Science & Technology HIGHLIGHTS

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FEMP Promotes Greening of Government Facilities

The Federal Energy Management Program (FEMP) ensures that the government practices what it preaches about saving energy. FEMP provides services to promote energy efficiency in federal agencies, including financial and technical help, energy audits, technology demonstrations, and energy efficiency information.

FEMP relies heavily upon DOE's national laboratories, including ORNL. In recent months, ORNL has demonstrated retrofitted cool storage systems for commercial buildings and reflective coatings for low-slope roofs and has completed technology reviews on heat pump water heaters for commercial buildings, hydronic boilers, building weatherization, and ultrasonic humidification.

FEMP is leading a drive to cut energy consumption in federal buildings by 30% (from 1985 levels) by 2005. ORNL has contributed to this goal by "greening" its facilities (see accompanying article).

With federal funding for capital improvements shrinking, there is not enough conventional funding to achieve the 30% reduction. A promising alternative financing strategy is energy savings performance contracts (ESPCs) with private energy service companies (ESCOs) or local utilities. In an ESPC, the ESCO or utility finances the improvements and is reimbursed from savings on utility costs. FEMP developed the "Super ESPC" program to streamline ESPC services by providing a pool of selected ESCOs from which facilities can choose. The program also provides technical support through national laboratories and support contractors.

ORNL teamed with the DOE Oak Ridge Operations Procurement Office and Atlanta Regional Support Office (ARSO) to establish a Super ESPC program in the Southeast. ARSO promotes ESPCs, DOE-ORO ensures agencies use them properly, and ORNL engineers aid with the delivery order and provide technical assistance. ORNL also helps FEMP implement technology-specific Super ESPCs for promising new technologies. The laboratory is helping procure the first installation of geothermal heat pumps, and may assist procurement of high-efficiency gas desiccant dehumidification units and building power distribution systems.

By: George Courville, 423-574-1945, courvillege@ornl.gov
Sponsor: Federal Energy Management Program

ORNL Leads by Example

In addition to saving energy and money, ORNL's in-house energy management program enables compliance with federal regulations, protects the environment, enhances the workplace environment, improves operations, and provides leadership in the adoption of new energy technologies. The program has yielded a 17% reduction in energy use per square foot of occupied space since 1985:

John Price (left) and Gary Ford, electricians at ORNL, replace inefficient magnetic ballasts with energy-efficient, environmentally friendly electronic ballasts.

- Lighting upgrades: 35,000 fluorescent lamps (about 40% of the inventory) replaced with more efficient lamps; more than 17,000 ballasts replaced with more efficient, non-PCB ballasts; and occupancy sensors installed to switch lights off in empty rooms. Energy usage and costs were cut by 30 to 70% in the affected areas.

Continued on page 12

ORNL Assumes New Duties for 21st Century Weatherization

ORNL will be an instrumental part of preparing the Weatherization Assistance Program for the 21st century. DOE's Office of State and Community Programs has asked ORNL to help with several tasks to facilitate the weatherization of low-income housing in the new millenium.

Assistant Energy Secretary Dan Reicher has urged the Weatherization Network to integrate its activities with new DOE EE/RE initiatives such as the Partnership for Advanced Technology for Housing (PATH), Million Solar Roofs, and Climate Change, as well as electric industry restructuring and new technology initiatives. ORNL will help evaluate the relationship between the program and PATH, the climate change initiative, and industry restructuring.

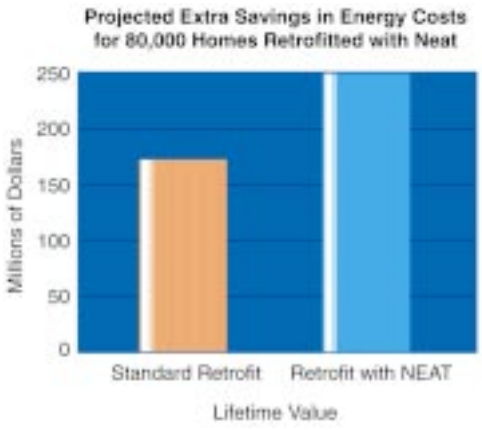
ORNL will receive funding and support to complete and field test Windows-based versions of the National Energy Audit (see accompanying article) and the Manufactured Housing Energy Audit. ORNL also is working to broaden the scope of state evaluation partnerships to include assessment of the program's impact on non-utility fuels, as well as technical assistance to the Weatherization Network regarding the impact of electric industry restructuring.

In addition, ORNL is helping develop metrics for DOE's State Energy Programs. To facilitate and standardize the program metrics, ORNL will develop a self-assessment tool for managers of State Energy Programs, working in conjunction with the Metrics Task Force of the National Association of State Energy Officials (see www.ornl.gov/divisions/energy/oscp).

By: Joel Eisenberg, 202-479-0439, eisenbergjf@ornl.gov
Sponsor: Office of State and Community Programs

A NEAT Way to Save Energy

The National Energy Audit (NEAT) software was developed at ORNL's Buildings Technology Center for DOE's Weatherization Assistance and Existing Buildings Programs. The advanced computer audit is designed for use by state agencies and utility companies to determine the most cost-effective ways to reduce energy costs while increasing the comfort level of low-income households.



About 500 local agencies in 31 states use NEAT to make retrofitting decisions for more than 80,000 low-income dwellings every year. Based on field tests, the use of NEAT has increased energy savings each year by about an additional $70 million over the lifetime of the retrofits performed.

The Weatherization Assistance Program reduces energy costs for low-income households by improving the energy efficiency of their homes. In the early years of the program, retrofit measures were simply selected from a standard list that included primarily building envelope measures (e.g., insulation). In 1985, field testing established the benefit of selecting the most cost-effective measures for retrofitting. The tests were done using such innovative techniques as blower-doors and advanced audits, which select energy conserving measures specifically for each house. Results of field tests in Wisconsin, New York, and North Carolina demonstrated average heating cost savings of 25% when NEAT and its measure selection strategies were used to guide retrofitting; savings averaged 18% using the earlier approaches.

