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News From Argonne's Transportation Technology R&D Center

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VIEWPOINT

New Fuels and Technologies are Focus of Garman's Visit

David Garman, Assistant Secretary for DOE's Energy Efficiency and Renewable Energy (EERE) Office, visited Argonne on March 21 to learn more about research, development, and deployment activities taking place at Argonne in support of key EERE strategic initiatives. *Page 2*

RESEARCH REVIEWS

Advanced Powertrain Research Facility Opens for Business

Argonne's Advanced Powertrain Research Facility (APRF) was dedicated at a ribbon-cutting ceremony on November 15 and is now open for business. The dedication was attended by members of the U.S. Congress, officials and staff from the U.S. Department of Energy (DOE) and Argonne, automobile manufacturers, and the media. Transportation experts at the facility use a flexible systems approach to test-drive hundreds of cutting-edge vehicles without ever venturing out on the road. *Page 3*

Argonne Scientists Team up to Develop New Diesel Reformer

In work sponsored by DOE's Office of Hydrogen, Fuel Cells and Infrastructure Technologies, a multidisciplinary group of Argonne researchers teamed up to develop a new technology to reform diesel fuel for use in fuel cell applications. *Page 5*

FASTRAX

Two Argonne Researchers Honored

Two Argonne researchers were recently elevated to Fellows in their respective fields — Ramanujam (Raj) Sekar in the American Society of Mechanical Engineers and Ali Erdemir in the Society of Tribologists and Lubrication Engineers. The announcements represent crowning achievements in two impressive careers, each spanning more than 30 years. *Page 6*

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New Fuels and Technologies are the Focus of Assistant DOE Secretary Garman's Recent Visit

David Garman, Assistant Secretary for the U.S. Department of Energy's (DOE's) Energy Efficiency and Renewable Energy (EERE) Office, visited Argonne on March 21 to learn more about research, development, and deployment activities taking place at Argonne in support of key EERE strategic initiatives.

Garman's visit included a discussion of biomass energy opportunities; a tour of Argonne's Industrial Process and Recycling Facilities; demonstrations and discussion of fuel cell vehicle modeling, simulation, and hydrogen use at the Transportation Technology Research and Development Center (TTRDC) and Advanced Powertrain Research Facility (APRF); a walkthrough of the Locomotive Engine Test Facility; and presentations showcasing innovative approaches to fuel cell design, auxiliary power, and hydrogen production at Argonne's Fuel Cell/Hydrogen Production facilities.

As Argonne's Laboratory Director Hermann Grunder (left) and Associate Laboratory Director Harvey Drucker (right) observe, Assistant U.S. Secretary of Energy David Garman (center) drives an emulated fuel cell vehicle over the Federal Urban Drive Cycle in the Advanced Powertrain Research Facility. His successful completion of this "hardware-in-the-loop" test earned him Argonne's first "virtual drivers license."

Hydrogen production and use were recurring themes as Laboratory officials showed Garman how current Argonne research supports DOE's work to promote fuel cell development, reduce dependence on oil imports, and increase use of such alternative domestic energy sources as biomass and hydrogen.

To learn more about the research areas toured by Assistant Secretary Garman, please check out the following web sites:

- Advanced Powertrain Research Facility (http://www.transportation.anl.gov/facilities/aptf.html)
- Electrochemical Analysis and Diagnostics Laboratory (http://www.transportation.anl.gov/facilities/batterylab.html)
- Fuel Cell Test Facility (http://www.transportation.anl.gov/facilities/fuelcelltest.html)
- Low-Temperature Thermochemical Generation of Hydrogen (http://www.cmt.anl.gov/science-technology/lowtempthermochemical.shtml)
- Multi-Fuel, Compact Fuel Processor/Reformer for Fuel Cells (http://www.transportation.anl.gov/fuelcell/reformer.html)
- "TuffCell" Solid Oxide Fuel Cell (http://www.cmt.anl.gov/science-technology/fuelcells/tuffcell.shtml)

Advanced Powertrain Research Facility Opens for Business

At Argonne's Advanced Powertrain Research Facility (APRF), staff test-drive hundreds of cutting-edge vehicles in grueling conditions without ever venturing on the road. Skillful transportation experts perform this feat by using a flexible systems approach that links accurate computer simulations with component and control development on the test stand (emulation) and vehicle testing (validation) in the facility. The U.S. Department of Energy's (DOE's) key laboratory for powertrain testing and validation, the APRF can assess any powertrain technology — including engines, fuel cells, electric drives, and energy storage systems.

