Science & Technology HIGHLIGHTS

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ORNL Reaches Out to State Energy Agencies

ORNL's EE/RE research has always involved partnering with outside organizations, but collaborations tended toward industrial and university partners. Recognizing the value of working with state energy agencies, ORNL began in the early 1990s to establish stronger relations with state energy offices (SEOs) and the Association of State Energy Research and Technology Transfer Institutions (ASERTTI).

In a 1993 meeting, states offered to help DOE deliver technology to the marketplace and indicated that the national laboratories could help them solve technology-related problems. In 1994, the National Renewable Energy Laboratory responded with a new program to establish federal-state collaborations. In 1996 ORNL began the State Partnerships Program (SPP), incorporating lessons learned from our sister laboratory.

Core funding for SPP is provided by ORNL's EE/RE Program to pay for ORNL staff expertise and assistance. Partners contribute through either direct funding or in-kind resources. SPP has funded 38 projects and technical-assistance activities in 18 states. Partners include SEOs, ASERTTI members, utilities, universities, industrial firms, trade associations, and DOE regional support offices. All four sectors covered by ORNL's EE/RE Program—buildings, transportation, industry, and utility—are represented in the project mix.

How can your organization participate? Twice yearly, calls for proposals are issued to ORNL staff, SEOs, and ASERTTI members. (Requests for 2- to 4-day technical assistance efforts are welcome any time!) Proposals must be developed in collaboration with ORNL researchers and must address issues integral to the EE/RE missions of DOE and ORNL. See www.ornl.gov/ORNL/Energy_Eff/sppwhole.html for more information.

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SPP Projects Cross All Energy Efficiency/Renewable Energy Sectors

SPP projects and technical assistance activities range from development of tools and technologies for immediate use, to feasibility studies of exciting, new ideas. The following are synopses of just a few of the SPP projects:

- Geothermal heat pumps almost always provide energy savings and reductions in peak load demand. A videotape of two different direct-expansion geothermal heat pump installations is being prepared. Builders and utility companies in East Tennessee and Virginia will be able to use this video for training purposes.
- Automobile manufacturers may soon have a simple answer to a big problem in making lightweight vehicles. The SPP participated in a feasibility study of a new way of processing polyacrylonitrile fibers into carbon fibers. The study showed that the method works in a batch process and could produce less expensive fibers than the conventional process.
- How smoothly the electrical power and steam delivery systems interact in industrial process plants can affect energy efficiency, resource utilization, and system downtime. A new measurement-based model using intelligent system techniques will focus on the delivery systems in Maine pulp and paper mills. The new method will rely on fuzzy logic and neural networks instead of detailed engineering models and, if successful, will enable real-time process optimization and control.
- Assistance is being provided to Arkansas and North Carolina in developing strategies for promoting renewable energy in electric utility restructuring legislation.

Rebuild America Spearheads Deployment of Energy Technologies

Rebuild America is a program designed to accelerate the adoption of energy-efficient techniques and practices, as opposed to developing technologies and shepherding them into the market. ORNL's Buildings Technology Center (BTC) is actively involved in Rebuild America's efforts to bring local governments, institutions, and businesses into community partnerships to improve local buildings, thus reducing energy consumption and pollution.

The prospect of keeping money in the local economy, promoting job growth, and meeting community goals captures the imagination of communities that need to improve their building stock and stimulate economic growth. The 3-year-old program has about 200 partnerships and more than 500 million square feet of space committed for renovation.

ORNL staff share expertise in buildings and energy efficiency and provide guidance to communities as partnerships are formed, plans are laid, and renovation projects are carried out. BTC staff spearhead Rebuild America's efforts to improve financial services to partners in 1999. Through written guides, workshops, analytical tools, and customized technical assistance, the program helps partnerships choose the best ways to finance projects. It also works to strengthen market support for energy investments and to improve access to capital by working with providers of financial services, professional organizations, government agencies, and utilities.

Rebuild America will have a special focus on K–12 schools in 1999. The goal is to have 100 new community partnerships implementing action plans, with a minimum of 50 of those including K–12 schools. K–12 schools are a prime target for the program because of the critical need to repair and upgrade deteriorating school buildings, control energy costs, and ensure that school environments are safe, comfortable, and healthy.

See Rebuild America's web site for more information: http://www.eren.doe.gov/buildings/rebuild.

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A Habitat volunteer caulks around a window to reduce air leakage.

ORNL Supports Habitat for Humanity in Energy-Efficient Building

Energy efficiency is becoming the standard in homes built by Habitat for Humanity, with help from ORNL and DOE. Twenty homes built in Sumter County, Georgia, by Habitat volunteers during a five-day "blitz build" in April are twice as air-tight as the typical Habitat house and exceed efficiency standards set by the 1995 Model Energy Code.

Habitat Green Teams found that once volunteers were instructed in tasks and techniques for building energy-efficient homes, they were willing and able to do the job. To make it happen, ORNL helped develop a 76-item checklist describing first steps in a whole-house approach to energy efficiency. House plans incorporated design elements from the checklist such as insulated sheathing and T-wall framing; at the work site, the checklist guided volunteers through construction tasks such as sealing air leaks.

Contrary to accepted wisdom, energy efficiency does not add unacceptable expense to affordable housing. Habitat projects are demonstrating that even volunteers on a five-day blitz can build efficient homes that will save families hundreds of dollars each year.