Tom Petrie and Marilyn Brown (ORNL) explain to Mark Ginsberg (DOE) the window retrofit weatherization techniques being tested at ORNL's BTC.

Major extensions planned for NEAT, in addition to the Windows version, include an option allowing the user to draw the floor plan of the house; estimates of savings from duct sealing; estimates of infiltration through individual windows and the effect of window replacement, retrofitting, or storm windows; and possibly savings estimates from a solar hot water heater retrofit.

By: Mike Gettings, 423-574-4506, gettingsmb@ornl.gov
Sponsor: Office of State and Community Programs and Office of Building Systems

R&D in the Thermal Sciences for Sustainable Energy Technologies

A clean environment, strong economy, and secure energy future all depend in part on sustainable, highly efficient energy technologies. The Thermal Environmental Engineering program of ORNL's Buildings Technology Center conducts R&D in the thermal sciences to help in developing those technologies.

The group works on thermal engineering technologies for the U.S. industrial, transportation, and utility sectors and novel applications in terrestrial and space environments for both civilian and military uses. Current R&D activities include

- frostless heat pumps
- advanced environmental control devices for buildings and space applications
- energy-efficient appliances
- more efficient automotive air conditioning
- heat exchanger component technologies
- thermophysical aspects of hydrogen storage
- intelligent machine learning for fuel cell operation

ORNL researchers Fang Chen (standing) and Vince Mei are the developers of the liquid overfeeding technology.

The staff members are expert in heat pump technologies, thermodynamic cycle modeling and stimulation, fuel cell analysis, stationary and mobile air conditioning, hydrogen storage, thermal management, and testing and experimentation. A highlight of their work is the patented liquid overfeeding technology (see accompanying article) that has been tested and demonstrated on several types of cooling equipment.

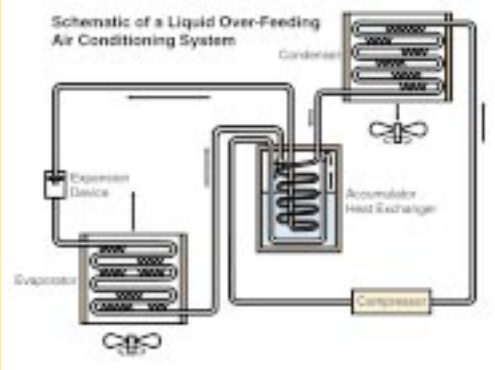
The program's achievements include five patents on instruments, heat exchange components, and heat pumps; an R&D 100 award for development of the ratiometer, an instrument for detecting coolant leaks; and an International Hall of Fame Advanced Technology Award for the liquid overfeeding air-conditioning system.

By: Fang Chen, 423-574-0712, chenfc@ornl.gov
Sponsor: Research is partially sponsored by the Office of Energy Efficiency and Renewable Energy

Overfeeding Saves Energy in Small Systems

Liquid overfeeding (LOF) is based on a simple concept: feed more refrigerant through a system to increase cooling capacity. The drawback is that overfeeding can allow liquid coolant to enter the compressor and damage it. Consequently, only large, complex industrial systems could use LOF. However, ORNL researchers have invented an LOF system simple enough for residential and other small cooling units.

The new technology has attracted interest from a number of government and industrial partners. It has been tested successfully in several types of cooling equipment, including heat pumps; residential, automobile, electric bus, and mobile military air conditioners; and vending machines.



Simplified schematic of an LOF system.

In a cooling system, the evaporator boils liquid coolant and sends the vapor to the compressor. Conventional systems have extra evaporator capacity to ensure that all the coolant vaporizes. The excess capacity protects the compressor but reduces evaporator efficiency. ORNL's LOF system adds an accumulator/heat exchanger between the evaporator and the compressor. Refrigerant vapor and any unevaporated liquid go from the evaporator into the accumulator. Vapor passes from there directly into the compressor, while the heavier liquid is trapped and evaporated using heat from the condenser. The resulting vapor then passes into the compressor, increasing the flow of coolant to the compressor and increasing the cooling capacity.

The LOF arrangement increases evaporator and compressor efficiency. Less power is needed because of the increased efficiency and because LOF units cycle on and off less often.

Tests show heat pumps and air conditioners that use LOF are 10 to 15% more efficient, and automobile air conditioners using LOF are 20% more efficient. The technology has also been tested successfully in soft drink vending machines through a CRADA with Cavalier.

By: Fang Chen, 423-574-0712, chenfc@ornl.gov
Sponsor: Office of Building Equipment

DOE and Chemicals Industry Collaborate on Aggressive Research Agenda

The U.S. chemicals industry, one of the Industries of the Future, is working with DOE's Office of Industrial Technologies (OIT) to support development of a relevant scientific research program. Several ORNL projects have resulted from that collaboration:

Plastic, fibers, and solvents from bioderived organic acids (succinic acid). A five-partner CRADA (NREL, ORNL, ANL, PNNL, and Applied Carbochemicals) resulted in a successful process to produce succinic acid as a platform chemical (see accompanying article for details).

Succinic acid from lignocellulosic hydrolyzates. ORNL and ANL are investigating fermentation and microbial modifications to use mixed sugars (glucose and xylose) from biomass hydrolyzates instead of corn glucose. The current patented strain consumes both glucose and xylose to produce succinic acid, but it needs to be made more efficient.

Biocatalysis under extreme conditions. Enzymes can be modified or used in nonaqueous media to carry out chemical transformations. A collaboration among ORNL, Massachusetts Institute of Technology, Rensselaer Polytechnic University, and UC-Berkeley seeks to extend the use of nonaqueous enzymes to oxidative enzymes for epoxidation or polyphenol polymerization.

Computational fluid dynamics for multiphase flow. This six-partner project will develop and validate a scalable parallel version of the MFIX code to enable it to predict fluid behavior during dense phase bubbling and spouting fluidization of fine cohesive particles. ORNL staff are characterizing temporal and spatial patterns and translating the MFIX code into FORTRAN 90.

