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

Initial design of the system has begun.

Technical Progress

Initial modular design layout and equipment sizing has been completed. See table below.

Project Summary

Project Categories	Equipment Supplier	Equipment Capacities
RE Prime Mover	Guascar 300 kWe	600 kW
RE Chiller/Heat Recovery/CTower	Cention	115 Tons/ 3,014,260 btu/hr total
Engineering	MPE/SPS	
Controls & BAS	Woodward/Allen-Bradley	
Project Management	RealEnergy	
Packager/Modular Design	Sierra Precision Services	Engine Modules Chiller Module Aux. Equipement Module Switchgear Module Utility Protection Module
Swichgear/MCC	Siemans	1000 amps

Status of Milestone(s)

The design package is at the 10 percent state.

Industry Interactions

SUBTASK 4.2.9. SEMCO INCORPORATED

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

Objective

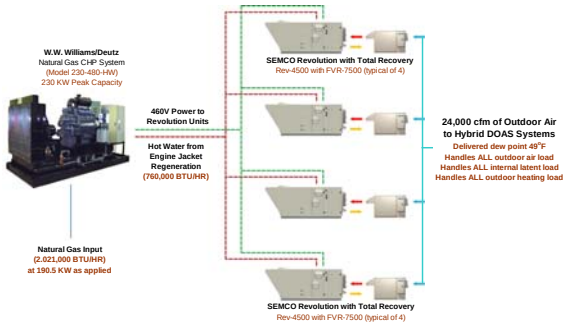
Utilize a 200 kilowatt reciprocating engine generator coupled with an integrated active desiccant system in a high school in Floyd County, Georgia. Partners are C&M Engineering, Floyd County Schools, Deutz Engines, and WW Williams electrical generation equipment. Develop an islanded Integrated Energy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

Highlights

External building structure essentially completed.

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

Building envelope construction nears completion



Grid Independent Packaged CCHP System with IADR Hybrid Dedicated Outdoor Air Systems with Recovery

W.W. Williams/Deutz 230 KW Natural Gas IC Engine: Developed with SEMCO for the Pepperell High Project

Active desiccant rooftop equipment being installed on Pepperell High School roof

Technical Progress

Completed the HVAC design for an entire 200,000+ square foot high school to incorporate eleven integrated active desiccant rooftop (IADR) systems with total energy recovery, including four served by a natural gas fired IC engine.

Designed, sized, and constructed a 230 kW IC engine packaged for "plug and play" integration with IADR systems.

Designed hot water regeneration IADR systems including vapor-compression heat pump options and complete controls integration for "plug and play" with IC engine.

Completed CHP testing at ORNL CHP Integration test lab to confirm IES performance anticipated at Pepperell site.

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. Garland
Oak Ridge National Laboratory, Oak Ridge, Tennessee
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

This reporting period [June –December 2005] has seen the publication of six issues of the *Connecting to the Grid* newsletter, as well as continued updates to and maintenance of the project web site. The December 2005 edition of the newsletter is available at www.irecusa.org/connect/enewsletter.html. Project staff continue to work with state regulators, federal regulators, utilities, and local and national nonprofit organizations to develop appropriate interconnection rules for distributed energy resources (DER), including combined heat and power (CHP) systems. During the six-month period, the project staff also participated in conference calls regarding various state-level interconnection and net-metering proceedings.

Technical Progress

Status of Milestone(s)

Industry Interaction

SUBTASK 4.2.11. SENTECH

P. Garland
Oak Ridge National Laboratory, Oak Ridge, Tennessee
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.

Highlights

In anticipation of the DE Peer Review Meeting, project staff worked with the NREL webmaster to post the final reports developed under the CHP Outreach, Communications and Marketing area within the DOE DE Program.

Technical Progress

Status of Milestone(s)

Industry Interactions

SUBTASK 4.2.12. ORNL PROJECT DIRECTION AND ANALYSIS

R. Hudson, J. Berry, T. Stovall, J. Sand
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 574-0578; Email: hudsoncrii@ornl.gov

Objective

ORNL will provide oversight and guidance of the Integrated Packaged Systems Demonstration Subcontracts and other subcontract activities described under 4.2.1-11. ORNL will provide a critical technical review and provide analysis for verification of subcontracted activities. 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 industrial applications.

