Science & Technology HIGHLIGHTS

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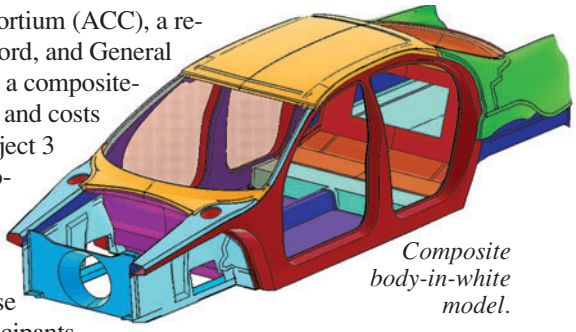
ORNL Research Is Putting Carbon Composites on the Road

The Automotive Composites Consortium (ACC), a research partnership of DaimlerChrysler, Ford, and General Motors, is working with DOE to develop a composite-intensive auto body that weighs less than and costs about the same as a steel body. Focal Project 3 (FP3), a part of DOE's FreedomCAR program, will guide and showcase the polymer composites research efforts of ACC and DOE.



Composite body-in-white model.

FP3 combines the research expertise of several private- and public-sector participants in design optimization, rapid joining methods, and faster manufacturing processes for carbon-fiber composite materials. The first phase of the project produced a detailed design of a vehicle "body-in-white" (BIW) and computer analysis of its properties. Current work involves the design, production, and analysis of one composite component to demonstrate high-volume manufacturing. The final phase will produce a complete BIW.

ORNL is developing several technologies to support FP3:

- Design methods to ensure materials perform for at least 15 years under exposure to various fluids, loads, and temperature extremes
- Methods of joining metals to composites
- A rapid, reliable, repeatable method of making carbon fiber preforms
- Constitutive models of component behavior in crashes
- An intermediate strain rate test machine to test materials and substructures at crushing rates consistent with those experienced in automobile crashes
- Processes to reduce the cost of carbon fiber

An ORNL scientist also works with the FP3 development team in Detroit.

Computer modeling of the BIW design predicts a mass 67% lower than that of a steel body. (The FP3 target was 60% lower mass.) Models project the bending strength and torsional stiffness will exceed targets by 12% and 103%, respectively, and durability will meet targets.

ORNL also is pursuing the development of the programmable power performing process (P4) for high-volume manufacturing of carbon fiber preforms. The P4 goal is to preform and mold random-oriented carbon composites at a 1.5-mm thickness, a 40% fiber volume, and a 100,000-unit annual production volume.

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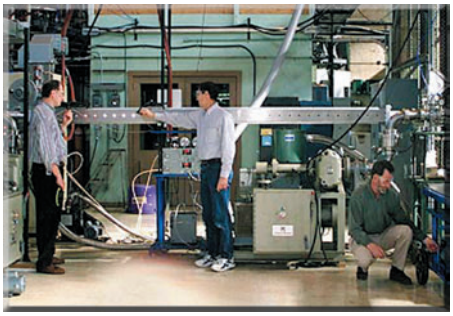
Sponsor: DOE/EERE FreedomCAR and Vehicle Technologies

Carbon Fiber Composites Key to Reducing Vehicle Weight

Increased use of carbon fiber (CF) composites in vehicles is essential to DOE's FreedomCAR goals. To realize the potential of CF composites for automotive applications, national labs, automakers, suppliers, and universities are cooperating in a CF composite materials research partnership through the Automotive Lightweight Materials program. In addition to participating in all facets of the CF composites research, ORNL supplies technical coordination for the DOE program.



Microwave-assisted carbon fiber production unit at ORNL.

The main technical needs being addressed by the CF composites program are

- Low-cost CF precursors, resins, and precursor processing methods
- Cost-effective high-volume production of components
- CF composites design data, testing methods, analytical tools, and durability data
- Joining technologies for composites and dissimilar materials
- Cost-effective recycling and repair

Carbon fiber is currently produced by pyrolysis of three types of precursor materials. Both the process and the raw materials are prohibitively expensive for automotive applications. To reduce costs, the CF composites research portfolio includes new precursors, novel fiber production methods, and a user facility in which advances can be further refined.

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ORNL and Partners Building Village of "Zero Energy" Houses

Houses that produce as much energy as they use—"zero-energy" houses—would dramatically reduce U.S. energy consumption, energy costs, and pressure on the utility grid. ORNL is active in DOE's zero energy building initiative and at the same time working to ensure that the benefits extend to families with modest incomes.

(Left) Structural insulated panels are lowered into place to form the roof of the zero-net-energy Habitat house.

(Right) Solar panels on the roof will generate electrical power for the home. Any surplus power can be sold to TVA.

To that end, ORNL's Buildings Technology Center (www.ornl.gov/btc/index.html) is working with Habitat for Humanity, building materials manufacturers, and the Tennessee Valley Authority (TVA) to build a "zero-energy village" of super-efficient Habitat for Humanity homes. The goal is to build 20 prototype houses showcasing various energy-producing methods—such as solar photovoltaic (PV) panels, fuel cells, and biomass-fired microturbines. Energy-saving technologies will also be featured, such as structural insulated panels (SIPs), heat pump water heaters, waste water heat recovery, and advanced heating/cooling systems.

ORNL had already helped Habitat build several test houses using advanced energy-saving technologies in a subdivision in Loudon County, Tennessee. The 20 new prototype houses in the subdivision will consist of both Building America houses, which use 50% less energy than average American homes, and net zero-energy dwellings, which are up to 90% more efficient. The latter can buy power from the utility grid as necessary and sell any surplus power they produce to TVA. This push-pull is expected to result in zero, or near-zero, net annual energy use.

The first prototype house was completed in August. Its entire building envelope is made of SIPs, which consist of a thick panel of foam insulation glued between two layers of oriented strand board. The SIPs are joined to form an airtight outer structure. Five SIP makers are contributing panels to complete another five houses in the subdivision. Glenn McCullough, chairman of the TVA board of directors, has committed TVA to sponsor five homes, and makers of other energy-efficient materials are expected to join the project.

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Sponsor: DOE/EERE Building Technologies

National Park Service Builds CHP Showcase in NYC

New York has some of the nation's highest electricity rates, air pollution, and transmission congestion. Both city and state governments recognize the potential of distributed energy resources and cooling, heating, and power (CHP) technologies to address these problems and actively support their deployment. At Floyd Bennett Field in the Gateway National Recreation Area in Brooklyn, a demonstration CHP project is taking shape in one of the nation's hottest markets for CHP.

Public and private partners are collaborating on this highly visible showcase with support from the New York State Energy Research and Development Authority, the National Park Service (NPS), DOE, and Keyspan Energy, a gas distribution company. ORNL contributed expertise in CHP systems and helped develop the proposal for the showcase. ORNL is also providing technical support and analyzing energy data to document savings.

Floyd Bennett Field, New York City's first airport and now an historical site, is home to the city's only campground and an NPS Center for Sustainable Design Excellence. The CHP project will be a working example of energy-efficient technologies in the urban landscape. NPS is renovating the existing buildings as public education centers focusing on conservation, urban renewal, and energy efficiency. Gateway receives tens of thousands of visitors annually.

