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

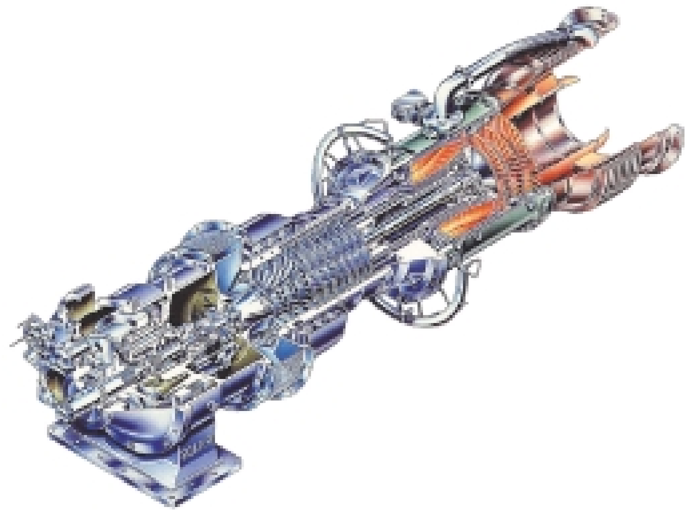
In 1992, DOE set a goal to develop and demonstrate ultra-high-efficiency natural gas turbine systems within 8 years. The Advanced Turbine Systems (ATS) effort has been successfully completed, and ORNL research played a key role in its success.

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

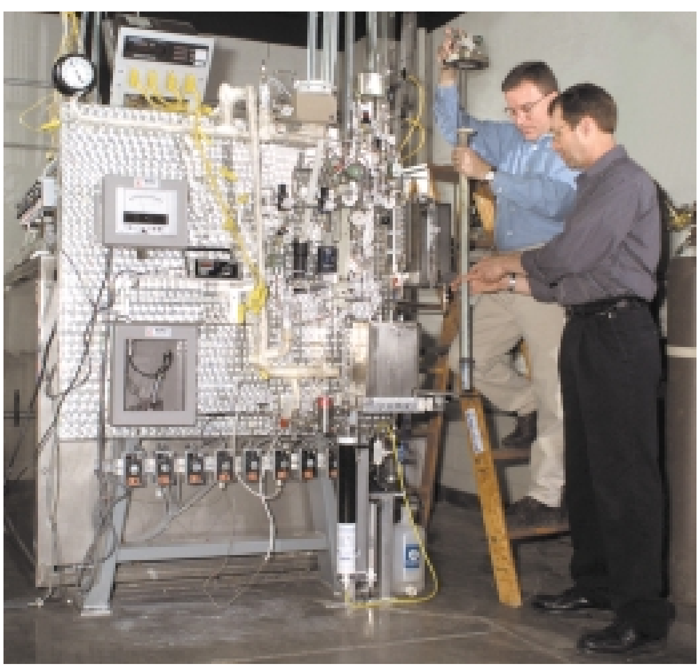
DOE began the program because projections indicated natural gas turbines would make up over 80% of the new power-generating capacity expected in the United States over the next 10 to 15 years. More than 96% of new power plant projects under way or planned in the United States will use natural gas, and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

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

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



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



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

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

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

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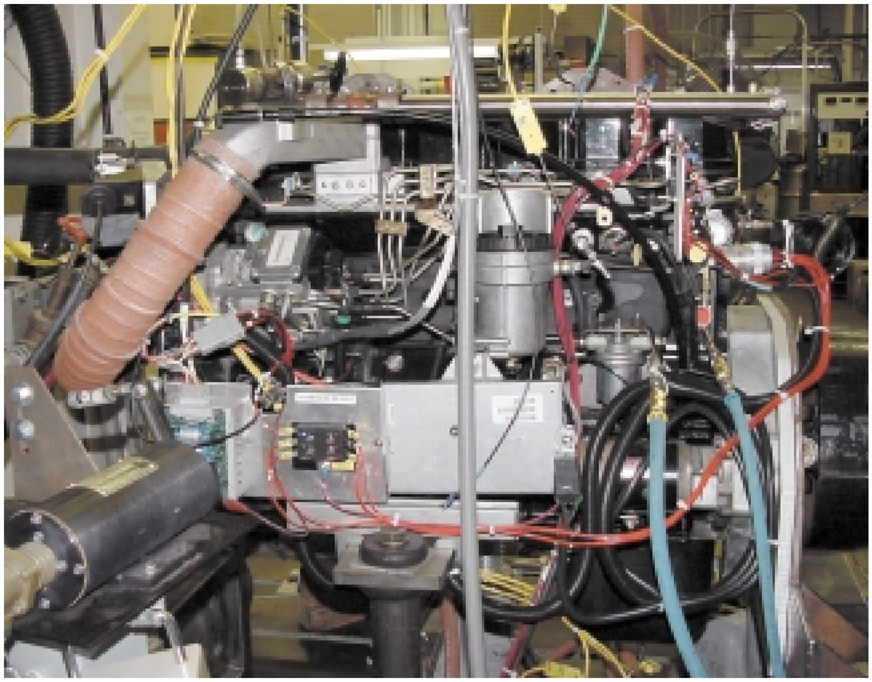
Cleaner Reciprocating Engines for Transportation and Power

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

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



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

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

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

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

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

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

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