A more comprehensive DOE research program, involving some $12 million in funding, is planned in FY 2000. The areas of work are expected to include catalysis, computational fluid dynamics, separations, and structural materials, among other topics.

By: Tom Schmidt, 423-574-4977, schmidttw@ornl.gov
Sponsor: Office of Industrial Process Systems

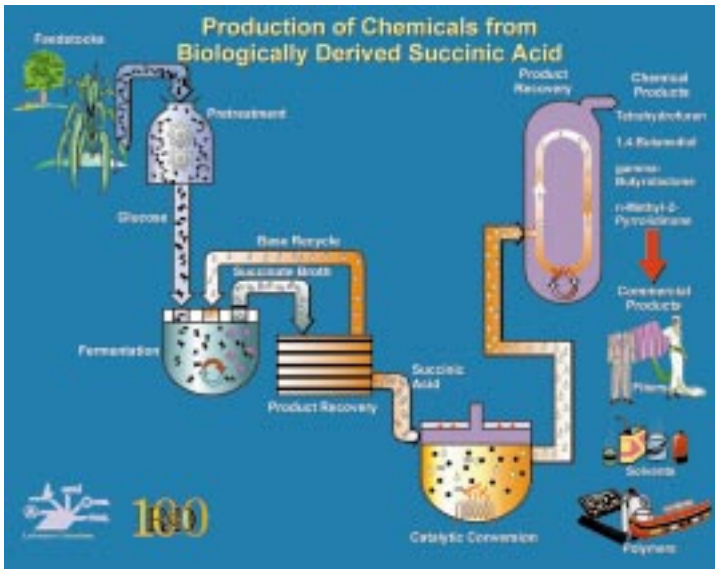
Brewing Corn into Feedstocks

Fermenting corn is a time-honored tradition in the Tennessee hills. So it seems particularly appropriate that ORNL researchers have helped develop a process to ferment corn into a chemical feedstock to make dozens of industrial and consumer products.

The process, developed by ORNL and three other national laboratories, employs a new microorganism to ferment the glucose sugar in corn efficiently into succinic acid. The succinic acid can then be converted into chemical feedstocks used to manufacture plastics, fabrics, paints, inks, food additives, and other products. The bioprocessing method is much less expensive than conventional petroleum-based methods of producing succinic acid and is competitive with current petrochemical commodities such as butanediol. In addition, it eliminates gypsum, a by-product of conventional fermentation methods that must be landfilled.

ORNL was the technical leader of the project. ORNL researchers developed the fermentation process using a novel microorganism, developed by ANL, that converts corn-derived glucose to succinic acid at very high yields. ORNL also scaled the process from bench to 500 L. The dilute broth was concentrated and purified into pure succinic acid at ANL. NREL performed economic analysis, and PNNL researchers focused on catalysis of succinic acid to commodity chemicals, including tests with the actual purified succinic acid.

The bioprocess has been licensed to Applied Carbochemicals of Pennsylvania. The company plans to break ground for a manufacturing plant in 2001 and has developed several new markets for succinate derivatives. Existing



domestic markets for such chemicals total almost 1 billion pounds—and more than $1.3 billion—a year. The project team received a 1997 R&D100 award.

The new process promises to reduce reliance on imported oil and expand markets for domestic agriculture. It is estimated that if chemical feedstocks normally produced from petroleum were instead generated using a single combined biological and chemical plant, the oil saved would be enough to heat 80,000 single-family homes for a year.

By: Brian Davison, 423-576-8522, davisonbh@ornl.gov
Sponsor: Office of Industrial Process Systems

Bioprocessing Research Facility: Infrastructure for Biotechnology Research

The Bioprocessing Research Facility (BRF) at ORNL provides laboratory facilities for investigating advanced bioprocessing concepts and a fermentation pilot plant for large-scale batch and columnar experiments. Other research and support laboratories are available on site. Outside users have included industries (see accompanying article) and universities.

Research Opportunities

The BRF is equipped with stirred-tank and advanced columnar bioreactors ranging in size from bench scale to 500 L. Several instrumented stirred-tank fermentors, 50 to 500 L, can be used for large-scale demonstrations, process scale-up studies, or production of kilogram quantities of microorganisms or biochemicals under controlled conditions. Either aerobic or anaerobic operation is possible. The large fermentors are approved for use with nonhazardous recombinant microbes.

Controls have been upgraded on the 500-L New Brunswick Fermentor, the centerpiece of the user facility. It was used recently to scale up the production of succinic acid (see related article on p. 4) and to produce TNT-detecting microorganisms for ORNL's Environmental Sciences Division for field testing.

BRF director Brian Davison with the New Brunswick fermentor.

The columnar bioreactors range from 2.5 to 40.6 cm in diameter and vary in height from ~30 cm to ~10 m. Equipment for producing small, uniform, immobilized biocatalysts was used to demonstrate the scale-up of an immobilized-cell fluidized bed for ethanol production. Large equipment available for product separation and recovery includes continuous centrifuges, homogenizers, and a crossflow filtration unit.

Facility users have access to a variety of analytical equipment: gas, ion, and high-pressure liquid chromatographs; spectrophotometers; and carbon and nitrogen analyzers. A cold room, environmentally controlled growth chambers, anaerobic hoods, autoclaves, sterile culture-transfer areas, refrigerators and freezers, freeze-dryers, microscopes, a hammer mill, and other laboratory equipment are available, as are computer facilities. Containment facilities for recombinant DNA studies can be used for developing advanced analytical techniques and for conceptual investigations of advanced bioreactors.

R&D activities include, among others, feedstock pretreatment and fractionation, microbial culture selection and improvement, genetic manipulation, microbial and enzyme immobilization, advanced bioreactor concepts, biotreatment of wastes, process feasibility and scaleup, advanced analytical concepts, bioprocessing monitoring and control, and biochemical separations.

