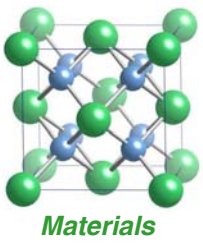
Distributed Energy Program

DE Quarterly Progress Report

For the Period

January 1, 2005 to March 31, 2005



OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

SECTION 1. Advanced Natural Gas Recipricating Engine Development

Subtask 1.1 Rotating Arc Spark Plug, RASP (PIC 466)

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Objective

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

Highlights

Multiple iterations of the Rotating Arc Spark Plug were evaluated in a small natural gas engine. No improvement in performance over either standard J-plugs or annular gap spark plugs was detected. The results are being summarized and will be circulated to outside ignition experts for review. A go/no-go decision on future RASP designs will be made based on feedback from that review.

Technical Progress

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

A second ignition system was developed using an MSD Blaster high power inductance discharge unit. Using a Labview field programmable gate array board to control timing, a high current, long duration spark was produced. The spark plugs were thoroughly evaluated, and though there was significant improvement in the performance of all the plugs at lean conditions, no improvement could be seen in the RASP over the Standard J-plug or the annular gap plug with no magnet. The results are being summarized and will be circulated to outside ignition experts for review. A go/no-go decision on future RASP designs will be made based on feedback from that review.

Status of Milestones

1. Complete evaluation of RASP using multiple ignition systems. Compare RASP to standard J-plug in small 2-cylinder natural gas engine. June 2005 – complete
2. Report results of RASP evaluation. June 2005 – on track.

Industry Interactions

Several outside experts are being consulted about the results received to date on the Rotating Arc Spark Plug (RASP). These experts in academia and industry are being given test results and background information and are being asked to help assess the merit of the concept.

Subtask 1.2 Spark Plug Erosion & Degradation Investigation (PIC 690)

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Objective

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

Highlights

Multiple spark plugs including ORNL alloys, and control Champion® alloys, and replicates were manufactured by Federal Mogul (FM)/Champion and delivered to ORNL for evaluation in an industrial gas engine.

Technical Progress

The first of three planned sets of spark plugs was successfully manufactured by FM in March 2005 and will be engine tested at NTRC beginning in late Spring/ early Summer 2005. A total of 58 spark plugs, incorporating 4 developmental ORNL alloys, 3 control Champion® alloys, and replicates were made. The developmental alloys were used to make the center electrodes, the ground electrodes were made from a standard FM material. This 1st set does not utilize precious metal inserts and will be used to establish baseline behavior. The 2nd set of plugs will utilize a control precious metal insert, and the 3rd set will utilize a developmental high performance ORNL replacement alloy for the precious metal insert. All 58 spark plugs have been characterized in the pressurized test chamber. A data base of the spectral emissions during the arc process has been established as a baseline for characterizing changes produced by engine operation. Voltages required for breakdown are also included in the data set.

Status of Milestones

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

Industry Interactions

- Conference calls and communications with Drs. Iryna Levina and Jim Lykowski at FM to discuss the engine testing of the spark plugs using ORNL developmental alloys.
- The project was presented at the 2nd Annual NG Reciprocating Engine Conference in March with positive results. Project results to date are contrary to conventional wisdom on spark plug erosion so the project is generating a great deal of interest.

Subtask 1.3 Adaptive Controls for Lean Burn Engines

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Objective

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

Highlights

Preliminary analysis of engine emissions confirms that a clear correlation exists between the occurrence of extreme combustion events and elevated emissions. This supports the argument that stabilizing combustion under lean conditions can decrease unburned hydrocarbons and oxides of nitrogen.

Technical Progress

Under extremely lean operating conditions, combustion instabilities typically force the engine into a repeating pattern in which a partial-burn event is followed by a high-pressure, high-temperature "recovery" event. We have theorized that these extreme combustion events are responsible for the majority of the high emission levels seen during this type of operation. Preliminary fast nitric oxide (NO) measurements taken from the Kohler engine confirm that high levels of NO are produced during the so-called recovery events. Further tests are being conducted to develop better estimates of the emission reduction that adaptive control can provide.

Status of Milestones

1. Demonstrate technique for estimating potential benefits of adaptive control. June 2005 – on track.
2. Transition and demonstrate adaptive control on an ARES-sized NG Engine. Sept. 2005 – on track.

Industry Interactions

1. Presented results demonstrating the correlation between NOx emissions and combustion performance at the 2nd Annual Advanced Stationary Reciprocating Engine Conference in Diamond Bar, CA.
2. Interacting with each engine manufacturer, natural gas compression companies, and other research labs (GTI, SWRI) to collect engine data under very lean conditions for analysis.

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

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Objective

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

Technical Highlights

1. Studied longer-term sensing performance under both "dry" and "wet" (~1–3 % H_2O). This was in response to CRADA partner requests.
    a. Element resistance appears to "plateau" under both "dry" and "wet" conditions.
    b. Changes due to NO_x variations (between 20 and 190 ppm_V) are clearly distinguishable against "background".
    c. Varying H_2O causes changes in element resistance.

2. Discovered that current electrode material (Sr-modified $LaCrO_3$) decomposes when exposed to H_2O, NO_2 (and perhaps NO), and electrical bias.
    a. Decomposition not observed when electrode powder only subjected to moisture and elevated temperature (600 ^oC).
    b. Decomposition also not observed in absence of H_2O.
    c. Indicates some "synergy" between electrical stimulus, presence of NO_x, and H_2O.

3. Pursuant to discovery above, have re-opened investigation into new materials.
    a. Results in (obtained testing in dry air with $La_{0.75}Sr_{0.25}Cr_{0.5}Mn_{0.5}O_3$) are promising, indicate that "total NO_x" behavior may be possible with a variety of oxides.

Future Plans

- Investigate use of Mg-modified electrodes. This will help determince whether decomposition problem mentioned above is caused by use of alkaline earth modifiers.

- Work with CRADA partner to develop a screening test for sensitivity to moisture and bias.

- Initiate collaboration with Georgia Tech on Raman, FTIR investigation of NO_x species, crystallography of electrode material at sensor surface.

Status of FY 2005 Milestones

(1) Characterize NOx sensor performance in actual NG engine exhaust (9/05).
We are on track to meet this milestone.

Communications/Visits/Travel

1. Biweekly teleconference were initiated this quarter between DOE, Ford, LLNL, and ORNL.
2. A meeting was held at LLNL in March with all members attending to discuss technical progress and continue to define the path towards commercialization.

Problems Encountered

None to date.

Subtask 1.5 Emissions Characterization: Lube oil/Catalysts Interaction

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Objective

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

Highlights

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

Technical Progress

- In October, a planning meeting was held at the ASME-ICED meeting in Long Beach, CA between ORNL and GTI. Subsequently, the statement of work was finalized and the contract put in place between ORNL and GTI.

- At GTI, the single-cylinder research engine that will be used in Phase 1 and Phase 2 testing is installed and operational on natural gas with micro-pilot diesel injection. The engine will be converted to spark ignition during the following quarter.

- Field aged catalysts suitable for Phase I of this project have been identified by Miratech and will be delivered to ORNL for post-mortem analysis in the next reporting period.

Status of Milestones

1. Characterize available aged NG catalysts for lube oil impact. (September 2005)
2. Conduct tests on a single cylinder engine measuring the impact of lube oil on catalysts. (September 2005) On track.

Industry Interactions

The technical Advisory Committee has been formed with representatives from each ARES engine manufacturer, Miratech, Chevron Oronite, MIT, and University of Alabama agreeing to participate. A formal kick-off conference call will take place early in the next reporting period.

Subtask 1.6a Natural Lean Aftertreatment (PIC 687)

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Objective

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

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

Highlights

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

Technical Progress

- Bench Reactor Analysis of Opportunity for Cost Reduction

  Bench reactor studies of the NOx capacity of NOx adsorber catalysts have been analyzed to investigate the opportunity for cost reduction via lowering the precious metal content of the catalyst. Capacity for NOx storage was found to not vary significantly in the temperature ranges associated with the NG application; therefore, opportunities to use lower cost NOx adsorbers appears to exist.

- Setup for Methane Utilization Studies

  Activities on the engine test platform have been focused on setting up analytical equipment for experiments planned to investigate the chemistry occurring during methane utilization for regeneration of the NOx adsorber. Poor methane utilization was observed in the experiments conducted in FY04; however, high NOx reduction efficiencies were still obtained. We plan to study the chemistry behind the methane utilization and the effect of the chemistry on NOx adsorber regeneration.

Status of Milestones

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

Industry Interactions

Results on the lean NOx trap project were presented at two conferences in Q2FY05; the conferences also provided valuable exchange of information related to natural gas reciprocating engine applications. The two conferences were:

- Gas Technology Institute Conference and Exhibit on Jan. 30-Feb. 2, 2005 in Orlando, FL.
- 2nd Annual Advanced Stationary Reciprocating Engines Conference: Moving Forward in Low-Emissions and High-Efficiency Technologies, March 15-16, 2005 at SCAQMD Headquarters in Diamond Bar, CA.

Subtask 1.6b Natural Lean Aftertreatment (PIC 687)

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Objective

Demonstrate that natural gas can be reformed to species (dimethylether – DME) that are selective for NOx reduction over suitable catalysts. Build bench scale reformer-enhanced catalytic system to assess performance. Build slip stream demonstration system and perform engine test at Oak Ridge National Laboratory.

Highlights

Bench scale validation of individual components is complete. Attention has turned to integration of components to assess system performance and examination of partial oxidation of methane at pressures representative of engine fueling.

Technical Progress

All components (reformer, DME synthesis, and lean NOx catalyst) have been demonstrated separately. Therefore, proof of the original concept of reformer-enhance lean NOx catalysis is complete. Results from reformer testing show that methane can be reformed at conversions above 90% to mixtures of CO and H_2 gas with CO selectivity above 80%. Independent testing on DME synthesis from CO and H_2 shows CO conversions as high as 50%. Therefore, single pass conversion of natural gas to DME could be as high as 30%. This result suggests that a single pass system may work well. Residual fuel value as H_2, CO, and unconverted methane could likely be recovered by sending the residual gas to the fuel inlet for combustion. This not only improves efficiency, but may result in lower NOx levels from the combustion process.

DME has been screened as a NOx reductant and shows exceptional selectivity for reduction. C_1:NOx levels as low as 2:1 demonstrate reduction levels above 70%. This indicates that low fuel penalty is a high probability. More will be known when tests of the integrated system are complete.

Status of Milestones

-Complete integration of bench systems – 03/05: This milestone is delayed. FY05 funds have not been received at PNNL due to continuing resolution. Schedule will slip accordingly.
-Complete parametric study and characterization of whole system operation – 05/05: This milestone is delayed. FY05 funds have not been received at PNNL due to continuing resolution. Schedule will slip accordingly.
-Complete slipstream system design – 06/05: This milestone is delayed. FY05 funds have not been received at PNNL due to continuing resolution. Schedule will slip accordingly.
-Complete construction and shakedown of slipstream prototype – 09/05: This milestone is delayed. FY05 funds have not been received at PNNL due to continuing resolution. Schedule will slip accordingly.

Industry Interactions

All industry interactions have been through the prime contractor, Oak Ridge National Laboratory.

Subtask 1.6c Natural Lean Aftertreatment (PIC 687)

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Objective

The current work is seeking to improve on precious metal catalyst performance for lean-NO_x reduction with H_2-rich reformate by optimizing nanoparticle catalyst composition and architecture. Lean-NO_x reduction catalysts require catalyst/support designs that provide a combination of selectivity (toward N_2) with bifunctional behavior. The precious metal catalysts are promising but improved selectivity (lower reductant consumption) is still sought. The use of reformate as a more effective reducing agent than hydrocarbons is being considered.

Highlights

Further tests under lean exhaust conditions revealed that the PtCu bimetallics including the promising Cu@Pt and Ag@Pt revealed decrease in catalyst performance likely due to partial Cu and Ag oxidation. Tests with controlled pure Pt particles continued to explore the effects of support, catalyst loading, and nanoparticles size for optimizing N_2 yield under O_2-rich conditions revealed a very strong dependence on particle size and catalyst loading. Results suggest that low loadings and small particle size (~ 5 nm) may provide satisfactory performance in terms of N_2 yield under lean conditions for exhaust temperatures below 350ºC.

Technical Progress

Further tests on bimetallic nanoparticles revealed that under lean exhaust conditions, activity of bimetallics for H_2-driven NO_x reduction fell off to an extent that precious metal loadings would not be improved with the lower activity bimetallics. Tests are being established for Pt-Au systems including core-shell particles which are expected to demonstrate the bimetallic N_2 selectivity enhancement under lean exhaust conditions observed for the other bimetallics under non-oxidizing conditions.

Tests on catalyst nanoparticle size and on catalyst support effects continued with pure Pt nano-particles. Increased support interaction with smaller sizes encourages improved conversion and N_2 selectivity. This also explains the good performance observed under low Pt loading conditions where catalyst sintering is minimized.

The completion of the PtCu bimetallic characterization has led to an accepted publication in Angewandte Chemie entitled “Pt-Cu Core-Shell and Alloy Nanoparticles for Heterogeneous NO_x Reduction” by S. Zhou, B. Varughese, B. Eichhorn, G. Jackson, and K. McIlwrath”.

Status of Milestones

1a.) Finished catalyst and structural characterization of Pd-Cu and Pt-Cu systems.(completed)
1b.) Begun to develop synthesis techniques for Pt-Au nanoparticles.

2.) Continued lean exhaust tests for Pd-Cu and Pt-Cu and Pt-Ag bimetallic nanoparticles and tested Pt nanoparticles catalysts to determine effects of nanoparticles size. (completed)

3.) Improved tools for kinetic model analysis to be studied this year (Aug. 2005)

Industry Interactions

1. Discussed testing promising catalysts for slip-stream testing at ORNL for presentation to engine manufacturers. Tests to be conducted later in 2005.

SECTION 2. Materials Based Technology for Distributed Generation

Subtask 2.1.1 Advanced Alloys for High Temperature Recuperators

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Objective

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

Highlights

Allegheny-Ludlum has completed processing and delivery of various sheets and foils of AL20/25+Nb alloy to recuperator OEMs. ORNL has completed creep-rupture testing of Phase I foils and sheets. 4 mil foils of AL20/25+Nb have creep resistance exceeding HR120 at 700-750°C. For Phase II, Allegheny-Ludlum has processed 10 mil sheet for creep testing at ORNL and is in final steps of processing foils.

Technical Progress

Recuperators made from 347 stainless steel suffer severe moisture-induce oxidation attack, mechanical deformation, and failure if moisture and stress exceed critical levels at temperatures above 650°C. Properties characterization and recuperator trials demonstrated that the Ni-based superalloy 625 had sufficient oxidation and creep-resistance for use to about or slightly above 700°C, but at 3.5-4X the cost of stainless steel, it may not be cost effective for all applications. Austenitic stainless alloys HR120 and AL20/25+Nb have also been identified as more cost effective, higher performance alternatives to 347 stainless steels for recuperator applications.

Last year, ORNL began a collaborative program with Allegheny-Ludlum to produce a wide range of commercial sheets and foils of the new AL20/25+Nb alloy appropriate for recuperator air-cell manufacturing. Phase I of this project took standard processing of this alloy and produced materials with significantly better creep-rupture resistance at 700-750°C relative to 347 steel (see results of creep tests in plot below). Phase I material has been delivered to recuperator OEMs for manufacturing trials. ORNL and Allegheny-Ludlum have defined a Phase II effort to examine processing/microstructure effects on optimizing the creep-resistance of various sheets and foils. Phase II foil and sheet production will be completed next quarter and ORNL properties and microstructural characterization will begin.

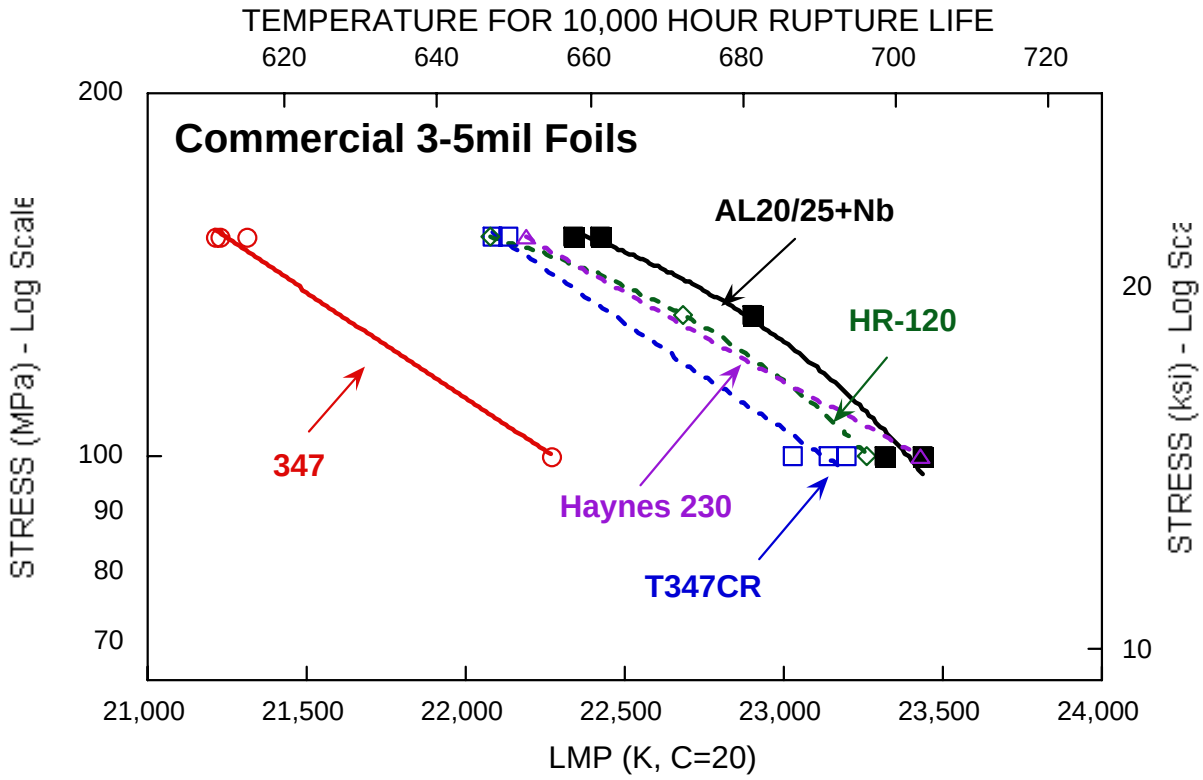
Status of Milestones

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

finished and microstructural characterization is in progress. Air cell manufacturing trials are in progress at Ingersoll Rand Energy Systems. Milestone will probably not be completed until July-August, 2005.