Highlights

ORNL witnessed performance testing of the Solar Centaur 50 turbine and met with Vanderweil Engineering to review data acquisition plans for Eastern Maine Medical Center. Instrumentation included in the system was Inadequate to close the mass and energy balances. ORNL comments are being review by Vanderweil Engineering with plans to improve the proposed data acquisition system.

Technical Progress

Status of Milestone(s)

Industry Interactions

SUBTASK 4.2.13. TECHNICAL ANALYSIS AND SUPPORT

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

A poster presentation on the CHP Capacity Optimizer was given at the DOE-DE Peer Review in Washington, D.C.

Technical Progress

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

Status of Milestone(s)

On target.

Industry Interactions

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

Energetics
Energetics, Columbia, Maryland
Phone: (410) 290-0370; Email:

Objective

- One element of this project consists of technical analysis and planning of various technical workshops and roadmaps with the goal of coordinating technical information development and dissemination regarding high potential CHP scenarios nationally, regionally and internationally.
- Another activity is to coordinate Regional CHP Roadmapping efforts. Energetics has assisted and coordinated Roadmapping workshops held in the Pacific, Northwest, Northeast, and Mid-Atlantic.
- Energetics is also facilitating and coordinating activities and information between multiple agencies, regional entities, trade associations, and non-profit groups.

Highlights

- The CHP Roadmap meeting was held on October 26-27, 2005 in New York City. The workshop agenda can be found at: http://www.internationalchp-de.net/pdfs/roadmap_agenda.pdf The workshop agenda included a revisit of past work documented in the CHP Action Agenda and a review of progress to date. New for this year, was the introduction of the CHP Café, which provided an intimate setting for sharing ideas among fellow workshop participants.
- Held one CHP Team Meeting on December 12, 2005.

Technical Progress

2005 marked the sixth year that a national workshop on combined heat and power had been sponsored by the Department of Energy, the Environmental Protection Agency, the U.S. Combined Heat and Power Association, and numerous national, state, regional, and local government organizations, private companies, research institutions, and non-profit associations. Each year since the first CHP workshop – the CHP Summit in 1999, at which the CHP Challenge was established – CHP stakeholders have gathered to discuss both the progress of CHP development in the country as well as the barriers that remain.

In 2005, this annual meeting was combined with the 6th Annual World Conference on Decentralized Energy and CHP, sponsored by the World Alliance for Decentralized Energy (WADE). Combining the two meetings provided an opportunity for attendees to learn about the world market for CHP, technical advances in CHP and DE technology and systems, and policy, regulatory, economic, and environmental issues that still need to be addressed throughout the US and the world for a robust CHP market.

Two-hundred and fifty-six (256) delegates and speakers attended the International DE and CHP Conference; approximately 165 of them stayed to participate in the 6th Annual Roadmap Workshop. Delegates from outside the United States hailed from:

- Brazil
- Scotland
- Canada
- Portugal

- Turkey
- Australia
- The Netherlands
- France
- Finland
- Japan
- China
- Korea
- Belgium
- Sweden
- India
- New Zealand
- Czech Republic
- Nigeria
- Lithuania

The 2005National CHP Roadmap Workshop focused on the market for CHP today in the US, and on the opportunities and actions needed to improve that market during 2006. A "situation analysis" was presented to Roadmap Workshop participants in the form of a CHP Action Agenda, in which the strides made since 1999 were described and the changes in technology, market development, policies, regulations, and education and outreach activities were outlined. All eight Regional CHP Application Centers (RACs) provided short updates on their activities, illustrating the breadth and depth of CHP activities in regions throughout the country. Delegates to the workshop then contributed their thoughts about activities undertaken in their communities and/or organizations during the last year.