ORNL continues to support and train Green Team members to oversee and advocate for Habitat's energy work, to provide design assistance, and to develop fact sheets and other materials to make affordable housing more resource-efficient.

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Buildings Technology Center Helps Construction Industry Solve Building Problems

The Buildings Technology Center (BTC) at ORNL provides the buildings industry with a unique collection of testing and analysis capabilities. To improve the energy efficiency of buildings, the BTC pursues solutions that are environmentally sound and cost-effective, as well as energy-efficient.

The BTC occupies six buildings with more than 20,000 ft^2 of space. Its permanent staff of about 50 people is continuously supplemented by 10 to 20 guest researchers. Several programs make up the center: Heating and Cooling Equipment, Thermal Environmental Engineering, Building Envelope Systems, Building Design and Performance, State and Community Programs, Federal Energy Management Program, Power Systems, and Communications and Market Outreach.

Testing Capabilities

The centerpiece facility for building envelope research is the **large-scale climate simulator,** which sandwiches large roof sections between two environmental chambers. The upper climate chamber can simulate any outdoor weather condition; the lower chamber typically models interior conditions.

The **rotatable guarded hot box** is used to test full-size wall, fenestration, roof, and floor systems. It is currently testing its 60th wall system to complete a comparative whole-wall rating database, which is available on the BTC home page (http://www.ornl.gov/ORNL/BTC/).

The **roof thermal research apparatus** is testing 24 different reflective roof coatings for low-slope roofs. The 3-year study will provide durability data for establishing the long-term thermal performance of the coatings. The roof thermal research apparatus also contains four replaceable wall test panels, a controlled interior, and two calibrated slab-foundation edges to measure the thermal performance of slab-on-grade foundations.

The **envelope systems research apparatus** is used to study energy and moisture flow through building envelopes. Half of the roof section of the apparatus is testing 17 different highly reflective single-ply membranes on a low-slope roof. The other half is being prepared to test sloped and low-slope metal roofs with various types of reflective surfaces. When complete, the 30-by 70-ft roof area will be simultaneously testing the thermal performance of more than 40 different roof systems. These data will aid in defining the long-term thermal performance of these roof systems, accounting for changes in rooftop surface reflectivity over time. Installation of several photovoltaic systems is planned to enhance the largest simultaneous thermal performance roof test ever conducted at a single site.

A large, two-room (indoor/outdoor) **environmental chamber** simulates temperatures and humidity conditions for the development of air-conditioning, refrigeration, and heat pump technologies. These chambers are being used to test cutting-edge gas-cooling technologies, including the generator-absorber-heat exchange (GAX) heat-pump technology for small residential applications (3- to 5-ton peak capacity), which is expected to be commercially available soon.

Dan Reicher, DOE Assistant Secretary for EE/RE, examines the "Fridge of the Future" with BTC researcher Ed Vineyard during a recent visit to ORNL.

A **heat exchanger test facility** helps in designing, developing, and testing the performance of novel air-to-refrigerant heat exchangers (HXs) without lubricant additives. Research under way focuses on reconfiguring HXs to optimize equipment system efficiency using new refrigerant blends (zeotropes) that are more environmentally safe. The BTC is working through a DuPont/ORNL CRADA to evaluate heat transfer, conducting HX redesign for a co-invented zeotrope blend. This work could improve air-conditioner efficiency by 10% at ambient air temperatures of 95°F and above.

Another project under way in the BTC is a desiccant systems test that supports certification procedure efforts. ORNL is working with industry partners to expand market opportunities for this next-generation comfort-conditioning technology. Desiccant technologies promise to improve indoor air quality, reduce hydrochlorofluorocarbon (HCFC) usage, save energy, and reduce CO_2 emissions.

The thermal environmental engineering laboratory works with industry to develop frostless heat pumps, energy-efficient vending machines, advanced heat pump water heaters, and fuel cell systems. Staff in this program hold almost a dozen patents on various aspects of these systems.

The BTC provides calorimeters and specialized test apparatuses for evaluating chlorofluorocarbon and HCFC replacement refrigerants and a wide array of sensors and data acquisition systems to analyze building performance in the laboratory and in the field.

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Advanced Turbine Systems Program Aims for Super-Efficient Gas Turbines

A prototype single-crystal land-based gas turbine blade (left) compared with a currently available single-crystal aircraft turbine blade (right).

The Advanced Turbine Systems (ATS) Program is a cooperative effort of DOE, universities, and industry. Its objective is to develop gas turbine systems for utilities and industry that will improve efficiency, reduce the cost of electricity, lower emissions, and maintain or increase reliability.

U.S. turbine makers working in the ATS Program say turbine inlet temperatures of over 1427°C (2600°F) are needed to achieve ATS goals. To operate at these temperatures for extended periods requires materials and manufacturing development. Therefore, the overall program includes a design initiative for combustors, airfoils, and cooling capability. For small industrial turbines, the initiatives include cycle modifications and use of ceramic components.

A major supporting element of the program is the materials/manufacturing task. ORNL manages the primary objective for this element—providing materials and fabrication support to complement manufacturers' demonstration programs. The materials effort addresses improving manufacturing processes for single-crystal airfoils, processing thermal barrier coatings, generating mechanical property data for candidate ceramics, and characterizing degradation modes of critical components (e.g., thermal barrier coatings) for use in modeling life prediction and monitoring performance.