Industry Interactions

1. ORNL communicates regularly with Allegheny-Ludlum Technical Center (Chuck Stinner) to provide input, get feedback and monitor progress of this project. ORNL also communicates when needed with Capstone Turbines, Inc. and Ingersoll Rand Energy Systems.



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

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Objective

Commercially-available and ORNL compositionally-modified alloys for high temperature recuperators (650°C-750°C) to replace 347SS are being mechanically tested and laboratory exposed (corrosion-tested) at ORNL as part of 3 separate 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"

2.1.4 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

ORNL-modified compositions of 3 mil thick 347 stainless steel foils were exposed in ORNL's Microturbine Recuperator Test Facility (MRTF) for 500 h. Each of 4 different compositions was exposed simultaneously to two different intermediate temperatures in the MRTF.

Technical Progress

The compositions (in wt.%) of the 4 ORNL-modified 347 stainless steels were:

- SS 18115 (58.3Fe-19.3Cr-12.6Ni-0.25Mo-0.37Nb-0.029C-0.25N-0.36Si-4.55Mn-4Cu)
- SS18116 (61.1Fe-19.3Cr-12.5Ni-0.25Mo-0.38Nb-0.03C-0.14N-0.38Si-1.8Mn-4Cu)
- SS 18529 (52.5Fe-20.9Cr-20.2Ni-0.3Mo-0.25Nb-0.28Co-0.09C-0.17N-0.25Si-4.82Mn-0.3Cu)
- SS 18554 (60Fe-17.5Cr-13.1Ni-0.3Mo-0.29Nb-0.29Co-0.077C-0.29N-0.33Si-3.87Mn-3.99Cu)

Cross-sectional characterization using electron probe microanalysis (EPMA) showed that the 2 compositions having similar Fe, Cr, Ni, Mo, Nb, Si, and Cu contents but with a 2.4X difference in Mn content (SS 18115 and SS 18116) exhibited the best corrosion-resistance in the microturbine and had much improved performance compared with standard 347 SS foil. The other 2 compositions (SS 18529 and SS 18554) showed extensive nodule formation on the gas-path surface similar to that observed for 347 SS.

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 – on track*

Industry Interactions

1. Conducted microstructural characterization of Capstone engine-tested recuperators January 7-11, 2005. Results reported to Wendy Matthews @ Capstone Turbines.

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

Subtask 2.1.3 Composition Optimization for Corrosion Resistance to High Temperature

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Objective

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

Highlights

Electron microprobe analysis (EPMA) of commercial alloy foils, NF709, HR120 and 625 oxidized for 10,000h in humid air at 650° and 700°C has shown similar amounts of Cr depletion at each temperature in the different alloys. These results suggest that Cr evaporation is the primary mechanism for Cr loss in both Fe- and Ni-base alloys and that the addition of Mn does not significantly change the rate of Cr consumption.

Technical Progress

Based on the EPMA chemical composition results of after long-term exposures of 100μm commercial foils, a clearer understanding of the role of water vapor has been developed. In both Fe-base (NF709: 20wt.%Cr-25Ni-1Mn and HR120: 25wt.%Cr-35Ni-0.7Mn) and Ni-base (625: 23wt.%Cr-0.04Mn) foils, the rates of Cr consumption from the metal were similar at 650° and 700°C with the Cr-consumption rate being ≈50% higher at 700°C. Evaporation of the Cr by the formation of an oxy-hydroxide compound led to significantly higher Cr consumption rates than observed in laboratory (dry) air. The various Mn levels in these materials did not appear to affect the rate of Cr consumption in humid air at these temperatures.
Three new laboratory-scale versions of Fe-20Cr-20Ni have been rolled to sheet and foil thickness and creep and corrosion specimens are being prepared. Long-term testing of new commercially made foil versions of HR120 and AL20/25+Nb are being tested in humid air at 650°-800°C.

Status of Milestones

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

Industry Interactions

Discussed 347 oxidation behavior with M. Newnham of Midland Turbine Ltd in February 2005

Discussed recuperator performance issues with W. Matthews of Capstone in February 2005

Subtask 2.1.4 Recuperator Materials Testing and Evaluation

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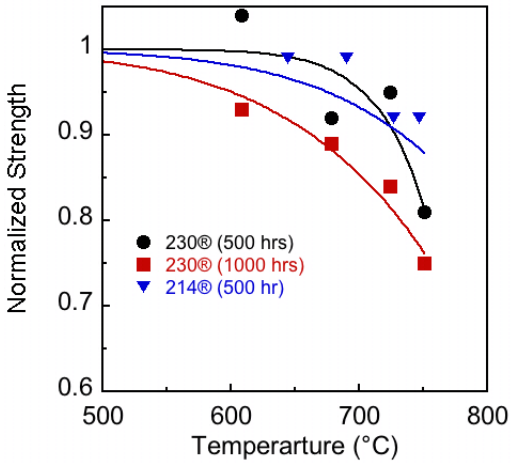
Objective

The objective of this sub-task is to screen and evaluate candidate materials for the next generation of advanced microturbine recuperators. To attain this objective a microturbine was modified to operate at recuperator inlet temperatures as high as 850°C. The durability of candidate recuperator materials is determined by placing metallic foil test specimens at a location upstream of the recuperator, followed by determination of the evolution of the material's physical and mechanical properties as a function of time of exposure. Metallic foil test specimens can be subjected to various levels of mechanical stress by pressurizing a specially designed sample holder onto which the metallic foil test specimens are welded. The selection of materials for evaluation is determined in collaboration with other tasks in this program and with manufacturers of microturbine recuperators.

Highlights

Tests are in progress to complete 3000-hr exposure of alloy 120® in ORNL's Microturbine Recuperator Testing Facility.

Technical Progress



During the reporting period a test campaign was completed during which test specimens of alloys 120®, 214®, 230® and EMS's FeCrAlY-R were exposed in ORNL's microturbine recuperator testing facility. A new 500-hr test campaign was initiated with test specimens of alloys 120®, pre-oxidized 214® and AL20/25+Nb with the objective of achieving 3000 hrs of exposure for alloy 120®.

It was found that the ultimate tensile strength of alloy 230® decreased by 25% after a 1000-hr exposure at 750°C, whereas the ultimate tensile strength of alloy 214® decreased by less than 10% after a 500-hr exposure at 747°C. Work is in progress to correlate these results with the microstructural evolution in these materials. Foils of alloys 120® and AL20/25+Nb were prepared to evaluate their resistance to intermittent microturbine operation and these tests are scheduled to be carried-out in the near future.

Status of Milestones

1) Complete 1000-hr test campaigns and characterization of HR-120® and ORNL-modified stainless steels (December 2004). Completed.
2) Publish a technical paper that summarizes the testing of HR 120 and NF 709 in ORNL's microturbine recuperator test facility (June 2005). On Track.

Industry Interactions

Continued collaborating with Solar Turbines (San Diego, CA) on the evaluation of the creep resistance of alloy 625 and various grades of stainless steels.

Subtask 2.2.1 Keiser Rig Testing and CFCCs and Advanced Ceramics

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Objective

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

Highlights

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

Status of Milestones

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

Subtask 2.2.2 Microturbine Characterization of CFCCs and Protective Coatings

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Objective

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

Highlights

The exposure of ATK-COI Ceramic's oxide/oxide ceramic matrix composite, designated A/N 720 CMC, for 3000 h at each of three temperatures, 1135°C, 1200°C, and 1250°C and 10% H_2O, has been completed in ORNL's Keiser Rig. Extensive microstructural and mechanical evaluation following each high temperature exposure condition (1000 h exposure intervals for 3000 h total at each temperature) is well underway. In addition, short-term (~150 h) exposures in a microbalance at the same temperatures have been completed.

Technical Progress

A total of twenty-seven (17.8 cm X 2.5 cm X 0.3 cm) in-plane tensile strength A/N720 CMC coupons were provided for exposure in ORNL's Keiser Rig. The tensile stress-strain response of the oxide/oxide specimens was determined at ambient temperature according to ASTM standard test method C1275. The tests were conducted using an electromechanical testing machine at a constant crosshead displacement rate of 25 mm/min. The retained UTS was determined for the A/N720 CMC (eight tensile specimens were tested for each time/temperature condition) exposed for 1000, 2000, and 3000 h at 1135°C, 1200°C, and 1250°C. The UTS data clearly shows little effect of long-term exposure of the A/N720 CMC at 1135°C in the Keiser Rig's high H_2O pressure environment. While there appears to be a downward trend of average strength with time for A/N720 CMC exposure at 1200°C, an analysis of variance showed that the differences among the mean values for the as-processed and 1200°C exposed test specimens was not significant at the 90% confidence level. An ~25% decrease in UTS was observed for all A/N 720 CMC exposed at 1250°C.

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 – on track*

Industry Interactions

1. Attended 29th International Conference on Advanced Ceramics and Composites in Cocoa Beach, Florida, and Co-Chaired Session on Environmental Barrier Coatings. Gave presentation "EBC Volatility at High Water-Vapor Pressures."
2. Conference call with Andy Szweda, ATK-COI Ceramics, on March 21, 2005 to discuss results of completed Keiser Rig exposures of A/N 720 CMC materials and hybrid liner evaluation.
3. St. Gobain, NASA Glenn, Ceramatec, UTRC, and ATK-COI Ceramics currently have EBCs being exposed in the Keiser Rig.

Subtask 2.2.3 Advanced Ceramics for Gas Turbines and Microturbines

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Objective

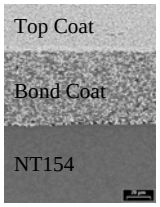
The goal of this program is to develop and optimize a high temperature silicon nitride based ceramic material and forming process suitable for microturbine hot section component applications.

Highlights

A novel EBC composition has been defined based upon thermodynamic computations and CTE simulations to match with the NT154 substrate. The rare earth di-silicate based composite EBC composition so defined was synthesized and tested in the in-house recession rig. The testing showed at least a factor of three improvement over the bare NT154 substrate. Because of its excellent CTE match with the substrate, this composite system will be utilized as a bond coat for a rare earth di- silicate based top coat already proven to be a recession resistant composition.

Technical Progress

Using the novel EBC composition previously defined, the development of a suitable EBC coating technique is on-going. The two layer dip-coated EBC system has been successfully sintered to closed porosity without showing any undesirable cracking between the layers. Coating process optimization is on-going to improve the coating uniformity and eliminate the observed drying cracks. Hot pressed test samples of the bond coat and the top coat compositions have been delivered to ORNL for testing in the high pressure Keiser rig, to verify the good results achieved in the in-house recession rig.



Additional effort has been redirected towards further improvement in the slow crack growth resistance of NT154. Mechanisms have been identified and possible improvements in the processing are now being explored.

Status of Milestones

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

Industry Interactions

1) Technical papers were presented by V.K. Pujari and R.H. Licht at the 29th ACerS Cocoa Beach Conference and the 29th USACA ITAR Restricted Conference on Composites, Materials and Structures (January 23-29, 2005) respectively, highlighting our progress towards ceramic microturbine component and EBC development. During the meetings useful contacts were

made with microturbine OEMs (UTRC, GE), DoD, and government labs (ORNL, NASA, AIST, Japan).

2) Hosted a visit to Northboro by Terry Tiegs and H.T. Lin of ORNL to review program technical results and prioritize Phase III program activity.
3) Discussions with Bill Tredway and John Holowczak of UTRC on silicon nitride turbine components.

Subtask 2.2.4 Oxidation/Corrosion Characterization of Microturbine Materials

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Objective

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

Highlights

The exposure of several candidate EBC compositions (in stand-alone form, i.e., not applied to a substrate, and applied as a coating on SiC/SiC composite substrates) to extremely high water-vapor pressures in the Keiser Rig has been initiated. Recent exposures of Si-based standards and hot-pressed BSAS-based coupons has 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 will be used to "rank" numerous EBC formulations being investigated for ceramic composites and monolithics.

Technical Progress

Several proof-of-principle specimens were included in the initial 1500 h high water-vapor-pressure exposures to demonstrate and measure volatilization in the Keiser Rig (see DE Quarterly Report for October-December, 2004) and volatilization trends were clearly differentiated between the different materials using the gravimetric data. Following the exposure of this series of standard materials, numerous candidate EBC compositions are currently being exposed in ORNL's Keiser Rig at high water-vapor pressures (20 atm total system pressure and 18 atm H_2O) and 1250°C. The EBC materials being exposed for the first 500 h include:

(1) 5 proprietary (industrial) EBC compositions
(2) stand-alone coupons of $Y_2Si_2O_7$, $Yb_2Si_2O_7$, $Lu_2Si_2O_7$, $Sr_2Al_2Si_2O_8$, BSAS, and SAS
(3) plasma-sprayed BSAS, SAS, and Y_2SiO_5 coatings on SiC/SiC composites
(4) A/N 720 oxide/oxide composite and stand-alone friable-graded interface.

Microstructural characterization is being conducted on all the as-processed EBC compositions for comparison with the materials after sequential 500 h exposures in the Keiser Rig. Coupon thickness and weight changes will also be monitored. The first 500 h run is scheduled to end on or about April 18, 2005.

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 – on track*

Industry Interactions

1. Attended 29th International Conference on Advanced Ceramics and Composites in Cocoa Beach, Florida, and Co-Chaired Session on Environmental Barrier Coatings. Gave presentation "EBC Volatility at High Water-Vapor Pressures."
2. Conference call with Andy Szweda, ATK-COI Ceramics, on March 21, 2005 to discuss results of Keiser Rig exposures of A/N 720 CMC materials.
3. St. Gobain, NASA Glenn, Ceramatec, UTRC, and ATK-COI Ceramics currently have EBCs being exposed in the Keiser Rig.

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

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Objective

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

Highlights

The mechanical behavior of NT154 silicon nitride developed in the early 1990s was compared with that of the current vintage of NT154. The implication of these data on the reliability of the Ingersoll-Rand rotor was assessed using the Integrated Reliability Assessment Software (described in a previous highlight).

Technical Progress

Extensive mechanical property data sets were collected for old (1995) and current vintages (2005) of the NT154 silicon nitride. These data included flexure strength as a function of temperature and slow crack growth as measured using dynamic fatigue testing. While the fast-fracture strength versus temperature data for the old and new vintages were comparable, the new vintage was more susceptible to slow crack growth (reflected by lower N values). The Integrated Reliability Assessment Software was subsequently used to assess the impact of these differences upon the reliability of the Ingersoll-Rand rotor. As expected the probability of survival for the current NT154 material decreased more rapidly as the exposure time increased.

Status of Milestones

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

Industry Interactions

1. Discussions were held with John Holowczak concerning possible collaborations in response to the recently released BAA from the Air Force.
2. Communications with Steve Duffy of CRT concerning use of the Integrated Reliability Assessment Software.
3. Discussions were held with Ara Vartabedian from Saint-Gobain Ceramics & Plastics concerning incorporation of current NT154 data into database.

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

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Objective

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

Highlights

The Si_3N_4 - $BaAl_2Si_2O_8$ system was selected for oxidation studies together with the system Si_3N_4 –Si_2N_2O –$Sc_2Si_2O_7$-Sc_2SiO_5.

Technical Progress

Dating back to the early work of Pickup and Brook, studies on the addition of Si_3N_4 to barium aluminosilicates (BAS) have been reviewed. The system produces a low melting eutectic glass, which facilitates densification, and the glass transforms to a refractory ceramic $BaAl_2Si_2O_8$ (Celsian) on cooling. K. White and coworkers have conducted numerous studies on a 70vol% Si_3N_4 – 30 vol. % BAS showing that a significant amount of second phase material can coexist with silicon nitride and can give rise to reasonable mechanical properties. Several samples designed to study the effect of increasing amounts of Celsian on the oxidation of silicon nitride have been prepared.
Scandium monosilicate was prepared by hot pressing an appropriate mixture of Sc_2O_3 and Cabosil^{TM} grade SiO_2 at 1800 °C at 5000 psi for 2 hours. The thermal expansion coefficient of Sc_2SiO_5 was found to be 5.2 x10^{-6} per degree centigrade over the temperature range 0 to 1200 °C. This is slightly higher than that for the disilicate (4.5 x 10^{-6} per degree centigrade).

Status Of Milestones

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

Industry Interactions

1) Discussions with Vimal Pujari of St Gobain about delivery of NT154 silicon nitride Creep samples.
2) Oxidation testing of candidate ceramics was discussed with John Holoczak of United Technologies.

Subtask 2.2.7 Reliability Evaluation of Microturbine Components

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Objective

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

Highlights

Mechanical strength evaluation of MOR bar machined from the hubs of NT154 rotors has been completed. Results show that the flexural strength of MOR bars from rotor hubs is lower than that measured from the billets, presumably due to differences in microstructure and chemistry.