By: Brian Davison, 423-576-8522, davisonbh@ornl.gov
Sponsor: Office of Industrial Technologies and Office of Fossil Energy
url: www.ornl.gov/divisions/ctd/Chem_Dev/Biochemical/userfacility.htm

BRF Helps Small Biotech Firm Meet Marketplace Challenges

Collaboration with the BRF has helped Oxyrase, a small biotechnology company near Oak Ridge, Tennessee, meet the challenges of biotechnology commercialization. Oxyrase produces a biological product, also called Oxyrase, to remove oxygen from liquids; it is used for convenient growth and culturing of anaerobic microbes for medical and research uses.

Oxyrase was founded by a former ORNL researcher, based on a discovery he made while working at the Laboratory. The company needed to increase its fermentation yields, particularly as it entered larger markets, so it began collaborating with the BRF in late 1993. The initial yields from the effort were about 2 kg of cell material from each 500-L fermentation batch.

The Oxyrase R&D staff improved yields by manipulating the media ingredients. These improvements and other suggestions from ORNL consultants resulted in stepwise improvements in yield from 2 to 8 kg, to 14 kg, and finally to a record of nearly 22 kg. Manipulation of another fermentation process parameter increased the enzymatic activity per cell: cells grown currently contain nearly three times as much enzyme as cells grown in the early stages. Further improvements are considered possible.

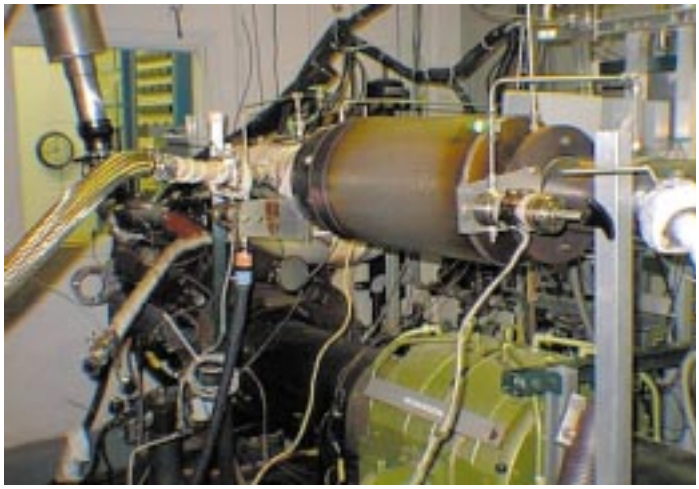
Overall, the company now harvests nearly 25 times as much material for about the same amount of effort as in the early years, and the material is of higher quality. The improvement in yields resulting from the collaboration has allowed the small biotechnology company to survive and grow during its early years.

By: Brian Davison, 423-576-8522, davisonbh@ornl.gov

ORNL Contributes to Ambitious Goals for Heavy Vehicles

The DOE Office of Heavy Vehicle Technologies (OHVT) sponsors research into fuel-flexible, energy-efficient, near-zero-emissions diesel engines and systems technology for all classes of trucks. Its primary goals are

- By 2002, develop technology supporting large-scale dieselization of light trucks, improving fuel efficiency by 35% over equivalent gasoline trucks and reducing emissions.
- By 2004, develop the enabling technology for a class 7-8 truck with a fuel economy of 10 mpg (at 65 mph) that meets prevailing emissions standards, using either diesel or a liquid alternative fuel.
- By 2005, develop advanced powertrain technology for medium/heavy-duty trucks with triple the current fuel economy (up to 30 mpg) and reduce criteria pollutant emissions to 30% below proposed regulated levels.
- By 2006, develop flexible-fuel diesel engines with a thermal efficiency of 55% with liquid alternative fuels and dedicated gaseous fuels.



A diesel particulate filter undergoes evaluation in ORNL's Advanced Propulsion Technology Center.

ORNL performs research in several technologies critical to meeting these goals. We are working on diesel emissions control technologies, including NO_x catalysts and particulate filters. We also are developing a technical roadmap for reducing rolling resistance, key to developing the 10-mpg heavy truck. ORNL supports the Heavy Vehicle Alternative Fuels R&D Program with research on enabling technologies for natural gas engines and on the performance and emissions characteristics of advanced compression ignition fuels. Innovative measurement methods are being applied to characterize particulate emissions from various fuel formulations, for example, including the effects of fuel sulfur content.

ORNL also leads an effort to develop materials for advanced truck engines. Materials requirements for high-efficiency, low-emission engines have been identified and R&D efforts initiated with industry partners. Other work focuses on materials and processing technologies to introduce lightweight materials in trucks. Needs have also been defined for materials for critical applications such as brakes and cooling systems. Ongoing projects address casting of ultra-large aluminum components and optimization of the metal compression forming process for cost-efficient production of high-quality, sound cast aluminum components. The High Temperature Materials Laboratory enables industry and university researchers to collaborate with ORNL researchers on energy-related materials problems.

By: Ron Bradley, 423-574-6095, bradleyra@ornl.gov
Sponsor: Office of Heavy Vehicle Technologies

Heavy Hybrid Engines Could Lighten up Emissions in Urban Areas

The Office of Transportation Technology (OTT) plans to work with automakers to develop affordable "heavy hybrid" engines that can improve the fuel economy and reduce the emissions of trucks and buses driving in urban areas.

Most trucks and buses are powered by gasoline or diesel engines. Under urban driving conditions—frequent stops, starts, and long periods of idling—these engines yield poor fuel economy and high levels of emissions. Hybrid electric propulsion systems are more efficient and cleaner. But although prototype hybrid systems have been built and installed in test vehicles, they have not been commercialized, mainly because they are more expensive than conventional engines.

A hybrid propulsion system includes an engine, an electric motor, an energy storage system, and power electronics to handle different forms of electrical energy. (Batteries are normally used for storage, but flywheels and ultracapacitors are also possibilities.) In a typical system, the engine or electric motor, or both at once, can propel the vehicle. The engine can be smaller and be optimized for sustained cruising, resulting in increased efficiency and reduced emissions. When additional power is needed, the motor supplements the engine. Hybrid vehicles can operate for short ranges as zero emissions vehicles by using only the electric motor.

