Science & Technology HIGHLIGHTS

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Distributed Generation: A Powerful Approach for the Future

This is DOE's vision for the year 2020: The United States will have the cleanest and most efficient and reliable energy system in the world by maximizing the use of affordable distributed energy resources.

Customers will be able to choose from an array of ultra-high-efficiency, ultra-low-emission, fuel-flexible, cost-competitive distributed energy resource products and services. Those resources will be easily interconnected to the national power infrastructure, and they will be operated to provide the maximum value to users and energy suppliers while protecting the environment (from *U.S. Department of Energy Strategic Plan for Distributed Energy Resources*, September 2000).

Distributed energy resources, or DER, refers to small-scale power-producing systems located close to the point of use. DER systems can be owned and operated by businesses and individuals. They can incorporate a range of renewable energy sources and advanced technologies, such as fuel cells and microturbines. More conventional elements such as energy storage and reciprocating engines also have a role in DER. In addition to power, DER will produce space heating, cooling, and/or dehumidification. The power and space conditioning will be used by local industrial or commercial operations and homes, and excess power will be fed into the central power supply grid.

The use of DER is a strategy that accomplishes several objectives. For businesses, DER can reduce peak demand charges, reduce overall energy use, provide a hedge against grid reliability problems, ensure power quality, and reduce emissions. For large utilities—power producers—DER can augment overall system reliability, avoid large investments in transmission system upgrades, reduce transmission losses, closely match capacity increases to demand growth, and open markets in remote or environmentally constrained areas.

The need and the opportunity to reengineer the nation's energy generation and delivery systems are driven by several factors. Electricity demand in the United States is expected to increase by more than 1 trillion kWh over the next 20 years. That will require an additional 300 gigawatts of generating capacity. Unreliable power can create big problems and big costs for business, especially businesses that rely on computers, information, and telecommunication. Utility restructuring and rising energy prices are forcing utilities and consumers to think about their power supply and use in new ways. Although large, central power stations have always been more efficient than smaller systems, technological advances are producing small, modular equipment that is cleaner and more efficient than large systems.

This issue of *Science & Technology Highlights* focuses on some areas of research where ORNL contributes to achieving the DER vision. ORNL has a long history of R&D in the areas of combustion technology, emissions characterization and mitigation, and materials development for advanced reciprocating engines and turbine systems. It is extending this expertise to smaller gas turbines. Both solid oxide and proton exchange membrane fuel cell systems and components are being developed at ORNL. We have R&D programs investigating many aspects of electric power systems: transmission and distribution, interconnection of DER resources, reliability, restructuring, advanced control systems, simulation and modeling. ORNL also has expertise in many base technology areas—areas where advances will benefit more than one aspect of DER—such as power electronics, high-temperature superconductivity, sensors and controls, materials and manufacturing processes, and combustion. Our National User Facilities give industry and academia unparalleled access to this unique assemblage of expertise, facilities and equipment.

Putting It Together: Cooling, Heating, and Power for Buildings

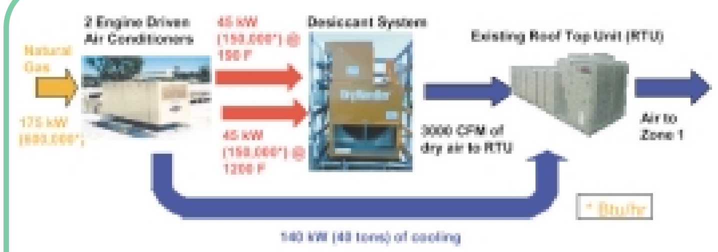
Over the past 20 years, the energy efficiency of buildings has improved dramatically as a result of technologies such as low-emissivity windows, compact fluorescent lamps, better heating and cooling equipment, and improved insulation. Researchers at ORNL believe distributed energy resource technologies represent one of the most significant opportunities that remain for improving energy efficiency in buildings.

Integrating building cooling, heating, and electricity systems with on-site or near-site electricity generation could increase energy efficiency by as much as 30%, reduce carbon emissions by 45% or more, and improve indoor air quality through humidity control. This integration is called cooling, heating and power (CHP) for buildings.

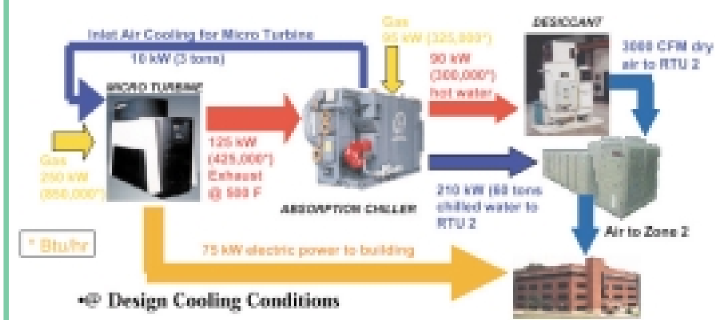
ORNL has led an R&D program on heating, cooling, and ventilating equipment since the early 1970s. This expertise is now being focused on technologies essential to successful CHP: turning waste heat generated by power-producing equipment, such as microturbines or fuel cells, into useful heat for thermally activated cooling and desiccant regeneration.

The Buildings CHP Consortium

ORNL has entered into a partnership with equipment manufacturers, utilities, building operators, industry associations, energy service companies, and universities—the Buildings CHP Consortium—to demonstrate these technologies. The Chesapeake Building at the University of Maryland—College Park is the demonstration site.



The first CHP system, now operating at the Chesapeake Building, includes rooftop air-conditioning units and a desiccant dehumidification system.



The second CHP system to be tested in the Chesapeake Building will incorporate a microturbine and an absorption chiller, as well as a desiccant dehumidification system.

The Chesapeake Building at the University of Maryland. This 10,000 ft^2 building is typical of buildings that make up a quarter of the U.S. building stock.

In the first CHP system to be installed (see drawing), two engine-driven air conditioners send cool air to roof-top ventilating units; a desiccant system in between removes some of the humidity from the air. The desiccant system improves indoor air quality and contributes to reductions in cost and carbon emissions.

Work is under way on the second CHP system. It will consist of a microturbine that produces electricity and sends its exhaust air to an absorption chiller that transforms the very hot exhaust into conditioned air for the building (see drawing). The chiller also cools inlet air for the microturbine. Like the first CHP system, this one uses a desiccant dehumidification system. The microturbine has been installed and is providing building power. The chiller is being tested and will soon be integrated with the microturbine.

This test bed serves as a platform to integrate equipment into CHP systems, integrate CHP systems into buildings, test advanced control systems, and provide essential technical knowledge to manufacturing partners.