Technical Progress

Studies of dynamic fatigue response of NT154 silicon nitride processed with diffusion barrier coating (DBC) have been initiated. Preliminary results at room temperature indicate that the NT154 with DBC exhibits comparable characteristic strength (~950 MPa) and Weibull modulus (m = 10) to those manufactured without DBC. The fatigue exponent (N) at room temperature is 86, which is higher than those obtained for samples without DBC (N = 32-40).

Studies of toughness measured via indentation technique as a function of location on the polished airfoil samples machined from NT154 rotors were initiated. The results show that the toughness in the airfoil region is ~ 3 MPa√m, which is much lower than that obtained from the hub region (~ 5 MPa√m). Note that the reported toughness for the NT154 is ~ 5 MPa√m. Detailed SEM analysis will be carried out to understand origin for the low toughness of airfoil region.

The US-Japan joint project under the US-Japan High-Level Consultation on Climate Change Science and Technology Working Group has been completed by the end of March 2005. This joint research provides an important insight into the effect of high-temperature steam on the long-term stability of various RE-disilicates, and development of potential EBC for gas turbine application.

Status of Milestones

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

Industry Interactions

1. Communication with Vimal Pujari and Ara Vartabedian at Saint-Gobain on the initial dynamic fatigue results of NT154 with DBC at room temperature.
2. Communication with John Holowczak and Bill Tredway at UTRC to on the dynamic fatigue results of Saint-Gobain NT154 silicon nitride.
3. Communication with Tatsuki Ohji and Shunkichi Ueno at AIST, Japan on the progress of the high-temperature steam jet testing of RE-disilicates.

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

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Objective

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

Highlights

Presented a paper entitled "Producing Surface Coatings on Silicon Nitride by Pack Cementation" at the 29th International Conference & Exposition on Advanced Ceramics and Composites in Cocoa Beach, FL. The talk described the coating process and the composition and microstructure of coatings that have been produced on commercially available silicon nitride ceramics.

Technical Progress

A billet of the new-production NT154 Si_3N_4 material from Saint-Gobain was sliced to produce specimens for coating. The slicing was planned so that each specimen would retain a large area of as-processed surface, similar to what would be found on production component. Samples have been processed under conditions that produce a $Yb_2Si_2O_7$ + SiO_2 coating on the silicon nitride surface. Additional samples are being prepared for pack cementation coating to produce a $Yb_3Al_5O_{12}$ surface layer. The coated specimens will undergo environmental exposure testing in the Keiser rig.

Specimens of SiC/SiC composite have completed pack cementation coating to form $Yb_2Si_2O_7$ and are ready for exposure testing in the Keiser rig.

Status of Milestones

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

Industry Interactions

1. Met with Vimal Pujari and Ara Vartabedian of Saint-Gobain at the Cocoa Beach Conference to discuss pack cementation coating of NT154 Si_3N_4.
2. Discussed the possibility of using pack cementation to coat silicon carbide with John Holowczak of United Technologies Research Center.
3. Met with Irene Spitsberg of GE Aircraft Engines at ORNL to discuss coating results for EBCs on SiC/SiC composites.

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

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Objective

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

Highlights

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

Technical Progress

Work continues on the collaborator's candidate materials systems. Surface charge and rheological characterization was completed on materials received to date, and dipping studies were initiated. Iterations of coating, sintering, and characterization to minimize sintering temperatures and maximizing coating uniformity, desired thicknesses and densities are currently in process. Promising systems will be submitted for simulated exposure testing. ORNL material system evaluation nears completion after coated bend bars of AS800, SN282, and NT-154 were removed from 500 hours simulated exposure testing in HT Lin's steam rig. Post-mortem analysis is on-going.

Status of Milestones

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

Industry Interactions

Communications continue with Drs. Charles Lewinsohn (Ceramatec) and Vimal Pujari (Saint-Gobain) to discuss utilization of ORNL's colloidal expertise. Collaboration with Honeywell continues.

Subtask 2.2.10 Life Prediction Development and Support for Microturbine OEMs

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Objective

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

Highlights

The time dependent parameter estimation and component reliability modules of CARES and WeibPar have been updated. The WeibPar treatment of censored data has been updated. License key technology has been added to CARES and WeibPar.

Technical Progress

Given a dynamic fatigue (monotonically increasing load) data set, WeibPar now calculates the dynamic fatigue parameter B, and provides an equivalent static fatigue material specific parameter for use in CARES. This now allows the user to evaluate subcritical crack growth parameters using one type of load application, and apply this information to a component that is subject to another type of load application using what is commonly referred to as g-factors in the literature. Additional load application formats will be added next quarter. With these updates WeibPar 3.2 is compatible with CARES 6.3.

When analyzing a censored data set each data point can now be identified by a string of characters rather than the numerals 0, 1, etc. Any designation beginning with the letter 'V' will be analyzed as a volume flaw (e.g., volume, v, vol, vol1, vol2, vol3, etc). Likewise any designation beginning with the letter 'S' will be analyzed as a surface flaw. Designations beginning with anything else will be analyzed as an unknown flaw.

New licensing key technology will allow CRT to provide executable versions of the algorithms as FTP downloads. Files can be downloaded free of charge and run in demonstration mode. When a user decides to license the software, they simply run the licensing program and e-mail a Client Information text file to CRT. Upon validation that the customer is a DER industrial partner, CRT will create and e-mail a license key to the customer to "unlock" the full capability of the codes. With a valid license key a customer may download upgrades to the codes as they become available.

Status of Milestones

1. ANSCARES Update for Compatibility with ANSYS 9.0. ***June 2005 – on track***
2. CARES and WeibPar updates. ***October 2005 – on track.***
3. Support for DER Industry Partners. ***Ongoing***
4. Support for the Interfacing of IRASoft with CARES and WeibPar. ***January 2006 – on track***

Industry Interactions

CRT met with a major manufacturer of heavy duty diesel engines to discuss the use of CARES and WeibPar in the design and analysis of next generation, ceramic diesel particulate filters.

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

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Objective

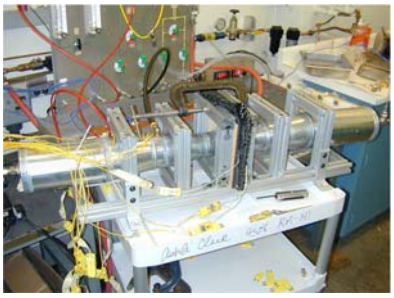
Because of low efficiency in power generation, as much as 90 GWh of energy are lost in the United States every year. However, by recovering waste heat, the efficiency of power generation systems can be significantly improved. In the case of recuperated microturbines, heat in the exhaust gases can be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

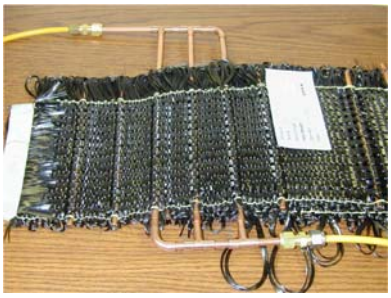
Highlights

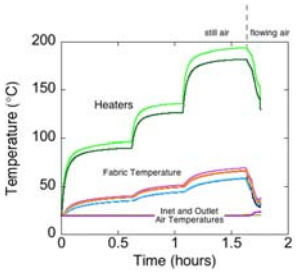
The permeability and heat transfer characteristics of woven graphite fiber structures incorporating copper tubing were determined.

Technical Progress

A test facility was designed, fabricated and instrumented with thermocouples, pressure gauges and flow meters to simultaneously evaluate the permeability and heat transfer characteristics of woven graphite fiber structures that incorporate copper tubing. Measurements were obtained for woven fiber structures with different porosities to identify the structure that maximizes heat transfer while minimizing pressure drop. The test facility also incorporates a water recirculating system with temperature control and a fan to quantify, for example, the heat removal rate as a function of air volumetric flow and the porosity of the woven structure.







Work is in progress to identify conductive epoxies to maximize heat transfer between the water-carrying tubes and the woven fiber structure.

Status of Milestones

Complete prototype fabrication of advanced heat exchanger using high conductivity fibers. (June 2005) On Track.

Industry Interactions

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

Subtask 2.2.13a Silicon Carbonitride EBC Development

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Objective

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

Highlights

Three point bending (TPB) tests on hydrothermal tested SiCNO-50v% hafnia samples showed that these samples showed a significant decrease in the strength because of the cracks arising in bigger SiCNO particles (when oxidized to SiO_2). The SiCNO particles were eliminated by making a hafnia-5 v% SiCNO composite in which SiCNO was coated on the hafnia particles. This SiCNO aided in the interparticle bonding by forming hafnium silicate. These specimens were then hydrothermally tested at 1300 °C, v = 35.5 $cm.s^{-1}$. TPB tests revealed that these specimens did not undergo any appreciable strength degradation even after 200 hr. of exposure.

Technical Progress

The time dependent strength evolution of hydrothermally tested samples were measured by TPB tests. Hafnia-50v%SiCNO particulate composite showed a sharp decrease in strength after 30 hr. of hydrothermal testing (T= 1300°C, v = 17.6 $cm.s^{-1}$). SEM studies revealed that this decrease in strength could be related to cracking of bigger (> 5 μm) SiCNO particles. In order to eliminate the SiCNO particles a hafnia-5v%SiCNO composite was prepared by adding hafnia to Ceraset (preceramic polymer). This causes the SiCNO to coat the hafnia particles and prevents SiCNO from forming a distinct particulate phase. The coated SiCNO aids in particle bonding by forming hafnium silicate (confirmed by XRD). TPB tests revealed that the mechanical strength of this composite did not degrade even under more severe hydrothermal tests (T=1300°C, v = 35.5 $cm.s^{-1}$). Further trials are being conducted to optimize the SiCNO volume content to obtain a stronger and hydrothermally robust bond coating material.

Status of Milestones

1. Understand microstructural origin for the stable mechanical strength in Hafnia – SiCNO composites. June, 2005; on track
2. Optimize SiCNO content to design a robust coating material and evaluate its performance under severe hydrothermal testing. July, 2005; on track

Industry Interactions

1. Discussed the results with Dr. Kang Lee of NASA at the American Ceramic Society Annual Meeting, Apr. 10-13, Baltimore.
2. Presented these results to Dr. Brian Lawn's group at NIST, Gaithersburg, MD.

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

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Objective

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

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

Highlights

Particle size control was used to sinter promising, geomimetically selected, top coat materials to full density.

Technical Progress

Powder processing methods were applied to modify the particle size distribution of geomimetically selected top coat powder. Experiments were performed to select powder processing and sintering conditions to produce dense specimens of a material which has been shown to have promising hydrothermal corrosion resistance in screening experiments. Samples of this material were provided to ORNL for exposure in the Keiser Rig. Processing of specimens of additional compositions that varied slightly from the first material was initiated to refine material selection. Specimens of these materials will be provided to ORNL next quarter. A designed series of experiments was initiated to optimize bond coat processing and performance. Discussions with researchers at ORNL to improve top coat slurry dispersion and rheology have begun.

Status of Milestones

Industry Interactions

Frequent conference calls and e-mail communications occur between Ceramatec, Inc. and Dr. Vimal Pujari and Mr. Ara Vartebedian at Saint Gobain, Ceramics and Plastics.

Subtask 2.3.1 Advanced Materials for Reciprocating Engine Components

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Objective

Next generation natural gas reciprocating engines will have higher in-cylinder pressures and temperatures in order to meet the goals of higher power density increased efficiency, and lower emissions. Component materials face the paradox of increased life and reliability while operating in higher temperatures that limit material performance and durability. In collaboration with ARES OEM's and their component suppliers, ORNL is characterizing the effects of long-term engine exposure on intake and exhaust valves, their seats, and on exhaust components.

With an appropriate baseline of current material/components mechanical and oxidation properties behavior, and underlying microstructural changes in various alloys, ORNL will work with the OEM's and their suppliers to establish the best materials and processing options for components with higher performance.

Highlights

Characterization is complete on an initial set of intake and exhaust valves with significant long-term ARES engine exposure. Ni-based superalloy exhaust valves show significant coarsening of the gamma-prime structure that provides high-temperature strength. The initial casting trials for making exhaust components from the new CF8C-Plus austenitic stainless steel were successful, and components have been sent to Waukesha, and bars for test specimens were sent to ORNL.

Progress

Comparison of fresh components with a series of components exposed to engine testing ranging from several thousand to up to twenty thousand hours was completed this quarter at ORNL. Steel intake valves show little change so far. By contrast, Ni-based superalloy exhaust valves show significant effects of aging after only a few thousand hours of engine service; significant grain boundary $M_{23}C_6$ carbide precipitation and coarsening of the γ' precipitates that strengthen the alloy at high temperatures. Coarsening of g' matrix precipitation continues after much longer engine exposure times. Last quarter, new discussions began between one of the ARES OEM's and their exhaust manifold supplier to define a critical experiment to test the performance of the CF8C-Plus cast stainless steel relative to standard manifolds made of Ni-resist austenitic cast iron. Initial casting trials with the new CF8C-Plus austenitic stainless steel were successful and components were sent to Waukesha for engine testing, and bars were sent to ORNL for tensile and creep testing.

Milestones

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

Meetings

Conference calls and communications with principal investigators at OEMs or component suppliers occurs regularly (1-2 times/month) to guide this project.

Subtask 2.3.2 Characterization and Development of Spark Plug Materials

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Objective

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

Highlights

A total of 58 spark plugs, incorporating 4 developmental ORNL alloys, 3 control Champion® alloys, and replicates were manufactured by Federal Mogul (FM)/Champion and delivered to ORNL.

Technical Progress

The first of three planned sets of spark plugs was successfully manufactured by FM in March 2005 and will be engine tested at NTRC beginning in late Spring/ early Summer 2005. A total of 58 spark plugs, incorporating 4 developmental ORNL alloys, 3 control Champion® alloys, and replicates were made. The developmental alloys were used to make the center electrodes, the ground electrodes were made from a standard FM material. This 1st set does not utilize precious metal inserts and will be used to establish baseline behavior. The 2nd set of plugs will utilize a control precious metal insert, and the 3rd set will utilize a developmental high performance ORNL replacement alloy for the precious metal insert. All 58 spark plugs have been characterized in the pressurized test chamber. A data base of the spectral emissions during the arc process has been established as a baseline for characterizing changes produced by engine operation. Voltages required for breakdown are also included in the data set.

Status of Milestones

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

Industry Interactions

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

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

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Objective

In order to achieve optimum performance of natural gas engines in terms of efficiency and durability at comparable or lower cost, it will require the integration of research on materials and processes development, lubricant formulation, surface characterization and extensive rig and engine testing. The approach of this effort is to define the operating environment, identify desired materials properties, select materials and/or processes to meet these requirements and to characterize the compatibility of materials with common lubricants in the new and used condition by use of advanced surface analytical techniques. This includes impact of lubrication on components, such as deposit formation or catalyst poisoning. In collaboration with Waukesha, a two-step approach is being taken to address these issues:

Objective 1

1.) Characterize the engine and identify new materials, surface treatments and lubrication formulations that improve engine performance and durability.

Objective 2

2.) Develop a strategy to prevent or minimize deposit formation. The initial phase is to develop a test method to determine precursors to deposit formation.

Highlights

Surface characterization was completed on two sets of engine-exposed intake valves exhibiting significant deposit formation for comparison with intake valves characterized after ~2000 h engine use.

Technical Progress

Objective 1

Fixtures to allow for the testing of candidate valve guide materials are in fabrication. This will allow for the testing of graphite foam materials as a replacement for cast iron to reduce the amount of lubrication which can migrate past the valves and deposit on the valve sealing surfaces. A paper has been accepted for the upcoming World Tribology Congress which describes torching in intake valves due to oil deposits.

Objective 2

A test method using thermogravimetric analysis has been developed to measure the amount of higher molecular weight organic contamination (sludge) in used oil. These contaminants can act as a precursor to deposit formation. Progressively-aged oil samples were collected from Waukesha and are currently in testing using this method to look for correlation between oil chemistry and sludge formation.

Status of Milestones

1. Report on the characterization of current valve materials deposit formation as well as used oil. June 2005 – on track

Industry Inteactions

1. Conference calls and communications with Roger Rangarajan and Joseph Derra of Waukesha Engine Division to discuss the results of oil deposit characterization.

Subtask 2.4.2 Power Electronics Strategic Plan

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Objective

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

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

Highlights

- Developed an action plan that includes the use of power electronics to increase the utilization of distributed energy assets
- Held meeting to define the action plan for the strategy document

Technical Progress

Developed an action plan that incorporates essential technical areas of power electronics systems. This information will feed into the strategy document. Topical areas include materials development & processing, wide band gap materials, topology, thermal management, controls and system applications.

Technical leads are being assigned for each area and they will provide technical background, identify technical challenges, determine key organizations performing work and develop recommendations for DOE and ORNL to support research and development in power electronics. This work will be leveraged with activities from the Gridworks program in the Office of Electricity and Energy Assurance.

Status of Milestones

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

Industry Interactions

Defining list of companies and organizations to visit. These visits will likely occur in the summer.

Subtask 2.4.3 Solid-State NOx Sensor Development

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Objective

To develop non-catalytic and catalytically selective electrodes for use in NOx and ammonia sensors and to build and test sensors using the materials and technology developed. This project is jointly funded by the ARES Program and the Materials Program.

Technical Highlights

1. Studied longer-term sensing performance under both "dry" and "wet" (~1–3 % H_2O). This was in response to CRADA partner requests.
   a. Element resistance appears to "plateau" under both "dry" and "wet" conditions.
   b. Changes due to NO_x variations (between 20 and 190 ppm_V) are clearly distinguishable against "background".
   c. Varying H_2O causes changes in element resistance.

2. Discovered that current electrode material (Sr-modified $LaCrO_3$) decomposes when exposed to H_2O, NO_2 (and perhaps NO), and electrical bias.
   a. Decomposition not observed when electrode powder only subjected to moisture and elevated temperature (600°C).
   b. Decomposition also not observed in absence of H_2O.
   c. Indicates some "synergy" between electrical stimulus, presence of NO_x, and H_2O.