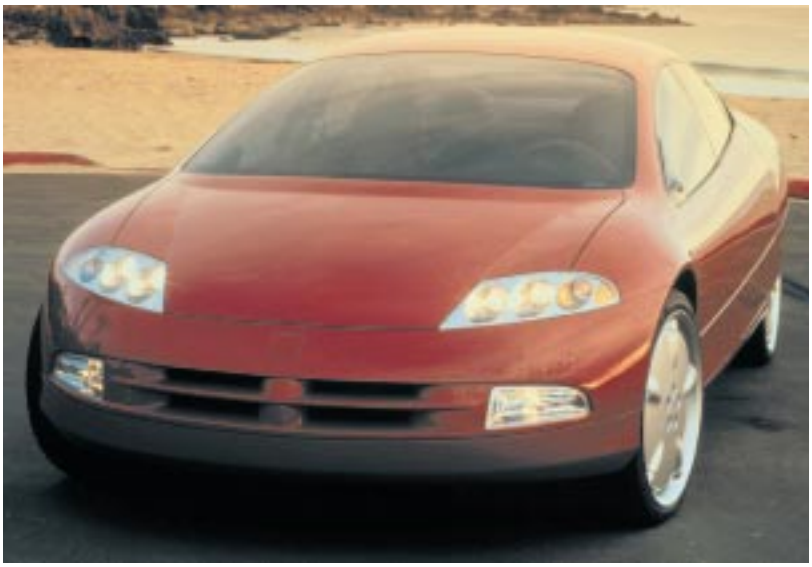
OTT will begin a new program in FY 2000 to support the development and commercialization of hybrid electric engines for heavy vehicles. It will involve contracts with two to four industry teams, and the emphasis will be on commercializing hybrid systems for urban trucks and buses.

By: Dave O'Kain, 423-576-0268, okaindu@ornl.gov
Sponsor: Office of Heavy Vehicle Technologies

Supercar: Materials Infrastructure Challenges

A joint ORNL–University of Tennessee (UT) study conducted for Partnership for a New Generation of Vehicles (PNGV) finds that materials-related barriers are unlikely to impede the use of lightweight materials in vehicles. Use of lightweight materials is expected to bring environmental gains overall, although their production may have some adverse impacts.

ORNL and UT are assessing the constraints associated with the increasing production and use of eight lightweight materials—aluminum, titanium, Lexan, lithium, glass fiber, carbon fiber, composites, and magnesium—in advanced vehicles called 3XVs. Two prospective 3XVs are the focus of the research: the aluminum-intensive Ford P2000 and the plastic-body Chrysler ESX2. Designed to be three times more fuel-efficient than conventional autos, both will use diesel fuel.



The plastic-body Chrysler ESX2 is one of two prospective advanced lightweight vehicles. It and the aluminum-intensive Ford P2000 are designed to be three times more fuel-efficient than conventional autos.

The project considers natural resource, capital investment, cost, and manufacturing process constraints associated with manufacturing the vehicles. Energy requirements, environmental burdens, repair, use, market acceptability, and the economic viability of recycling 3XVs also are being considered.

Raw material, financial, or process barriers to production and use of the lightweight materials appear minimal. Lifetime energy consumption and emissions of greenhouse gases and carbon monoxide promise to be much lower than for conventional autos. The PNGV goal of recycling 80% of the 3XVs will require new technologies and infrastructure.

The study notes some concerns, for example, the environmental impacts of producing some of the materials and the higher NO_x and particulate emissions of conventional diesel engines. Repair and insurance costs for 3XVs may be higher, at least initially. Market acceptability of the vehicles is expected to hinge upon consumer reaction to the combination of sticker price, reliability, comfort and convenience, and operation and maintenance costs.

By: Sujit Das, 423-574-5182, dass@ornl.gov
Sponsor: Office of Advanced Automotive Technologies
url: www-cta.ornl.gov/Research/tm/index.html

Patent Awarded for New Bipolar Plate for Fuel Cells

ORNL researchers have developed a carbon composite bipolar plate for fuel cells that meets PNGV goals for cost, weight, and thickness reduction. A patent was recently awarded for the plate, which is designed for use in proton exchange membrane fuel cells.

Bipolar plates serve as the positive and negative electrodes of a fuel cell. Standard plates of machined graphite are too costly and relatively thick and heavy. Therefore, PNGV's PEM Fuel Cell Program supports efforts to develop materials that are sufficiently conductive, strong, hermetic, and corrosion resistant, as well as lighter, thinner, and cheaper.

The ORNL process yields a plate less than 2 mm in thickness, hermetically sealed to resist hydrogen leakage. Its electric conductivity is greater than 200 siemens/cm, the program goal. Cost estimates from suppliers indicate that the plates can be produced for less than $2 each, another program goal.

The bipolar plate (right) showing gas channels

The plate is formed by slurry molding of carbon fibers. The plate surface is sealed using a chemical vapor infiltration process that deposits carbon on surface fibers to seal the surface. The infiltrated carbon provides an impermeable surface with high electrical conductivity that also extends through the thickness of the component.

Specimens have been provided to Los Alamos National Laboratory and to potential industrial partner AlliedSignal for testing. Work continues to improve the plate's power production rate and explore lower-cost materials and processes.

By: Theodore Besmann, 423-574-6852, besmanntm@ornl.gov
Sponsor: Office of Advanced Automotive Technologies

Nifty Carbon Foam Soaks up Heat

A new material discovered "accidentally" by an ORNL researcher may dramatically improve heat exchanger technology and enable miniaturization breakthroughs in products from laptop computers to automobiles.

The revolutionary substance, called "carbon foam," first appeared as a peculiar substance adhered to a composite disk treated in a pitch bath. It piqued the curiousity of ORNL researcher James Klett, who experimented with it and discovered its amazing ability to transfer heat.