ORNL is working with Westinghouse Power Generation and Pratt & Whitney to develop highly reliable thermal barrier coatings; ORNL assists by characterizing the coatings. Howmet and PCC Airfoils are developing the manufacturing technologies for single-crystal airfoils for industrial and large utility gas turbines. ORNL's aim is to hasten the incorporation of new materials and components into land-based gas turbines.

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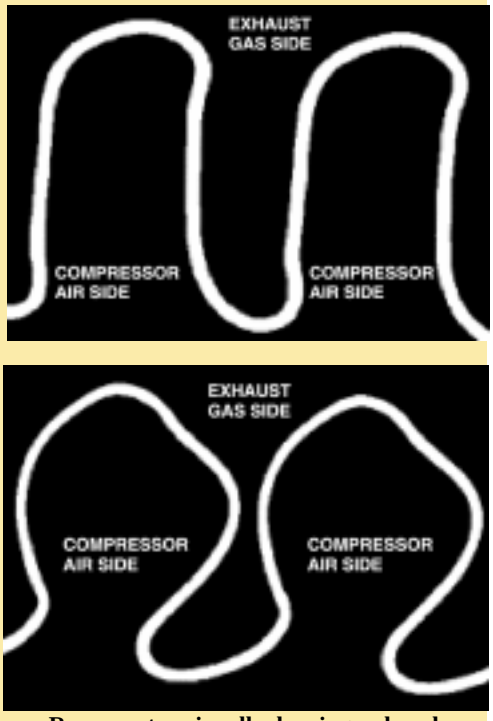
Stainless Steel Creep Strength Dramatically Improved

A CRADA between Solar Turbines and ORNL has produced significant improvements in type 347 stainless steel (SS). Solar Turbines, ORNL, and Allegheny-Ludlum Corporation collaborated on research to modify the microstructure by using alloy processing to improve the creep strength of standard type 347 SS foil for use in gas turbine recuperators.

Type 347 SS foil is the standard material for Solar Turbine's commercial recuperators. Processing on Allegheny-Ludlum's continuous annealing line (CAL) produces a fine-grained foil (0.0035 to 0.004 in. thick) that is fabricated into recuperator cores. The goal is to develop a recuperator material that will operate above 1100°F.

Previous work at ORNL on advanced austenitic SS and alloys showed that outstanding creep resistance could be obtained by ultrafine dispersions of MC carbide that remain stable (resist dissolution or coarsening) for long times. Achieving these microstructures in commercial-grade type 347 SS foil produced by Allegheny-Ludlum's CAL equipment was a formidable challenge. Work at ORNL that simulated the CAL processing with higher annealing temperatures for short times dramatically improved the creep strength at above 1250°F. This was clear proof of concept; the next step is to demonstrate that the same results can be achieved with commercial-scale processing. Allegheny-Ludlum is currently producing a 30-ton heat of type 347 SS that will then be processed into 0.004-in.-thick foil and used to manufacture recuperator air cells for Solar Turbines' new Mercury gas-turbine engine.



Recuperator air cells showing reduced creep (top) and deformation caused by creep (bottom).

By Mike Karnitz
Sponsor: Office of Industrial Technologies and Office of Fossil Energy

Forest Products Research Agenda

Lumber undergoing microwave drying at ORNL.

The forest products industry, one of the largest segments of the U.S. economy, faces tough challenges in the areas of energy, environment, and global competition.

To meet the challenges, industry leaders have established a research collaboration with DOE, as part of the Industries of the Future program, to identify appropriate areas of joint research and development (R&D). Fifteen DOE national laboratories cooperate in the research initiative.

Representatives of industry have written a vision statement, *Agenda 2020*, establishing six areas in which strategic R&D is needed: sustainable forestry, environmental performance, energy performance, improved capital effectiveness, recycling, and sensors and controls.

The outcome or the collaboration will be the accelerated development of technologies that address several R&D goals:

- advance global competitiveness through technological leadership
- improve sustainable management of forest resources
- develop the capability to meet environmental demands cost-effectively
- build energy self-sufficiency and take full advantage of by-product biomass
- increase the economic viability and use of recycled wood and paper

Seven ORNL projects support this initiative. The topics include developing materials for kraft recovery boilers (see highlight), the use of microwaves for drying wood, characterizing the paper web at the “wet end” of the paper-forming process, the impact of high-intensity forest management on water quality and soil nutrient reserves, computer modeling of how soil quality affects forest productivity, biochemical and molecular regulation of the shape of tree crowns in tree plantations, and identifying molecular markers that can be used to select superior strains of trees.