The project design focused on a system with heat recovery to meet peak summer thermal loads and provide the most efficient systems possible for winter heating and cooling. The turbine and heating system will be installed in late 2002 and the cooling system in the spring. A detailed study will document preconstruction baseline conditions, estimate savings from the new system, and then document its performance.

This project is one of the first opportunities to collect and analyze detailed data to assess CHP technology. It will also contribute to the development of software models to aid in the design and performance estimation of other CHP applications.

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Sponsor: DOE/EERE Federal Energy Management Program and Distributed Energy and Electric Reliability

The Outlook Is Sunny for Hybrid Solar Lighting

ORNL's revolutionary hybrid solar lighting (HSL) technology is proceeding steadily toward commercialization. Prototype hybrid lighting fixtures are being tested at ORNL, and a national partnership to develop HSL systems is taking shape.

ORNL's Jeff Muhs displays sunlight-carrying fiber optic cables to Energy Secretary Abraham during the G8 Energy Ministers Summit in Detroit.

HSL works by collecting and distributing the visible portion of sunlight using large-core optical fibers, which are combined with electric lamps in lighting fixtures. The fibers convey sunlight inside a building for illumination. When less sunlight is available, the electrical light can be increased to maintain illumination levels. HSL has the potential to substantially reduce the amount of electricity used for lighting.

A broad-based public–private alliance to develop HSL systems has developed. In addition to ORNL, its members include the Tennessee Valley Authority (TVA), Wal-Mart, the Sacramento Municipal Utility District (SMUD), JX Crystals, SAIC, 3M, Honeywell, ROC Glassworks, Array technologies, Edison Electric Institute, several prominent universities, and other national labs. The partnership will pursue the R&D needed to make HSL a viable commercial technology.

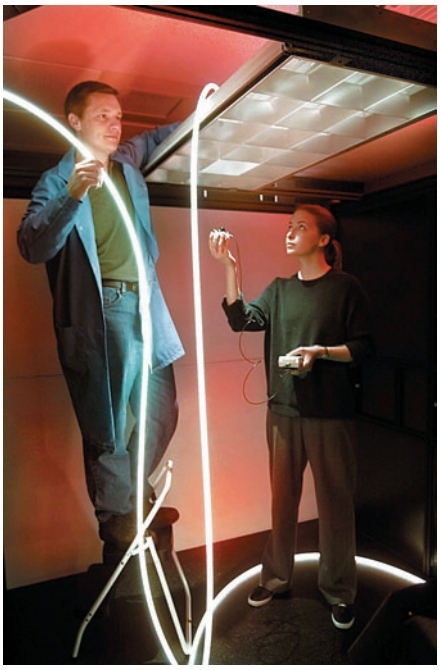
TVA is helping fund development of the lighting fixtures, or luminaires, that combine electrical lamps and optical fibers. During FY 2002, ORNL modeled the performance of luminaire designs and selected two for further development. 3M has donated several hundred meters of its optical fiber for use in the prototype systems.

One luminaire prototype has been installed and tested in ORNL's illumination cell. It incorporates two sunlight-carrying acrylic diffuser rods with four fluorescent bulbs. The optical efficiency of the fiber source measured about 60% and ORNL's team expects to increase that easily to 75%. According to ORNL's Duncan Earl, "Discrepancies in illumination patterns between the fiber optics and the electric lamps are perceivable but tolerable."

The other design, still under investigation, uses holographic diffusers to convert the "spotlight" distribution of a fiber optic source into a more suitable large-area illuminator. Testing of the second design began in September.

Both designs require efficient large-core fiber optic connectors and "splitters" (to channel light from one optical fiber into two others). Recent patentable advances at ORNL have increased the efficiency of connectors to more than 97% and of splitters to nearly 90%.

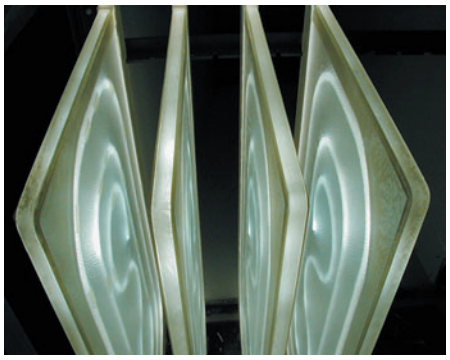
Field testing of the first luminaire design, with the improved connectors and splitters, is under way at ORNL. It will incorporate a daylight photosensor, developed at ORNL, that automatically adjusts and balances sunlight and electric light.



Duncan Earl and Tonya McFadden of ORNL install optical cables in a hybrid luminaire.

ORNL installed its first sunlight collector and associated fiber optic lighting system in June at Ohio University, where it is used in a photobioreactor to light algae. (OU is studying the feasibility of using algae-based photosynthesis to sequester carbon emitted by coal-fired power plants.)

TVA is interested in an HSL demonstration in its Public Power Institute during 2003. In addition, ORNL and SMUD have been awarded a contract by the California Energy Commission to install a first-generation HSL system in an office building in Sacramento. SMUD and ORNL will select a site, define requirements, and determine building code requirements during 2003. ORNL will install and operate the system in 2004. Wal-Mart and ORNL have developed a draft agreement for installation of second-generation prototype systems in 2004. Wal-Mart is interested in HSL, particularly for its new smaller "neighborhood markets," because it will drastically reduce the number and size of roof penetrations required for traditional skylights. Other daylighting strategies will not be used in these stores for several reasons, including ceiling height constraints, heat gain losses, and leaks caused by traditional skylights.



Illumination sheets for a photobioreactor contain an optical fiber and a membrane for algae growth.

For more information, see www.ornl.gov/hybridlighting/index.html.

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Sponsor: DOE/EERE Building Technologies; Tennessee Valley Authority

ORNL Research Creates Industrial Materials of the Future

Materials research at ORNL benefits greatly from the Laboratory's active role in DOE's Industrial Materials of the Future (IMF) program. In just one proposal solicitation last year, ORNL researchers won funding for 19 IMF projects. That accomplishment will bring $3.2 million annually to ORNL's materials programs for three years.

The 19 funded proposals cover a wide array of materials research areas, ranging from alloy characterization to welding joint design, and involve dozens of industrial, academic, and national laboratory partners. The following projects are representative of the varied types of IMF-sponsored research under way at ORNL.

HDI Surface Treatment of Refractories

Innovative surface processing will reduce the penetration, wetting, and reaction behavior of refractories

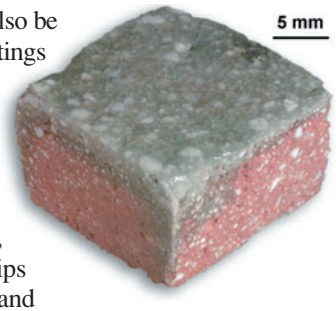
ORNL and several partners are using the Laboratory's Infrared Processing Center to explore the use of high-density infrared (HDI) heating to improve the performance of ceramic refractory materials by making them more resistant to corrosion and erosion. The technology could significantly extend the life of refractories, improving productivity and reducing energy consumption, downtime and waste in the industries that use them.