3. Pursuant to discovery above, have re-opened investigation into new materials.
   a. Results obtained from testing in dry air with $La_{0.75}Sr_{0.25}Cr_{0.5}Mn_{0.5}O_3$ are promising and indicate that "total NO_x" behavior may be possible with a variety of oxides.

Future Plans

- Investigate use of Mg-modified electrodes. This will help determince whether decomposition problem mentioned above is caused by use of alkaline earth modifiers.

Status of Milestones

(1) Characterize NOx sensor performance in actual NG engine exhaust September 2005 – On Track

Industry Interactions

1. Biweekly teleconference were initiated this quarter between DOE, Ford, LLNL, and ORNL.
2. A meeting was held at LLNL in March with all members attending to discuss technical progress and continue to define the path towards commercialization.

SECTION 3. Thermally Activated Technologies

Section 3.1 TAT Ammonia-Water Absorption

Bob DeVault and Abdi Zaltash
Oak Ridge National Laboratory

Objective

Transfer of contract activity with Rocky Research to NETL

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

In-House ORNL Lab and Performance Evaluations

ORNL will continue lab testing to independently verify the performance of the beta prototype *heat pump* Units and any future units on an as-needed basis in support of NETL.

Highlights

- The advanced ammonia-water absorption heat pump unit (heating only unit) has been received February 2005. This unit is expected to have a COP heating of 1.4 at 47^{o}F standard rating condition (ARI Standard 210/240-94, March 26, 1998). Testing on this unit will start after the conclusion of tests on the 10-ton GEDAC heat pump unit.
- Coordination with NETL is on schedule for a May 1 transition to the new NETL contract with Rocky Research.

Technical Progress

ORNL has been working with NETL on the transfer of this subcontracted activity from ORNL to NETL. Current plans are for the NETL subcontract to be signed effective May 1, 2005

Summary of Rocky Research technical progress:
Tests of a Beta unit were performed with three different generators to determine the variability in performance as part of the metrics effort. Differences in COP and flue gas temperatures and temperature gradients in the generator were found to be significant. Differences in the weak solution outlet temperature were found to be much smaller.

Work on the weak solenoid included performing a test to verify that the new coil design would function adequately with a thin flux return, developing an envelope drawing of a potted coil assembly and ordering bobbin-wound coils to use instead of the unsupported coils used in the first prototypes.

The modified design of the reversing valve was tested. A test valve was built and tested with no leaks or blow outs from actuation. A metrics optimization exercise was initiated that incrementally increased the inner diameter of the valve body to determine the proper diameter that provides a seal and that can be actuated with minimal force. The test results show that both valve bodies leaked after being actuated multiple times which was likely due to the valve spool being used had been modified too many times and was giving inconsistent results.

Inspection of some solution pumps after disassembly has shown some cylinder wear, but it has not been concluded whether this is a normal break in issue or that this could limit pump life.

Ongoing corrosion test results continue to show significant differences in performance between corrosion inhibitor packages. Some of the test simulators with their inhibitor packages have failed under continuous

operating conditions. Twelve of the forty units started on May 7, 2003 have logged at least 16,300 hours of operation. Five of the eight remaining units in the original charge matrix have been running since September 17, 2003 with over 13,200 hours of operation. The twenty additional units (A17-40) with the corrosion inhibitor used in units R33–R36 started operation on December 10, 2004. These have shown no really significant differences in performance to date.

All modifications to the winding apparatus for performing the absorber metrics work are complete.

Work continues on the metrics effort for the generator which is presently focusing on the manufacture of the fire tube. The company contracted to produce fire tubes for generator fabrication is experiencing difficulties with the fit-up of existing parts prior to brazing. Because of their difficulties, Rocky Research ordered new material for assembling firetubes in house. Two fire tubes were assembled using braze foil and shipped to the brazing vendor. A new brazing procedure was developed and was forwarded to the brazing company to incorporate into this next run.

A final report from Rocky Research for the technical work performed under the current ORNL subcontract is nearing completion and will be submitted on April 30th.

Status of Milestones

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

Section 3.2 Solid-vapor Sorption Commercial Refrigeration

Bob DeVault and Abdi Zaltash
Oak Ridge National Laboratory

Objective

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

Transfer of contract activity with Rocky Research to NETL

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

Highlights

Coordination with NETL is on schedule for a May 1 transition to the new NETL contract with Rocky Research.

Phase 2 of this subcontracted project to Rocky Research was completed during the 1st Quarter of FY05. The Phase 2 report has been finalized.

Technical Progress

- $800,000 in FY2004 TAT carryover funding was returned from ORNL to DOE for transfer to NETL to fully fund the new Rocky Research Absorption Refrigeration System subcontract at NETL.
- Phase 2 of this subcontracted project to Rocky Research was completed during the 1st Quarter of FY05. The capacity of the system was designed to be 9,000 Btu/h of refrigeration at -20°F evaporator temperature. The Phase 2 report shows the necessary steps taken in the fabrication, testing, redesign and re-testing of the engineering prototype. By the successful end of this phase the engineering prototype was sufficiently tested so it can be replicated and tested in the field.

Status of Milestones

Coordination with NETL is on schedule for a May 1 transition to the new NETL contract with Rocky Research. ORNL will provide technical support as requested by NETL. Ongoing
On schedule.

Section 3.3 Desiccant Humidity Control Technology by Industry Partners

Section 3.3a Kathabar – *No FY05 Funding*

Andy Lowenstein, Kathabar
Jim Sand, Oak Ridge National Laboratory

Objective

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

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

Highlights

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

Technical Progress

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

Status of Milestones

No FY05 milestone

Section 3.3 Desiccant Humidity Control Technology by Industry Partners

Section 3.3 b SEMCO

John Fischer, SEMCO
Jim Sand, Oak Ridge National Laboratory

Objective

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

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

Highlights

John Fischer, SEMCO's Director of Research and Development met with the corporate engineering staff at Home Depot's corporate center in Atlanta and Dr. Steve Lee and Dr. David Archer at Carnegie Mellon University to discuss pending field validation and performance monitoring installations of IADR units in their facilities.

Technical Progress

Jim Sand and John Fischer provided a technical project overview during a regularly scheduled DE Staff Meeting. A 2004 R&D-100 Award application has been prepared and will be submitted by ORNL for the SEMCO, ***Revolution™*** product. An ORNL subcontract modification was completed to authorize SEMCO IADR field verification installations at Carnegie Mellon's Intelligent Workplace and at a Home Depot retail outlet store.

Status of Milestones

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

Industry Interactions

Project partners are SEMCO, Inc.

Section 3.3 Desiccant Humidity Control Technology by Industry Partners

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

Jim Sand
Oak Ridge National Laboratory

Objective

- In previous fiscal years, ORNL worked with Trane Company to design, build, and test a new, all electric desiccant/vapor-compression hybrid HVAC product that better fits the sensible to latent load characteristics of today's commercial buildings. Research work was initiated in 2004 to demonstrate and document the energy saving and improved performance features of the Trane Active Cromer Cycle, combined desiccant system through installation and monitoring of four to six units in several demanding field applications not adequately served by current, conventional air conditioning systems.
- **Trane offered a new product designated the Trane CDQ™ (Cool, Dry, Quiet) HVAC system in 2005.** Certified testing shows that it reduces HVAC energy use by 50% compared to systems that use reheat for humidity control and by 10% compared to heat pipe/run-around-loop alternatives. Field verification studies of this Trane CDQ™ product concept in selected building applications were initiated in 2004. Both the SEMCO and Trane desiccant hybrid concepts impact the packaged equipment, rooftop market in the United States, which accounts for 90-95% of the commercial building air conditioning marketplace.

Highlights

Trane's kick-off for the CDQ™ line was held in Dallas for sales people and distributors in February. Of the six units sold so far, two have agreed to monitoring of their site when the equipment is installed this summer.

Technical Progress

This Trane Cool, Dry, Quite (CDQ^{TM}) hybrid desiccant system is now commercialized with production models available from Trane. The Dallas kick-off was their annual business meeting where new products and offerings are presented to regional sales offices. Trane has completed its catalogue specifications and technical manuals on the new product. Web-based system-monitoring and remote data acquisition packages are complete and ready to be installed for four field monitoring installations. Two sites are now "go" for monitoring this summer. The first is a UCF/FSEC, humidity controlled, equipment and document storage pre-manufactured building in Cocoa, Fl. The second site is an operating suite located in Franklin Memorial Hospital in Farmington, Maine. Both these sites are expected to be operational by June. Three additional CDQ planned installations have been identified as potential monitoring sites: a) Lincoln Library, a Museum in Springfield, IL; b) St Vincents Hospital, a Hospital Operating Room in Birmingham, AL; and c) Triple Crown Room, a conference room in Lexington, KY. Four demos for this summer are planned with real time performance data to be web accessible.

Status of Milestones

No FY 2005 Milestones

Industry Interactions

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

Section 3.4 Desiccant Performance Evaluation and Industry Partnerships

Jim Sand
Oak Ridge National Laboratory

Objective

- ORNL supports industries integral to the DOE TAT, IES, and CHP missions with laboratory benchmark testing and evaluation of desiccant "systems" performance. Through a User's Agreement, ORNL will generate controlled laboratory performance data on SEMCO's integrated active desiccant rooftop module (IADR) hybrid desiccant system (a) to map performance and verify control strategies for integrated desiccant/vapor-compression system operation, (b) to provide diagnostic support for field data evaluations several field installations, and (c) to verify desiccant CHP integration potential in support of a National Accounts Energy Alliance (NAEA) desiccant installations in Texas and in Pinellas Park, Florida.
- ORNL will continue to independently benchmark and measure the relevant performance characteristics of thermally activated desiccant equipment regenerated with primary and/or waste heat sources in the laboratory. A DryKor liquid desiccant TAC-10, thermal air-conditioner has been ordered for installation this fall. Data and results from these contemporary systems will assure the availability of important performance results of interest to the U.S. HVAC and IES/CHP engineering communities.
- Work planned for the remainder of 2005 work will include extensive in-house testing of hybrid solid-desiccant and liquid desiccant systems in the laboratory and continued promotion of desiccant and thermal system method of test and rating certification standards.

Highlights

In January and February of 2005, testing of the SEMCO Integrated Active Desiccant Rooftop (IADR) air conditioning system was continued at ORNL for operation in a heat pump mode. This analysis focused mostly on baseline conditions of IADR operation in heating mode over the wide range of outdoor temperatures (30-55 ^{o}F), while successfully maintaining a constant lab space temperatures of 72^{o} F. These baseline conditions were characterized by supply air flow rate of 3000 cfm with a blend of 50% outdoor air and 50% return air from the space. Also, the IADR operation in a defrosting mode was compared to normal operation at the same outdoor temperatures. Comparisons were made between the IADR's experimentally measured heating efficiency data and catalog efficiency parameters for different types of TRANE equipment.

Technical Progress

- IADR heating performance shows substantial efficiency improvement over current Trane products.
- DOE/ORNL Desiccant van successfully exhibited at ESC technical forum in Nashville TN.
- Continuing ASHRAE Special committee work developing MOT for desiccant containing products.

Status of Milestones

- Provide DOE a go/no-go decision relative to the Desiccant Control Van. June 2005
  On schedule
- Draft report on performance of DryKor desiccant air-conditioner. June 2005
- Delayed because of unit late delivery from vendor-

Industry Interactions

February meetings at ASHRAE with Hadas Levin and Bruce Buchholz of DryKor to discuss test unit

delivery delays, February presentation of DOE/ORNL Desiccant van at Energy Solution Center – Technology and Market Assessment Forum in Nashville coordinated with Desiccant Workshop collaborative work with SEMCO on failed compressor replacement/diagnosis for ORNL IADR laboratory test unit in January, and specification and recommendation of Munters and SEMCO dedicated outdoor air pretreatment systems suitable for application in new Oak Ridge High School design – Jan.-Feb.

Section 3.5 TAT Roadmap and Other Support

Section 3.5b TAT Controls Survey

Kofi Korsah and Bruce Warmack
Oak Ridge National Laboratory

Objective

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

Highlights

A program plan was developed and reviewed.

Technical Progress

-

Status of Milestones

- Based on technical analysis and evaluation, prepare recommendations and strategy for future TAT controls and sensors development for humidity and CO_2. (August 2005) On-schedule.

Industry Interactions

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

Section 3.6a Advanced Thermal Recovery Cycles

Section Task 3.6a UTRC

Bob DeVault
Oak Ridge National Laboratory

Objective

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

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

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

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

Highlights

FY05 work is underway.

Technical Progress

For Task 13.2, Steam Evaporator Critical Risk Reduction, the following activities have been conducted: Design review of the system/facility layout, and design review of the oil-reclaim system.

Status of Milestones

Demonstrate a steam-driven evaporator design for an organic Rankine cycle, applicable to the PureCycle 200 Power System (June 05) On schedule

Industry Interactions

Partners in this project are UTRC.

Section 3.6 Advanced Thermal Recovery Cycles

Section 3.6b Thermochemical Active Working Cycles

Solomon Labinov and Jim Sand
Oak Ridge National Laboratory

Objective

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

Highlights

Infrared spectroscopic measurements completed this year confirm that the Reversible Water Gas Shift recombination Reaction [$CO_2 + H_2 \rightarrow CO + H_2O$] can quickly be driven to 98% completion at 1 atmosphere of pressure and 70° F in the presence of nano-sized, iron oxide catalysts. These results indicate that a thermally driven, Active Working Fluid (AWF) cycle can use this reversible reaction as a working fluid in a 50-60% efficient thermal-to-mechanical conversion cycle .

Technical Progress

In the 2nd Quarter 2005 an experimental gas conditioning system intended for physical modelling of the basic processes that take place in a working fluid was developed and constructed . The experimental set-up allows mixing of reaction components at the channel inlet in broad interval of molar concentrations (0.1 - 1) , to heat a working fluid up to 800° C at pressures of 3 - 5 atm , to expand a working fluid up to 1 atm and to cool it to 30 - 50° C. The composition of a working fluid during heating, expansion and cooling is determined with a spectrometer in real-time mode. It is planned to complete the initial test of the manifold by April 25, 2005 and then to begin the study of reaction parameters under practical conditions. Repairs required for the spectrophotometer and the high-temperature/high-pressure infrared sampling cell were completed this quarter. A dynamic gas-blending manifold was added to the experimental set-up in the laboratory which will permit laboratory simulation and measurement of all the active working fluid cycle state points.

Status of Milestones

Complete systematic search of active working fluids for thermochemical cycle and report updated findings to DOE. (April 2005) On schedule.

Section 3.7a Heat & Mass Laboratory Development

Eddie Vineyard and Randy Linkous
ORNL

Objective

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

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

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

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

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

Potential benefits:

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

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

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

Highlights

- A meeting with Tim Wagner at ASHRAE was held to discuss next steps for colloborative research with UTRC. Tim will talk with Tom Rosfjord and Dave Sobel at UTRC to determine the possibility of joint testing of a heat exchanger to establish baseline differences between the test facilities at each research laboratory. UTRC also provided a letter of support for the DOE Lab Call in the area of advanced cycles.
- Ed Vineyard traveled to Champaign, Illinois to conduct an acceptance test of the wind tunnel test rigs. Both rigs operated as expected and appeared to be of high quality construction. While in Champaign, Will Stoecker indicated that Caterpillar may be interested in collaborative research with ORNL on an Organic Rankine Cycle to utilize waste heat. Plans are to have Mr. Stoecker and Pega Hrnjak follow up with Caterpillar to determine the next steps.
- During ASHRAE, Ed Vineyard met with Don Bivens (DuPont) to discuss advanced cycles. DuPont also submitted a letter of support for the DOE Lab Call for advanced cycle research.

Technical Progress

Two wind tunnel heat exchanger test loops were completed and will be shipped to ORNL during the first week of April 2005. Modifications to the lab facilities in Building 5800 to increase the available electrical demand required by the heaters and additional chilled water piping for heat rejection were completed.

The upgrade of the existing wind tunnel in Building 3115 was also completed. A microchannel heat exchanger was installed in the test rig to enable the tests on heat exchanger maldistribution to begin.

Status of Milestones

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

Industry Interactions

UTRC and Southwest Gas Research

Section 3.7b Micro-Channel Heat Exchanger Development

Eddie Vineyard
Oak Ridge National Laboratory
AMTI and Clark Bullard

Objective

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

Highlights

- Ed Vineyard met with Bob Linstroth of Modine to determine interest in development of micro channel heat exchangers for a 10 ton heat pump. Bob indicated that he would help to design a heat exchanger using Modine's software.
- Discussions were also held with Larry Copeland of Southwest Gas to determine the design parameters for the heat exchangers on the 10 ton unit.

Technical Progress

Larry Copeland submitted the design requirements for the heat exchangers at the end of March. They will be forwarded to Modine to design micro channel heat exchangers that will be much smaller than the present finned tube heat exchanger arrangement.

Status of Milestones

Complete initial design, fabrication, and testing of prototype. (September 2005) On Schedule

Industry Interactions

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

Section 3.7c Heat Exchanger Maldistribution

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

Objective

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

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

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

Highlights

- Several thermal imaging cameras were evaluated to determine those most suitable for evaluating maldistribution in heat exchangers. ORNL has decided to purchase a FLIR Thermacam S65HS. This particular camera was demonstrated at ORNL and was quite impressive. In addition to having high resolution images, the camera also has advanced software which enables the temperatures on the heat exchanger surfaces to be downloaded directly to an Excel file. This feature saves valuable research and analysis time.
- Initial proof of concept tests with a thermal imaging camera were completed with excellent results for a micro channel heat exchanger with no flow maldistribution (baseline case).