In March 2001, the University of Maryland was named "Outstanding Educational Institution" at the ORNL Small Business Awards Ceremony for work conducted on this project.

More detailed information on the CHP test bed is at http://www.enme.umd.edu/ceee. The Buildings CHP Consortium web site is at http://www.bchp.org/.

Contact: Patti Garland, 202-479-0292, garlandpw@ornl.gov
Sponsor: Office of Distributed Energy Resources

Tying Distributed Energy Resources to the Grid

When distributed generators connect to the power system, both the owner of the energy resource and the central power system benefit. Reliability increases for both because they can support each other. However, there are many questions regarding system stability, safety, and control.

ORNL has a strong R&D capability in power transmission and distribution systems, which is now being focused on system simulations that can help provide answers. ORNL collaborates with the Consortium for Electric Reliability Technology Solutions (CERTS)—a consortium of laboratories, universities, and utilities—on computer modeling to predict the behavior of multiple distributed generators connected to the power system. The effort is aimed at lowering the cost and maximizing the benefit of using distributed generation as an integral part of the electric power grid.

ORNL is studying the use of distributed resources for ancillary services and simulating the impact of distributed resources on utility distribution networks. The work to date has studied single placements of distribution resources on electricity networks. The next phase of the research will study the concept of the microgrid—a group of distributed resources with a common interface to integrate communication, control, and protection and to allow the group of distributed generators to operate as a single entity with respect to the utility grid.

ORNL has a significant capability for system analysis using utility-standard, commercially available software codes. The use of industry-standard databases and codes ensures high-quality, repeatable results that are widely acceptable; and in-house modeling expertise ensures appropriate handling of unusual requirements. The analysis codes available include Power System Simulator, Production Costing (both in-house models and DYNASTORE), Electromagnetic Transient Program, Power System Harmonic Simulation and Analysis, System Reconfiguration Analysis Program, Oak Ridge Competitive Electricity Dispatch model, National Energy Modeling System, and Powerdat Database System. The North American Electric Reliability Council provides actual regional utility network and load data to be used in the computer models.

Contact: Brendan Kirby, 865-576-1768, kirbybj@ornl.gov
Sponsor: Office of Distributed Energy Resources

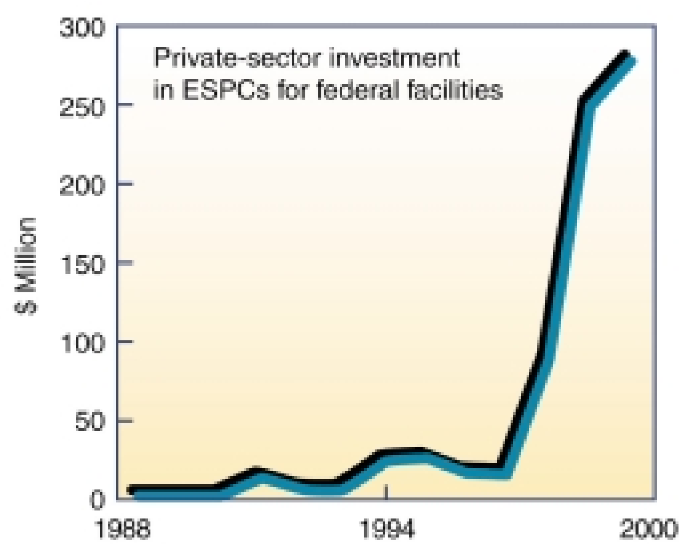
ORNL, FEMP Lead Push for CHP at Federal Facilities

The Federal Energy Management Program (FEMP), in close coordination with the Office of Power Technologies, began to focus on combined cooling, heat, and power (CHP) technologies this year. FEMP tapped ORNL to lead its push to make CHP a visible, accessible, and feasible option for federal agencies.

The ORNL CHP team works within FEMP's efforts to help agencies get more value from funds they are already spending, rather than look for infusions of new dollars. FEMP's design assistance helps secure optimum value from capital appropriations for new construction, and FEMP's technical assistance ensures that building improvements yield more energy-savings bang per buck. FEMP also supports agencies' use of energy service performance contracts (ESPCs) and utility energy service contracts (UESCs), which bring private-sector financing to federal building improvement projects. A top priority for the CHP team is helping agencies use these alternative financing vehicles for their CHP projects.

Agencies need hard evidence to support a decision to implement a CHP project. To provide unbiased, reliable documentation of costs, savings, and financial merit, the team evaluates federal CHP projects, analyzing technology performance and application engineering and addressing issues such as permitting, grid interconnection costs, exit fees, and stand-by charges.

Where energy supplies are constrained, agencies are keenly interested in CHP as a way to add to electricity supplies as well as increase energy efficiency. CHP technology makes economic



Private-sector investment in federal energy projects through ESPCs has increased sharply. The ORNL FEMP team ensures that CHP projects will be feasible under alternative financing vehicles.

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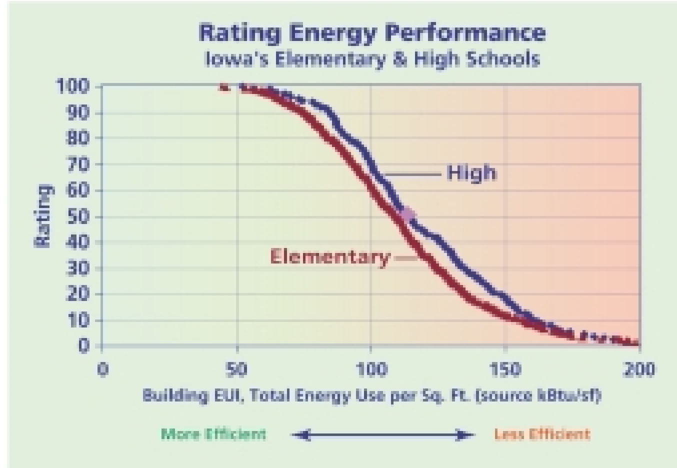
ORNL Helps Iowa Schools Rate Their Energy Performance

Do you need help benchmarking the energy efficiency of your schools? Want to estimate how much their energy bills could be cut or identify the schools with the most potential for energy savings?

Iowa state officials came to ORNL for help with those questions. The Iowa Department of Natural Resources wanted to construct a rating system for Iowa's schools based on building energy use benchmarks and rating tools developed by ORNL for DOE and the Environmental Protection Agency. Terry Sharp of the Buildings Technology Center helped Iowa officials understand the benchmarking and rating processes, reviewed their data, helped them interpret and use the rating methodology, and reviewed materials to be used to educate school administrators and the public about the effort.