Plasma arc lamp in operation in ORNL's Infrared Processing Center.

Refractories are brick-like materials used in high-temperature, chemically harsh environments. Often used in furnaces and furnace linings, they are critical in energy-intensive industries such as glassmaking, metal refining, papermaking, power generation, and chemical processing.

Refractories have changed little over the past few decades, and modern industrial processes have pushed them to their performance limits. A major weakness is their vulnerability to penetration and corrosion by metals, glass, gases, and molten salts. The foreign materials degrade the refractory material and decrease its performance.

The research team will use HDI lamps to surface-treat refractories to seal them against penetration. ORNL's Infrared Processing Center has a unique 300,000-W plasma arc lamp that produces an extremely high power density over a precisely defined area. It will be used to heat the near-surface region of refractories to extremely high temperatures so that they melt or sinter to form a new, less porous surface. HDI will also be used to bond corrosion-resistant coatings onto refractories to seal their surfaces against penetration.



Mullite refractory surface fused by HDI heating.

Surface modification of refractories with high-intensity heating is a largely unresearched area. So, along with the processing tasks, the research will explore relationships among processing, microstructure, and material properties. The data will be correlated with material behavior in simulations and actual test conditions.

ORNL's partners in the HDI project are the University of Missouri-Rolla, Allied Mineral of Ohio, Emhart Glass of Missouri, and Kyanite Mining of Virginia.

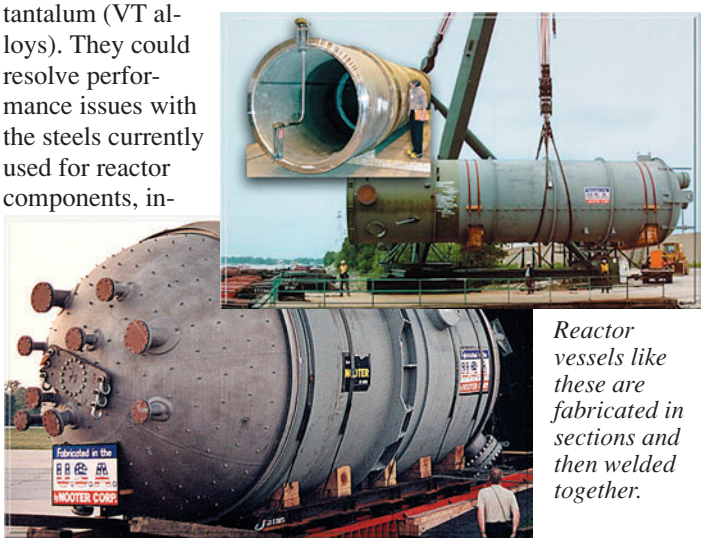
Super Steel Alloys for High-Temperature Use

Ferritic alloys will lead to weight reduction, reduced fabrication time, and energy savings.

Chromium steels are the material of choice for high-temperature equipment such as chemical reactor vessels and petrochemical hydrocrackers. ORNL has created a new class of chromium steels with dramatically improved properties and is working with several partners to develop them for industrial applications.

The payoff is potentially huge. The new steels could save U.S. industry an estimated 20 trillion Btu in energy and $237 million in costs annually by 2020.

The new materials are iron-chromium-tungsten alloys with small percentages of vanadium (V alloys) and vanadium and tantalum (VT alloys). They could resolve performance issues with the steels currently used for reactor components, including strength and toughness limitations and the need to heat-treat structures after they are welded.



Reactor vessels like these are fabricated in sections and then welded together.

Reactor vessels made from currently available steels must have 10-inch-thick walls to withstand operating conditions. The thickness of the walls results in non-uniform microstructure, which makes them vulnerable to cracking. The V and VT alloys have 50% more tensile strength at temperatures above 600°C and substantially greater resistance to fracturing at low temperatures. Vessels made from them would need walls only half as thick, so the microstructure would be more uniform, vessels would weigh much less, and welding wall sections together would be easier. In addition, since the weld material is weaker than the steel in the vessel, decreasing the surface to be welded would increase the strength of the structure.

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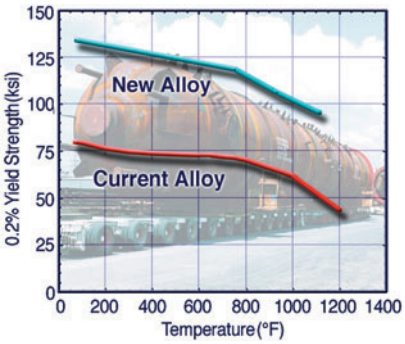


Comparison of properties of the new steels and the alloys currently available.

Eliminating the need to heat-treat structures made from V and VT alloys after welding them together would make fabrication much simpler and less costly. Reactor vessels can be 100 feet long and weigh as much as 300 tons. Heat-treating a vessel that size requires a huge amount of energy and adds significantly to the manufacturing cost. The need for heat-treatment also makes it infeasible to modify vessels once they are installed.

ORNL and its partners are working on optimizing the new alloy compositions and improving the microstructure of welds. The team includes partners in the chemical, steel, welding, and energy industries and is led by Nooter Fabrication in St. Louis.

Stress-Assisted Corrosion in Boiler Tubes

Understanding the mechanisms of stress-assisted corrosion in boiler tubes will allow for mitigation and control.

Stress-assisted corrosion (SAC) of tubes in industrial boilers is a major problem for U.S. industry. It can lead to cracking and eventual failure of boiler tubes, which can in turn result in boiler explosions that damage facilities and endanger workers. ORNL is working with the Institute of Paper Science and Technology and industry participants to identify the conditions that have the most effect on SAC and ways to control them.

Surface cracking on boiler tube interior (top) and metallograph showing its penetration of the tube wall.

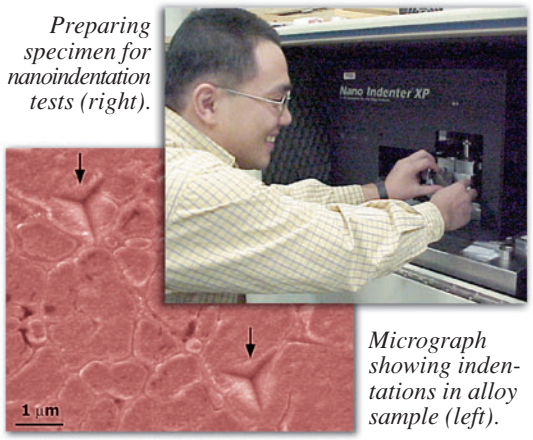
SAC is indicated by tiny fissures that begin on the inside of boiler tubes and then slowly advance through the tube wall. These tiny cracks inside tubes are very difficult to detect and measure nondestructively. Operating boilers with cracks in tubes is a violation of boiler codes and can lead to de-rating of boilers. If they remain undetected and unrepaired, the cracks can eventually penetrate the tube wall, leading to tube failure and even a boiler explosion when steam spewing from a tube reacts with hot chemicals in the boiler.