The facility was dedicated at a ribbon-cutting ceremony on November 15 and is now open for business. The dedication was attended by more than 100 representatives, including members of the U.S. Congress, officials and staff from DOE and Argonne, automobile manufacturers, and the media. U.S. Representative Judy Biggert (R-Ill.), DOE Deputy Assistant Secretary for Energy Efficiency and Renewable Energy (EERE) Richard Moorer, Argonne Laboratory Director Hermann Grunder, Argonne Associate Laboratory Director Harvey Drucker, and USCAR Executive Director Bob Culver gave opening remarks at the dedication. Others who attended the event included auto industry executives from Ford, General Motors, BMW, DaimlerChrysler, and Honda; DOE sponsors Bob Kost, Vehicle Systems Team Leader, Office of FreedomCAR Vehicle Technologies, and Lee Slezak, who is a member of the team.

"Besides being a cleaner place, America will be a safer place because of this facility — safer because of the environmental implications such as reduced vehicle emissions and our lessened dependency on foreign oil," commented Representative Biggert in her remarks.

Added DOE's Moorer, "This facility provides researchers with the tools needed to develop and evaluate vehicle components that will meet America's changing transportation needs. It will help industry enhance energy efficiency and productivity by bringing clean, reliable, and affordable energy technologies to the marketplace. This will make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life."

During the dedication, attendees toured the APRF. After a luncheon hosted by Affiliated Engineers, Inc., and Flad & Associates, the staff from Argonne's Center for Transportation Research (CTR) demonstrated the APRF's integrated research and development capabilities with three interactive sessions. The sessions showcased Argonne's vehicle modeling/simulation tools, hardware-in-the-loop capabilities, and four-wheel-drive testing capabilities, featuring a unique fuel cell emulator vehicle (see sidebar, page 4.)

"Argonne is an ideal place for this R&D to occur," asserts Argonne's Grunder. "We have one of the largest EERE transportation R&D budgets in the national laboratory system, with 10 divisions actively participating in developing cutting-edge technologies in engines, fuel cells, batteries, advanced materials, heat exchangers, aerodynamic and thermal modeling, and fuel processing. We are centrally located near the automotive and truck industries, have unique scientific research facilities, and have excellent working relationships with many of the major industry players worldwide."

While similar instrumentation is in use at research facilities operated by vehicle manufacturers, the APRF is the only facility in North America that combines the best available emissions instrumentation with such a wide range of fuels — including

(Left to right) U.S. Representative Judy Biggert (R-Ill.); Argonne Laboratory Director Hermann Grunder; DOE Deputy Assistant Secretary for Energy Efficiency and Renewable Energy Richard Moorer; and Argonne Associate Laboratory Director Harvey Drucker dedicate Argonne's Advanced Powertrain Research Facility.

gasoline, hydrogen, natural gas, and diesel fuel. In addition, the APRF's researchers possess extensive industry experience and provide unbiased R&D results. They have tested more advanced technology vehicles than any other public sector group, including over 100 different hybrid electric vehicles.

"This unique combination of analytical, development, and testing experience provides DOE with the latest techniques to evaluate new vehicle technologies in both emulated and real-vehicle environments," says CTR Director Bob Larsen. "Argonne's long history in modeling, developing, and testing advanced engines, hybrid-electric vehicle powertrains and control systems, traction batteries, fuel cells, and vehicles is a large part of making Argonne an important laboratory for vehicle technology development and validation."

The APRF is sponsored by DOE's Assistant Secretary of Energy Efficiency and Renewable Energy, Office of FreedomCAR and Vehicle Technologies.

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The APRF's Integrated Systems Approach

Simulation: the Powertrain Systems Analysis Toolkit (PSAT)

It's not quick or easy to determine the best design for a hybrid vehicle because of the many possible vehicle configurations, powertrain control complexities, and wide variety of applications. Argonne staff demonstrated how PSAT (Powertrain System Analysis Toolkit), a realistic and flexible vehicle simulation tool, has been validated using one of the most complex hybrid vehicles.

CTR Director Bob Larsen describes the newest tool in the APRF — a four-wheel-drive dynamometer system — to U.S. Representative Judy Biggert.