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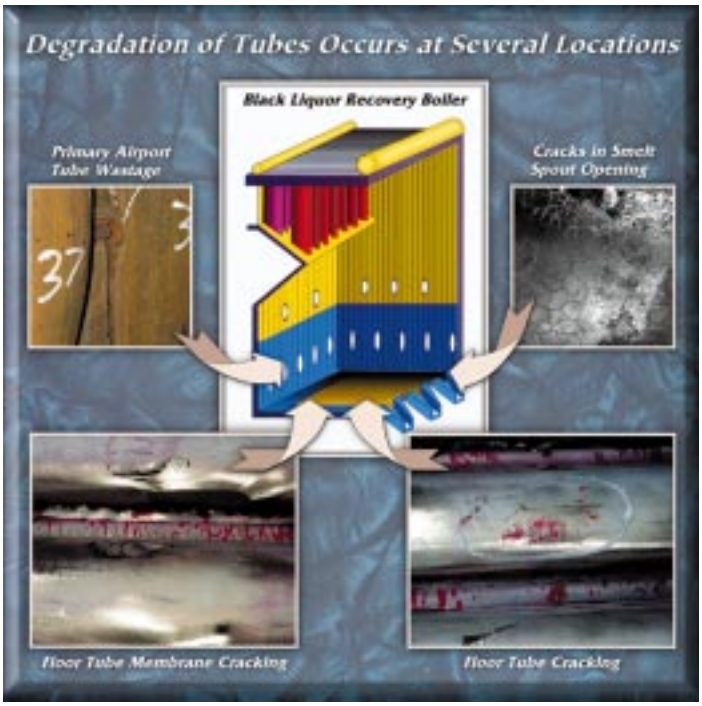
Preventing Boiler Tube Failure

Recovery boilers serve a critical function in pulp and paper mills. The pulp and paper industry has identified the cracking of boiler tubes as a top research priority and has asked DOE for help in determining the causes of tube failure and in developing new materials. ORNL is coordinating a project on this issue and is conducting R&D related to materials, stress measurement, and computational modeling. Paper institutes in the United States and Canada are also conducting R&D, and paper companies and their suppliers are participating actively.

Recovery boilers process chemicals for reuse and burn organic matter to generate steam and electricity. The boilers (about 40 ´ 40 ´ 150 ft) consist of metal tubes welded into panels. The tubes carry high-pressure water. Especially in the lower portions of boilers, the tubes can come in contact with corrosive chemicals and molten salts as hot as 800°C. They may crack and corrode and sometimes fail. If a tube ruptures, high-pressure water may jet into the boiler and vaporize on contact with the molten chemicals, causing an explosion.

The objectives of the R&D are to determine why tubes fail, identify materials and processing conditions that will minimize or eliminate tube cracking, and predict how long different types of tubes can perform under various conditions. Researchers at ORNL are analyzing the microstructure of cracked tubes to identify mechanisms and processes. The High Flux Isotope Reactor is being used to measure residual stresses in both new and exposed tubes, and computer models are being developed to simulate the effects of boiler operation and to calculate stresses on tubes under various operating conditions.



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Sponsor: Office of Industrial Technologies

Less Is More: Lightweight Vehicle Materials Improve Fuel Economy

Because lightweight materials cost more than iron and steel, their widespread use in manufacturing automobiles has been limited. To make the switch to lightweight materials, auto makers and their suppliers must be able to produce a range of these materials at the rates and robustness needed for auto manufacturing schedules and volumes.

DOE's Lightweight Vehicle Materials (LVM) Program helps U.S. companies develop advanced materials and process technologies to encourage the production of lightweight vehicles. The goal is to develop materials that reduce automobile weight without compromising vehicle performance, safety, or cost. Specific targets are to reduce the weight of the automobile body and chassis by 50% by the year 2004 and by 60% by 2011. [Those targets are consistent with the Partnership for a New Generation of Vehicles (PNGV) goal of a 40% reduction in the mass of an average vehicle with three times the fuel economy.]

The rewards of success: cleaner air and greater independence from imported oil

LVM activities are coordinated with the auto industry primarily through the PNGV Materials Technical Team and the United States Automotive Materials Partnership. The program interacts with auto industry suppliers, universities, and national laboratories in addition to the "Big Three" automakers.

An R&D plan, based on a roadmap developed by PNGV, will guide the development and integration of LVMs. To reduce the total life-cycle cost of these materials, technologies are being developed to

- reduce the cost of primary materials
- improve the manufacturability of lightweight materials
- provide material design data
- improve materials joining techniques
- provide cost-effective recycling and repair methods.

The early emphasis has been on cost-effective fabrication of aluminum and glass-fiber polymer matrix composites; upcoming work will focus on fabrication of magnesium and titanium and production of carbon fiber composites.

ORNL assists in technical management of the LVM program and conducts R&D in a number of projects:

- devising reliable joining techniques for dissimilar materials
- creating more-reliable, better-performing cast aluminum components
- inventing alternative processing technologies for lower-cost carbon fiber
- assessing the long-term durability of polymer composites
- developing creep-resistant magnesium alloys for die casting automotive components
- modeling and simulating energy absorption characteristics of lightweight materials

The technical challenges are not small, but the rewards of success are large: cleaner air and greater independence from imported oil through improved fuel economy.

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Predicting the Results of Heat Treatment

ORNL's predictive heat treatment program is developing a modeling methodology and software tool to simulate and predict the results of heat treatment, especially distortion, for carburized components of automotive transmissions.

Manufacturers devote significant time and resources to dealing with unanticipated effects of heat treatment. Often, unpredicted changes in component shape or performance during heat treatment force multiple design revisions or substantial redesign. The results are wasted time, lengthened time to market, and additional expense to restore the shape of the treated components to the desired configuration. The additional time and expense means higher capital equipment and product costs.