The research team will gather information from the industries that use boilers and will measure water chemistry and strain in operating boilers. The research participants will develop a laboratory simulation of SAC that permits the control of key conditions to determine which parameters have the greatest impact on SAC initiation and propagation. The data gathered on environmental, operating, and material characteristics will be used to identify conditions that reduce the frequency and severity of SAC. Risk factors that contribute to SAC also will be identified to help determine optimum inspection intervals and set priorities for controlling conditions.

The research will produce a set of recommendations for industrial boiler operators. The findings will be communicated to industry through various forums to encourage industry-wide implementation of the recommendations.

Combinatorial Methods for Alloy Design

Combinatorial methods for alloy optimization can accelerate the development of new alloys with improved properties.



Preparing specimen for nanoindentation tests (right).

Micrograph showing indentations in alloy sample (left).

To increase their operating efficiency, U.S. industries need improved alloys that retain their properties at higher temperatures. To speed the process and lower the price of introducing improved alloys, ORNL and the University of Tennessee–Knoxville (UTK) are using a new approach to alloy design.

Phase diagrams, a type of complex chart, are currently used to design alloys. They show the compounds that form, and their properties, at different temperatures and proportions of the alloy constituents. Data for the diagrams are generated by heat-treating and examining large alloy specimens. The process is time-consuming and expensive, and the range of compositions that can be characterized is limited.

ORNL and UTK are exploring the use of combinatorial methods for more efficient alloy design and optimization. The research team is devising a test specimen with a continuous distribution or "library" of alloy compositions across its surface. The proportion of the elements used will vary continuously across the sample so that each tiny site will represent a different alloy. Researchers hope to be able to structure 1000 different alloys on a sample the size of a quarter.

Probing techniques, such as nanoindentation, the scanning electron microprobe, and microfocus X-ray methods will be used to analyze the structure, composition, and properties of the alloy library. Researchers envision being able to test and characterize dozens of different sites on a sample in a matter of minutes.

The methodology will initially be applied to the Fe-Ni-Cr alloy system, which makes up the H-series and C-series of heat- and corrosion-resistant alloys widely used in industry. However, the technology is expected to be applicable to a wide range of alloys.

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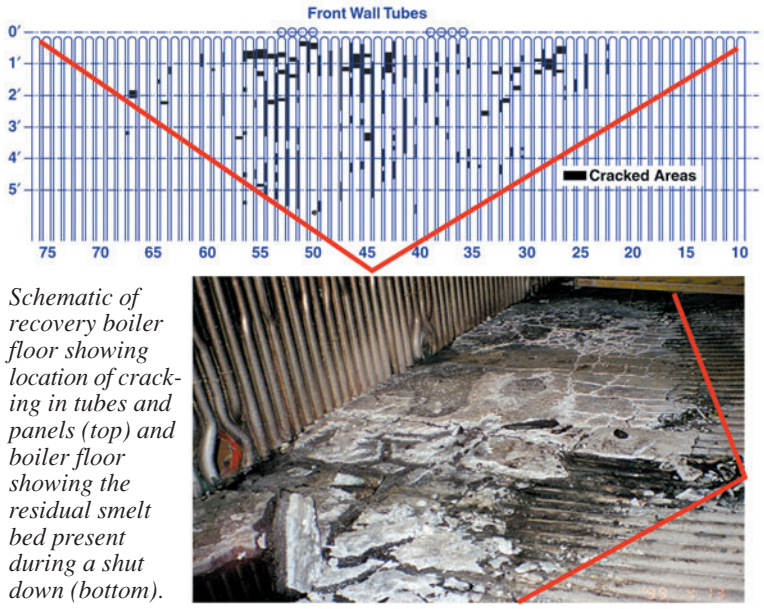
Sponsor: DOE/EERE Industrial Technologies

ORNL Helps Keep Boilers From Cracking Under Stress

Through DOE's Industries of the Future program, ORNL and the paper industry are addressing a key industry problem—the cracking of tubes in chemical recovery boilers. So far, their research has produced recommendations for operating procedures that help preserve tube integrity and identified metal alloys that are more resistant to cracking.

Recovery boilers, whose walls and floors are constructed of metal tubes, burn waste organic material and recover corrosive pulping chemicals at high temperatures. The harsh operating conditions can cause corrosion, cracking, and eventual failure of these tubes.

The tubes are made of a stainless/carbon steel composite. Cracking of the outer stainless steel layer in floor tubes occurs with unacceptably high frequency. ORNL found that most floor cracks begin as a result of stress corrosion cracking (SCC) caused by simultaneous exposure to tensile stresses and liquid corrosive chemicals. Once a crack begins, it may continue to grow by SCC but at an accelerated rate because of thermal cycling.



Schematic of recovery boiler floor showing location of cracking in tubes and panels (top) and boiler floor showing the residual smelt bed present during a shut down (bottom).

Laboratory studies show SCC usually occurs in the presence of sulfides and hydroxides between 160 and 220°C. Operating practices that create such an environment include washing hot floors with water and leaving moist smelt (inorganic salts) on the boiler floor during shutdown. Sudden, localized temperature spikes and subsequent cooling during operation also can create conditions conducive to SCC and should be avoided, the ORNL team found.

Computer modeling and laboratory studies indicate that combinations of carbon steel and the alloys 825 and 625 are more resistant to cracking than the metals currently used. Floor tubes incorporating 825 and 625 have not cracked after 5 years in a recovery boiler in an American mill, and an equivalent alloy used in a Scandinavian mill has resisted cracking for 8 years.

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Buying Guide for Low-Emission Boilers & Combustion Equipment

Purchasing boilers and combustion equipment is a complex process that involves resolving technical, financial, legal, and environmental issues. Operators must select properly sized, energy-efficient, low-emission units that will operate in compliance with state and federal emission standards.

ORNL has developed a guide to boiler selection that facilitates the processs. To ensure that it covers the technical and regulatory issues of interest to the boiler industry, the guide was developed in cooperation with the American Boiler Manufacturers Association (ABMA) and the Council of Industrial Boiler Owners (CIBO).

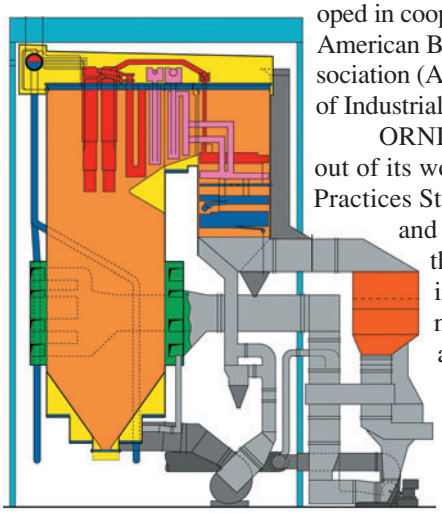

Diagram of a coal-fired boiler.

ORNL's involvement grew out of its work with DOE's Best Practices Steam program. ABMA and CIBO, both members of the Best Practices steering committee, noted the need for the publication and asked ORNL to respond.

The guide covers several topics pertaining to industrial, commercial, and institutional boilers, including types of boilers available; fuels used; emissions produced; and emissions standards, compliance, and control.