Emulation: Hardware-in-the-Loop/Rapid Control Prototyping

Argonne has developed hardware-in-the-loop — a unique, advanced testing methodology combining hardware and computer models — to maximize the efficiency and minimize the emissions of a diesel hybrid powertrain. The APRF demonstration showed how control strategies are translated directly from PSAT to control hardware in the test facility.

Validation: 4-Wheel-Drive SULEV Chassis Dynamometer Facility

Illustrating how advanced component technology is tested in a realistic vehicle context, this demonstration showcased a drive-by-wire vehicle powered by the combination of a virtual fuel cell; a real battery; and a real, integrated electric motor to illustrate the impact of both present-day and advanced fuel cell characteristics on energy storage, power requirements, and vehicle performance.

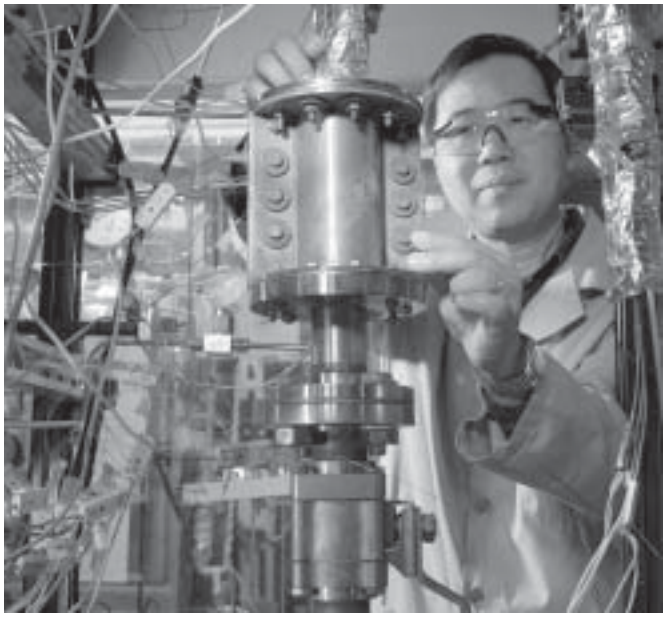
Argonne Scientists Team up to Develop New Diesel Reformer

Sometimes, the road to scientific discovery is a marathon: a scientist diligently works alone in his laboratory for years until — eureka! — he hits upon the solution to splitting an atom or freeze-drying coffee. More often, though, researchers work together as a team and build on the knowledge and discovery of those who have come before. So it was in the case of Argonne's new technology to reform diesel fuel for use in fuel cell applications.

The first efforts began when a team of scientists led by Michael Krumpelt in Argonne's Chemical Engineering (CMT) Division developed a new type of sulfur-resistant catalyst for use in fuel processors that efficiently converts a variety of fuels — including methanol, natural gas, and gasoline — into a hydrogen-rich gas for use in automotive fuel cell systems. The catalyst was named one of the top 100 technological innovations of 2001 by *R&D Magazine*.

Getting the reformer to convert diesel fuel to hydrogen — a process for which there is a substantial commercial market (see sidebar) — posed a whole new set of challenges because diesel is difficult to vaporize. The vaporization requires high temperatures, which lead to pyrolysis and coking (carbonaceous deposits). Also, the conversion reaction to hydrogen from diesel requires three things — fuel, water/steam, and air — that must be present in specific proportions and must be very finely mixed. The key to solving these challenges is the kind of nozzle that is used in the autothermal reactor. So, building on the success of CMT's reformer catalyst and sponsored by the U.S. Department of Energy's Office of Hydrogen, Fuel Cells and Infrastructure Technologies, researchers Rajesh Ahluwalia and Vince Novick in Argonne's Nuclear Engineering Division designed a new nozzle to overcome the limitations of existing nozzle technology for diesel applications: namely, mixing and dispersion. Because the three feeds (high-temperature steam, air, and fuel) cannot be premixed, the trick is to mix them *in situ* — right at the tip of the nozzle — to provide a uniform droplet size and dispersion across the catalyst bed.

Back in CMT's laboratories, another team made up of Tom Kaun, Candido Pereira, Kai Liao, Dan Applegate, and Sheldon Lee took the new nozzle, combined it with the Argonne catalyst,



Argonne's Di-Jia Liu conducted extensive testing of the diesel reformer; his experiments are the first to show that an autothermal reformer can be operated without vaporizing diesel fuel.