Technical Progress

The initial proof of concept testing with the thermal imaging camera proved that this may be the most desirable approach, compared to using phosphor paint to determine temperatures throughout the heat exchanger. Images from the camera showed temperature distributions across a micro channel heat exchanger that were reasonable considering there was no flow maldistribution in this particular design. The next step will be to install a heat exchanger that is known to have areas of maldistribution as the result of purposely collapsing tubes. The new FLIR Thermacam S65HS camera is scheduled for arrival the first of April and will be used in the evaluation.

While conducting the acceptance test for the wind tunnels, the use of thermal imaging to evaluate maldistribution was discussed with Pega Hrnjak, an expert in this field. Pega indicated that this was an

excellent idea and desirable in terms of being noninvasive. He did mention that a high resolution camera should be used. Although the cost of the camera that ORNL ordered was high, it is justified by Pega's comments. He also indicated that it will be a very valuable tool and the University of Illinois may be interested in collaborative research using the camera at ORNL.

Status of Milestones

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

Industry Interactions

University of Illinois

SECTION 4.1.1 Packaged/Modular IES Development

Section 4.1.1.a Burns and McDonnell

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

Objective

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

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

Highlights

ORNL submitted an R&D 100 Award application for the project. Burns & McDonnell submitted a Post Commissioning Test Report. A kick-off meeting for the Dell Children's Hospital project was held in San Diego, CA.

Technical Progress

- The following reports were submitted: (1) Optimization and Analysis Report, prepared by Burns & McDonnell; (2) Post Commissioning Test Report, prepared by Burns & McDonnell; (3) Initial Efficiency Evaluation, prepared by the University of Texas at Austin; and (4) Initial Equipment Layout for Dell Children's Hospital. ORNL and Burns & McDonnell co-authored a technical paper, "Advanced Absorption Chiller Converts Turbine Exhaust to Air Conditioning," which summarizes field data collected during post commissioning for the International Sorption Heat Pump Conference.
- Community aesthetic concerns resulted in a requirement to move the Dell Children's Hospital central utility plant. However, the project is being managed so that significant slippage of the schedule is not expected.

Status of Milestones

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

Industry Interactions

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

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.b Capstone Turbine Corporation

Bob DeVault
Oak Ridge National Laboratory

Objective

- Capstone Turbine Corporation in Woodland Hills, California, to design and test packaged IES Systems based on using waste heat from Capstone's 30 kW and 60 kW microturbines coupled with absorption chillers for air-conditioning.
- In FY03, Capstone formed a strategic alliance with UTC Power which resulted in the production of the Pure Comfort product line.

Highlights

- A planned ribbon cutting at the A&P Supermarket has been postponed from late-February until May 17, 2005. The Secretary of Energy and DE Program Managers have been invited. ORNL Lab Management has also been invited to the event.

Technical Progress

See Section 4.1.1.g United Technologies Research Corporation report for this activity.

Status of Milestones

See Section 4.1.1.g United Technologies Research Corporation report for this activity.

Industry Interactions

Partners in this project are UTRC and Capstone.

Section 4.1.1 Packaged/Modular IES Development

Section 4.1.1.c Gas Technology Institute

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

Objective

- The Phase I technical effort has concentrated on maximizing efficiency and reducing installation costs for the GTI IES system. The Waukesha Model VGF36GLD, lean burn, 615 kW rated output engine-generator was selected as the power plant for the project.
- The FY05 work plan is currently under development for resolving remaining R&D gaps.

Highlights

- GTI performed an IES packager assessment and selected Cummins Power Generation as the OEM for the IES system since Waukesha decided to withdraw as the package system subcontractor. Plans are to use two different absorption chiller manufacturers since Trane has made a business decision not to produce the absorption chiller for this unit.

Technical Progress

- GTI completed an initial Failure Modes and Effects Analysis (FMEA) to determine which parameters need to be monitored by trending and diagnostic software.
- The Phase I Report is being prepared to incorporate comments from ORNL received during the 4Q04 and final test results data.
- GTI submitted a work plan for completing Phase I.
- GTI testing of the Waukesha engine continues in accordance with the ASERTTI laboratory protocol. Testing is expected to be completed in April 2005.
- GTI conducted an IES Seminar to review IES final design and obtain input on the FMEA. This meeting included Equity Office Partners, Northern Power Systems, Hess Microgen, Redwood Power, and Vaporphase.
- The demonstration site of the Phase I alpha unit will be the Purchase Park office complex in White Plains, NY, appears to be a very satisfactory site for this alpha unit.
- GTI has experienced several issues with the engine-generator skid during recent testing. All issues have been resolved. The scope of testing is approximately 85% complete.

Status of Milestones

- Engine-driven Modular CHP System – Complete site location analysis for Phase I and provide recommendations for reviewed selection. August 2005
- On-schedule, however, the status may change pending further discussions with GTI.

Industry Interactions

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

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.d Honeywell Laboratories

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

Objective

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

Highlights

FY05 contract extension was negotiated. Field data acquisition implemented with North Carolina State University and coordinated with the Southeast Regional Application Center.

Technical Progress

Meetings held during the ORNL project review meeting resulted in collaboration between project participants and the SensorNet project, an ORNL project funded by Ft. Bragg. This collaboration is expected to result in Ft. Bragg expanding the capability of on-site energy monitoring and control for purposes of improving energy security.

The CHP system provided electricity and heating (steam and hot water) to the buildings on the post. Commissioning of the Broad chiller will be completed when the cooling season begins. Data collection activity continued with data covering heating operation being collected and archived each month for the remainder of the project.

CHP Reference Designs are nearing completion nearing completion with a final round of revisions being incorporated in the designs. ORNL has provided preliminary comments and will review of the final designs.

Status of Milestones

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

Meetings

- Project review meeting planned for April 21, 2005 in Minneapolis, MN.
- ORNL, Honeywell Laboratories, Broad International, Solar Turbines, U.S. Army, FEMP, IC Thomasson are planning a dedication ceremony in for June 7, 2005.
- Prepared technical paper to be presented at the International Sorption Heat Pump Conference, Denver, CO, in June 2005.

Industry Interactions

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

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.e Ingersoll-Rand

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

Objective

- Ingersoll-Rand in Portsmouth, New Hampshire will combine a new 70 kW microturbine with an ammonia-water absorption refrigeration system. The absorption system will be used to cool the turbine's inlet air and to produce refrigeration for building space conditioning and for refrigerator-freezer applications.
- In FY04, Ingersoll-Rand had a management change and made a decision not to pursue this project further. While awaiting word from Ingersoll-Rand on how to proceed, preferably with on of their subcontractors, Ingersoll-Rand had another change in management and the new Marketing Manager, Jay Johnson, would like to revive the project and get moving.
- FY05 objectives and goals are forthcoming.

Highlights

AMTI and Ingersol Rand have identified a vendor who can manufacture the aqua-ammonia chiller system in an 8-week period. Jay Johnson has presented the proposed project, including a possible ice storage system to the Ingersol Rand management. We are awaiting their decision on whether or not to proceed.

Technical Progress

AMTI obtained a cost proposal from a chiller manufacturer. Ingersol Rand identified two existing 70 kW microturbines that are installed at Ingersol Rand facilities and are available for this project, which would expedite the project by removing the need to consider interconnection and customer coordination issues.

Status of Milestones

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

Industry Interactions

Ingersoll-Rand, AMTI, Energy Concepts.

Section 4.1.1 (cont.) Packaged/Modular IES Development

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

Bob DeVault
Oak Ridge National Laboratory

Objective

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

Highlights

Work continues at NiSource on completing the final report.

Technical Progress

Work continues at NiSource on completing the final report.

Status of Milestones

Hotel/Motel CHP Packaged System – Complete the testing of the Integrated Packaged System at the selected hotel and preparation of the final report. June 2005.

Industry Interactions

Project partners include NiSource and Hilton Hotel.

Section 4.1.1 (cont.) Packaged/Modular IES Development

Section 4.1.1.g United Technologies Research Corporation

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

Objective

- UTRC in East Hartford, Connecticut developed an IES system based on off-the-shelf components to make a packaged system within the project's first year. Early in FY 2003 (November 2002), United Technologies Power formed a strategic alliance with Capstone. UTRC's Pure Comfort System is based on the use of Capstone's 60kW in multiple-unit IES packages coupled to Carrier absorption chillers. The new 240kW Capstone Microturbine system was launched as a product line by UTC Power in FY2004.
- FY2005 work will include a field test verification and demonstration and development of reference designs for systems with varying electrical loads and thermal capacities.

Highlights

A planned ribbon cutting at the A&P Supermarket has been postponed from late-February until May 17, 2005. The Secretary of Energy and DE Program Managers have been invited. ORNL Lab Management has also been invited to the event.

Technical Progress

Work during this reporting period focused upon Tasks 12.2, 12.3, 12.4, 12.5, 13.1 and 13.2 of the program plan. These tasks were to investigate integration of a reciprocating engine with a novel absorption chiller, co firing for CHP applications, development of advanced supervisory control software, development of high-efficiency CHP concepts, evaluation of enhancements to a double-effect absorption chiller, and steam evaporator critical risk reduction testing, respectively.

Task 12.2 (Critical Risk Assessment) involves construction and testing of a modified single/double-effect ("hybrid") absorption chiller designed for use in a reciprocating engine CHP system. The hybrid chiller was constructed in November/December 2004, and testing is currently in progress. Full capacity at two engine conditions was demonstrated and start-up testing was successfully completed, as reported in the previous update. In the past month, envelope testing was completed, and load controllability testing was started. The most recent results indicate that the chiller performance and operation meets design requirements for full load capacity, start-up, and envelope testing.

For Task 12.3, Co-firing for CHP Applications, the feasibility of independent microturbine control was demonstrated using the 6-pack of C60 microturbines. This capability could be utilized to operate the turbines in a way so as to minimize the emissions. In addition, a burner system that would provide the additional heat input for the system in the co-fired configuration previously described was developed in conjunction with a burner supplier.

For Task 12.4, PureComfort Optimal Supervisory Controls CRR, the project objective is to develop design specifications for Optimal Supervisory Control (OSC) for UTC Power PureComfort and PureThermal systems. The team has completed conceptual design and is entering the detailed design and project risk reduction phase.

For Task 12.5 High Efficiency CHP Product Development, market assessment for a next-generation

(high-efficiency) distributed generation system with heat recovery was completed for the New York market. The results predict that the higher efficiency and lower $/kW cost of the C200 microturbine will substantially improve the business opportunity. An assessment of the performance and cost of potential PureThermal heat recovery designs was initiated.

For Task 13.1, PureComfort Technology Readiness, facility modifications to integrate the instrumentation from the two C200 microturbines with the existing data system are in process. A Level 1 test plan was developed; a detailed Level 2 plan is in process. The test plan includes: 1) Commissioning and initial startup / shutdown, 2) Reliability data gathering, 3) Electrical power characterization vs. T(ambient), 4) Exhaust energy characterization vs. T(ambient), 5) Control effectiveness and reliability and 6) Noise and vibration.

Status of Milestones

Demonstrate technology readiness of enhancements including electric load following control capability for installations of multiple microturbines, applicable to PureComfort CHP Systems (April 05) On Schedule

Industry Interactions

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

Section 4.1.2a/b University of Maryland Collaboration

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

Objective

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

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

Highlights

- Equipment installation of the Broad absorption chiller continues.
- Discussions were held with Kathabar, AIL, NREL and DOE related to testing of the advanced liquid desiccant dehumidification components for the Kathabar unit. See Section 3.3.a for more information.
- Discussions were held with Darrell Massey regarding installing his neural net smart software in parallel with the U of M control system. A simple MOU for a working relationship between USMA and U of M was completed.

Technical Progress

- Information on the U of M installation can be found at: http://www.enme.umd.edu/ceee/bchp/index.htm. By clicking on "Data Acquisition System" you can see the current readout of the DAS which is updated every minute. By clicking on "Control & Monitoring" you should see a sign in page. Type in Userame: guest and Password: user to get to a screen that gives you the option of seeing the detailed performance of selected equipment. There are a few options on how to get the data.
- The approach to be used for monitoring temperature of the turbine exhaust gas was finalized and the new instrument was procured. The instrument will be installed in March.

Status of Milestones

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

Section 4.1.2c,d DE Integration Lab Test and Evaluation

Abdi Zaltash and Andrei Petrov
Oak Ridge National Laboratory

Objective

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

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

Highlights

Testing of the industry confidential prototype gas-fired heat pump with R22 has been completed. Industry partners had project review meetings at ORNL. Report on performance test results will be completed by the industry partners.

Technical Progress

Arrival of the new liquid desiccant DRYKOR TAC-10 is expected this summer. This unit will be powered by low quality thermal energy (hot water) from prime movers (microturbine and/or reciprocating genset) of CHP System.

Several articles were published in the proceedings of different conferences:
Proceedings of the 2004 ASME International Mechanical Engineering Congress and Exposition, Anaheim, CA:
"Baseline, Exhaust-Fired, and Combined Operation of Desiccant Dehumidification Unit," "Generic Performance Characterizations of Distributed Energy CHP Systems," and
"Evaluation of Different Efficiency Concepts of an IES."

Proceedings of Ninth International Gas Research Conference, IGRC 2004, Vancouver, B.C., Canada:
"Effect of Microturbine Inlet Air Cooling and Humidification on IES Performance."

Proceedings of the 2005 ASHRAE Winter Meeting, Orlando, Fl:
"Dynamic Performance of a 30-kW Microturbine-Based CHP System."

Several articles were submitted and accepted for publication in peer reviewed journals and at conferences:
Applied Thermal Engineering Journal:
"Laboratory R&D on Integrated Energy Systems (IES)".

International Sorption Heat Pump Conference, Denver, CO:
"Integration of the Indirect-Fired Absorption Chiller in the Microturbine-Based CHP System".

2005 ASME International Mechanical Engineering Congress and Exposition, Orlando, Fl:
"Performance Analysis of Integrated Active Desiccant Rooftop Air-Conditioning System Operating in

Heating Mode".

Status of Milestones

Completed baseline testing of industry confidential prototype gas-fired heat pump with R22 - April 2005. COMPLETE: The performance and emissions data collected on this unit with R22 at various outdoor conditions were reported to the manufacturer.

Industry Interaction

- Partners include: SEMCO, Southwest Gas, Capstone.
- Quarterly meetings are held with the CHP Laboratory Advisory Council, which includes the following industry partners: Solar Turbines, UTRC, GE Power Systems, Georgia Tech, Caterpillar, Munters, and Austin Energy

Section 4.1.3 Integrated Energy Systems Design Tool

Steve Fischer
Oak Ridge National Laboratory

Objective

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

- FYO5 work will focus on in-house modifications to the user interface, databases, and miscellaneous changes such as: 1. clean up (delete or optionally delete) temporary files 2. incorporate check(s) on equipment compatibility (e.g. recip-engine / double-effect chiller), and 3. correct "internal" error.
  a. currently the user can specify different electric tariff schedules as needed for each scenario in a calculation
  b. the simulations & economic calculations can be run and the input data file saved for future use
  c. reading the saved file for subsequent "re-use" causes an "internal" error and all data following the rate schedule selection is lost.
- ORNL will also evaluate the potential to have the BCHP Screening Tool to interface with Energy Plus.

Highlights

During the first quarter of FY05, items 1-3 under “Objective” were completed finishing the beta version 2 of the IES design tool.

Technical Progress

During the second quarter of FY-05 the computer code and data template were modified to provide the user with tabular output for hourly energy use and performance of each component of the CHP system (e.g. natural gas-fired generator, absorption chiller, heat recovery heat exchanger). The access to hourly results allows the user to understand the impacts of changes in data selections and to make selections that lead to optimal efficiency and life cycle cost.

Status of Milestones

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

Industry Interactions

ORNL staff met with Ted Bronson to coordinate presentation and distribution of the model to the CHP RAC’s; copies of the β test version sent to industry and academia.

Section 4.1.5 Regional Outreach on IES Applications and RAC Coordination

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

Objective

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

In FY2005, the University of Illinois at Chicago will continue subcontracted work in support of the Midwest CHP Application Center. The FY 05 funding will be provided to help bridge their existing work and resources until future resources are secured. The MAC will continue to focus its activities on providing targeted education, information, and technical assistance in the area of CHP applications in the eight state Midwest Region.

Highlights

The most significant highlight for the MAC during the second quarter (Jan thru March) was the launching of the modified and updated MAC website on March 31st. The website is now independent of the National BCHP website (disbanded on March 31st). The revised website includes new sections on Project Profiles, Energy Pricing, Opportunity Fuels, and MWCHPI Task Force Committees.

Technical Progress

During this quarter, the MAC was very active in the area of technical assistance for potential CHP sites. Analysis work was underway on Waste Water Treatment Plant – Indiana; Paper Mill – Wisconsin; Pharmaceutical Plant – Illinois; High School - Illinois; Prison – Indiana; University – Minnesota; Hospital – Ohio. Initial contact & meetings were held with the Municipal Electric Utility Associations in the States of Iowa, Ohio, and Wisconsin. The Municipal Utility Industry has been identified as a potential CHP targeted market. The state associations will assist in developing a plan to outreach to the Municipal Electric Utilities. A project profile was completed on the Elkhart (Indiana) General Hospital (745kW Recip Engine System). This brings the number of completed project profiles to 28. The MAC is currently organizing the 3rd Annual CHP Regulatory Workshop to be held in Michigan on June 8, 2005. The workshop topic is CHP and Its Impact on State Economy and Jobs. The MAC completed an economic & environmental analysis on the cost and benefits of a renewable portfolio standard for the State of Illinois that includes biomass CHP as one of the technologies included in the standard.