Using the tools is easy. The information needed is the gross floor area of the school(s), the amount and cost of electricity used annually, and the amount and costs of other fuels used annually. Based on these data, the tool calculates an "annual total source energy use intensity" (EUI) for each building. EUIs are plotted on a chart, assigning a score of 100 to the best and 0 to the worst. In the chart, an elementary school with an EUI of 100 would have a rating of about 60; that is, 60% of similar buildings in the group use more energy. The higher the rating, the better the relative energy performance of the building.

Based on these building ratings, Sharp has estimated the potential for energy cost reductions. If a building is rated between 20 and 40, energy use and cost could be reduced by 35 to 50%. A walk-through energy assessment can identify specific savings opportunities. For buildings with low ratings, improvements often can be implemented inexpensively to cut energy costs significantly. For buildings with high ratings, sizeable cost reductions more often require significant capital investment.



The rating tool calculates an annual energy use intensity for each school and plots the group on a chart.

Contact: Terry R. Sharp, 865-574-3559; sharptr@ornl.gov
Sponsor: Office of Building Technology Assistance; ORNL State Partnerships Program

Geothermal Heat Pumps Could Help Wisconsin Schools Save Energy

The Energy Center of Wisconsin (ECW) came to ORNL with a question: How do geothermal heat pumps compare with conventional heating and cooling equipment in Wisconsin, in terms of life-cycle cost, energy use, and pollutant emissions? Patrick Hughes and John Shonder of ORNL's Energy Division agreed to help ECW find an answer.

ORNL helped ECW select the applications—building types and equipment designs—for the analysis. The team settled on four building types: a medium-sized office building, a school, a residence, and a 200-unit multi-family residence. Both geothermal and conventional systems were analyzed for each building type.

Annual energy use for the selected applications was predicted for three Wisconsin climatic conditions, represented by Eau Claire (west), Green Bay (east, on Lake Michigan), and Madison (south). Then utility data were used to estimate energy costs, capital and maintenance costs were estimated, and a life-cycle cost was calculated for each application.

Two of the GHP applications were all-electric, and two included gas-fired outside air preheating. The conventional systems included central cooling with gas furnace heating for the two residential applications, and variable-air-volume with reheat for the two commercial applications. The modeling yielded the following results.

- GHPs provided modest source energy savings—below 10%—except in the school application, where savings were estimated at 22%.
- GHPs resulted in moderate emissions reductions, corresponding to the energy savings.
- The life-cycle cost of a GHP was only 10% higher than that of conventional systems except in the residential applications, where the premium was estimated at 15%.
- There is little variation in the results by climatic region.

Because two of the GHPs are all-electric, the relatively high cost of electricity and relatively low cost of natural gas worked against geothermal technology in this analysis. Given recent increases in natural gas prices, however, GHPs would look more attractive if the analysis were done now.

For Wisconsin, the team concluded it would be beneficial to promote the GHP in schools. In the summer of 2000, ECW began a program called "Wisconsin Geothermal Partners for Schools" that encourages schools to consider installing GHPs by providing them with technical and financial assistance.

Contact: John Shonder, 865-574-2015; shonderja@ornl.gov
Sponsor: Office of Building Research Standards, ORNL State Partnerships Program

Advanced Turbine Systems: ORNL Plays Key Role in DOE Success Story

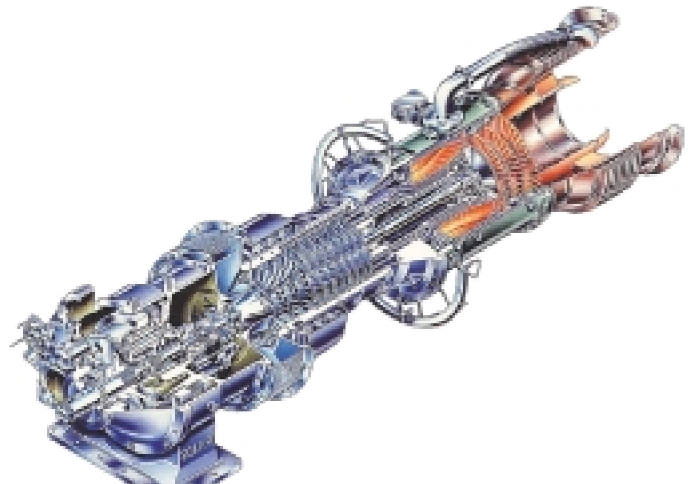
In 1992, DOE set a goal to develop and demonstrate ultra-high-efficiency natural gas turbine systems within 8 years. The Advanced Turbine Systems (ATS) effort has been successfully completed, and ORNL research played a key role in its success.

ATS was a cooperative effort among DOE, gas turbine manufacturers, universities, natural gas companies, and electric power producers to develop and demonstrate ultra-high-efficiency natural gas turbine systems. Adoption of such systems will reduce the cost of electricity, as gas turbines are increasingly used to generate power, and will improve air quality.

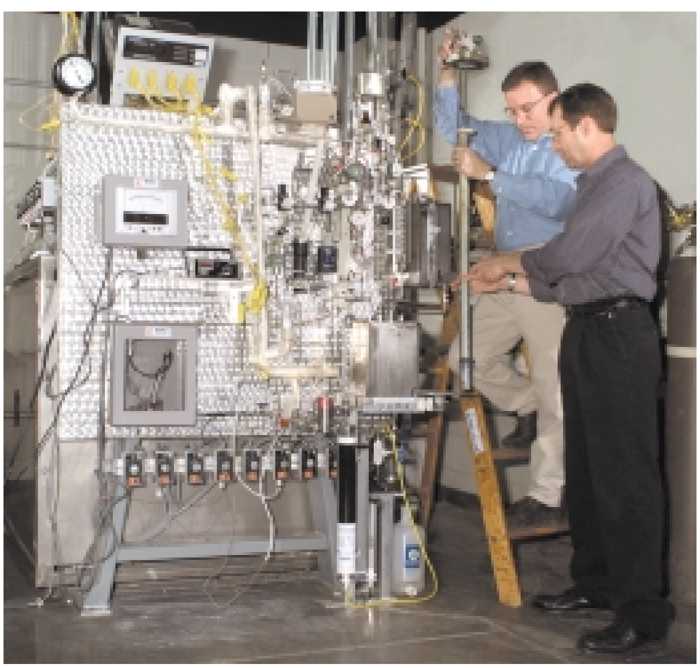
DOE began the program because projections indicated natural gas turbines would make up over 80% of the new power-generating capacity expected in the United States over the next 10 to 15 years. More than 96% of new power plant projects under way or planned in the United States will use natural gas, and most of those will use turbines.