Major Potential Applications of Diesel Reforming

Military Applications

The military has a policy of "one fuel forward." The equipment they design must be able to run on the worst fuel available where military operations are taking place. If operations involve fuel cells, they must be able to run on diesel fuel.

Idling of Diesel Trucks

Regulations due out within the next few years will prohibit trucks from idling at night. The auxiliary power units that will heat and cool the truck cabs may be based on fuel cells, and diesel is the onboard fuel.

NO_x Reduction

Upcoming emissions regulations will require that diesel trucks significantly reduce emissions of nitrogen oxides (NO_x), which requires catalytic reactions in the presence of reducing gases such as hydrogen. The hydrogen can either be injected into the intake manifold of the engine or directly into the exhaust gases from the engine. In either case, some method of generating hydrogen is needed, and again, diesel is the onboard fuel and therefore the most logical source for the hydrogen.

now commercially available from Süd Chemie, Inc. (under a licensing agreement with Argonne), and designed a reactor setup that would allow Argonne to test the nozzle on an engineering scale.

The reactor team then turned to CMT's Di-Jia Liu, who conducted extensive testing of the reactor and generated data revealing that diesel *can* be converted to hydrogen by using the new nozzle. These experiments are the first to show that an autothermal reformer can be operated without vaporizing diesel fuel and therefore, without having to solve the kinds of problems that vaporization causes. According to CMT's Shabbir Ahmed, "The technology proved a success on three fronts: temperature and product distribution, product composition, and sustainability. Under typical operating conditions, we can sustain operation of the reactor for 5-6 hours. And we've done it for many, many days."

For commercial applications, the diesel reformer technology has a way to go. Argonne needs to test the reformer over thousands of hours. Researchers have obtained substantial industry input in the form of information about priorities and potential constraints, and the new nozzle technology and the data obtained thus far represent a big step forward.

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Two Argonne Researchers Honored

A Distinguished Career in Engine Research

The American Society of Mechanical Engineers (ASME) recently honored Argonne's Ramanujam (Raj) Sekar by elevating his membership to the status of a Fellow, in recognition of his many "significant engineering achievements and contributions to the engineering profession" over a career spanning more than 33 years. Sekar manages the Engine and Emissions Research Group at Argonne's Transportation Technology R&D Center.

The achievements in engine research that the society specifically mentioned in its citation were his involvement in heat exchanger development at Cummins Engine Co. But for Sekar, his greatest achievements have come while at Argonne and include the establishment of the Engine and Emissions Research Group. When he joined Argonne eighteen years ago, Sekar effectively *was* the Engine and Emissions Research Group. Now this renowned unit includes nine professional researchers and three technicians and has an annual budget of about $4 million. Primary support for Sekar's research at Argonne has come from a number of transportation projects now under the current Office of FreedomCAR and Vehicle Technologies within the U.S. Department of Energy's (DOE's) Energy Efficiency and Renewable Energy Office.

The test facilities and programs Sekar has established at Argonne testify to his wide-ranging research interests. Argonne now boasts a locomotive engine test facility fully funded by the Electro-Motive Division (EMD) of General Motors and automotive test facilities for compression-ignition direct-injection (CIDI) diesel engines made by Caterpillar and other manufacturers. Because fuel injection is central to the operation of diesel engines, Sekar's group participates with other researchers across the Laboratory in an innovative fuel-spray research program at the Advanced Photon Source (APS). The idea is to use powerful x-rays from the APS to penetrate and quantitatively map fuel-spray development over time, thereby providing an unprecedented look into the operation of diesel fuel-injection systems. This ambitious program has made Argonne uniquely qualified to conduct fuel-injection research.

The success of the fuel-spray program has sparked Sekar's interest in developing an x-ray engine test facility at the APS to provide fundamental insights into the operation of diesel

engines. As with the fuel-spray program, x-rays from the APS will permit scientists to see details of engine operation that cannot be viewed in any other way. Following Sekar's lead, several Argonne divisions have become involved in this area of research. For example, Chemical Engineering (CMT) researchers are now studying soot formation inside diesel engine cylinders at the APS, and members of the Reactor Analysis group are using the data to build computer models of the process. In about a year, a surrogate engine, called a rapid compression machine, will be evaluated at the APS. The next step will be to put a real diesel engine in the APS and study its operation while running.