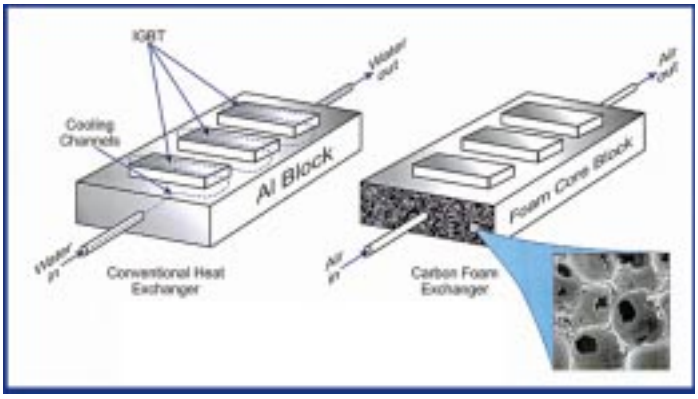
The graphite-based foam has a highly porous structure that gives it a large surface area, allowing rapid heat transfer, and low density, so that it weighs very little. Because of its low density, it conducts heat nearly six times as well as copper and five times as well as aluminum. And despite its low density, it is strong and rigid and can withstand temperatures as high as 3000°C.

James Klett holds a heat exchanger and heat sink for power electronics formed from carbon foam. They can be much smaller and lighter than conventional aluminum heat transfer devices.

Several auto makers are interested in the possibilities the new material presents. Its pores can be filled with resin to produce a material potentially strong enough to build automobile engine parts. They would weigh half as much as aluminum parts and, because of the foam's low thermal expansion, could be machined to higher tolerances. Klett is experimenting with a radiator design using the foam; it could be much lighter and smaller than aluminum fin radiators, allowing more aerodynamic automobile designs. He even believes the foam might eventually be used to make air-cooled engines.

Its potential uses to manage heat generated in electronic equipment are equally intriguing. The material may be the basis for much lighter, smaller heat exchangers and heat sinks for cooling equipment, computers, and power electronics. Laptop computers currently cannot use the highest-power processors because they cannot handle the heat generated; carbon foam heat sinks could change that.

In addition, like carbon fibers, the new material can be used to reinforce composites and improve their heat transfer capability. Since it is cheaper than high-conductivity carbon fibers, it would help lower the cost of composites and increase their competitiveness.



150 W/m·K----------thermal conductivity----------150 W/m·K
2.7 gm/cm³----------density----------0.5 g/cm³
~1000 W/m²·K---------heat transfer coefficient------100,000 W/m²·K
Yes----------water pump----------No
Yes----------water----------No
No----------air compressor----------Yes

PNGV is providing funds to investigate possible uses of the material in automotive applications, and dozens of companies have expressed interest in it. If it lives up to its early promise, carbon foam may become ubiquitous in applications where excess heat must be disposed of.

By: James Klett, 423-574-5220, klettjw@ornl.gov
Sponsor: Office of Advanced Automotive Technologies
Initial research sponsored by the ORNL LDRD Program
url: www.ms.ornl.gov/OTT/ee09.htm

Anthony Schaffhauser, Director
Marilyn Brown, Deputy Director
Kathi Vaughan, Business Analyst

Energy Efficiency and Renewable Energy Program
Oak Ridge National Laboratory
Mail Stop 6186, Post Office Box 2008
Oak Ridge, Tennessee 37831-6186

Telephone: 423-241-4292
Facsimile: 423-576-7572
e-mail: vhk@ornl.gov

ornl

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ORNL is Working on Lighter, Safer, Cheaper CNG Storage Tanks

Compressed natural gas (CNG) has the potential to become a popular alternative transportation fuel. For that to happen, however, a suitable onboard high-pressure CNG storage tank must be available. ORNL is aiding the effort to develop carbon fiber CNG tanks that are safe, lightweight, and cost-effective.

CNG storage tanks commonly used in weight-sensitive applications have either a metal or a plastic liner overwrapped with a carbon fiber composite material. The composite wrapping is designed to bear the pressure load, and the lining

Composite CNG tanks mounted inside an automobile trunk *(Photo courtesy of Lincoln Composites)*.

prevents leakage of the gas. Composite tanks are desirable for their light weight and resistance to corrosion and fatigue. However, carbon fibers are expensive and do not resist impact damage well. So ORNL engineers are evaluating technologies to reduce the costs and increase the durability of fiber-reinforced composites.

A cost analysis of a typical composite-wrapped plastic liner found 40% of the cost of the tank is for the carbon fiber raw material. In a project sponsored by the Gas Research Institute, ORNL—along with Battelle, Lincoln Composites, and Powertech Labs—is testing low-cost carbon fibers to determine whether they are sufficiently durable for use in such a tank.

ORNL also recently completed a project demonstrating nondestructive evaluation techniques that could warn a vehicle operator if hazardous conditions are developing as a result of impact damage (see the accompanying article). Solutions to these cost and safety issues will help the United States move toward cleaner transportation and energy independence.

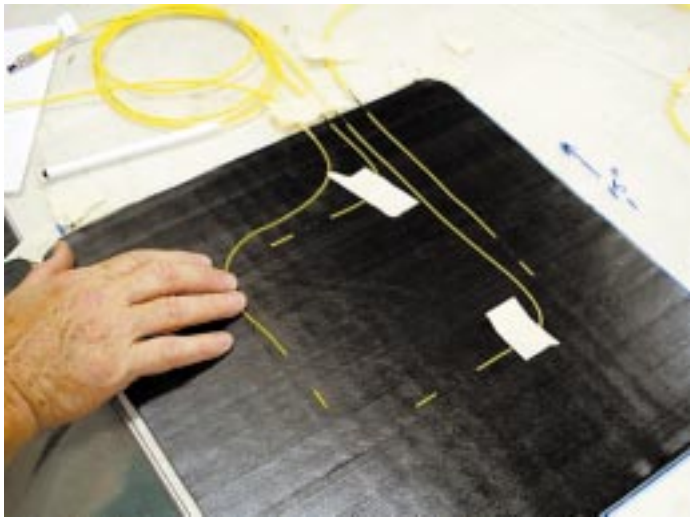
By: J. Michael Starbuck, 423-576-3633, starbuckjm@ornl.gov
Sponsor: Office of Advanced Automotive Technologies

"Smart" Onboard Inspection of CNG Fuel Tanks

Tests conducted by ORNL's Composite Materials Technology Group demonstrate the feasibility of nondestructive evaluation (NDE) to detect impact damage in high-pressure composite cylinders. If NDE can be used to warn vehicle operators of potentially hazardous impact damage to composite CNG storage tanks, widespread use of CNG as a transportation fuel will be more feasible.