The workshop then continued with the first-ever CHP Café. This facilitated series of conversations on CHP was designed to engage participants in small group discussions on CHP issues that they thought would have the most impact on their organizations' successes; on what and where the best opportunity for deployment of CHP was; and what might be needed to improve or expand those opportunities. This Café process resulted in conversations on the following topics:

- Target markets for CHP
- Target audiences for CHP
- Utility inter-relationships
- Economics of CHP – Monetizing CHP
- Strategic issues, such as climate change, grid connections, and environmental externalities
- Regulatory environment
- Technology development

The conversations were captured on "butcher-block" paper, which is now being recorded, categorized in the above-noted topic areas, and analyzed into activities and actions that might be addressed by national, state, regional, and local CHP stakeholders and advocates. Among the preliminary issues of concern and the best opportunities for deployment of CHP are the following:

Target Markets for CHP - Targeted region-specific markets include New York City, Southwest Connecticut, and the Midwest. Target vertical markets include hospitals; supermarkets; hotels; wastewater treatment plants; nursing homes; federal government buildings; agricultural environments where waste heat can be capture; high-end residential buildings; and critical infrastructure facilities that operate 24/7.

Target Audiences for CHP - CHP can meet most needs in a wide variety of industrial, commercial, and institutional buildings. Among the best market opportunities are energy security facilities, including hospitals, police, and fire station, and municipal buildings. The major messages for these markets include valuable energy efficiency resulting from installation; reliability; and economic benefits.

Utility Inter-Relationships – Key issues include convincing utilities of the use of CHP as a customer retention strategy; addressing utility opposition to microgrids because they are seen as competitive to the utility business; and analysis of the utility requirement to "serve all customers" which leads to large back-up capacity requirements and fees for distributed generation. A major topic includes the need to "incentivize" utilities to adopt CHP, simplifying our message; and allowing utilities to make money on DG, rather than purely through-put.

Economics of CHP – Key issues include local electric rates (spark spread is poor in some geographic locations); high first costs, which in turn lead to subsidies; high gas prices; financing constrains; the need to value reliability; and the need for packaged systems to reduce installation costs.

Strategic Issues – Energy has become a national issue – a major topic of conversation. Among the key issues are grid reliability and stability, vis a vis combined heat and power and distributed energy; inclusion of CHP in renewable portfolio standards; valuing and accounting for externalities; monetizing the environmental and energy efficiency benefits of CHP; selling CHP projects and framing the risk of not investing in CHP and DE; and acting on "pain", e.g., using national disasters to our advantage by underscoring the value of CHP and DE in these situations.

Regulatory Environment – The regulatory environment for CHP continues to be uneven across the country. Key issues for action include involvement with FERC and standard interconnection proceedings both nationally and at the state level; and educating regulators about the benefits of DE and CHP, particularly when the power grid is being re-built or expanded.

Technology Development – The primary need is development of reliable packaged systems, using off-the-shelf products and systems that can be assembled off-site and installed as a package, or modular, system on site.

The full results of the 2005 National CHP Roadmap Workshop are expected to be released in draft format for review by the CHP Team, and then by all participants in the workshop, during the first quarter of 2006.

Status of Milestone(s)
Facilitate the CHP Roadmap Meeting. October 2005. COMPLETE.

Industry Interactions
N/A

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

Energy & Environmental Analysis Corporation
Columbus, Ohio

Objective
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.

Highlights
None

Technical Progress
Regulatory database continues to be updated.

Status of Milestone(s)
******CPS/CONTROL MILESTONE****
Complete and post regulatory database. September 2006.

Industry Interactions
N/A

SUBTASK 4.3.12. EVAULATION OF CHP MARKET POTENTIAL

Energy & Environmental Analysis Corporation
Columbus, Ohio

Objective

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

- CHP Installation database continues to be updated.
- The CHP Emissions Calculator was updated

Attached is a modified version of the CHP Emissions Calculator that includes the improvements that the EPA CHP Partnership had us add. There were a number of tweaks, but the primary modifications were:

- Include Absorption Cooling as a thermal output option - this required the addition of a variety of default profiles for displacement of existing electric chillers
- Include duct firing as an option for gas turbines
- Include back pressure steam turbines as a CHP option
- Simplify Displaced Grid emissions options
- Revised operating schedule inputs
- Allow multiple CHP units
- Revise and expand user manual documentation

In addition to the above, we made as number of refinements to simplify and clarify the data input process. We also included logos for DOE DE and the EPA CHPP as part of the spreadsheet itself.