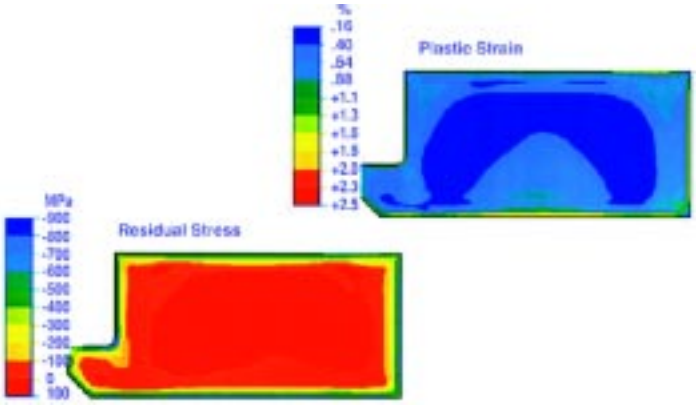
To produce the simulation software, ORNL researchers developed capabilities to model the carbon diffusion cycle, heat transfer during quenching, phase transformation behavior, and material stress-strain response as a function of microstructure, temperature, and strain rate. In the predictive tool, these analyses are interdependent.

Meshed shape used to simulate a helical gear.

In the upcoming (final) year of the Phase II effort, the capability to simulate heat-up and post-quench–tempering heat treatment will be added to the predictive tool.

Predicting (continued on page 7)

Predicting (continued from page 6)



Predicted residual hoop stress and plastic strain distributions in a gear blank after quenching.

The enhancement will expand the capability of the software to model the solution heat treatment and aging process used in other alloy systems, such as aluminum, titanium, and nickel-based alloys.

Plans are to release a commercial version of the predictive heat treatment tool to the National Center for Manufacturing Sciences (NCMS) in the project by early 2000. After the terms of the initial CRADA are met that allow exclusive use of this tool to NCMS, the simulation tool will be available for public use from NCMS for a licensing fee.

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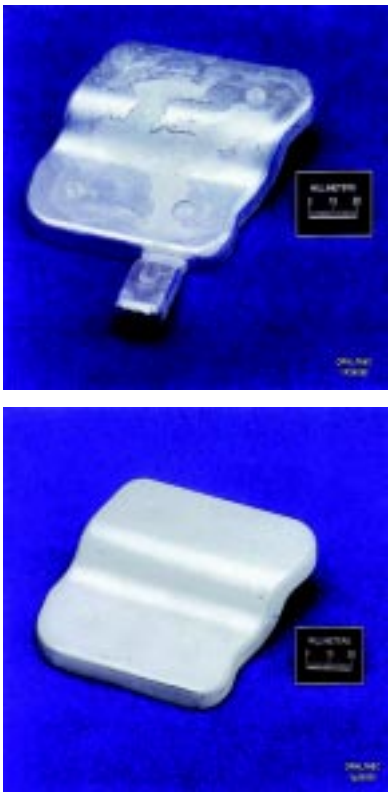
MCF Means Stronger, Lighter, Cheaper Auto Parts

Researchers from ORNL and Thompson Aluminum Casting (TAC) have optimized a new process called metal compression forming (MCF) to produce an aluminum 356 alloy motor mount bracket. The MCF process is a variant of squeeze casting that reliably and consistently produces parts with fewer defects. Fewer defects result in a stronger part.

The project was aimed at enabling wider use of lightweight materials in the transportation sector.

To optimize the process to produce commercial components at the cost and performance specifications of the transportation industry, TAC teamed with ORNL researchers to take advantage of computer modeling and simulation expertise not available to TAC in-house. The use of casting and solidification models of the filling of the die cavity and the solidification of the part, together with determination of accurate thermophysical properties for the alloy, were crucial to the development of optimum process parameters.



Aluminum alloy motor mounts produced without (top) and with the metal compression forming process.

The effort resulted in a metal-forming process that produces an aluminum part that is not only more consistent and sound, but also more resistant to service stress cracking.

In some applications, aluminum components produced by this process will replace cast iron or steel components, resulting in a substantial weight savings per vehicle. In other cases, substituting the cast parts for more costly forged aluminum parts will provide an economic incentive for increased use of aluminum components.

This development will enable parts suppliers to provide lower-cost, lighter-weight components to vehicle manufacturers, thereby improving the fuel economy of trucks and cars and reducing U.S. dependence on imported fuels.

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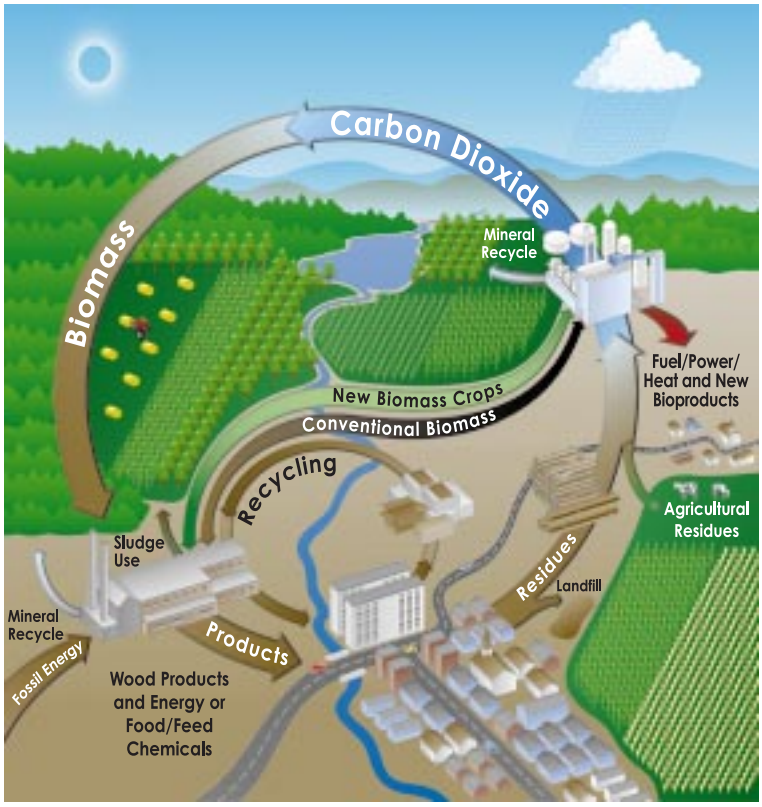
Biomass Follows Multiple Pathways to Renewable Energy