Although directed primarily toward new or expanded generating capacity, the guide also may apply to existing installations. It will aid those involved in selecting low-emission boilers and combustion equipment that complies with established emissions requirements. Regulatory authorities who deal with emissions and boiler permit applications may also find the guide useful.

The guide includes discussions of

- planning steam or hot water boiler systems
- boilers, fuel feed systems, fuels, and emissions
- firetube, watertube, cast iron, and tubeless boilers
- issues pertaining to solid, liquid, and gaseous fuels
- solid and gaseous emissions regulated under the Clean Air Act
- how nitrogen oxides, sulfur dioxide, particulate matter, and carbon monoxide are formed
- techniques used to reduce those emissions
- emission control options for 14 of the most widely used boiler and fuel combinations

The *Guide to Low-Emission Boilers and Combustion Equipment Selection* (ORNL/TM-2002/19) is available from the Industrial Technologies Clearinghouse at 1-800-862-2086 or on the web at www.oit.doe.gov/cfm/fullarticle.cfm/id=653.

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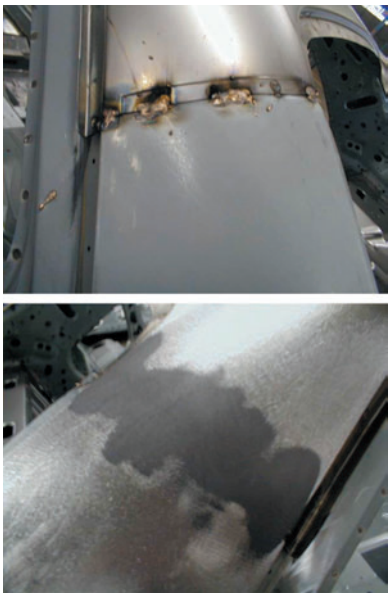
Sponsor: DOE/EERE Industrial Technologies

Ford Adopts ORNL's Infrared Curing Process for Lincoln LS

Auto workers at Ford Motor Company will save time, money, and energy with a production process developed at ORNL. Using equipment in the MPLUS National User Facility (www.ornl.gov/Energy_Eff; click "National User Facilities"), ORNL researchers developed a material joining/curing process for the Lincoln LS vehicle in cooperation with Ford researchers.

The Lincoln LS has a welded seam in the middle of the C-pillar behind the rear door. The finishing process for the seam included covering it with stitch metal-inert-gas welds and thermal spraying it with silicon bronze before painting. Five manual grinding stages were required to give the joint a smooth surface. The process was labor-intensive and susceptible to quality problems. In addition, the highly porous silicon bronze coating required additional glazing in the paint shop to produce an acceptable finish.



Seam in vehicle roof before (top) and after filling and infrared curing.

To replace the silicon bronze, Ford and ORNL researchers chose an epoxy material that is conductive to the electrostatic-coat, fully paintable and sandable, and low in porosity. The focused tungsten halogen lamp line heater in ORNL's Infrared Processing Center was selected as a heat source to cure the epoxy. This infrared (IR) lamp goes to full power in less than a second, converts electricity into radiant energy at 90% efficiency, and targets energy only to the area to be cured. It was able to cure the epoxy in brief process cycles.

In commercial-scale process trials, the IR lamp cured the epoxy in only 20 seconds from a distance of 6 inches and in a 10-inch-wide sweep to achieve a 92% cure suitable for grinding and sanding. (The cure is completed later in the electrostatic-coat oven.) Ford has adopted the epoxy filler and IR curing process for full production in one of its plants.

Use of the process is expected to save $28 per vehicle, eliminate five grinding steps, reduce energy consumption, and produce a less porous coating. The new process also is safer for workers and more environmentally friendly.

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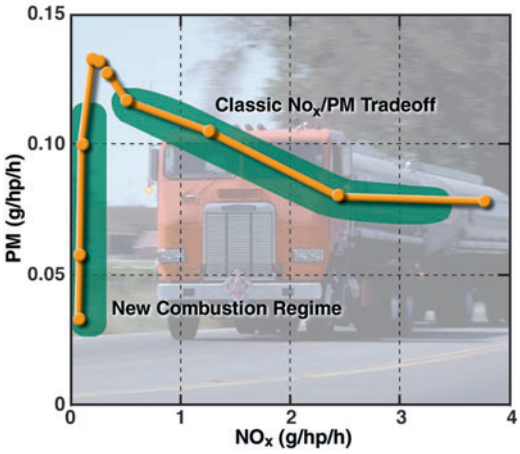
Sponsor: DOE/EERE Industrial Technologies

ORNL Team Confirms Low-Emission Diesel Combustion Regime

Researchers at ORNL have discovered a diesel combustion regime that exhibits a simultaneous reduction in emissions of both nitrogen oxides (NO_x) and soot, the primary pollutants in diesel engine exhaust. The ORNL team is the first to explain how this mode of combustion can be achieved and to demonstrate its feasibility on multi-cylinder engines without expensive hardware modifications or significant fuel penalties.

The accepted diesel combustion model has been that any change in engine operating parameters to reduce NO_x emissions results in an increase in soot. Conversely, higher combustion temperatures to promote complete oxidation of the fuel and reduce soot cause more NO_x formation. In recent years, exhaust gas recirculation (EGR) has been studied for use in diesel engines to reduce NO_x. The exhaust gas dilutes the combustion process, lowering the temperature and NO_x. As expected, however, EGR causes soot to increase.

Researchers at the Fuels, Engines, and Emissions Research Center in ORNL's National Transportation Research Center (www.ntrc.gov/labs/feerc.html) have for years investigated methods to extend the EGR limit for maximum NO_x reduction while balancing the soot increase at an acceptable level. Their approach relies heavily on non-linear (chaos) analysis of engine data to predict the operating boundary where soot increases dramatically. Recently, in experimenting with a diesel engine equipped with a flexible electronic control system, the team found a combustion regime at very high EGR levels where soot emissions reached a maximum and then decreased. After adjustments in this regime, the experiments achieved simultaneous NO_x reductions of about 90% and soot reductions of 45% (compared with typical operating conditions) with no loss of efficiency.



A simultaneous drop in particulate matter (soot) and NO_x emissions was observed in the new combustion regime.

By applying powerful analytical methods to characterize the exhaust constituents, ORNL is improving the understanding of the combustion process in this regime and its impact on aftertreatment components such as diesel particle filters, oxidation catalysts, and NO_x adsorbers.

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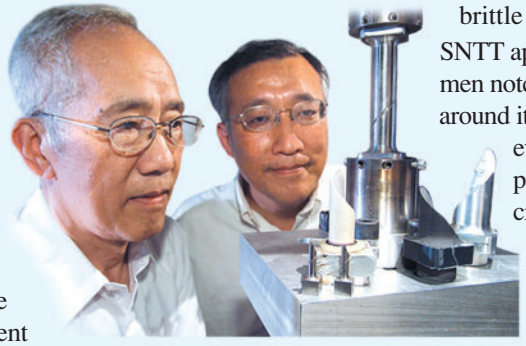
Sponsor: DOE/EERE FreedomCAR and Vehicle Technologies

Spiral Notch Torsion Test Predicts Toughness Under Pressure

ORNL's R&D 100 awards this year include one for the spiral notch torsion test (SNTT), a fracture resistance testing system that is more accurate and reliable than any other current testing method.