Status of Milestone(s)

Ongoing activity. No specific milestone.

SUBTASK 4.3.16. COORDINATION OF REGIONAL APPLICATION CENTERS

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

Objective

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

Highlights

- Coordinated development of the 8 RAC poster presentations for use at the DE Peer Review
- Held RAC face-to-face meeting in conjunction with the October CHP Roadmap meeting held in New York.
- Coordinated a RAC overview session as presented to the Roadmap meeting audience.

Status of Milestone(s)

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

SUBTASK 4.3.17. PROJECT DIRECTION AND TECHNICAL SUPPORT

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

Objective

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

Highlights

- Completed the CHP Action Agenda and presented the information at the CHP Roadmap Meeting held in October in New York City.
- Prepared and made a presentation on the CHP Program and 18 subcontracts at the DE Peer Review Meeting held in Washington DC in December.
- Prepared the RAC Overview poster presentation for use at the Peer Review Meeting

Status of Milestone(s)

Publish monthly financial reports on subcontracted and in-house activities. Ongoing.

SUBTASK 4.3.18. CHP REGIONAL APPLICATIONS CENTER SUPPORT

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

Objective

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

Highlights

- Completed one-on-one training on the BCHP screening tool with Rohini Brahme, a staff member at the Gulf Coast CHP RAC.
- Responded to questions regarding the BCHP screening tool from the Midwest and Northeast RACs
- Answered an initial request by the Gulf Coast RAC for assistance in doing a hospital feasibility analysis.

Technical Progress

Steve Fischer visited Dan Bullock and Rohini Brahme at the Gulf States RAC and HARC on December 8. Most of the visit was spent working one-on-one with Rohini to help her move up the learning curve with the BCHP Screening Tool. RAC staff requested the following modifications be made to the BCHP screening tool: the Tool should display project cash flow and user specification of future energy and labor costs (GARD had hard wired future rates using EIA projections from 2001). These changes are being made to the tool. In the process, we learned that GARD Analytics built in a 7 year, 200% declining balance depreciation schedule, which isn't realistic today. Previously the depreciation schedule only affected the salvage values of equipment in the life cycle cost calculations (and was insignificant compared with the initial capital and annual energy costs). Implementing a display of project cash flow required a better means of handling equipment depreciation. This parameter was changed to be user input with a default value of the straight-line, 39 year method identified by USCHPA as prevalent for commercial installations generating for their own consumption.

Work continues on developing an extensive user HELP file that provides
Much more information than was provided in the GARD HELP file and also is easier to use because it resembles internet web pages (it is self-contained and is resident on the user's computer rather than being acessed on line from a server).

Status of Milestone(s)

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

Industry Interactions

N/A

SUBTASK 4.3.19. HUD SUPPORT

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

Objective

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

Highlights

- HUD and ORNL are working on an FY06 work-for-others agreement.
- The HUD CHP screening tool was completed and posted on the ORNL CHP website at: http://www.ornl.gov/sci/engineering_science_technology/cooling_heating_power/success_analysis_HUD.htm

Technical Progress

HUD CHP screening tool – Economic evaluation of proposed installations of combined cooling, heating, and power (CHP) systems in multi-family housing units requires calculations that consider building heating, cooling, hot water, and electrical loads, the costs of power and natural gas, and the simulated performance of generators, chillers, boilers, and water heaters. Sometimes it is possible to simplify this process to get a "go/no-go" answer as to whether or not a building owner or operator should look more carefully into CHP and perhaps enlist some engineering support in conducting a site inspection and conducting a rigorous economic analysis. The HUD CHP Screening Tool is one of several programs available for "screening level" CHP analysis; this tool is "non-technical" and is directed specifically toward building owners and operators.