ORNL's Bioenergy Feedstock Development Program (BFDP) supports DOE's goal of developing efficient new technologies that could work together in integrated bioproduct/bioenergy cycles. BFDP is developing new crops to increase future supplies of biomass, creating analysis systems to project costs and supplies of biomass crops and biomass wastes, and investigating how energy crops can provide solutions to environmental problems.



An integrated bioenergy/bioproducts cycle would help solve energy, environmental, and resource problems.

Universities and U.S. Department of Agriculture (USDA) research units are long-term partners in BFDP crop development research. USDA's Office of Energy is working with BFDP to develop an economic analysis system to project interactions between energy crops and other crops. The forest products industry is working with BFDP to increase the efficiency of tree crop production and to examine the potential for recycling non-toxic wastes to biomass crops as soil amendments. BFDP collaborates with the Biomass Power for Rural Development Program to improve large-scale biomass supply systems for utility applications.

As market demand for ethanol and biofuels expands, analyses conducted by ORNL (see p. 9, "Predicting Growth in Ethanol Demand") show that lower-cost biomass residues will be sought first, but that energy crops could enter the supply chain early in some areas. American farmers could be major suppliers to emerging bioenergy industries, selling excess crop residues and producing biomass crops on lands not needed for food crops, especially on soils sensitive to erosion.

American farmers could be major suppliers to bioenergy industries

By emphasizing perennial grasses and woody crops, BFDP is developing crop species that protect the soil and have the potential for high yields, efficient use of water and fertilizer, and pest and drought resistance. BFDP's environmental research is defining sustainable crop production systems that will produce profitable crops using environmentally acceptable farming practices, even on sensitive crop land. New approaches under study include evaluating how bioenergy can be integrated into solutions for problems caused by animal wastes.

Bringing biomass energy technologies successfully to market requires cooperation among the energy, agricultural, forestry, and environmental sectors. The forest products industry is creating a market pathway for short-rotation woody crops and a new, concentrated source of biomass residues that could be used for energy. Collaborations with forest products industries include field trials of genetically improved trees and research to understand the interactions between genetic and environmental factors in controlling tree-growth processes (see p. 10, "Biomass Productivity Puzzle in the Southeast").

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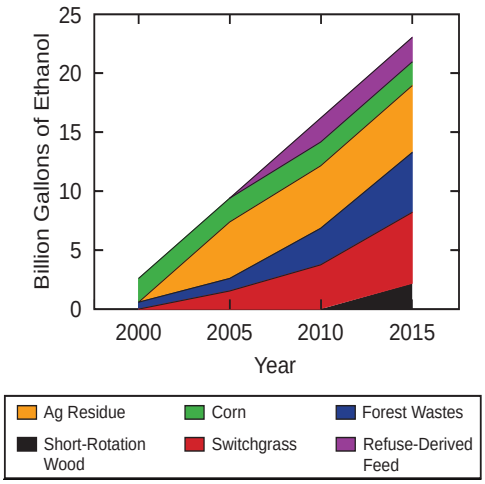
Short-rotation wood crops can be used to produce energy.

Predicting Growth in Ethanol Demand

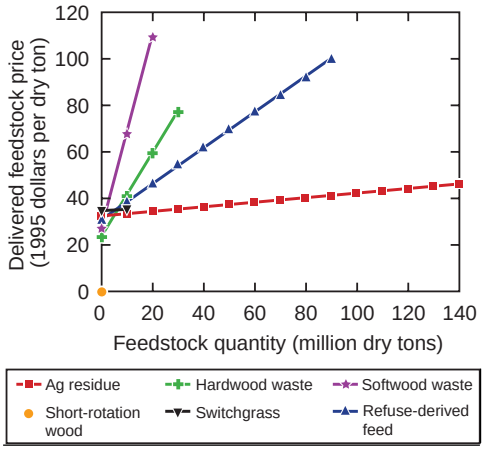
Successful commercialization of new fuels depends largely on their economic competitiveness, and ORNL is leading the way in evaluating the economic potential of biomass-derived ethanol.

Feedstock supply curves (below) have been estimated for the years 2000, 2005, 2010, and 2015 for biomass sources that include forest wastes (logging residues, tree thinnings), agricultural residues (corn stalks, wheat straw), dedicated energy crops (switchgrass, short-rotation hybrid poplar and willow crops), and refuse-derived feedstocks (from municipal solid waste). The feedstock supply curves, combined with information about the cost of converting various feedstocks to ethanol, have been used to create ethanol supply curves that relate quantities of ethanol produced to price.



Estimated biomass supply curves for the year 2000.