Two NDE methods, fiber optic sensors and modal analysis, were demonstrated by laboratory experiments consisting of impact tests on a composite plate and pressurization tests on a composite cylinder designed for CNG storage.

The key findings are that embedded Fabry-Perot optical fiber strain gages can be used to monitor strain continuously during operation. Embedded fibers, along with a low-cost light input and detection circuit, can be used during pressurization to monitor the life history of a composite cylinder; and the modal analysis damping measurement can discriminate between damaged and undamaged composite vessels for some damage levels.



Fabrication of embedded fiber optic sensors in a composite plate.

CNG cylinders are manufactured according to strict safety standards. Rigorous design qualification tests include pressure cycling, environmental exposure, hydrostatic burst, bonfire, drop, penetration, permeation, and accelerated stress rupture. Inspection guidance calls for periodic detailed visual inspection by trained inspectors every 3 years, and periodic general visual inspection by drivers and mechanics. Existing standards do not identify NDE techniques as approved inspection methods, but the ORNL researchers are hopeful their work eventually will lead to approval of NDE inspection.

By: J. Michael Starbuck, 423-576-3633, starbuckjm@ornl.gov
Sponsor: Office of Advanced Automotive Technologies

Supporting Inventions and Innovations in the Southeast

ORNL has been designated the Southeastern Resource Center for Innovation (RCI) by DOE's Office of Industrial Technology (OIT). It will aid DOE's entrepreneurial customers in Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, South Carolina, Tennessee, Virginia, and West Virginia. Every state has access to the services of one of the five RCIs nationwide.

The RCIs are a part of OIT's new Inventions and Innovations (I&I) Program that promotes non-R&D efforts to aid the commercialization of energy-efficient technology–specifically ventures that have received OIT grants. I&I consolidates the Energy-Related Inventions Program (ERIP) and the Innovative Concepts Program, along with added activities. These programs have achieved significant success in bringing energy-related inventions to the market; with their merger, OIT hopes to multiply these successes.

One reason many new technologies have delayed or limited commercial impact is lack of private investment and market support. I&I will address those barriers by helping inventors find capital, access appropriate networks, and mature products to meet market requirements.

I&I provides financial assistance at two levels–up to $40,000 or up to $100,000, depending on the stage of development–to establish technical performance and develop ideas and inventions. Grantees are selected by competitive solicitations based on energy savings and commercial market potential. Details, including solicitations, are available from the I&I web page at www.oit.doe.gov.

As the Southeastern RCI, ORNL has the tasks of

- helping inventors find necessary services, including investment
- increasing awareness of I&I opportunities through Industries of the Future teams
- providing links between inventors and local resources
- increasing inventors' awareness of OIT programs

The principal strategic goals for ORNL's RCI are to

- develop substantial relationships and networks with leading venture capitalists in the South
- establish a network of "angel" investors
- establish referral networks for professional services in each of the Southern states
- conduct a continuous awareness campaign through regional forums, Industries of the Future teams, and contacts at appropriate state departments or programs.

While these activities can benefit all aspiring entrepreneurs, the emphasis will be on energy-efficient products and processes.

By: Dave Jamison, 423-576-9679, jamisondf@ornl.gov
Sponsor: Office of Technology Access

Documenting the Commercial Progress of Inventions

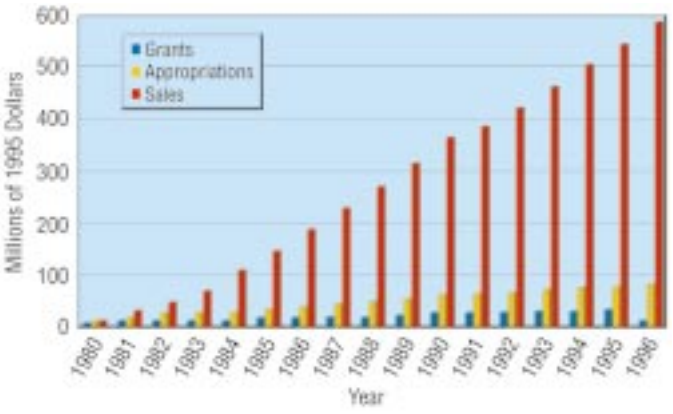
The Energy-Related Inventions Program (ERIP) was established in 1974 to aid development of non-nuclear energy-related inventions with outstanding potential for saving or producing energy. Since then, more than 32,000 inventions have been evaluated for technical merit by the National Institute of Standards and Technology, and about 740 have received commercialization and financial assistance from DOE. About 75% of these have been supported by DOE grants.

Since ERIP began, DOE and ORNL have monitored and documented the commercial progress of these technologies. Of the inventions receiving a grant, 25% have had commercial sales—a rate generally higher than for technological innovations as a whole. Total cumulative direct and licensed sales through 1996 exceed $700 million (1995 $); cumulative sales of spinoff technologies have reached $90 million.

The program has generated a 20:1 return of sales over grants (see figure) and an 8:1 return in sales over program expenditures. In 1996, ERIP inventions supported nearly 1200 full-time equivalent jobs, generating more than $6 million in federal income taxes annually (more than ERIP's annual appropriation). Energy savings attributable to ERIP inventions are estimated at 80 trillion Btu, for a savings of $190 million (1995 $). The reduction in carbon emissions associated with these inventions exceeded 1.6 million metric tons in 1996.

In 1998, the inventions program was reorganized to align ERIP more closely with Industries of the Future and to capitalize on synergies with Office of Industrial Technologies programs. The Inventions and Innovations Program will offer inventors greater access to commercial assistance through five Regional Centers for Innovation.