For the gas turbines to meet DOE's goals for efficiency and reduced emissions, turbine manufacturers concluded they must operate at higher temperatures and pressures than ever before. For gas turbines to hold up at the extreme operating conditions, changes had to be made not only in the materials used, but also in the ways they are manufactured.

ORNL assisted manufacturers in identifying ceramic composite materials for combustor liners that would allow turbines to operate more efficiently at higher temperatures and reduce emissions of oxides of nitrogen. Using a unique piece of equipment developed at ORNL called the "Keiser rig," researchers tested the materials in a simulated combustor environment and found the liners thinned over time because of corrosion reactions due to water vapor. ORNL began identifying coatings that could protect the composite materials from degradation. This ORNL research, along with field testing by manufacturers, laid the foundation for coated composite liners that are used in a Solar Turbines low-emission engine that now powers Malden Mills in Lawrence, Massachusetts.



This Centaur turbine is used in a low-emission engine that powers Malden Mills in Massachusetts.



The Keiser rig, a facility developed at ORNL, was used to evaluate how combustor liner materials and coatings would react under exposure to combustion gases in gas turbines.

ORNL also provided technical oversight to a project to develop improved manufacturing processes for making airfoils—single-crystal superalloy turbine blades. Single-crystal blades were first developed for use in aircraft, where typical turbine blades weigh up to 5 pounds. Blades for advanced turbines can weigh as much as 40 pounds. When the ATS program first began, single-crystal turbine blades of this size could not be made. Now they can be made and will be used in the first U.S. utility-sized combined-cycle gas turbine engines to result from the ATS program. Sithe Energies of New York City is building a power plant near Scribna, New York, that will incorporate two of the turbines developed by General Electric Power Systems. The first unit passed verification testing and was shipped to the plant site in spring of 2000.

In other ATS materials and manufacturing projects managed and supported by ORNL, Siemens-Westinghouse and Pratt Whitney have improved thermal barrier ceramic coatings used on turbine airfoils, enabling increased turbine rotor inlet temperatures needed to reach ATS efficiency goals. ORNL continues to develop techniques to identify and characterize degradation processes for thermal barrier coatings that will help predict service lifetimes. ORNL's materials expertise was also applied to improving a stainless steel material used in the

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BestPractices Program Helps Industry Blow Off Steam Efficiently

Steam is a critical requirement for many industrial processes and an output of many distributed energy systems. It powers equipment, heats buildings, is used in manufacturing processes, and can be used to generate electricity. According to DOE's Office of Industrial Technologies, about 45% of the fuel used in U.S. manufacturing facilities is burned to produce steam. In many facilities, improvements to steam systems could save 20% of this energy.

To help U.S. industry capitalize on this opportunity, DOE and the Alliance to Save Energy established a program called BestPractices Steam. Its goal is to help steam users adopt a systems approach to designing, installing, and operating boilers, distribution systems, and steam applications. ORNL provides technical assistance and support to the program and its steering committee of steam system users, service providers, and trade associations.

BestPractices Steam includes elements of training, information collection and dissemination, awareness seminars, and tool development. ORNL is working on the following projects.

The average steam distribution system, such as this one at ORNL, typically offers savings opportunities on the order of 20%.

- An assessment of the industrial market for steam improvements. It will focus on the chemical, pulp and paper, and petroleum refining industries, identifying how much steam is used in these industries and how much opportunity there is for improvement. It is expected to be complete by fall 2001.
- Development of assessment tools to help users upgrade their system operations and identify improvement opportunities. One completed tool is the Steam System Scoping Tool, an easy-to-use spreadsheet that users can complete for a self-assessment of energy savings opportunities. It can be downloaded from the Steam BestPractices web site.
- Technical assistance to DOE's Industrial Assessment Centers in using the Scoping Tool to perform assessments in their regions. The data gained in these assessments will be used as benchmark data and to assess the effectiveness and usefulness of the Scoping Tool. There are 26 Industrial Assessment Centers throughout the United States. A complete list with contact information can be found at www.oit.doe.gov/iac/#schools.
- Steam "Energy Tips," one-page descriptions of energy savings opportunities. Twelve have been published and others are being prepared. They are available on the Steam BestPractices web site.
- Development of a steam systems sourcebook aimed at plant engineers, facility managers, and steam system operators. The sourcebook is scheduled to be published in fall 2001.

Bethlehem Steel Success Story

By rebuilding a steam turbine to incorporate the latest steam path technology, Bethlehem Steel Corporation was able to significantly increase the capacity and efficiency of its steam turbine generator system. The cost was $3,400,000 more than a standard maintenance overhaul. The payback: annual savings of nearly $3,300,000, 40,000 MWh of electricity, and 85,000 MMBtu of natural gas. The project also reduced high-temperature water discharge into the harbor and decreased coke oven and blast furnace gas emissions.

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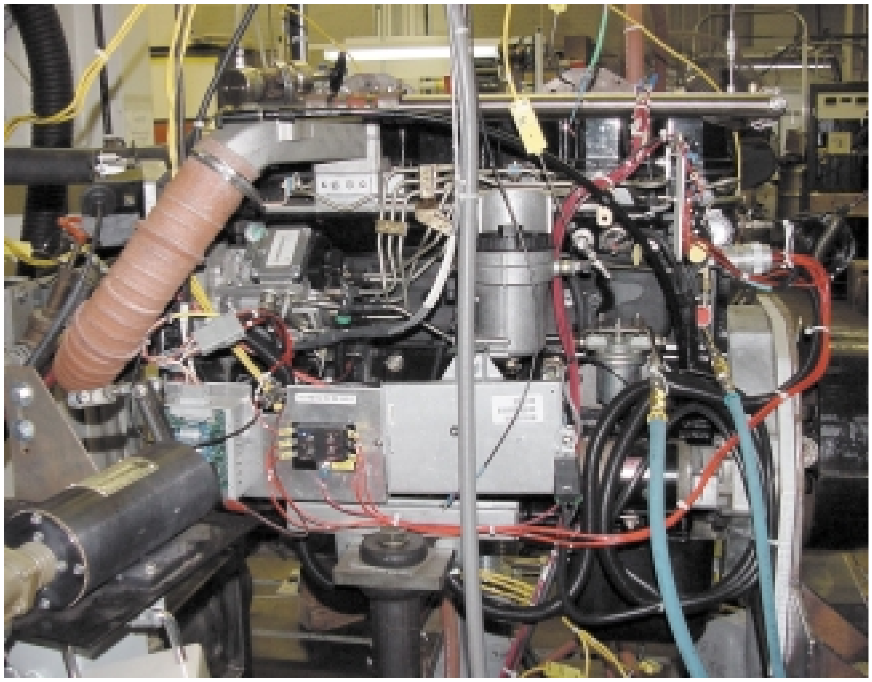
Cleaner Reciprocating Engines for Transportation and Power

Large reciprocating engines ("recips") make up about 48% of today's combined heat and power installations, dominating the small-scale distributed power market. These recips are internal combustion, piston-driven engines much like the ones that pull big rigs down the highway. While recips for transportation are generally fueled by diesel, those being used in distributed generation applications run on propane or natural gas. However, some of the goals and technology needs for both types of engines are similar: reduce emissions, improve efficiency, and hold or reduce costs.