SNTT was developed to determine the "fracture toughness" of materials ranging from metallic alloys to brittle ceramics, glass, graphite, high-performance concrete, and their composites. Fracture toughness represents a material's resistance to uncontrolled brittle fractures from inherent flaws existing inside the materials.



ORNL researchers Jy-An Wang (left) and Ken Liu examine their award-winning spiral notch torsion testing system.

The SNTT system overcomes many of the limitations inherent in traditional techniques and introduces new possibilities for fracture toughness testing:

- it conforms to classical fracture mechanics theory, so resulting data are more reliable;
- it tests small or large specimens;
- it is portable and can test samples in the field;
- it can test multiple modes of stress simultaneously;
- it controls crack propagation and thus produces consistent results;
- it can test a wide variety of materials (including the heat-affected zone of welds, for which fracture toughness is virtually unknown);
- it does not require fatigue precracking of brittle samples.

SNTT applies pure torsion to a cylindrical specimen notched with a machined groove that spirals around it at a 45° pitch. Fracture toughness is evaluated, based on the torque required to produce a fracture and the final length of the crack that develops, with the aid of a computer code, TOR3D-KIC, also developed at ORNL.

Fracture toughness is a critical design element for structures where safety is a paramount concern and for materials used in aircraft and assemblies bound for space, where fracture toughness properties fluctuate because of extreme temperature swings. SNTT is particularly suitable for brittle materials such as high-temperature ceramics that are replacing many key components of turbine engines used in transportation systems.

SNTT development received support from DOE/EERE FreedomCar and Vehicle Tehnologies, ORNL's Laboratory-Directed R&D Program, the Radiation Safety Information Computational Center, and ORNL's industrial partner Inventure Laboratories.

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Triple-Effect Chiller Begins Its Vegas Run

A triple-effect chiller developed by ORNL and York International is undergoing its first real-world trial in the challenging climate of southern Nevada. The Clark County Government Center in Las Vegas is the site of a field demonstration of the high-efficiency absorption cooling system.

DOE, ORNL, York, and Clark County agreed in October 1998 to field test a triple-effect chiller at the Center. In laboratory tests, the triple-effect prototype unit was substantially more efficient than single- and double-effect chillers currently available. It is hoped the efficiency boost will expand the market for absorption cooling. (The "triple effect" refers to feeding the refrigerant solution though low-, intermediate-, and high-temperature generators. The design also incorporates heat recovery to increase efficiency and cut polluting emissions.)

The Clark County chiller was installed in February 2002 and began operating in April under controlled conditions. It is now providing baseline cooling to the Government Center campus, which includes a six-story, 385,000 ft^2 building. The field test will continue through the end of the 2002 cooling season. Data gathered will be used to verify the efficiency of the system under the intense Las Vegas ambient conditions.

Issues involved in developing the triple-effect chiller included ensuring that alcohol additives in the refrigerant mix do not degrade at high temperatures and resolving concerns about corrosion in the high-temperature generator.

Absorption chillers offer several advantages over electric cooling systems: Gas cooling reduces peak electricity demand, especially important in the Southwest. The refrigerants they use do not contribute to ozone layer depletion or global warming. Maintenance is simpler because absorption chillers have fewer moving parts than electric chillers. They also operate more quietly. In addition, because

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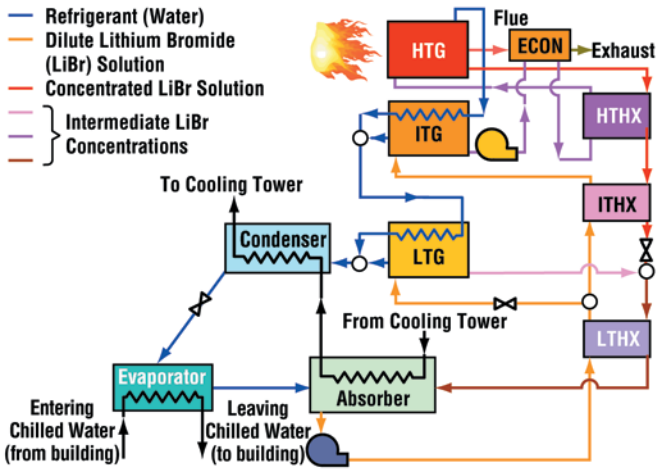

Schematic of the direct-fired triple effect absorption chiller.

ACCR Wires Power Grids for Greater Capacity and Efficiency

Power transmission cables using a new composite conductor are expected to greatly increase the capacity and efficiency of the U.S. electricity grid. ORNL is working with 3M, the developer of the aluminum-conductor composite-reinforced (ACCR) wires, to analyze the performance of the new conductor.

The high-performance conductors consist of a core of aluminum metal matrix composite wires surrounded by temperature-resistant aluminum-zirconium wires. They enable power lines to carry significantly more power than the aluminum-conductor steel reinforced (ACSR) cables used in the United States for nearly a century. ACCR operates at temperatures up to 210°C (410°F) with no degradation of its properties, while ACSR can operate only at 100°C (212°F) or below. The higher operating temperature allows ACCR to transmit two to three times more power than ACSR. In addition, the low thermal expansion of the new composite core reduces line sag when power flow increases.

ACCR wires being installed at ORNL's PCAT facility for 3 years of operation and testing.

ORNL researchers will provide performance data for ACCR wires based on both laboratory and field tests. An outdoor test facility, the Powerline Conductor Accelerated Test (PCAT), was built at ORNL in July of 2002. The ACCR conductors will be installed on steel poles at the PCAT and tested at high-current, low-voltage and at the rated conductor temperature of 210°C for 500 thermal cycles. Sag, tension, current, and conductor temperature will be measured. Beginning in the fall of 2002, three ACCR sizes—477, 795, and 1272 kcmil—will be tested over 3 years. The Tennessee Valley Authority is helping design and install the test lines.

3M is selecting field sites to test ACCR in use on utility networks. The first field installation under the DOE program will be conducted by the Western Area Power Administration (WAPA). It is scheduled for late 2002. ORNL is working with 3M and WAPA to provide monitoring hardware and to collect and analyze data to evaluate ACCR performance on the utility grid.

ACCR can replace conductors already in use in overhead transmission cables. ACCR wires can be installed quickly with little disturbance of neighborhoods and the natural environment.

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Sponsor: DOE/EERE Distributed Energy and Electricity Reliability

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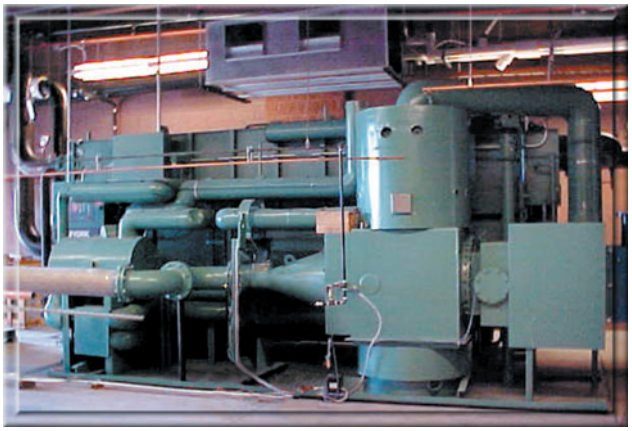
absorption chillers are heat-activated (powered by heat rather than electricity) and produce waste heat, they are a good fit for cooling, heat, and power applications.