Status of Milestones

Update CHP Regional Application Center Guide. August 2005 On Schedule

Meetings

Attended Waste Heat to Power Workshop and HEATMAP training – March, California
Presented at Food & Beverage Processing Workshop – January, New York
Attended ASERTTI / NASEO Annual Meeting (STAC DER Planning Committee) – Feb., Wash. DC
Presented at Power Generation Renewables Conference – March, Las Vegas
Presented MWCHPI meeting – March, Wisconsin

Next Quarter:

Presenting at Electric Power Gen Conference – April, Chicago
Presenting at NCEMBT Workshop on Healthcare Industry – April, Las Vegas
Attending USCHPA Policy Days – May, Washington DC

Section 4.1.8 IES Efficiency Maximization for Reciprocating Engines While Minimizing Emissions

Jim Parks, Tim Theiss
Oak Ridge National Laboratory

Objective

Combined heat and power systems have been demonstrated to dramatically increase the energy efficiency of reciprocating engines by recovering power as heat and using the power to provide heating and cooling to building systems. Research and development of existing and new technologies for emissions control from lean-burn engines is being conducted to facilitate the continued and potentially growing use of lean engines. The technologies being investigated for emission control are primarily catalytic, and thermal management is generally beneficial to catalytic systems. Since exhaust systems for lean burn engines may contain both catalytic systems for emissions control and combined heat and power systems for heat recovery, studies of combined emissions control and heat recovery systems would be useful optimizing exhaust systems for increased energy efficiency. The initial work to evaluate integrated thermal management devices with a lean NOx trap emission control system on a dynamometer-base engine test platform. The test engine will be a Cummins CG-280 lean-burn natural gas engine (8.3-liter displacement). Tests of heat recovery at different locations in the emissions control system will be conducted, and data for heat quality and emissions reduction efficiency will be generated. The resulting data will be evaluated to determine the feasibility for integration of emissions control and combined heat and power systems.

Highlights

ORNL has demonstrated that the system is capable of reducing the NOx emissions by >90% to very low levels.

Technical Progress

ORNL has been evaluating the performance of a Lean NOx Trap (LNT) catalytic system for reducing NOx in lean engines. We have demonstrated that the system is capable of reducing the NOx emissions by >90% to very low levels. However, the LNT evaluation also revealed that the thermal management of the system is very important. As a result, follow up testing will focus on the thermal management of LNT and the optimum method of integrating an LNT into a CHP system. The additional heat exchanger and related equipment necessary to examine the thermal management has been ordered and received and is being installed at this time.

Status of Milestones

Complete feasibility analysis of integration of emissions control and combined heat and power. August 2005 on-schedule

Industrial Interactions

ORNL has published this work in multiple forums and has interacted with the ARES manufacturers (Caterpillar, Cummins, and Waukesha) about the LNT technology.

SECTION 4.2 IES End-Use Systems Integration

Section 4.2.1 DG Improvements in Industrial Applications

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

Objective

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

Highlights

- The microturbines are now fully operational at the Higgins Brick Company in Chino Hills, CA. Connected Energy is completing instrument tie-ins to allow access to the data and operating parameters over the internet.
- A preliminary site assessment has been completed for the Arrow Linen project in Brooklyn, New York and the additional instrumentation for meeting the ASERTTI protocol have been identified.

Technical Progress

At the Higgins Brick project, all three microturbines have been commissioned and have been operated under partial load conditions by Simmax, the energy service provider for the Higgins plant. The micro-turbine exhaust is being used to preheat the kilns in anticipation of the restart of brick drying operation in the month of April. During this quarter Simmax, in cooperation with Bowman, replaced the natural gas pressure regulators on the microturbines and corrected the power control scheme for one of the microturbines. Southern California Edison has provided the necessary approvals for this installation. In addition, the high-speed DSL line has been installed by the local phone company and Connected Energy is making final tie-ins to allow access to the data collection system and turbine operating parameters over the internet. The Energy Solutions Center, and its subcontractor, Energy and Environmental Analysis (EEA), will now initiated the data collection effort and complete the instrument installation report for this project.

The Energy Solutions Center has received approval to proceed with the new and final project, Arrow Linen. This project evaluates a highly effective CHP system and is in cooperation with NYSERDA, who is providing significant cost-share for equipment purchases on this project. The Energy Solutions Center worked with Keyspan and Arrow Linen to complete an initial assessment of the Coast Intelligen/MAN engines, the overall heat recovery scheme, and the facility operations in order to identify any additional instrumentation to satisfy the needs of the ASERTTI long term testing protocol. The Energy Solutions Center is now working on completing a host site agreement with Arrow Linen and executing the necessary subcontract agreements with EEA, its primary subcontractor on this project.

Status of Milestones

Complete case study on a CHP Installation that uses heat from a microturbine to provide plate tank heating and sludge drying at an industrial facility, contributing to the PART long-term measure of developing a 70% efficient CHP Integrated System. September 2005 [JOULE Milestone June 2005….working hard to meet it with new case study.] On-schedule

Complete 12 month data evaluations at the Higgins Brick plant and at Arrow Linen. September 2006. On-schedule

Industry Interactions

- Partners are the members of the Energy Solutions Center DG Consortium comprised of: Atmos Energy – TXU Gas, Dominion Energy, DTE Energy/MichCon Gas, Enbridge Gas, Exelon Corporation – PECO Energy, GTI, Keyspan, National Fuel Gas, NICOR, NiSource, NW Natural, Southern California Gas Co, Southern Natural, Wisconsin Gas Company, and Yankee Gas Services – Northeast Utilities.
- ORNL provided a technical presentation at the February 2005 meeting of the Energy Solutions Center in Nashville, TN and conducted a site visit to the Higgins plant in March.

Section 4.2.2 National Accounts DE Projects

Rich Sweetser, ExergyPartners/AGF
John Kelly, NAEA, GTI
Patti Garland, Oak Ridge National Laboratory

Objective

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

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

Highlights

1) **200 Market Street:** Project is complete. 2) **HEB:** Equipment Installed, microturbine commissioned and exhaust ductwork in fabrication. 3) **Walgreen's:** IADR installed and commissioned. Rotary engine installed and test run. The latter is awaiting interconnection agreement with utility. 4) **Cinemark:** Project is complete. 5) **A&P Supermarket:** Project is complete.

Technical Progress

Cinemark – This project is complete. **Lessons Learned:** There were several critical lessons learned at Cinemark;

- The desiccant dehumidifiers saved a modest amount of energy costs and primary energy under today's energy market. But the desiccant units emphatically provide a high degree of comfort where conventional rooftop units simply cannot.
- Cinemark and SEMCO are working on a new design HVAC system that may well be capital cost neutral to conventional rooftops, control humidity and save even more money and energy.
- DTE did not work closely with Cinemark, as they were tasked to do, which delayed the interconnection agreement with the municipal electric utility. The industry needs to provide tools to help – at the local level – DG/CHP sales agents to secure interconnection agreements for their customers.

- Cinemark has other priorities at this point and is not concentrating on the ICE. This became problematic as it delayed the team's ability to communicate with the electric utility for a critical two months – effectively pushing any possible installation beyond the magic 1/1/2005 deadline.
- Installing new small DG/CHP in Texas will become extremely difficult if the TCEQ NOx emissions standards remain in force.

HEB –

- The complete system was commissioned the first week of January 2005.
- Data collection started on December 16, 2004.
- Microturbine commissioned and briefly operated December 16, 2004.
- Chiller was fully commissioned on January 14, 2005.
- Because of TXV problems on Racks 3L and 3M, the subcoolers for these racks were disabled on January 27, greatly reducing the load. The TXVs were replaced on February 24, 2005 and all racks were valved-in for subcooling.

Walgreens -

- Rotary engine generator test run completed.
- Reached agreement with Florida Power on technical interconnection issues including protective relay settings. (Last minute Florida Power required we execute an interconnection agreement which we now believe as been accomplished which means we sill start the generator).
- IADR operated since December, but no meaningful dehumidification data due to weather (also note Walgreens secure server system only started to provide data in late March).

Status of Milestones

Complete Cinemark final test and verification report. February 2005
COMPLETE

Industry Interactions

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

Section 4.2.3 DE in Telecommunications Switching Center

Verizon
Randy Hudson, Oak Ridge National Laboratory

Objective

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

Highlights

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

Technical Progress

All long-lead material items, including the two 70 ton Thermax absorption chillers that shipped on 12/23/04, are now on site. The commissioning process is still in progress, with most of the work concentrated on the seven 200 kW fuel cells.

Status of Milestones

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

Industry Interactions

Project partners Verizon

Section 4.2.4a – Ritz Carlton

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

Objective

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

Benefits:-Document reductions in hotel operating costs through use of combined cooling, heating, and power.

-Provide high visibility demonstration of CHP benefits in the hotel sector.

-Reduce peak electric demand through "free" waste heat generated chilled water.

Objectives

-Establish confidence in the traditionally risk adverse hotel building design community that integrated CHP systems are technically and commercially viable alternatives to traditional power and HVAC products.

-Validate building power and HVAC load integration and cost benefits of integrated systems.

-Demonstrate an integrated energy system that can be replicated throughout the Host Marriot system, as well as other hotel chains.

Highlights

All contractual agreements were finalized, interconnection and air quality permit applications were submitted, and the equipment was ordered.

Technical Progress

The progress to date includes: site evaluation, equipment selection, completed contractual agreements, interconnection and air quality permit applications, created and reviewed mechanical and electrical site drawings with host, and ordered PC240 equipment.

Status of Milestones

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

Industry Interactions

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

Section 4.2.4b Ramapo College

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

Objective

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

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

Objectives:

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

Highlights

Ramapo College decided not to host this facility based on a third-party's analysis. An alternate site is under consideration.

Technical Progress

The proposed engine emissions reduction technology was reviewed and possible synergies with other DOE engine development projects were pursued. At the request of the college, an additional economic analysis of the combined heat and power system was completed to consider increased natural gas prices. This analysis was completed and the university decided to use an alternate system proposed by the third-party analyst.

Status of Milestones

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

Industry Interactions

Partners on this project are: unknown at this time.

Section 4.2.4c - Basin Electric

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

Objective

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

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

Objectives

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

Highlights

Most significant contractual hurdles have been overcome; the last contract is in progress and is expected to be in place by late April.

Technical Progress

A legal mess has been straightened out and site work will resume as soon as weather permits. The local utility has completed most of the substation work and has stockpiled the materials needed to complete the remainder of the interconnection transmission line. Supplemental information: Four sites are under development, one of which will be monitored for DOE. The organic Rankine cycle equipment has been fabricated for all four sites, following the resolution of the critical exhaust dew point control / metallurgy issue. The environmental assessment for the Rural Utilities Service was completed. The routing and right of way of all four interconnection lines and the construction of three of the four lines were completed. Basin Electric has completed specifications for the site transformer and has requested bids from manufacturers. Telecommunications criteria and protocols between the Project, OREG1, Basin Electric and the Western Area Power Administration are being developed.

Status of Milestones

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

Industry Interactions

Partners include the Gas Technology Institute, the Basin Electric Power Cooperative, and OREG1 (a new

corporate entity formed to construct, own, and operate the project).

Section 4.2.5 -Butler Hospital

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

Objective

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

Benefits:

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

Objectives:

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

Highlights

Hospital air emissions will be reduced when the UTC Packaged System is installed. Carrier submitted draft milestone deliverables. Documentation is being modified to meet contract requirements.

Technical Progress

Existing Butler Hospital systems were assessed to evaluate how to accommodate the UTC Package System. This assessment identified improvements that can be made because of the installation, such as eliminating use of No. 6 fuel oil.

Draft milestones were submitted including: Task 1.1 CHP system conceptual design, Task 1.2 Develop Lay Layout Design to Incorporate CHP System, Task 1.3 Finalize CHP System Design, Task 1.4 Develop Monitoring Plan, and Task 2.1 Procure PureComfort System and BOP Equipment. ORNL review indicated that deliverables must be revised before they meet contract requirements. Modifications are in progress.

Status of Milestones

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

On schedule.

Industry Interactions

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

Section 4.2.6 – Eastern Maine Medical Center

Eastern Maine Medical Center

Jeff Mylen, Project Manager, Eastern Maine Medical Center
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Jan Berry, Oak Ridge National Laboratory

Objective

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

Benefits:

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

Objectives:

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

Highlights

The State of Maine approved EMMC's application for a Certificate of Need, which is required prior to project construction.

Technical Progress

Hospitals are required to obtain a Certificate of Need (CON) from the Commissioner of the State of Maine Department of Health and Human Services (DHHS) for major capital expenditures. Resources within the CHP community submitted case study documentation on how hospitals have benefited from on-site CHP systems to aid in the decision process. The DHHS Commissioner approved EMMC's CON on February 4, 2005. However, Bangor Hydro filed a "Petition for Reconsideration of CON" with DHHS on March 4, 2005. The Commissioner reasserted approval of the CON on March 31, 2005, citing CHP case study information as influencing his decision. Findings were summarized and are being reviewed for circulation to the CHP community. The project remains on schedule with major construction planned for FY05.

Status of Milestones

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

Industry Interactions

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

Section 4.2.7 – Sheraton Hotel

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

Objective

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

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

Objectives

Demonstrate a CHP system that will:

-Be replicated in other hotels and larger buildings and businesses.

-Be grid-independent with overall efficiency and environmental benefits.

-Provide service to areas beyond the grid, and locations within the grid where capacity is constrained.

Highlights

The development of the Sheraton Shenandoah Springs application has not proceeded as originally planned. The search for a new site, using the same technologies, is underway.

Technical Progress

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

Status of Milestones

Complete fabrication of integrated system and initiate system testing. September 2005.
On schedule.

Industry Interactions

Partners are now to be determined.

Section 4.2.8 Metropolitan Hospital

Anand Gangadharan, NOVI Energy, 248-735-6684, aganagadh@novienergy.com
Jan Berry, Oak Ridge National Laboratory

Objective

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

Benefits:

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

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

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

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

Objectives

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

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

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

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

Highlights

Novi Energy placed the project on temporary ‘hold’ pending review of project economics and hospital financing. This uncertainty is expected to be resolved by mid-April.

Technical Progress

Novi Energy continued to provide deliverables. Preliminary Analysis of Energy Alternatives and Central Utility Plant Energy Plan were returned to NOVI because they were marked ‘confidential.’ The Project Management Plan was rejected because it did not meet contract requirements. NOVI revised and resubmitted Central Utility Plant Energy Plan and the Project Management Plan incorporating ORNL comments. Invoices have not been submitted pending resolution of uncertainty about project financing and economics. NOVI also submitted letter reports describing: (a) how this process may have differed because of the use of the Inland CHP package, (b) how responsive vendors were to the concept of supplying pre-engineered integrated equipment modules, and (c) changes made to the CHP package specifications, why they were made, and any resulting schedule or performance implications.

The CHP system is a state of the art facility that is being evaluated by a LEED subcommittee to establish appropriate credit for CHP installations.

Status of Milestones

Complete analysis of how packaged system compares in complexity and cost to equivalent on a custom basis. (August 2005**)** On hold until mid-April.

Industry Interactions

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

Section 4.9a/b Real Energy

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

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

Highlights
The Real Energy subcontract has been novated from the original subcontractor Real Energy, Inc., to Real Energy, LLC.

Technical Progress
Real Energy LLC is in the process of trying to develop two projects in California. They are in negotiations with several hotels and hospitals. A proposal for at least one of the two projects is expected from them in June 2005.

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

Industry Interactions
Dave Stinton visited the Real Energy Offices in California and toured several their perspective new sites. Randy Hudson and Patti Garland participated on a telecon to discuss the new sites.

Section 4.2.10 – Floyd County, Georgia, Pepperell High School

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

Objective

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

Objectives

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

Highlights

Construction and manufacturing of the active-desiccant, hybrid rooftop units to be used on this jobsite has been initiated in SEMCO's new plant in Morrilton, Arkansas. Since this is the first attempt at combining these components in a system that will be turned over to the owner, careful engineering is required to provide a convenient and trouble free piece of hardware for this school's HVAC system. The IADR units with their hot water regeneration coils will be produced and thoroughly tested at SEMCO's engineering laboratory facility in Columbia, Missouri to ensure all control systems are working as required and all the hardware instrumentation is functional.

Technical Progress

Hess-Microgen failed to honor their commitment to this project, so Deutz Corporation, an alternative supplier of IC engine gensets in the 200 kW range was contacted for the distributed power generation and waste heat source component for the school's integrated energy system. Deutz's North American office is located in Atlanta, and they are very interested in participating in this project with SEMCO and DOE. Design drawings have been released to secure a maximum installation price guarantee for the project. In addition to the four SEMCO integrated active desiccant rooftops (IADRs) that are going to be powered and regenerated by the natural gas DG system for this integrated energy system project, the school has ordered an additional eight natural gas regenerated SEMCO IADRs for normal installation based on the performance they witnessed in another Georgia school application. So there will be a total of 12 SEMCO hybrid desiccant/vapor-compression units installed on Pepperell High School when construction is completed.

Status of Milestones

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

Industry Interactions

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

Section 4.2.11 TIAX LLC

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

Objective

TIAX, LLC, of Cupertino, California, has teamed with Hess Microgen to utilize two reciprocating engines to generate approximately 280 kilowatts of electricity, and provide cooling with two 30-ton capacity absorption chiller units, in a Raley's supermarket in Loomis, California. One absorption chiller will provide cooling for the building space and the second chiller will be used for sub-cooling of the refrigerant used in the in-store food chillers.

CHP has not realized its full market potential in the commercial sector due in part to power interconnect issues that constrain economical access to the grid or limit in-house power dispatch. This project work will establish an integrated system of pre-engineered cogeneration and power inversion equipment to address these constraints and thereby enable improved cogeneration system performance and expanded CHP access to commercial markets.