Ongoing Interactions – At the request of Bob Groberg [HUD], the following modifications were made to the HUD CHP Screening tool:
- Code modification so users can read and write information to data files so that it does not need to be re-keyed each time the user wants to use the same information.
- Modification of the "Print" feature so that users can select from the list of printers available to their computer rather than the printed output always being routed to the default printer.

Status of Milestone(s)

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

Industry Interactions

SUBTASK 4.3.20. TECHNICAL ANALYSIS AND SUPPORT TO LEED

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

Objective

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

Highlights

No activity this quarter.

Technical Progress

Status of Milestone(s)

Complete LEED analysis for Dell Children's Medical Center using the revised LEED EA1 credit interpretation that includes CHP. April 2006

Industry Interactions

Section 4.4. Power Electronics

SUBTASK 4.4.1A ANCILLARY SERVICES OFFERED BY DISTRIBUTED ENERGY RESOURCES

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

Objective

This task will develop needed methods for local voltage regulation that are not currently available utilizing programmable inverters in several different sizes (62, 129, and 250 kW).

Highlights

The necessary controls for the 75A (62 kVA rated) PowerEx programmable inverter have been developed in Matlab/Simulink for the dSpace real-time controller to produce reactive power from the inverter. In addition, the controls can handle unbalanced loading and compensate for this unbalance.

Technical Progress

The 75A PowerEx inverter has been undergoing limited off-grid and on-grid testing at the NTRC to develop the necessary controls for producing lagging and leading reactive power. Also, the controls can handle an unbalanced loading condition and compensate for this unbalance. The transition of inverter testing of the 75A inverter from the NTRC to the Reactive Power Laboratory is occurring today. The plan is to set up the inverter along with the computer (loaded with Matlab/Simulink) and the dSpace Controller in the Reactive Power Laboratory in building 3114 at ORNL where it will be interfaced with circuit #2 of the ORNL distribution system. The resistive (500kW) and reactive (375kVar) load banks at the Reactive Power Laboratory will be used to confirm different loading situations in addition to the changing condition of the utility circuit. Once setup is complete, testing will resume at the Reactive Power Laboratory.

Status of Milestone(s)

The inverter has been demonstrated to be able to compensate for fundamental reactive power, harmonics, and unbalanced load conditions for limited loads (less than 15 A). We are now transitioning to higher power loads at the reactive power laboratory. We have met the milestone on a limited power basis and now plan to demonstrate at a higher power level that is closer to the full rating of the inverter. Testing at higher power levels will start in February.

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

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

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

Technical Progress

The controls for the Synchronous Condenser are being developed in Matlab/Simulink. The necessary software for controlling the 6.6 kW DC power supply which is used to overexcite the 250hp Motor so that it operates as a synchronous condenser has been developed. Furthermore, the necessary coding for accessing and recording voltage, current and power data on the synchronous condenser from the Yokogawa power meter during operation has been developed. Eventually, the controls will be transitioned to the dSpace Controller once the potential transformers (PTs) are installed in the Synchronous Condenser Test Area at the motor starter. We hope to have those installed in 1-2 weeks.

The instantaneous and RMS controls for the 75A inverter have been developed in Matlab/Simulink for the dSpace Controller. The inverter has been operating and tested in a limited fashion at the NTRC and is transitioning to the Reactive Power Laboratory today where full range testing will proceed. After testing of the 75A inverter is complete, we will move next to the testing of the 150A (125 kVA rated) and 300A (250 kVA rated) inverters to confirm the controls and enhance as necessary to accommodate the higher capability of these inverters to produce reactive power.

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 in FY05 and plans for FY06. In addition, 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

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

Objective

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

Highlights

- A topical report describing the potential for DE in municipal and rural co-op utilities was completed.
- The report describing the Southern California Edison feeder study was completed.

Technical Progress

Input was provided for the National Research Council's review of the benefits of the DE program.
In support of the Benefits Study required by the Energy Policy Act, a literature search was completed and draft outlines were prepared and discussed with a team of co-authors.

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 the reduced budget for that effort.

Industry Interactions