The triple-effect chiller being demonstrated in Las Vegas.

One of DOE's aims for the demonstration is to encourage more widespread use of absorption cooling in the Southwest. Some of the innovations resulting from the triple-effect R&D (e.g., improved refrigerants, additives, control systems) have also improved the efficiency and performance of other absorption technologies.

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Sponsor: DOE/EERE Distributed Energy and Electricity Reliability

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The effort will culminate in production of the FP3 body-in-white (see accompanying article on p.1).

Several R&D projects at ORNL attempt to lower CF composite costs. One is developing low-cost precursors based on kraft lignin, a by-product of paper-making. Millions of tons of lignin are produced annually, most of which is burned as fuel. Another project seeks to enable the use of commodity-grade polyacrylonitrile (PAN) as a carbon fiber precursor. Commodity-grade PAN sells for about half the cost of carbon- fiber-grade PAN. The work has focused on evaluating PAN-based precursors and stabilizing the fibers using chemical modification and radiation pretreatment.

Textile-grade PAN before (left) and after being converted to carbon fiber.

A third effort is using microwave energy to convert PAN precursors into carbon fibers. Early stages of the research proved microwave-assisted processing to be a feasible alternative to oven treatment. Successive phases have scaled up the process to run continuous fiber samples at increasing lengths and production rates. The fibers produced surpass the technical targets, and the process promises to cost almost 20% less than conventional methods.

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Sponsor: DOE/EERE FreedomCar and Vehicle Technologies

ORNL's New Buildings Feature "Green Building" Principles

ORNL is attempting to "walk the talk" in a facilities modernization campaign under way at the Laboratory. New buildings incorporate energy-saving and environmentally friendly features that make them more environmentally sustainable.

The building designs were evaluated by Leadership in Energy and Environmental Design (LEED®) principles developed by the U.S. Green Building Council. ORNL is aiming for a "silver" LEED rating, said Tim Myrick, the project coordinator.

As a first step toward sustainability, most of the new buildings were sited on a former parking area to avoid bulldozing undeveloped land.

On the outside, "cool roofs" that reflect solar rays reduce the energy needed for cooling. Trees will be planted to shade paved areas and avoid the creation of heat islands. Rainwater will be collected to water trees and landscaping. Parking lots will be partially paved with permeable asphalt through which rain can soak into the ground instead of running off into waterways.

Inside, high-efficiency heating/cooling systems will use refrigerants that do not damage the ozone layer or contribute to climate change. Motion sensors to shut off lights in empty rooms, dimming switches, and natural light will curb the demand for electric lighting. Low-flow plumbing fixtures will control water use.

For occupant health and comfort, paints and coatings used inside will be low in compounds that release irritating chemicals into the air, and the indoor air quality will be continuously monitored.

In purchasing materials and furnishings, the amount of recycled content is a criterion. Another criterion is how far they must be shipped—at least 20% of materials used will be produced locally or regionally. At least half the construction waste will be recycled.

Once the buildings are occupied, ORNL will operate them to obtain an Energy Star rating, which will require that they be maintained and controlled to take full advantage of the energy efficiency features.

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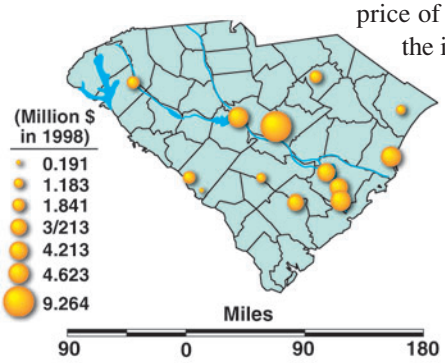
A crane lifts a pre-assembled wall into place on one of ORNL's new buildings.

ORNL Study Helps Assess the Whole Cost of Electricity Generation

Most power plants emit gases and particulates that affect air quality, the environment, and human health. These impacts are referred to as "externalities"—their costs (e.g., respiratory illnesses, and damage to ecosystems) are not reflected in the price of electricity. To estimate the impact of these hidden costs, an ORNL team analyzed power plant externalities for a year in the state of South Carolina.



Externalities of COAL power plants in South Carolina.

ORNL researchers estimated the external costs associated with airborne emissions (e.g., sulfur dioxide, nitrogen oxides) from fossil-fuel-burning power plants, as well as global-warming externalities associated with the emission of carbon dioxide (CO_2). Their study also suggested ways state government could address these costs. The study was conducted in collaboration with the South Carolina State Energy Office.

Results indicate that for 1998, South Carolina had external costs of $42 million from fossil-fuel power generation (see the table). The impacts depended on the amount of power generated by a given plant, its emissions, and the size and distribution of the exposed population. The study calculated the annual external cost of CO_2 emissions to be $105 million, based on a median value of $3 per ton of CO_2. Possible impacts of climate change on South Carolina include higher temperatures and more frequent heat waves, with concomitant health effects; sea level rise, with related flooding, loss of wetlands, beach erosion, and saltwater contamination of water supplies; and changes in ecosystems.

Estimated annual externality and global warming costs in South Carolina (1998$)

Power plant type	Global costs of pollutants ($ x 1000)	Warming costs ($ x 1000)
Coal	41,000	101,000
Natural gas	850	1,020
Oil	380	2,240
Biomass	250	[negligible]
Total	42,000	105,000

The study found that external costs associated with natural gas power plants, generally thought to be low, were surprisingly high. Two factors might account for this: a relatively high population density around many of these plants and their inefficient use to handle peak, rather than base, load.

To address these concerns, state government could consider policies that: (1) affect the location of new natural gas plants, (2) promote renewable energy sources; and (3) internalize some external costs through emissions permit trading so that generators bear the costs of the permits that allow them to emit pollutants.

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Sponsor: DOE/EERE State Partnerships Program

ORNL and TVA: Neighborhood Partners in Energy Research

ORNL is located within 30 miles of the headquarters of the Tennessee Valley Authority (TVA). Naturally, the largest U.S. public power company and a DOE national laboratory specializing in energy research find ways to work together. In the areas of energy efficiency and renewable energy alone, ORNL and TVA are cooperating on numerous projects.

"ORNL and TVA's Public Power Institute have identified a large intersection of research interests through a series of joint strategic planning meetings," says Marilyn Brown, Director of the ORNL Energy Efficiency and Renewable Energy Program. "Joint strategic planning is the ultimate in partnership."

ORNL's Buildings Technology Center (BTC), TVA, and Babb International concrete makers are testing autoclaved aerated concrete (AAC), which contains 70% flyash from TVA's coal-burning power plants. Tests in the BTC show AAC to have good insulating properties. AAC blocks were used to build a Habitat for Humanity house that is being monitored by the BTC for energy efficiency and airtightness. If AAC works well in the field, it will save energy as well as mitigate the environmental cost of providing it.