Benefits of the integrated cogeneration-inverter system are as follows:

-Innovative resolution to efficiency-limiting and market-limiting issues with proven, reliable technologies
-Enhanced load-following flexibility: Efficiency increase at low-load conditions by permitting operation at low RPM where losses are reduced
-Generator efficiency increase due to operation at unity power factor
-Expanded grid access by eliminating fault current output which could block interconnect
-Reduced emissions by expanding engine turn down range, eliminating starting emission transients, and operating at optimum low emission RPM since non-synchronos shaft speeds are tolerated with the inverter
-Enhanced equipment lifetime and reduced maintenance by operation at optimum, rather than at synchronous, RPM
-Power quality improvements that expand power end-use options

Objectives:

-Combine the current pre-engineered/integrated sub-systems into a fully cogeneration package.
-To open new markets for distributed generation and CHP, which are not currently accessible.
-Increase efficiency modes by removing or reducing utility concerns to grid access.

Highlights

Hess Microgen has undergone a major reorganization. Work planned for their Carson City, Nevada facility has been moved to their parent company office in New Jersey. The parent company, Amerada Hess, is reassessing their involvement, interest, and cost share in the project. Concerns over ability of the contractor to perform, risk to the government, and timing of any revised project may lead to cancellation of this effort.

Technical Progress

Due to restructuring of Hess Microgen, no technical progress has been made.

Status of Milestones

Continuation of project is in question.

Section 4.2.13 Technical Direction Analysis and Support

Randy Hudson
Oak Ridge National Laboratory

Objective

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

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

Highlights

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

Technical Progress

Modifications to the model to improve its user interface were made. The model was presented at the March DER staff meeting in Washington.

Status of Milestones

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

Subtask 4.2.14 Ancillary Services Offered by Distributed Energy Resources

J. Kueck, D. T. Rizy
Oak Ridge National Laboratory, Oak Ridge, Tennessee
Phone: (865) 946-1332

Objective

Reactive power, which is produced when current is out of phase with voltage due to inductive or capacitive loads, can place undo stresses on the utility system. Distributed Energy Resources could be controlled to correct the current phase angle and eliminate reactive power flow by producing/absorbing reactive power. They can also be controlled to regulate local voltage by the production/consumption of reactive power. The objectives of the reactive power lab are to research and demonstrate the following:

- To determine whether DER can economically provide reactive power for power factor correction and voltage regulation using either inverters or synchronous machines without creating new problems in equipment protection.
- Determine a practical, cost-effective method of supplying reactive power to the distribution network that produces value both to the user and system and receives associated return based on reactive power prices.
- Demonstrate the strengths/weaknesses of rotor machine-based versus inverter-based DER. For example, inverters can correct inactive power components (reactive power, harmonics, and flicker) while rotating machines only correct for reactive power needs.
- Demonstrate parallel operation of different DER systems. Simultaneously operate synchronous condenser and inverters at 3114 on two ORNL circuits.

Highlights

Construction of the synchronous condenser portion of the Reactive Power Laboratory started the end of March with a completion target for the fourth week of April.

Construction of the inverter portion of the Reactive Power Laboratory started the end of March although design details of that part of the lab are is still under development

Progress

The Reactive Power Laboratory, which will be testing both generator and inverter-based distributed energy resources (DE), received the last few major pieces of equipment which included a large 150kW DC power supply, line inductors (2/4/6 mH), and distribution power panels and motor starters. The other major equipment that has been moved into position in the laboratory includes a 250hp synchronous motor that will be used as a synchronous condenser, three sizes of 3-phase programmable inverters (75, 150 and 300A), a 6.6 kW DC power supply for exciting the motor, two load banks (500kW and 375kVar), power meters, real-time data control software and hardware, and mathematical simulation software. The majority of equipment is situated indoors in building 3114 with the exception of the load banks which are sitting outside to the east of 3114 next to the supply transformer which has recently been moved into place. The real-time control software and mathematical software have been installed on a PC workstation in the Lab. ORNL Electricians are proceeding with the installation of distribution panels, motor starters, cable tray and conduit based on a layout plan that we have developed for the synchronous condenser and inverter sections of the Reactive Power Laboratory. ORNL utility personnel are proceeding with the wiring of a 750kVA pad-mount transformer that will provide electrical service to the synchronous

condenser portion of the lab. An existing transformer behind 3115 will be used to provide electrical service to the inverter portion of the lab. The synchronous condenser portion of the lab is on track for completion by the end of April for operation in May. The inverter portion of the lab is scheduled for a later completion date.

Modeling of voltage regulation in the ORNL distribution system has begun using a steady-state model that was built by our facilities division. Coordination activities have been underway with ORNL engineering for the checkout of the Reactive Power Laboratory when construction and wiring is complete. Also, staff will be working with ORNL facility staff on the relaxation of capacitor compensation at the nearby substation and triggering of motor starts to provide a range of testing scenarios. Safety information and guidelines are being put in place to ensure the safety of staff in conducting tests at the Reactive Power Laboratory.

Milestones

The Reactive Power Laboratory Milestone for FY05 is:

Establish the capability of the DER reactive power laboratory to supply reactive power to the ORNL distribution system for the purpose of supporting voltage and VAR needs - May 15, 2005.

Milestone #1 is on track with the construction of the synchronous motor portion of the laboratory underway. We expect to be complete by the end of April allowing operation of the synchronous condenser in May to meet this milestone.

Meetings

During this quarter, meetings have been held with Rolls Royce and DTE to discuss their participation in the project. Also, SCE is considering providing an 80kW Elliott microturbine with Bowman power electronics for testing at the lab. The project kickoff meeting was held in the fall with utility and industry partners. These partners have continued to provide input on the test plan and commitments of in-kind contributions. Gil Bindewald visited the Reactive Power Laboratory on February 25th and was given both a briefing and tour of the lab. Most recently (March 24th), a meeting was held with Bill Parks, DOE and Lorie Krauss, OMB. A briefing on the reactive laboratory was given along with a tour. A second meeting of the Reactive Power Laboratory team is planned for June after the milestone is met and data has been analyzed.

SECTION 4.3 CHP

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

Neal Elliott, Anna Shipley

Objective

- A utility survey task will focus on interconnection and tariff practices for major utilities, with results compiled into a database that will be added to state by state information on state legislation, environmental office, and public utility commission's regulations that apply to CHP.
- Conduct a detailed review of existing CHP models to produce some basic rules of thumb for regulators and CHP system developers to estimate the general local environmental impact of a CHP system in a simple and timely manner.
- In 1996, DOE, EPA, and ACEEE organized an ad hoc group of analysts to support the assessment of CHP as part of a national global climate strategy. This task will provide for continued development and facilitation of Analysis Working Group Meetings.

Highlights

Work continues in reviewing utility CHP policies.

Technical Progress

ACEEE is currently identifying the target utilities and conducting the literature review and identification of key sources for target states. Research into utility policies and practices is being done, along with documentation of numerous PUC filings in various locales, and an historical look into previous Combined Heat and Power measures as a brief thematic examination. Once they have completed these initial tasks we will begin populating the database with detailed information on state and utility CHP policies. ACEEE is currently identifying the target utilities and conducting the literature review and identification of key sources for target states. Research into utility policies and practices is being done, along with documentation of numerous PUC filings in various locales, and an historical look into previous CHP measures as a brief thematic examination. Once we have completed these initial tasks we will begin populating the database with detailed information on state and utility CHP policies.

Status of Milestones

Facilitate CHP Analysis Working Group Meeting. January 2005

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

Subtask 4.3.4 CHP and DG Topical Issue Analysis

Susan Horgan
Distributed Utility Associates [DUA]

Objective

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

Highlights

Work continues in support of the Card II Study.

Technical Progress

Work on remaining tasks has been sparse this quarter. Susan Horgan, a principal at DUA, has completed negotiations with the widow of Joe Iannucci to buy the company. These negotiations and all legal paperwork were completed this quarter. ORNL is working with Susan to finalize the FY05 work scope.

Status of Milestones

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

Subtask 4.3.5 National and Regional CHP Roadmapping Activities

Jan Brinch
Energetics

Objective

- One element of this project consists of technical analysis and planning of various technical workshops and roadmaps with the goal of coordinating technical information development and dissemination regarding high potential CHP scenarios nationally, regionally and internationally.
- Another activity is to coordinate Regional CHP Roadmapping efforts. Energetics has assited 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

Energetics conducted follow-up activities resulting from the 5th Annual Combined Heat and Power (CHP) Roadmap Workshop, held in Austin, Texas, September 20-21, 2004. This workshop included site visits to institutional and commercial CHP installations and a full-day Regional Application Center Program Meeting. Other activities completed during the quarter included two CHP Team meetings on October 21 and December 9, 2004; support to the CHP Regional Initiatives and Regional Application Centers; and preliminary planning for the 6th annual CHP Roadmap Workshop, which will be held in conjunction with the World Alliance for Decentralized Energy (WADE) international conference on distributed energy.

Technical Progress

Annual CHP Roadmap

- Held a follow-up conference call on October 8th with the planning committee to discuss the workshop; obtain feedback on the results obtained during the roadmapping sessions; and identify changes to be made for next year's meeting.
- Conducted an electronic workshop evaluation of the Austin workshop, which included development of an e-mail to all attendees with a short set of questions to obtain feedback on the quality of the workshop and suggestions for the 6th annual meeting. Ten evaluations were returned, which although a low response, was from a diverse number of participants and which included thoughtful comments and suggestions for next year's meeting.
- Finalized the *CHP Action Agenda* and posted it on the USCHPA Website, which was distributed in Austin and is being used to identify opportunities for targeted activity within the CHP community.
- Conducted preliminary planning for the 6th Annual CHP Roadmap Workshop, utilizing the comments and suggestions from the evaluation questionnaire; and input from members of the CHP community. A meeting was held on December 20th to begin planning the next workshop, which will be held in conjunction with the 6th International Decentralized Energy and CHP Conference. The meeting will tentatively focus on best practices underway in the regions reflected by the Regional CHP Initiatives and the Regional Application Centers, as well as in local communities around the globe.

Education and Outreach Activities for Stakeholder Groups

- Coordinated two CHP Team meetings on October 21 and December 9, 2004
- Provided updates of the DG/CHP Meeting Calendar for dissemination among CHP Team members, and posting on the DOE, USCHPA, and EPA CHP Partners web sites
- Provided support to the Northeast CHP Initiative and Application Center by completing the Northeast CHP Roadmap Document for distribution at their annual meeting (April 2005) and posting on their website
- Prepared new materials to accompany the USCHPA Exhibit for the IDEA Campus Energy

Conference and other upcoming meetings and conferences

- Provided support to the USCHPA and other CHP stakeholder organizations by participating in Executive Committee meetings and the Executive Retreat; providing planning assistance in development of the CHP Policy Summit agenda; and taking over the distribution and assistance function for the CHP Recycling Energy Branding Materials *CHP Recycling Energy: It's Time.*

Status of Milestones

Facilitate the CHP Roadmap Meeting. September 2005

Roadmap meeting has been scheduled for October 25-27, 2005 in New York, New York

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

Joel Bluestein
Energy and Environmental Analysis

Objective

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

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

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

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

Task 3: Changing Applications for Steam - The goal of this task is to identify new applications for CHP, especially new non-steam applications.

There are several potential changes in CHP markets that this task must address:

- Changing uses of steam[1] due to process and technology change in industrial and commercial markets.
- Different sources of thermal energy from new prime movers available for CHP.

Task 4 – Revised Forecast of Industrial CHP

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

Highlights

The draft report on inventory of industrial boilers has been provided to ORNL for review.

Technical Progress

The draft report on industrial boilers was reviewed by Steve Fischer and Barry Oland [ITP support]. Comments were provided to Joel Bluestein for incorporation into the final report.

Status of Milestones

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

Subtask 4.3.6b Analysis of Environmental Regulatory Barriers and Incentives for CHP

Joel Bluestein
Energy and Environmental Analysis

Objective

This project consists of the following tasks:

- Air Quality Permitting Barriers to CHP Development-- Research and document air permitting barriers to CHP development and potential ways of addressing them
- CHP Emissions/Credit Calculator-- Develop simple but accurate analytical tool to allow calculation of environmental benefits of CHP
- CHP Permitting and Regulatory Requirements Database—Develop and maintain an on-line state-by-state data resource that provides basic permitting/regulatory requirements information for CHP projects.
- Environmental Regulatory Analysis on CHP/DG Issues—Activities include tracking of regulatory activities, analysis of specific issues, outreach to various groups and direct interaction with key regulators at various levels. Information includes CHP incentives, environmental permitting, siting regulations, reporting requirements, standby rates, building codes, exit fees, and incentives.

Highlights

EEA continues to update the Environmental Regulatory Requirements Database. Some of the users include ADM, Allegheny Power, Amerada Hess, Ameritech, Audi, Bell South, Boeing, Cat, CH2M, Chevron, Deere, Duke, Dupont, Enercon, Entergy, Environ, Fairchild, First Energy, GE, GTE, IBM, Kenilworth, Lennox, MidAmerican, Monsanto, Navigant, NYISO, Pacbell, Rolls-Royce, SAIC, Shell, SMUD, Sprint, State Farm, SW Bell. Telus, TVA, Walmart, Williams. Also included are: many state and federal government agencies, many universities and users from Canada, Japan, New Zealand, Italy, Australia, France, Germany, UK and a bunch of places I can't identify.

Technical Progress

--Air Quality Permitting Barriers to CHP Development
EEA continued drafting the report during this period.
--CHP Emissions/Credit Calculator
The draft calculator has been distributed for review.
--CHP Permitting and Regulatory Requirements Database
This is an ongoing activity.
--Environmental Regulatory Analysis on CHP/DG Issues
EEA continues to work with EPA staff working on permitting issues for CHP to assist them in promoting the benefits of CHP. EEA is providing similar assistance to states that are developing emission regulations for DG.

Status of Milestones

Maintain and update the regulatory requirements database. Ongoing

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

Bruce Hedman
Energy and Environmental Analysis

Objective

This project consists of multiple tasks:

- Task 1: CHP Installation Database - Identify and collect basic information on existing CHP facilities and track the installation of new facilities over time. This data measures progress toward the goal to double CHP capacity from 46 GW in 1998 to 92 GW by 2010, and tracks the progress of specific technologies and markets.
- Task 2: Applications Integration and Installed Costs Analysis for Small CHP Systems - Quantify the range of small CHP installation costs experienced in the field, document the driving factors for those costs, and identify areas for cost improvements to develop a consistent and complete understanding of total installed costs CHP projects based on various generation technologies with information from actual installations that have been completed within the last three years.
- Task 3: DG/CHP Financing - Document available financing options for customer-sited DG/CHP projects through interviews, analysis and case studies and to evaluate the effectiveness of these financing options to the implementation of DG/CHP in the U.S. Alternative financing, ownership and risk sharing arrangements that may accelerate customer acceptance will be explored. The focus of the effort will be on customer-sited DG and CHP systems less than 5 MW in size.
- Task 4: Electric Rate Primer - The objective of this task is to review the primary types of electric rate structures that exist throughout the country, categorize and measure the impact of these rate structures on the economic viability of on-site generation. Illustrative examples of the economic performance of representative distributed power projects within each type of rate structure will be presented. Rate structures designs that best encourage energy conservation and CHP will be highlighted. A limited number of rates from top electric utilities will be categorized and evaluated as to whether they are favorable or not toward energy efficiency and CHP.

Highlights

The Regional Application Centers have provided valuable information used by EEA to update the CHP Installation Database. Primarily the information provided by the RACs was updated contact information for existing sites.

Technical Progress

Task 1 - CHP Installation Database

Work through this period focused on continuing the updating of the database with new sites and enhanced data from various sources and on supporting the regional application centers and responding to industry contacts.

Task 2 - Applications Integration and Installed Costs Analysis for Small CHP Systems

The analysis is based on reviewing a sample of recent installations. Work in this quarter focused on analysis of the detailed cost data collected from the 15 sites. Preliminary survey results and the final cost analysis will be submitted in the upcoming quarter.

Task 3 – DG/CHP Financing

Efforts proceeded to develop an upfront “financing primer” piece from available resources; Interviews were completed with small CHP developers, equipment suppliers, customers, and financial organizations. The initial summary of the interviews were to be submitted in this quarter but were delayed by internal review.

Task 4 - Electric Rate Primer

To compare the affects of rate structure on DG economics, a normalized rate comparison was developed for a hypothetical customer. The comparison cases are normalized against a hypothetical load of 1,875,968 kWh/month that generates an electric utility bill of $300,192/month. A generator of 1,340 kW is installed to reduce this load. Various rate structures comprised of different features (time of day, declining block, etc.) were compared in terms of their impact on the electric savings resulting from the operation of the generator. The comparisons were conducted for a single month of operation. The generator was assumed to go down for one weekend day for scheduled maintenance during this hypothetical month. It was also assumed that the generator trips unexpectedly for one hour during the afternoon of a weekday. Results of this analysis and the preliminary results of the initial utility-specific analyses will be submitted in the first quarter of 2005.

Status of Milestones

Maintain and update the installed CHP database. Ongoing

Subtask 4.3.7

Rick Tidball
Energy and Environmental Analysis

Objective

- This project focuses on the 4-state region comprising the Pacific Northwest: Washington, Oregon, Idaho, and Alaska and includes an assessment of technical and market potential for the region and case studies. .
- Development of a market penetration model, evaluation of regional energy pricing and economic trends, and incorporation of current and advanced technology cost and performance parameters.
- Development of CHP Screening Calculator and development of four analysis scenarios related to Northwest region.

The project is divided into three tasks:

- Market Assessment
- Resource Development
- Western States Analysis

Highlights

- Task 1 was completed in FY2004. The second task, to develop technical tools and resources, is nearing completion. The third task was originally intended to involve an awareness campaign and outreach activities to promote deployment of CHP in the Pacific Northwest. However, this task has been revised to include an assessment of the CHP market potential in Arizona and Nevada and to provide a summary of the market potential in the eight Western states covered by DOE's Western Regional Office (WRO).