The supply curves have been used to estimate the least-cost combination of biomass feedstocks for any given quantity of ethanol under various scenarios (at right). ORNL has begun to derive ethanol demand curves using a refinery model (RYM) for ethanol blended with gasoline, and the "Transition to Alternative Fueled Vehicles" model for ethanol used as a neat fuel. By combining the ethanol supply curves with demand curves, it will be possible to estimate the potential size of the ethanol industry, the market price of ethanol, and the feedstock mix used to produce the ethanol. This modeling framework will provide DOE's Office of Transportation Technologies with economic information needed to evaluate constraints to commercialization, explore the impacts of policy on commercialization potential, and estimate the economic and environmental impacts of biomass-derived ethanol.



Least-cost combustion of feedstocks used to produce ethanol.

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Growing a Biomass Power Supply

ORNL staff of the Bioenergy Feedstock Development Program have worked with DOE and many collaborators for 20 years to develop cropping technologies that could result in environmentally beneficial and low-cost, profitable crops for energy production. These concepts are now being tested in real-world conditions.

The first willow trees to be planted specifically for electricity generation were established in spring 1998 in New York on idle crop and pasture lands. The willow planting is one of three Biomass Power for Rural Development projects that are getting farmers involved in growing energy crops to supplement biomass resources. In the New York project, 25 organizations—including several utility companies, state agencies, university researchers, U.S. Department of Agriculture units, and local farmers—have formed a consortium to demonstrate the use of

Willow trees to be used for generating electricity surround a power plant in New York state.

Biomass (continued on page 10)

Biomass Productivity Puzzle in the Southeast

ORNL researchers, working under a CRADA with Union Camp, initiated a large irrigation/fertilization or "fertigation," experiment in 1995 to determine the factors that limit biomass productivity in the southeastern United States. Growth rate (productivity) is the single largest factor determining landowner profits, environmental impact, land-use changes, and overall return on investment in biomass-based renewable energy.

Productivity varies according to planting stock, cultural practices, and region. Other things held equal, productivity in the Southeast is below observed growth rates in other regions and below expectations based on environmentally based growth and yield models. The objective of the Union Camp experiment was to characterize carbon use efficiency in trees grown in the Southeast under optimal conditions; the assumption was that higher temperatures during the growing season in the Southeast limit productivity through respiratory loss of carbon.

Results to date show that growth through age three in cottonwood and sycamore is as high as in other regions (projected productivities of 5 to 7 dry tons per acre per year). During the fourth growing season, however, the leaf area index decreases, respiratory losses increase per unit of biomass, water use decreases, and growth slows. Increased water availability through irrigation and nitrogen fertilization does not appear to prevent these changes in cottonwood and sycamore growth. The amount of carbon fixed through photosynthesis apparently decreases with age, and the carbon that is fixed is lost to respiration. In short, carbon-use efficiency decreases after three years of growth.

Paul Hansen of ORNL checks soil respiration data for young sweetgums.

With this information, it may be possible to adjust growing conditions to maintain high leaf area indices, reduce respiratory losses, and maintain growth through a full rotation (i.e., 8 to 10 years) in the Southeast. In addition, information is now available to breeders that should allow them to select superior planting stock: they can select for improved crown architecture, increased leaf area per tree during crown closure, improved water use, and integratively increased productivity.

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Biomass (continued from page 9)

willow trees as energy crops for power generation in the Northeast and upper Midwest.

Near-term project goals include demonstrating 30–40 MW of biomass power generation by co-firing a combination of willows and forest residues with coal, and by successfully producing willow on 1000 acres. Co-firing small amounts of forest residues is already under way, and co-firing the first willow biomass is anticipated to occur as early as the year 2000. A longer-term goal is to create a sufficient market for willow biomass at $2 per million Btu to encourage the establishment of several thousands of acres of willow on idle crop and pasture land.

ORNL is facilitating accomplishment of the goals of the New York Biomass Power for Rural Development project in several ways. ORNL staff participate on the DOE team that oversees and reviews the project. In addition, ORNL is working to facilitate the development of an effective farmers' willow cooperative by researching and sharing information on organizational modes of effective cooperatives. ORNL also provides funds for and collaborates with the State University of New York and the U.S. Forest Service to develop genetically improved willow varieties with the potential to bring a profit to farmers at the relatively low price of $2 per million Btu. Finally, ORNL researchers are using willows for basic research on the isolation of gender-determining genes. Although this research is not directly tied to the New York Biomass Power project, progress in the basic research could lead to higher-yield clones of willows that do not expend energy in producing flowers, and to mechanisms for ensuring the safe release of genetically transformed willow clones.

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Sponsor: Office of Solar Thermal, Biomass Power, and Hydrogen Technologies

Power Systems Technology—Delivering the Future

As the electric utility industry becomes a competitive market, transmission and distribution systems will take on tasks for which they were never designed. The North American Electric Reliability Council (NERC), in its 1997 *Reliability Assessment: 1997–2006*, states "open transmission access has resulted in increased electricity transfers over longer distances, and in directions and magnitudes unforeseen when the current transmission systems were planned and constructed. . . . Loading problems are expected to become more numerous." At the same time, concern over possible health effects of electromagnetic fields (EMFs) makes it difficult to construct new power lines. The Power Systems Technology Program has, for nearly two decades, been involved in developing technologies that can meet the upcoming challenges head-on:

- investigation of the need for special services to ensure system reliability in an open market
- technical support to groups such as NERC and the Secretary of Energy Advisory Board Task Force on Electric System Reliability
- improved and real-time system monitoring and control
- transmission upgrades such as high phase order (see the highlight) and high-voltage, direct-current (HVDC) systems
- investigation of EMF effects, including development of public information materials.