One barrier to the wider use of recips, in DG systems as well as in transportation, is emissions. Oxides of nitrogen (NOx) are of particular concern in natural-gas recips. Driven by increasingly stringent standards for heavy-duty diesel engines in large trucks, industrial partners are working with ORNL to decrease and control NOx and other emissions. That R&D is expected to improve the emissions characteristics of gas-fueled recips for DG applications, also.



A reciprocating engine undergoing emissions testing in ORNL's Advanced Propulsion Technology Center.

The goals of improved engine efficiencies, fuel flexibility, and maintenance intervals equal to or better than those for existing models will require materials that can withstand higher operating temperatures in a variety of combustion environments. Higher-temperature operation can mean higher efficiencies and lower emissions.

To help meet that need, ORNL is developing advanced materials to overcome specific technology barriers. These materials include advanced metal alloys, intermetallic alloys, high-temperature ceramics, metal-matrix composites, ceramic-matrix composites, cermets, and bulk amorphous metals. The High Temperature Materials Laboratory gives the ORNL R&D staff unmatched capabilities in atomic-scale microscopy, materials processing, and component grinding and finishing. Some of the materials work is focused on the fuel system, including the development of carbon storage materials for gaseous fuels, and wear- and scuff-resistant materials for fuel injection systems.

The Advanced Propulsion Technology Center is the site of R&D on just about every aspect of reciprocating engines other than materials. It can apply unique diagnostic and analytic tools for system simulation and optimization, emissions measurement, and emissions control R&D. ORNL collaborates with engine and auto industry partners in areas including improved catalyst development, studies of engine cyclic dispersion, NOx sensors, ignition modeling and diagnostics, and development of high-speed, mass spectrometer–based emissions instrumentation.

Contact: David P. Stinton, 865-574-4556, stintondp@ornl.gov
Sponsor: Office of Heavy Vehicle Technologies and Office of Distributed Energy Resources

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turbine engine recuperator (a heat exchanger that increases engine efficiency by using heat recovered from the exhaust to preheat inlet air). A team consisting of ORNL, Allegheny-Ludlum, and Solar Turbines developed a process for strengthening the material for improved durability at normal or higher temperatures and pressures. The new processing technique and improved recuperators are still being tested by Solar Turbines and Allegheny Ludlum and will eventually be incorporated into industrial-sized gas turbine engines.

What's next for turbines? Like most systems, they're getting smaller. Commercial businesses are interested in microturbines for distributed energy systems. Whereas large gas turbines generate from 3 to 30 MW of electricity, microturbines generate 500 kW or less. Many of the technical challenges are similar and involve materials R&D. ORNL's one-of-a-kind combination of research expertise, facilities, and equipment is making a major contribution toward ensuring that tomorrow's dominant source of electrical power is highly efficient and low in emissions.

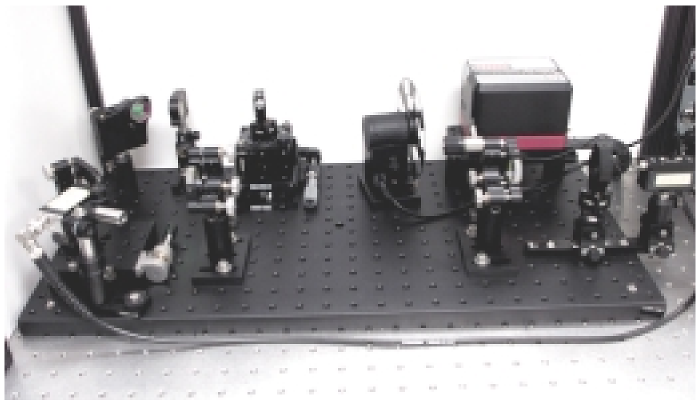
Contact: Michael A. Karnitz, 865-574-5150, karnitzma@ornl.gov
Sponsor: Office of Power Technologies, Office of Industrial Technologies Implementation A

ICOS Can Measure Exhaust Emissions in Real Time, on Real Vehicles

Advanced Propulsion Technology Center researchers have developed a new diagnostic instrument that probably won't stay in the lab. Proof-of-principle testing has been demonstrated for an instrument that can measure trace amounts of gaseous pollutants in engine exhaust in real time, aboard a moving vehicle.

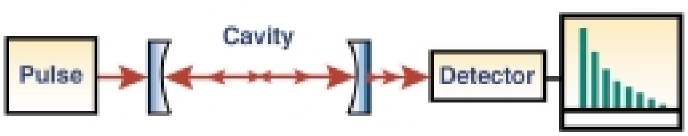
The development resulted from research conducted in collaboration with the University of Minnesota's Center for Diesel Research and the Minnesota State Energy Programs Office.

The instrument is called ICOS, or integrated cavity output spectroscopy. ICOS is based on a technique called cavity ringdown laser absorption spectroscopy (CRLAS). Whereas most conventional measurement systems measure direct absorption, CRLAS measures the rate of absorption in a closed cavity. Here's how it works.



The ICOS, developed at ORNL's Advanced Propulsion Technology Center, can measure trace amounts of specific compounds in engine exhaust precisely and quickly.

A gas sample is introduced into a cavity formed by a pair of highly reflective mirrors. A laser system injects a short-duration—less than 10 microseconds—pulse of light into the cavity. To measure CO_2, for example, the laser output is scanned over the narrow band of wavelengths that are absorbed by CO_2 but not by other species present in the sample. The light pulse reflects back and forth between the mirrors, and a constant fraction of the pulse intensity is absorbed by the sample during each round-trip pass through the cavity. The intensity of the light pulses leaking out of the cavity demonstrates a simple decay profile. The time required for the pulse intensity to decay to a specified proportion of the initial intensity is called ringdown time. The ringdown time can consist of thousands of round-trip absorption events. Because a ringdown profile and measured ringdown time is generated for each laser pulse, fluctuations in laser pulse energies from shot to shot do not affect the accuracy of the measurement. The ringdown time indicates the concentration of the specified gas in the sample.