Sekar's highly focused and inspired long-range vision for engine research has resulted in many awards and groundbreaking innovations, such as the use of gas separation membranes in diesels, which won a coveted R&D 100 Award in 1999. The fuel-spray program has also won recognition in the form of a 2002 National Laboratory Combustion and Emissions Control R&D Award. Sekar has also received two Laboratory Director's Awards for exceptional performance, an Achievement Recognition Award from EMD, an Energy Systems Division Director's Award for sustained accomplishment and consistently high performance, a Federal Laboratory Consortium Award for Excellence in Technology Transfer, and two ASME Internal Combustion Engine Division Awards for worthy contributions and loyal service. Sekar's innovations have also led to seven engine-related patents.

Given this track record, it's not surprising that the list of industrial partners that Sekar has worked with over the years reads like a Who's Who of diesel equipment manufacturers. Included are EMD, Robert Bosch Corp., Detroit Diesel Corp., Mack Trucks, Inc., Caterpillar, Inc., and DaimlerChrysler. His research group also works with small companies, such as Compact Membrane Systems, which is a spin-off company having roots at DuPont. Major U.S. universities have also sought collaborations with his research group, as have researchers at other DOE national laboratories.

Sekar continues to be a very active member of the ASME's Internal Combustion Engine Division. He is currently organizing a session on biodiesel engine technology for the society's next meeting, in Salzburg, Austria.

Another Impressive Fellow....

Ali Erdemir, of Argonne's Energy Technology Division, has been named a Fellow of the Society of Tribologists and Lubrication Engineers (STLE). To receive this honor, society members must practice the science and engineering profession of tribology for 20 years, maintain membership in the society for at least 10 years, and be nominated by the STLE Fellows Committee. Fellows must also demonstrate outstanding personal achievements in the fields of tribology or lubrication engineering.

Erdemir certainly meets those criteria. Last year, he received the Al Sonntag Award and the Allan A. Manteuffel Award from STLE's Chicago chapter for his development of a carbon coating that showed the lowest coefficient of friction (less than .001) when tested in a dry nitrogen atmosphere. The coating is 40 times slicker than Teflon, which has a friction coefficient of about .04. The breakthrough coating has many potential applications, including oil-less bearings, spacecraft mechanisms, rolling and sliding gear systems, and ultrahigh vacuum systems.

In addition to this breakthrough, Erdemir has provided his services to STLE for more than 10 years, serving as chairman of the Solid Lubrication Technical Committee, chairman of the 2001 Annual Meeting, and an associate editor for STLE's official journal, *Tribology Transactions,* from 1995 until 2000. Other honors and awards in recent years include a Fellow Award from ASM-International in 2001, a Distinguished Engineering Alumni Award from the Georgia Institute of Technology in 2000, two R&D 100 Awards (in 1991 and 1998), a Discover Magazine Award in 1998, and an Edmond E. Bisson Award in 1998. He has also published more than 100 refereed journal articles and holds six U.S. patents.

Erdemir is currently working to scale up the near-frictionless coating process for industrial applications, and he's also working on a new coating that will not only be low friction, but also extremely hard and wear-resistant in any type of operating environment. "It feels great to be noticed and recognized by my peers in the field," says Erdemir about his elevation to Fellow. "I feel that our work at Argonne is valued highly, and this brings more visibility and recognition to our laboratory."

PUTTING ARGONNE'S RESOURCES TO WORK FOR YOU

Industrial technology development is an important way for the national laboratories to transfer the benefits of publicly funded research to industry to help strengthen the nation's technology base. The stories highlighted in this issue of *TransForum* represent some of the ways Argonne works with the transportation industry to improve processes, create products and markets, and lead the way to cost-effective transportation solutions, which in turn lead to a healthier economic future.

By working with Argonne through various types of cost-sharing arrangements, companies can jump-start their efforts to develop the next generation of transportation technologies without shouldering the often-prohibitive cost of initial R&D alone. Argonne has participated in dozens of these partnerships and has even been involved in helping to launch startup companies based on the products and technologies developed here.

If working with world-class scientists and engineers, having access to state-of-the-art user facilities and resources, and leveraging your company's own capabilities sound like good business opportunities to you, please contact our Office of Technology Transfer and see how we can put our resources to work for you.

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