By: Bob Perlack, 423-574-5186, perlackrd@ornl.gov
Sponsor: Office of Technology Access



Grants, appropriations, and sales associated with ERIP.

Guiding the Electricity Industry through Restructuring

ORNL's Electric Policy Studies Group has a key role in helping the U.S. electric power industry prepare for restructuring. It conducts research and provides technical assistance for efforts to anticipate and address the impacts of restructuring on system reliability, consumer prices, and industry finances.

Research activities emphasize (1) changes in the way electric utilities are regulated, (2) unbundling of electricity costs, with emphasis on ancillary services, and (3) estimation of the costs of going from a regulated to a competition-based industry.

As part of the Interconnected Operations Services Implementation Task Force sponsored by the North American Electric Reliability Council, the ORNL group is helping determine the cost and value of ancillary services such as spinning and supplemental reserves and system blackstart capability. Spinning reserves (available within seconds) and supplemental reserves (on line in about 10 minutes) provide backup power if a plant is shut down accidentally or demand changes unexpectedly. Blackstarting is restarting after a total shutdown; power plants that need electricity to restart must be able to get it from plants that can restart without electricity.

In the past, costs for these services were bundled with all utility charges, so their individual costs are uncertain. The ORNL group is collecting and analyzing utility data to break down costs.

Other issues are also being researched. The Oak Ridge Competitive Electricity Dispatch (ORCED) model is being expanded to analyze a greater variety of air pollutants emitted by fossil fuel–fired power plants and analyze the market power effects of concentrating power plant ownership. The modeling aids in assessing the impact of energy efficiency and renewable energy sources, data that will help the Environmental Protection Agency and the states develop state implementation plans for reducing emissions.

By: Stanton W. Hadley, 423-574-8018, hadleysw@ornl.gov
Sponsor: Office of Power Technologies

Keeping the Lights on While the Industry Restructures

Restructuring of the U.S. electricity industry poses potential problems for system reliability. Researchers in ORNL's Electric Policy Studies Group are serving as primary staff to a Task Force on Electric System Reliability created by the Secretary of Energy to address the concerns. They drafted the initial versions of the final task force report released in September.

The report recommends action soon to ensure the reliability of the bulk power system: "The Task Force believes that the primary challenges to bulk-power system reliability are presented by the transition itself, rather than by the end state of competition. Failure to act will leave substantial parts of North America at unacceptable risk."

System reliability during the transition period should not be taken for granted, the task force cautions. Agencies working to ensure reliability must be independent of commercial interests so that their plans are "unbiased and untainted by the economic interests of any set of bulk-power market participants."

The report recommends Congress assign oversight of bulk-power reliability, including authority to coordinate with regulatory agencies in Canada and Mexico, to the Federal Energy Regulatory Commission (FERC). Given the tight link between commercial and reliability interests, the report urges FERC to use its existing authority to regulate on reliability matters that intersect with commercial markets to ensure nondiscriminatory access to reliable transmission services until Congress takes action.

By: Eric Hirst, 423-574-6304, hirstea@ornl.gov

The primary challenges to system reliability are presented by the transition itself . . . . Failure to act will leave substantial parts of North America at unacceptable risk.

News Briefs

Patrick Hughes: Outstanding Engineer

Patrick Hughes of ORNL's Buildings Technology Center received the 1998 Outstanding Engineering Achievement Award of the International Ground Source Heat Pump Association. Hughes used data from field tests of geothermal heat pump systems to calibrate Transient System Simulation Program models and develop rules for sizing residential ground heat exchangers in the northern United States.

Lee is Honored at the White House

James Weifu Lee of the Biotechnology Research Group has been selected for a Presidential Early Career Award for Scientists and Engineers. He was honored in a ceremony at the White House on February 10. Lee joined the Biotechnology Research Group as a post-doctoral research associate in 1992 and joined the ORNL staff in 1994. His research has supported the Hydrogen Research Program.

AIM Staff Hit the Mark

The American Welding Society awarded the A. F. Davis Silver Medal Award to a paper by staff from the Advanced Industrial Materials project on kraft recovery boilers. "Numerical Analysis of Residual Stress Distribution in Tubes with Spiral Weld Cladding,"—authored by B. Taljat, T. Zacharia, X. L. Wang, J. R. Keiser, R. W. Swindeman, all of ORNL; Z. Feng of the Edison Welding Institute; and M. J. Jirinec of Welding Services—appeared in the August 1998 *Welding Journal*.

ORNL staff also received two Industrial Recognition Awards from DOE's Office of Industrial Technologies at the OIT Expo in February. Vinod Sikka was rewarded for alloy development and Jim Keiser (along with Peter Gorog of Weyerhauser) for work on the composite boiler tube project.

HTS Cable Exceeds Design Goal

Tests conducted at ORNL show the first high-temperature superconducting (HTS) power cable in the United States, developed by Southwire, surpasses design criteria. The single-phase, 5-m HTS cable carried 1400 A, 12% above design. The cable was also tested at the design voltage of 7200 V ac. In the next phase of the project, Southwire will demonstrate HTS power distribution by testing a three-phase power system, each cable being 30 m long in an industrial setting.

Continued from page 1

- Chiller upgrades: 12 large CFC chillers replaced with high-efficiency non-CFC units, 3 more being replaced, 1 to be replaced, and 5 to be retired. Energy use dropped an average 21% for annual savings of $280,000, and CFC emissions were cut by 5000 lb per year, saving another $76,000 annually.
- Energy management control systems installed in 13 buildings.

In addition, the ORNL steam plant is to be converted from coal to natural gas. The change is expected to save some $1 million per year in operating costs and $8 million in capital funding over 10 years, as well as avoid emissions from coal combustion.

By: C. Wayne Parker, 423-574-8578, parkercw@ornl.gov
Sponsor: In-house Energy Management Program

Coming in Next Issue:

- Stronger than Dirt: New laundry technology in Bern, KS
- MPLUS: Metals Processing Lab offers access to unique facilities and knowledge
- Making the Wheels Go Round: New materials for vehicle propulsion systems
- International programs: EE/RE goes global

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