ICOS translates the CRLAS concept into a small, robust, relatively inexpensive package. In the preliminary tests, ICOS measured CO_2 concentrations of as low as about 400 parts per million (ppm)—only about 20 ppm above background levels of CO_2 in air. It needs less than 10 microseconds to make measurements that are accurate to 0.1 ppm. Of course, ICOS can measure concentrations of other gases; one of the next steps is to use it to measure carbon monoxide emissions. The APTC has been successful in continuing the work, landing a 2-year contract to extend the range of gas species measured, reduce the signal-to-noise ratio, and provide technical assistance in the design and engineering of a spruced-up package.

Contact: Bill Partridge, 865-946-1234, partridgewp@ornl.gov
Sponsor: Office of Advanced Automotive Technologies, ORNL State Partnerships Program

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- Awareness workshops for steam users. More than a dozen workshops have been held to alert users to opportunities to save energy and money by improving steam operations.
- Case studies of industrial and manufacturing facilities to document steam system improvements. The studies have documented energy savings valued at from $42,000 to $3,300,000 annually, with simple paybacks ranging from minimal to 1.5 years.

Contact: A. L. (Tony) Wright, 865-946-1353, wrightal@ornl.gov
Sponsor: Office of Industrial Technology Implementation A

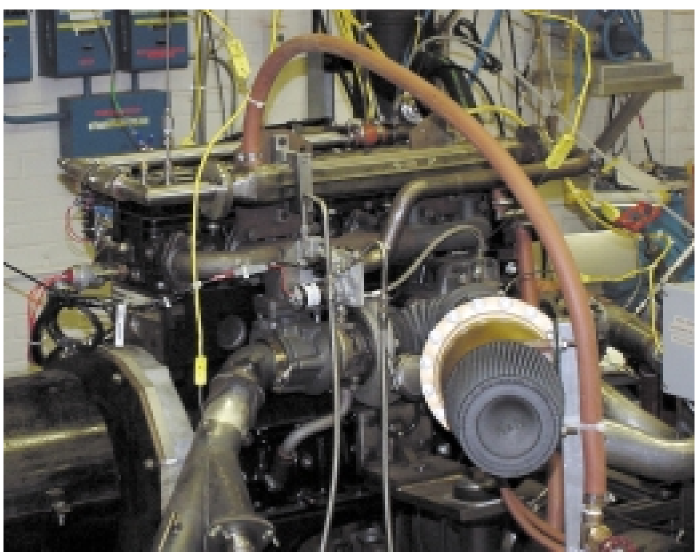
For help with information resources, databases, tools, events calendar and helpful links, visit Steam BestPractices on the web at http://www.oit.doe.gov/bestpractices/steam

Ethanol Blending To Reduce Emissions from Heavy-Duty Diesel Engines

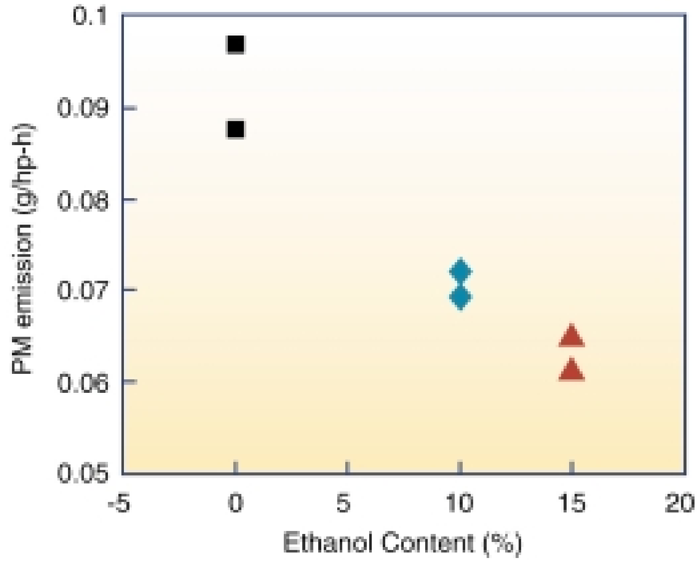
Ethanol has been added to gasoline for years to replace some of the imported oil used in light-duty gasoline vehicles. Additionally, several demonstration programs have explored the use of ethanol in diesel engines. Today, there is a renewed interest in ethanol/diesel blends for their potential to help reduce emissions from current and future diesel engines.

A team comprising Cummins Engine, the Illinois Department of Commerce, Betz-Dearborn, and Gromark Industries asked ORNL's Advanced Propulsion Technology Center to help evaluate changes in emissions from a heavy-duty diesel engine burning two ethanol/diesel blends of 10% and 15% ethanol. APTC researchers examined exhaust emissions of carbon monoxide (CO), total hydrocarbons (THC), oxides of nitrogen (NO_x), particulate matter (PM), formaldehyde, acetaldehyde, ethanol, and methanol.

The evaluation was conducted at APTC using a 1999 Cummins 5.9-liter turbo-charged direct-injection diesel engine (24 valves, in-line 6 cylinders). APTC evaluated exhaust emissions using the AVL 8-mode test regimen that collects data at eight steady-state operating points. The measured results are weighted to produce overall emissions estimates that simulate the results that would be obtained from the Heavy Duty Transient Federal Test Protocol.



A 1999 model year Cummins ISB, 5.9-liter, in-line 6-cylinder, 24-valve diesel engine was used to characterize the advantages of the ethanol-diesel fuel mixtures.



This chart shows PM emission measurements for the AVL 8-mode test. PM emissions decrease with higher concentrations of ethanol.

The emissions evaluations showed that PM dropped by 20% and 30% using 10% and 15% ethanol blends, respectively. As expected, CO and THC emissions increased for the two blends. The ethanol had no apparent effect on NO_x emissions.

Other studies also have shown that adding ethanol to diesel fuel can decrease PM emissions but increase CO and total HC emissions. Researchers are suggesting that the propensity of these fuels for elevated HC and CO emissions might be exploited for regenerating NO_x adsorber catalysts. NO_x adsorbers store NO_x during typical lean operation, but they must periodically be regenerated with fuel-rich exhaust that provides elevated CO and HC species for the desorption and reduction of the stored NO_x. These ethanol fuel blends might be able to enhance the overall performance of the engine, fuel, and emission control system.