By: Jim VanCoevering, 423-574-4829, v25@ornl.gov
Sponsor: Office of Utility Technologies

Moving More Power with High Phase Order Transmission Lines

Compact configuration for high phase order lines.

ORNL has helped utility companies develop higher-capacity power lines that will significantly increase the amount of power that can be moved over a given right of way. Tests conducted by ORNL and the utilities during operation of the High Phase Order Demonstration Project have confirmed that six-phase lines are a viable system option.

Most electricity generated in the United States is transmitted by three-phase alternating current systems. Theoretically, transmission lines with more than three phases, called "high phase order lines," can increase the power carrying capacity of a given right of way; use smaller, less obtrusive towers; and produce lower electric and magnetic fields than three-phase lines.

The utility industry, with technical assistance from ORNL, developed high phase order transmission lines with 6 and 12 phases over a 15-year period. A key issue remaining to be resolved was how seamlessly a six-phase line could be integrated with a standard three-phase network. ORNL and four partners (New York State Electric and Gas, New York State Energy Research and Development Agency, Empire State Electric Energy Research Corporation, and the Electric Power Research Institute) recently completed testing of the first six-phase transmission line to operate in a utility environment. The line, originally a double-circuit three-phase 115-kV line, was converted to six-phase operation to test relay protection schemes and designs for substation equipment. During the process, line voltage was increased to the equivalent of 161 kV with no changes in line conductors, towers, or insulators. This change alone increased the line's power-carrying capacity by more than 40%. A portion of the 1.5-mile line was converted to a special compact configuration (see photo), which reduced by 50% the amount of space the line occupies.

Tests were conducted during normal line operation to measure audible and radio noise, electric and magnetic fields, and operation of the protection system. Substation equipment was successfully adapted from three-phase designs and was installed at the two terminals of the line to interconnect the test line with the rest of the three-phase network. In all cases, the line functioned as designed, confirming that six-phase transmission can be incorporated into a utility grid with minimal disruption.

By Jim VanCoevering
Sponsor: Office of Utility Technologies

Breaking News . . .

Southwire Executives Visit ORNL

Executives from the leading U.S. manufacturer of utility and building wire and cable, Southwire Company, visited ORNL in October. Southwire and ORNL are jointly conducting R&D that will lead to demonstration of a 30-m-long, three-phase, high-temperature superconducting power cable at Southwire's Carrollton, Georgia, headquarters by the end of 1999. The cable will deliver power from the local utility to two of Southwire's manufacturing plants.

Dan Reicher Visit

Dan Reicher, DOE Assistant Secretary for EE/RE, visited ORNL and the DOE Oak Ridge Operations Office on July 29. He toured EE/RE National User Facilities (High Temperature Materials Lab, Metals-Processing Lab User Center, Buildings Technology Center, and the Advanced Engine and Fuels Technology Lab) and learned about ORNL capabilities and expertise in the facilities. Assistant Secretary Reicher was briefed on ORNL's advanced automotive programs, the new National Transportation Research Center, biomass feedstock development program, and high-temperature superconductors. The day ended with a visit to the ORNL/Southwire High Temperature Superconducting Cable Test Facility, where a 5-m-long prototype power cable is undergoing testing.

Champions of Energy Efficiency

The American Council for an Energy-Efficient Economy (ACEEE) honored the team responsible for the "5-Lab Study" with its Champion of Energy Efficiency Award during the 1998 Summer Study at Asilomar in Pacific Grove, California. This team led the effort by five DOE national laboratories to research, write, review, and publish the study, formally titled *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond.* Members included Joseph Romm and Eric Peterson, DOE; Mark Levine, LBNL; and Marilyn Brown, deputy director of our own ORNL EE/RE Program.

Composites Institute Honors ORNL Researchers

Charles R. Brinkman and Weiju Ren of ORNL received the Best Paper Award of the Composites Institute at the International Composites Expo 1998 in Nashville, Tennessee. The paper, titled "Creep and Creep Rupture Behavior of a Continuous Strand, Swirl Mat Reinforced Polymer Composite in Automotive Environments," covers research into lightweight materials for fuel-efficient automobiles. Brinkman is a group leader of the Metals and Ceramics Division. Ren is a post-doctoral fellow and assistant professor at the University of Tennessee's Center for Materials Processing.

Energy Management Awards

Joe Whitefield received two awards in recognition of outstanding achievement in energy management at ORNL facilities. The 1998 DOE Departmental Energy Efficiency Award and the Federal Energy and Water Management Award were presented to Whitefield in Washington, D.C., in October. The Energy and Water Management Award is a joint award from DOE and the Federal Interagency Energy Policy Committee.

Coming in February

- **Greening the Chemicals Industry:** *National labs work with industry and academia to make production of chemicals a greener, cleaner endeavor*
- **Heavy Hybrid Truck:** *Increasing fuel economy and decreasing emissions in heavy trucks*
- **A Helping Hand for Federal Building Owners/ Operators:** *The Federal Energy Management Program is pioneering "Energy Savings Performance Contracts" for federal facilities*
- **Restructuring Utilities:** *Assessing the consequences of a restructured electric industry*

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