Technical Progress

A CHP Policy Document (Subtask 2.5a) was completed as a draft report that is currently being reviewed by stakeholders in the Pacific Northwest. The objective of this task was to develop a clear regional message on the value of CHP as a high efficiency system that reduces resource consumption in the region and increases end-user efficiency and productivity.

The draft has the following sections:

- Introduction to combined heat and power systems
- Summary of existing CHP in the Northwest
- Economic benefits of CHP
- Energy efficiency
- Resource adequacy
- Environmental value
- Ancillary benefits
- Recommended Federal and State actions to promote CHP

Task 2.5(b), Information Dissemination, was completed by attending a meeting on November 30th cosponsored by the Energy Trust of Oregon and the Oregon Public Utility Commission to discuss mechanisms for providing support to CHP development in Oregon. This was the last of three meetings in which EEA attended and discussed the market opportunities for CHP in the region. The other two meetings were in the previous quarter:

- September 15, 2004 – Presented results of the Market Assessment to regional stakeholders group
- September 28-29, 2004 – Attended BPA "Energizing the Northwest" Meeting and talked with people at the DOE-WRO exhibit.

Status of Milestones

Subtask 4.3.7 An educational technical brochure will be developed for regulators and policy makers regarding the benefits of CHP in the Pacific Northwest. April 2005

The draft brochure was completed On-Schedule and provided to PEA and ORNL for review.

Industry Interactions

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

Subtask 4.3.9 Development of a Preliminary Environmental Permitting Screening Tool

Jay Dyer
I.C. Thomasson

Objective

- Develop an environmental permitting screening tool, useful in each state of Environmental Protection Agency (EPA) Region 4: Southeast, serving Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee.
- A computerized screening tool will be developed to assist users with permitting of any small gas turbine (1 MW to 5 MW) in any area of Region 4 with enough depth to cover the majority of permitting conditions. Users will be able to identify applicable regulations and standards, as well as supplemental analyses required by the respective regulatory agency.

Highlights

- The Environmental Permitting Screening Tool Task Report was completed on March 17, 2005. The tool is applicable to facilities interested in installing a gas turbine between one and five megawatts and located in the Environmental Protection Agency's region for the Southeastern United States, i.e. Region IV. The tool provides a brief overview of gas turbines, emissions produced by a cogeneration plant and how gas turbines are regulated, the applicable Code of Federal Regulations (CFR), and how to determine the type of permit required.

Technical Progress

The report contains the following Sections: 1. Project Summary, 2. Equipment and Technology, 3. Air Permitting, 4. Air Permit Types, 5. National Regulatory Standards, 6. Federal Facility Example, 7. Flow Diagrams, 8. Region IV Contacts, 9. Tennessee, 10. Florida, 11. Alabama, 12. Georgia, 13. North Carolina, 14. South Carolina, 15. Mississippi, and 16. Emission Factors form EPA Document AP-42

Status of Milestones

Subtask 4.3.9 Provide draft final report on environmental screening tool in Southeastern States. June 2005
COMPLETE

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

Patti Garland, Jan Berry
Rob Thornton
International District Energy Association

Objective

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

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

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

Task 1: Disseminate Technical Industry Information

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

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

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

Task 4. LEED

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

Highlights

Effort this quarter has focused on Task 4. Mark Spurr and Jan Berry participated on weekly teleconferences of the LEED CHP subcommittee resulting in development of a comprehensive review of issues associated with obtaining appropriate LEED credit for buildings served by CHP systems. The subcommittee's work has received positive recognition from the U.S. Green Building Council's EA Technical Advisory Group,

Technical Progress

- In preparation for the IDEA workshop being held in Washington DC in March 2005, IDEA has been working with the Regional Application Centers to pull together technical information for dissemination to workshop attendees. Additionally, DOE CHP IES packaged system subcontractors are preparing technical briefs on their project to provide face-to-face information to conference attendees.
- Mark Spurr and Jan Berry provided comments on LEED Version 2.2.
- The US Green Building Council recognizes that a methodology for obtaining LEED credit for CHP

has not been developed. A new version of LEED is in final review and comment. The guidance document that will accompany LEED 2.2 will include a CHP credit calculation methodology as developed by the LEED CHP subcommittee. A comprehensive review of issues was developed. Cost data from projects will be used as examples of how LEED credit are being identified including: UTC packaged system; Burns & McDonnell Dell Children's Hospital Project; NOVI Energy Metropolitan Hospital; and Veteran's Administration Hospital in San Diego.

Status of Milestones

Subtask 4.3.10 Review and comment on the draft LEED Application Guide for Campus. February 2005
Review and comment completed. Additional effort is required to obtain guidance from US Green Building Council on value of recovered energy and to incorporate guidance into the methodology.

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

Diane DuVaul, Suzanne Watson
Northeast-Midwest Institute, NESCAUM

Objective

Phase I of this work consists of several tasks:
Build and Support Regional & State CHP/DER Initiatives
Create a National CHP/DER Coalition Board, host/facilitate regular meetings among all regional groups and attend individual regional CHP meetings, monitor and analyze regional CHP materials, create and organize an annual meeting of regional CHP groups, create/organize regional efforts for CHP Roadmap and Policy Conferences, coordinate state level efforts to remove barriers through coordination of formal comment preparation and meetings with state PUCs, environmental regulators, state legislators, industry, etc.
Manufacturing Sector Initiatives
(Note that "manufacturing sector" does not mean CHP equipment manufacturers, but rather the US manufacturing sector). Utilize the existing Northeast-Midwest Manufacturing Task Force to reach potential end-users by holding two targeted DER/CHP workshops in Chicago and Boston regions working with the DOE Regional Offices to specifically highlight the benefits of CHP/DER to manufacturers; and by working to include representation from the manufacturing industry and the DOE Industries of the Future (IOF) program in the MW and NE CHP Initiatives.

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

Highlights

The Northeast-Midwest Institute staff and subcontractor Suzanne Watson, NESCAUM, continued monthly conference calls with the regional initiatives and organized and held a food processing opportunity fuels and food processing CHP workshop for January 27 at the Syracuse New York Fairgrounds. Suzanne continues to act in her role as USCHPA Board Coordinator for the Regional CHP Initiatives (officially re-elected to that role in January) in partnership with the Regional Applications Centers across the US attending all Board meetings and calls to give updates on regional activities. Dick Munson, Director of the Northeast-Midwest Institute, became Chairman of the Hill Day Coordinating Committee in order to improve the education and outreach activities.

Technical Progress

*Regional Initiatives Conference Calls***:** Watson hosted the regional initiatives conference calls throughout the quarter. Minutes of the calls will be taken next quarter and provided to DOE for internal use.

Opportunity Fuels and CHP Workshop for the Food and Beverage Processing Industries: DeVaul worked closely with Tom Bourgeois, Larry Ambs, and Beka Kosanovic of the Northeast RAC and Nag Patibandla and Dana Levy of NYSERDA to organize a workshop for the Northeast. DeVaul contacted the Northeast Regional DOE office, Mid-Atlantic Office and the Mid-Atlantic RAC to inform them about the upcoming workshop and to distribute materials to them to use to invite participants. In addition, flyers were e-mailed and mailed throughout the region by using NYSERDA, the Empire State Development Association, a list of food processors in Massachusetts and New England from the Northeast RAC, and the New York Food Processors Association. A replacement was found for the tour originally scheduled for Anheuser-Busch. Solvay Paperboard, a recycling plant hosted the tour of their use of waste streams to generate gas that is used for steam. Ninety-five participants attended the event.

Participants stayed for the entire day and many of them made a point at the reception of commenting on the usefulness of the workshop.

*CHP Briefings***:** DeVaul discussed the timing of briefings designed to highlight CHP successes, potential contributions to tight energy markets, and barriers to its potential with various interested groups. Given the national elections, it was decided that for maximum impact, briefings should be scheduled early in 2005. A briefing, focused primarily on the impact expanded utilization of CHP technologies could have on tight natural gas markets was held for policy makers January 31st. It generated significant interest with over forty-five from the policy making community in attendance.

Status of Milestones

Write a summary paper on status and lessons learned among CHP Regional Initiatives. March 2005
Behind Schedule. Expected in next quarter.

Subtask 4.3.12a Developing CHP Market Potential with Opportunity Fuels

Paul Lemar
Resource Dynamics

Objective

This project consists of several tasks:

- *Collect and summarize opportunity fuels information for fuels that already are or could be used in CHP applications.* Description of quality characteristics of the available opportunity fuel sources, their potential suitability as a CHP or DG fuel and their potential environmental implications. Rough supply availability and cost estimates for each reasonably suitable and available opportunity fuel will be developed.
- *Evaluate CHP Technology Options* – Analyze the set of CHP and DG technologies and applications that might benefit from use of opportunity fuels will be analyzed. From these, a set of cost, performance, efficiency and emissions data will be developed for each generator type consuming a particular opportunity fuel.
- *Analyze Potential Market Impacts and Develop Recommendations* - Scenario analyses will be performed with the DISPERSE model to examine in detail the influence of various opportunity fuel's use in its partnered generator set technology.
- Recommendations and conclusions will be drawn addressing barriers that are presently impeding expanded use of these technologies and opportunity fuels, and discussing potential solutions for barrier removal.

Highlights

The focus of activity this quarter was on task 3, analyze potential market impacts.

Technical Progress

For each of the top opportunity fuels identified, the following steps are being undertaken:

1. Examine current installations and future prospects for each opportunity fuel, and evaluate what types of installations are most likely to occur
2. Contact some existing facilities, and analyze current data, to paint a more realistic picture of each fuel's actual potential
3. Apply these findings for implementing and interpreting the results of the DISPERSE Model, which will determine the regional market potential for each fuel

Steps 1 and 2 are complete for all of the top fuels, and Step 3 is underway. The DISPERSE Model has been run for municipal wastewater treatment plants, industrial wastewater treatment plants, landfills, and facilities that can use wood, wood waste, or biomass.

Status of Milestones

Complete final report on Opportunity Fuels Market Analysis. May 2005
On-schedule

Subtask 4.3.12b A Review of DG Siting Procedures

Paul Lemar
Resource Dynamics

Objective

This project consists of several tasks:

- Task 1: Collect Siting Data – including financial case study information from and about a wide selection of DG and CHP installations. The focus will be on what steps the developer needed to take to complete the installation, how long each step took, and the cost to conduct each task. Barriers faced and actions taken to successfully mitigate these barriers will be identified.
- Task 2: Perform Siting Trends Analysis - Trends in each of the following 3 tracks will be analyzed to determine what impact they have on siting costs:
  1. Site analysis including engineering feasibility and financing,
  2. Permitting including an environmental analysis, air permit, zoning permit, building and construction permits, and
  3. Interconnection including engineering, inspection and coordination with the local distribution utility.
- Task 3: Analyze Siting Procedures and Recommendations –Prepare recommendations of ways regulators might help improve the siting process, and ways end-users and ISPs might minimize costs when installing DG and CHP units.

Highlights

Task 3 was completed: Analyze Siting Procedures and Recommendations

Technical Progress

Task 3 was completed, conducting the following steps:

- Examining ways to mitigate siting and permitting costs.
- Analyzing siting costs within these contexts.
- Exploring what has and is happening in the leading states, including those that have adopted DG interconnection and siting rules, or have large siting levels.

The results of Task 3 have been compiled into a draft report, which has completed internal review, and an external review is being organized.

Planned Activities:

During the next quarter, Resource Dynamics plans to complete external review of draft report and submit both the final report and the PowerPoint presentation.

Status of Milestones

NA

Subtask 4.3.14 Conveying Targeted CHP Messages through Industries Associations

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

Objective

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

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

Highlights

USCHPA organized and spoke at the plenary panel discussion of the Air & Waste Management Association Meeting held in Arlington Virginia on April 4-5, 2005. The title of the Plenary Session was: What is Non-Utility Energy and Why is it Important? Why are Environmental Regulations and Standards a Critical Area for Non-Utility Energy Practitioners? Speakers included: John Jimison, Mark Spurr, and Luis Troche.

Technical Progress

USCHPA organized a technical sessions entitled: Energy Production and Efficiency in Wastewater Treatment Facilities. Speakers included Doug Hinrichs, SENTECH, Inc. and U.S. Combined Heat & Power Association (Moderator), Katy Hatcher, EPA's ENERGY STAR Water and Wastewater Program, Walt Bailey, Blue Plains Wastewater Treatment Plant, Janet Joseph, NYSERDA, Paul LeMar, Resource Dynamics Corporation and James Schettler, Brown & Caldwell.

Status of Milestones

Finalize CHP in food processing web site and go live. November 2004

COMPLETE. http://www.sentech.org/CHP4foodprocessing/index.html

Subtask 4.3.16 Coordination of Regional CHP Application Centers

Ted Bronson
Power Equipment Associates

Objective

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

Highlights

- Worked with Gulf Coast RAC to Plan Gulf Coast CHP Regional Roadmap Workshop slated for April 26th and 27th in Woodland, Texas.
- Meeting with DOE indicated that the RAC Target Market Workshop listing at the last quarterly call was extremely useful and helped DER get acknowledged for strong work in the Regions.
- Planned, developed agenda, and recruited speakers for May 3rd RAC Face to Face Meeting prior to Policy Day.
- March 23rd, 2005 Quarterly Call discussed an update of the RAC Targeted Workshop Listing, Coordination of Project Profiles, and DOE project coordination.

Technical Progress

- Ted Bronson supported Roadmap Workshop Planning Phone calls for the Gulf Coast and Southeast RACs. The Gulf Coast Workshop is set for April 26 and 27 in Woodland, Texas. The Southeast Workshop is tentatively set for July 7th in Atlanta.
- Ted Bronson and Patti Garland (ORNL) met with US DOE Headquarters to get their assessment on performance of the RACs and intended future direction. DOE expressed a desire to have the RACs move to more of a Project Focus. This will be a major focus of our May Meeting. DOE indicated that the RAC Target Market Workshop listing at the last quarterly call was extremely useful and helped DER get acknowledged for strong work in the Regions.
- Planned, developed agenda, and recruited speakers for May 3rd RAC Face to Face Meeting prior to Policy Day.
- Met ORNL IAC personnel to begin discussion on establishing metrics for Regional Application Centers that can effectively measure regional impact and provide DOE a tool to provide for program justirfication.
- Presented “Regional Application Centers” to the Annual Campus meeting of the International District Enregy Association, to introduce RACs to this key end-user group.
- Held March 23rd Quarterly calls of the Application Center Steering Committee/Working Group. All conference calls focus on developing effective action between the Centers, not simply status. This calls focus was an update of the RAC Targeted Workshop Listing, Coordination of Project Profiles, and DOE project coordination.
- Work continued with ORNL to develop the CHP Tool Box, a resource guide for CHP Application Centers.

Status of Milestones

Subtask 4.3.16 Write a summary paper on status and lessons learned among CHP Regional Application

Centers (March 2005) On-Schedule

Section 4.3.17 Project Direction and Technical Support

Patti Garland and Jan Draine
ORNL

Objective

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

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

Highlights

- The CHP Subcontractor Coordination Review meeting was held on April 14, 2005 in Washington DC. Copies of the presentations have been provided to DOE for inclusion on the DOE DE website.

Technical Progress

- FY05 contract modifications are completed with all subcontractors except DUA, who has undergone management changes.
- The draft CHP Tool Box was completed on December 23rd and has been discussed with the Regional Application Centers, who are providing comments.
- ORNL's Jan Berry has been participating in the LEED conference calls for adding CHP to the Campus Energy Guide. See Task 4.3.10, as this task is being coordinated with IDEA.
- Patti Garland gave a presentation on CHP at the Waste Heat to Power Workshop held in California in March.
- Ted Bronson and Patti Garland met with Michaela Martin at ORNL [at the suggestion of Sandy Glatt] to discuss metrics for the CHP RACs. A first step is to flow chart the work processes of the RACs. This flow charting is in progress.

Status of Milestones

- Subtask 4.3.17 Facilitate and publish the results of the 3rd Annual CHP Subcontractor Coordination Review Meeting. May 2005 COMPLETE
- Subtask 4.3.19 Subtask Consolidate tools in "tool box" for use by CHP Application Centers. February 2005. Draft tool-kit COMPLETED on December 23, 2004.
- Subtask 4.3.15 Plan and implement the November NOVEM IEA Annex meeting to be held in New

Orleans, LA. November 2004. COMPLETE

Task 4.3.18 Application Integration Analysis

Randy Hudson
Oak Ridge National Laboratory

Objective

ORNL will continue to identify the most appropriate evaluation tools for assessing DE/CHP viability. ORNL will evaluate existing software tools and will work with stakeholders to ensure development of the appropriate tools and to assist in their use in studying potential DE/CHP applications. ORNL will provide an objective evaluation of the GTI building simulation tool and compare it to the BCHP quick screening tool, with a resultant recommendation to the Midwest Regional Application Center for use in their training workshops. ORNL will learn more about the HEATMAP tool for district systems.

ORNL will continue development of the IES optimization tool.

Highlights

- Cost-shared effort. See Task 4.2.13.

Technical Progress

See Task 4.2.13.

Status of Milestones

Develop a 2nd generation model for IES optimization (June 2005) on-schedule

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

Steve Fischer
Oak Ridge National Laboratory

Objective

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

Highlights

Two iterations of program development were completed with copies of the computer code distributed through HUD for comment and review; feedback was incorporated into program revisions.

Technical Progress

HUD requested that EERE assist them in adapting the NYSERDA "Cogen Manual" worksheets for use in screening multifamily housing outside of the New York City area. During the first quarter, a stand-alone Windows application was developed that implemented the NYSERDA printed worksheets "as is." The HUD CHP program was adapted to include user specification of gas and electric utility rates including electric utility standby capacity charges.

Status of Milestones

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

Industry Interactions

Bob Groberg, HUD, contacted housing and utility officials to get feedback on the computer program capabilities and data requirements.