ORNL, engine manufacturers, and other potential collaborators in research are discussing the potential for catalyst regeneration using ethanol and exhaust gases from blended ethanol/diesel fuel. This technology, if proven effective, could help engine manufacturers meet the more stringent diesel engine emission standards to be imposed over the next few years.

The test results suggest that diesel-ethanol fuels could also be used as low-emission fuels in current and older-model vehicles that will not be required to meet future emissions standards set by the Environmental Protection Agency. These fuels could offer a way of reducing the higher levels of PM emitted by older diesel engines. However, extensive testing of blended fuels in older and current-model diesel engines is needed to accurately assess their performance, and oxidation catalysts might need to be added to the older vehicles to alleviate the elevated CO and HC.

ORNL is proposing that further R&D be conducted using an engine that can be optimized for an ethanol/diesel blend, so that a fairer performance comparison can be made. There is a need to characterize the PM emissions to identify any significant differences in the chemistry, size, or structure of these emissions from blended fuel.

Contact: Ron L. Graves, 865-946-1226, gravesrl@ornl.gov
Sponsor: Office of Heavy Vehicle Technologies, ORNL State Partnerships Program

Fuel Cells: A Clean Power Source for Homes and Cars

Through materials and technology developments, ORNL researchers are finding ways to improve the performance of fuel cells and reduce their costs. Work is under way in the Metals and Ceramics Division on both solid-oxide and proton exchange membrane (PEM) fuel cells.

Solid-Oxide Fuel Cells

Tim Armstrong is leading an ORNL initiative to develop solid-oxide fuel cells and components using advanced materials. An advantage of this type of fuel cell is its fuel flexibility. Iron aluminide alloys developed by ORNL are candidates for solid-oxide fuel cell containment vessels. The iron aluminide alloys are stronger and more resistant to oxidation than the stainless steels currently used for containment.

"This solid-oxide fuel cell can also provide high-quality waste heat that can be used to warm the home or provide refrigeration and air conditioning," Armstrong says. "Its only emissions are steam, trace amounts of nitrogen oxides and sulfur oxides, and a small amount of carbon dioxide.

"Based on the results of our computer model, the ORNL conceptual design for a hybrid fuel cell–microturbine power plant is 80% efficient," Armstrong says. "The reason is that we combine our efficient heat-exchange technologies with membrane technologies for separating hydrogen and carbon monoxide from natural gas for use in the fuel cell." In addition, the power plant allows carbon sequestration because ORNL's carbon-fiber composite molecular sieve technology can capture the carbon dioxide leaving the fuel cell as a waste product. This gas can then be collected and used for enhanced oil recovery or sequestered in geological formations.

Contact: Tim Armstrong, 865-574-7996, armstrongt@ornl.gov
Sponsors: Office of Fossil Energy, National Energy Technology Laboratory

PEM Fuel Cells

Cars powered by electricity from hydrogen fuel cells eliminate discharges of carbon dioxide, nitrogen oxides, and particulate emissions. PEM fuel cells are an appropriate technology for such "zero emissions" cars because of their low-temperature operation and rapid startup.

PEM fuel cells have been plagued with problems, but recent developments at ORNL may make this technology more feasible and affordable. The problem with using today's PEM fuel cells to power cars is that their bipolar plates (positive and negative electrodes), which are made of machined graphite, are too heavy, too brittle, and too costly for use in automobiles. ORNL's solution is to make bipolar plates from a carbon-fiber composite, which is lighter, tougher, and cheaper than machined graphite.

Ted Besmann, James Klett, Tim Burchell, and John J. Henry, Jr., have developed a method for making composite plates that includes chemical vapor infiltration. Basically, carbon fibers are molded to make an electrode, and methane is flowed over the plate at high temperatures to deposit carbon that seals its surface pores. Because a fuel cell is a stack of bipolar plates with electrolytes between, the porous plate surfaces must be sealed to prevent leakage of hydrogen and oxygen from one cell to another—a showstopper for fuel cells.

ORNL researchers have shown that carbon-fiber composite plates not only can be made to perform as well as graphite plates but also are half as heavy, may cost one-fifth as much, are more conductive and corrosion resistant, and are easier to manufacture.

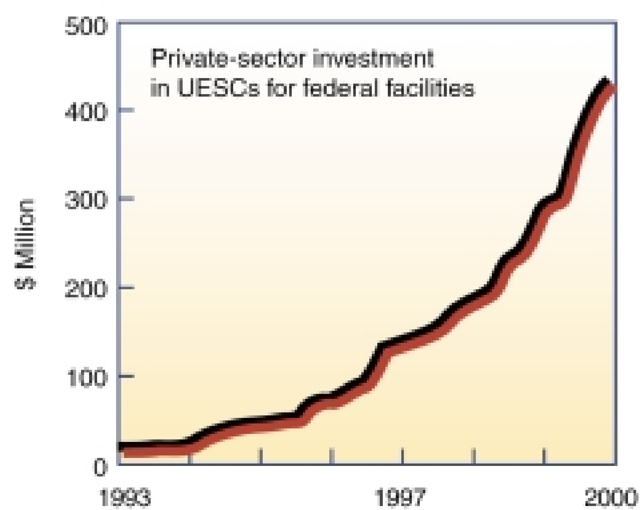
Contact: Ted Besmann, 865-574-6852, besmanntm@ornl.gov
Sponsor: Office of Advanced Automotive Technologies

Continued from page 3

sense especially where central plants provide heating or cooling. ORNL is taking a census of central plants to identify the best candidates for this technology and to ensure that FEMP's support reaches those that can benefit most.

The ORNL FEMP team is also encouraging local natural gas distributors, which have a more natural affinity for CHP technologies than electric utilities, to offer federal customers another option for implementing CHP projects. A workshop for gas utilities, developed by ORNL and co-sponsored by DOE's Atlanta Regional Office and the American Gas Cooling Center, was highly successful and will be replicated in other DOE regions.