TVA is supporting another joint effort between ORNL and Habitat for Humanity to build a neighborhood of Habitat homes that will produce nearly as much energy as they consume. TVA has agreed to sponsor the construction of five "zero-energy" Habitat houses (see p. 2 of this issue).

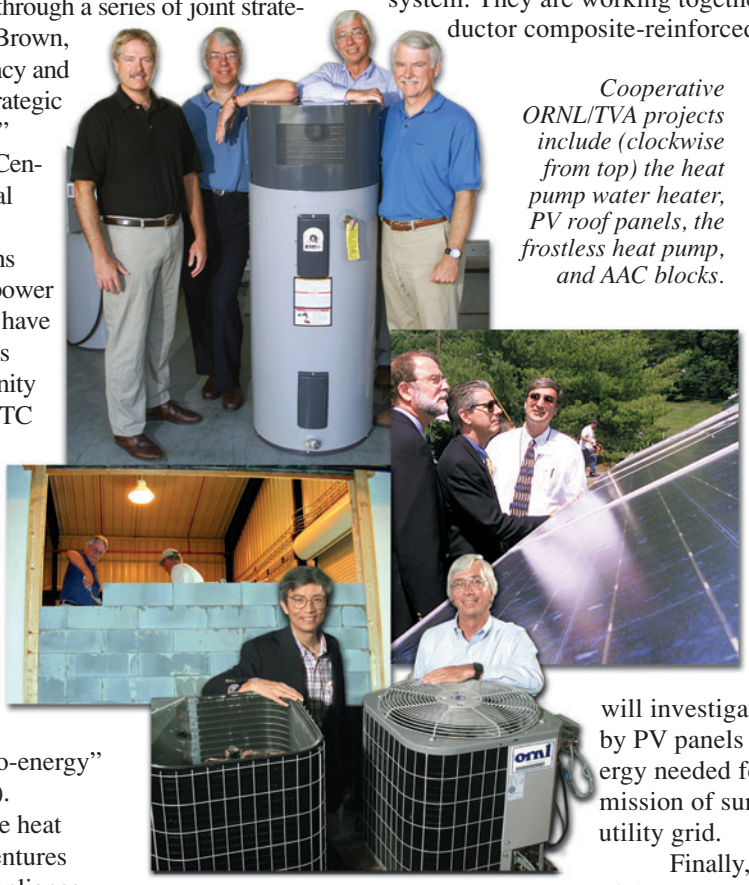
The frostless heat pump and the heat pump water heater (HPWH), joint ventures involving DOE, ORNL, TVA, and appliance manufacturers, are expected to be available to consumers soon. The heat pump reduces frosting on heat pump coils, improving energy efficiency and heating performance. TVA and Amana will test the heat pumps in homes during the 2002/2003 heating season.

HPWHs use a third as much electricity as conventional electric water heaters. ORNL's industrial partners EMI and A. D. Little are marketing HPWHs that replace conventional 50- or 80-gallon electric units. TVA and ORNL are working to commercialize a "bayonet" HPWH, a heat-pump insert that replaces the heating element in an existing electric unit. TVA is conducting residential field tests of two bayonet HPWHs and is bringing ORNL together with American Water Heater Company in Johnson City, Tennessee, to discuss commercialization opportunities.

Hybrid lighting uses fiber optic cables to deliver sunlight inside buildings for illumination to reduce the use of electric lighting (see p. 3 of this issue). ORNL researchers invented the technology and are developing it for commercialization. TVA helped fund the fabrication of the light fixtures used in the research.

TVA also helped fund the installation of a geothermal heat pump (GHP) at a school in Oak Ridge, Tennessee. ORNL researchers have developed an internet-based system being used to monitor the performance of the heat pump and control the system over the web. The monitoring system will compare conditions in a GHP-conditioned classroom with those in a room with a conventional heating/cooling system.

ORNL and TVA have a common interest in the efficiency and reliability of the electricity transmission and distribution system. They are working together to test aluminum-conductor composite-reinforced cables for power transmission lines that can carry two to three times more power than conventional conductors. The advanced conductors will be tested at an outdoor transmission test facility recently built at ORNL (see p. 9).



Cooperative ORNL/TVA projects include (clockwise from top) the heat pump water heater, PV roof panels, the frostless heat pump, and AAC blocks.

Renewable energy and its integration into the power grid are another shared interest. ORNL, TVA, and other partners are cooperating in research at the BTC to address issues associated with the integration of photovoltaic (PV) solar panels into roofs. Among other things, the project will investigate how shading of a roof by PV panels affects the amount of energy needed for cooling and the transmission of surplus solar energy to the utility grid.

Finally, ORNL was the first industrial customer to sign up for "green power" produced by TVA when the program was offered in 2000. ORNL looks forward to continuing its important strategic partnership with TVA.

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OAK RIDGE NATIONAL LABORATORY
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News Briefs

New User Facility Dedicated at ORNL

A facility to test distributed generation energy for building applications was designated June 17, 2002, as the 20th national user facility at ORNL. ORNL's Cooling, Heating and Power Integration Laboratory will enable researchers from industries, universities, and other institutions to conduct tests on distributed energy products and systems.

The facility designation was announced during a day-long Distributed Energy Resources and Zero Energy Buildings Showcase held at ORNL.

S&T Challenges Award

ORNL's Felix Paulauskas and Cliff Eberle won a Critical Science and Technology Challenges Award from the Battelle Technical Council for their ideas on inexpensive precursors and processes for manufacturing carbon fibers. The Battelle Technical Council invited all staff to provide ideas on the critical science and technology challenges facing Battelle and its affiliated national laboratories over the next 3 to 10 years. The challenges should have the potential to create interesting technical opportunities with good science and technology content for staff and to build robust long-term business opportunities for Battelle and its affiliated laboratories.

International Workshop on Superconductor Processing and Applications

The Materials Research Society recently sponsored an International Workshop on Processing and Applications of Superconductors in Gatlinburg, Tennessee, right before the 2002 Applied Superconductivity Conference. Organized by ORNL, ISTEC, Japan, and IGC-SuperPower, it presented work from an international group of 50 scientists from industry, national laboratories, and academia who are key players in the field of high-temperature superconductivity.

The workshop also provided overviews of the status of the second-generation YBCO-coated conductors in the United States, Japan, and Europe.

24th Biotechnology Symposium

The 24th Symposium on Biotechnology for Fuels and Chemicals in Gatlinburg, Tennessee, this spring registered 290 participants, 50% more than the last such conference in 2000. This conference is the longest-standing and most technically focused meeting on current trends in converting biomass to fuels and chemicals. It also covers broader aspects of biocatalysis, molecular biology, bioprocessing, separations, and economics in the conversion of one substance into more valuable chemicals.

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To communicate its findings to industry, the ORNL team is presenting them at industry meetings and workshops. The response has been positive—the recommended materials are being used in new tubes, and many mills are instituting revised operating procedures. Next, the research will address cracking in tubes that form air ports on boiler walls.

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