Contact: Patrick Hughes, 865-574-9337, hughespj1@ornl.gov
Sponsor: Federal Energy Management Program

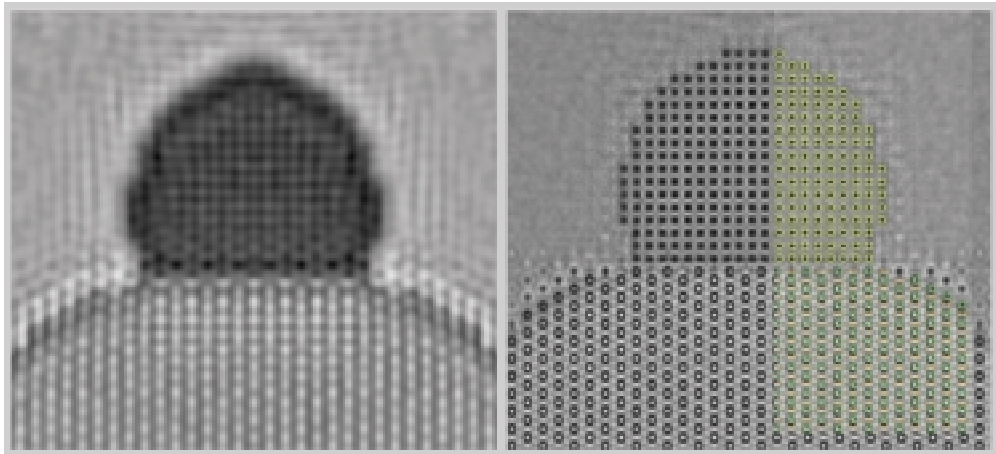


Private-sector investment in UESCs has grown steadily during the past several years.

Ultra-High-Resolution Microscope Offers Atomic-Scale Images

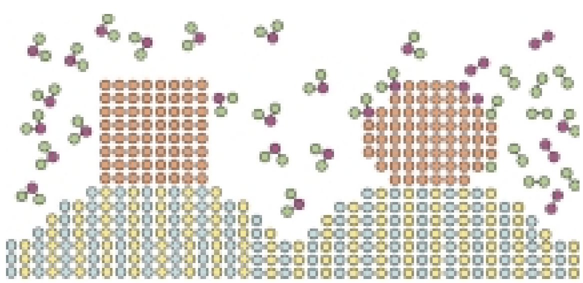
Staff at the High Temperature Materials Laboratory are excited about a new ultra-high-resolution electron microscope being built for delivery at ORNL in 2003. The aberration-corrected electron microscope, or ACEM, will be the first microscope of its kind in the United States.

ORNL is partnering with Japan Electron Optics Laboratory and Corrected Electron Optical Systems in Germany to add aberration correction to a next-generation electron microscope. The resulting instrument will routinely achieve direct-image resolution approaching 0.7 angstroms in annular darkfield or "Z-contrast" images. This significant improvement over the currently achievable resolution of about 1.3 angstroms will enable the subatomic characterization of materials.



Regular transmission electron microscope image (left) and ACEM image (right). ACEM corrects distortions to allow unambiguous determination of atom locations.

The ACEM provides an integrated aberration correction element to correct distortions that plague all current electron microscopes. The aberration corrector involves electromagnetic lens elements that require computer-control techniques and algorithms for image analysis to keep the corrector tuned. In some respects, the corrector is similar to the lens that corrects the distorted vision of the Hubble Space Telescope (although the Hubble corrector remains fixed).



Two platinum particles on a substrate. The particle on the right has sites that provide locations for surface reactions for gas molecules.

The ACEM will allow study of crystalline interfaces at the atomic level, an important advance because defects at the crystalline level are a key to determining properties of materials. The ability to study the atomic structures of materials will be important particularly in electronics, nanomaterials, thin-film science, and catalytic science. The primary purpose of the instrument is to study catalytic materials used to reduce emissions and particulates from diesel and automotive engines. Such research will be greatly enhanced by the energy filter built into the ACEM, which helps locate and identify chemical elements in a sample to the level of single atomic columns.

The ACEM will be digitally controlled by an operator with a computer (no knobs or dials on the microscope). Using the microscope from another city or even another country will be no more difficult than using it at ORNL—a feature that makes it significantly easier for scientists to collaborate. Remote operation also helps maintain the ideal environment for sharp images, because image clarity can be affected by the slightest vibration or magnetic field, or even the thermal disturbances caused by the presence of an operator. ORNL plans to build an addition to the High Temperature Materials Laboratory to house the ACEM and other ultra-high-precision electron microscopes.

Contact: Edgar Voelkle, 865-574-8181, voelkl@ornl.gov
Sponsor: Office of Heavy Vehicle Technologies

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Managing Editors
Marilyn A. Brown, brownma@ornl.gov
Kathi H. Vaughan, vaughankh@ornl.gov

Technical Editor/Writer and Designer
Deborah M. Counce, councedm@ornl.gov

Your comments are invited and should be addressed to
Kathi H. Vaughan
Oak Ridge National Laboratory
Building 4500N, MS 6186
P. O. Box 2008, Oak Ridge, TN 37831-6186
865-241-4292; fax 865-576-7572

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News Briefs

Edgar Lara-Curzio Awarded

Edgar Lara-Curzio received the 2001 Award of Merit from the American Society for Testing and Materials and received the honorary title of ASTM Fellow. His award cited "his tireless commitment to the technical excellence and introduction of new test methods for ceramics and ceramic matrix composites." The award is the highest one granted by ASTM to an individual member for distinguished service and outstanding participation in ASTM committee activities. Edgar is one of the youngest recipients of the award.

Southwire Celebrates a Year of Operation

Southwire Company's high-temperature superconducting power delivery system has operated for a year and has worked for 5000 hours at a 100% load. Southwire, located in Georgia, is negotiating with utility companies on a project to install superconducting power cables in a working utility grid. Company officials anticipate a working cable could be marketed by 2005. Southwire's partners include DOE, ORNL, Argonne National Laboratory, and several electrical utility and industrial partners.

New EE/RE Directors

Dr. Marilyn A. Brown became Director of ORNL's Energy and Renewable Energy Program on April 2, 2001. Dr. Michael A. Karnitz was named Deputy Program Director. Mike will also continue in his role as manager of ORNL's Distributed Energy Resources Program.

Marilyn succeeds Anthony C. Schaffhauser, who has taken a position as Distributed Energy Resource Center Director for the National Renewable Energy Laboratory in Golden, Colorado.

Energy 100 Awards

Seven ORNL energy-efficiency technologies were among DOE's Energy 100 Awards, 100 discoveries by DOE laboratories that benefit consumers, contribute to U.S. economic competitiveness, and have significant growth potential. In addition, one of the ORNL innovations—refrigerator R&D—was selected by a citizen panel for the Energy@23 Awards representing the cream of DOE's scientific and technical achievements during its first 23 years (1977–2000). The other six ORNL EE technologies in the Energy 100 are nickel aluminides; the energy-efficient large absorption chiller; the National Energy Audit (NEAT); CFC and HCFC alternatives for building materials; the RABiTs superconductor substrate; and durable, energy-efficient lighting for public housing. Four other ORNL innovations were part of the Energy 100: laboratory on a chip, iron aluminides, the Parallel Virtual Machine, and the electronic notebook V1.10.

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Oak Ridge, TN 37831-6186