



Trans Forum

News From Argonne's Transportation Technology R&D Center



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"The Time Is Right to Work Together"

DOE turns to industry to help map out a plan for improving diesel trucks

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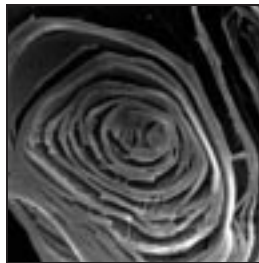
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A Solid Idea

Argonne finds an environmentally friendly lubricant for automotive metal forming

One of the best ways to increase fuel efficiency in today's vehicles is to reduce their overall weight by using lightweight aluminum- or magnesium-based alloys. But forming these alloys into automotive body parts is very difficult because of the inability of conventional lubricants to prevent wear under the extreme conditions encountered during metalworking. It is also difficult and costly to remove most conventional lubricants from finished products and treat them for disposal. Scientists at Argonne discovered that boric acid, used as a solid lubricant, can solve these problems. *Page 6*

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“The Time Is Right to Work Together”

DOE turns to industry to help map out a plan for improving diesel trucks

Representatives from industries and research institutions across the country gathered at Argonne on October 19–20 to help the U.S. Department of Energy (DOE) solve a major problem facing the heavy vehicle industry: how to improve the fuel economy of diesel trucks while reducing emissions to meet 2002 requirements. The focus of the workshop was thermal management, which is a large component of the fuel economy vs. emissions problem. How manufacturers manage the heat generated by an engine affects everything from fuel economy to driver comfort and from aerodynamics to emissions. Workshops like this one, the fifth in a series sponsored by DOE’s Office of Heavy Vehicle Technologies (OHVT), are giving industry an unprecedented chance to weigh in on where the Department should focus its research.

A Balancing Act

Solving thermal management issues as part of a successful industry/government partnership requires balance, persistence

Mark Moeckel of Caterpillar...

- “The big question is emissions reductions versus industry needs.”
- “EGR, the technology that is currently available for reducing emissions, adds significant heat loads that we have to find a way to manage.”
- “What we need is deep integration of engine, vehicle, and cooling systems.”
- “Caterpillar does different levels of research to solve different kinds of problems: simple/low technical risk, complex/moderate technical risk, very complex/high technical risk. It is the very complex problems with a high degree of technical risk where DOE’s help is most needed.”

Bob Weber of Navistar...

- “Customer and industry wants (higher horsepower, fuel-efficient engines, improved visibility, aerodynamic styling, durable vehicles) and public demands for clean air and less noise are challenging existing thermal management technologies.”
- “Customer demands require less cooling package space, public demands require more — we need larger fans turning faster or new technology *now*. Which is where the government/industry partnership comes in.”

Sid Diamond of DOE...

- “Our method of increasing fuel efficiency and reducing emissions is to view and analyze heavy vehicles as a total integrated system — if we tweak something in front, what effect does it have on the remainder of the vehicle?”
- “Industry was, at first, reluctant to participate. The attitude was, ‘You show me something. I’m not going to tell you a thing.’ The first workshop bombed. It was horrendous. We had to go back to the beginning and establish a relationship...get to know and learn to trust each other.”

Dr. James Eberhardt, Director of OHVT, opened the workshop by challenging those present to work with DOE to come up with innovative solutions to thermal management issues and other challenges facing the heavy vehicle industry. Other keynote speakers at the workshop — Sid Diamond, Team Leader of OHVT’s Vehicle Systems Technologies Group; Marty Wambsganss, who leads Argonne’s thermal management efforts; Mark Moeckel, of the Engine Research Division at Caterpillar, Inc.; Bob Weber, Chief Engineer of NGV Chassis for Navistar International Transportation Corporation; and Frank Stodolsky of Argonne, who has been a key player in DOE’s heavy vehicle research programs — amplified Eberhardt’s message that the time is right to work together to develop and implement new technologies.

With input from workshops such as these, OHVT is developing a technology roadmap for heavy vehicles that will serve as a foundation for OHVT’s multiyear program plan to guide its research and development efforts.

The following are excerpts from Eberhardt’s presentation.

How Important Are Trucks to the U.S. Economy?

A healthy national economy depends on efficient heavy vehicle transportation. Much of the gross domestic product depends on our ability to move goods around efficiently. Industry no longer has the luxury of warehousing its products — these goods have to be moved when they come off the line. It’s difficult to name one manufacturing product that was not on a truck at some point.

OHVT has a \$60 million budget this year. While others’ budgets are being cut all over Washington, ours has gone up 33%. Congress recognizes the importance of trucks to the national economy. But this large and growing number of high-way trucks has had a nationwide impact on fuel consumption and emissions.

What Are the Impacts of Trucks?

In just 25 years, from 1973 to 1997, the United States has increased its energy consumption from 74 to 91 quads per year. One quad of energy equals 340,000 tank cars of crude oil — enough to stretch end to end from Miami to Seattle.

Virtually all of the U.S. increase in fuel consumption of the past few years is caused by trucks, including vans, pickups, and sport utility vehicles (SUVs) — all of which are trucks. In 1996, for the first time, the amount of fuel used by trucks exceeded that used by cars. Class 3–8 trucks are responsible for 25% of total U.S. fuel consumption. Here are some



other statistics that indicate the importance of over-the-road (Class 8) trucks in the United States:

- Class 8 trucks: 300,000 units/yr sold
- 2 1/2 million on the road
- 5,000 people/yr killed in truck-related accidents
- A net of 100,000 trucks/yr added to the road



Experts from industry and the national laboratories gather at Argonne to help DOE solve thermal management problems in heavy vehicles.



“If you don’t believe global warming is real now, what about in 10 years, when we add a million more trucks to the road?” — OHVT Director Dr. James Eberhardt.

If you don’t believe global warming is real now, what about in 10 years, when we add a million more trucks to the road?

What Steps Need to Be Taken?

After the oil embargo in the 1970s, we were going to be independent of imported oil by 1985. Although we’ve made some progress, we’ve got a long way to go. We have the capability to cut our dependence on imported oil, but there is no one, easy answer to the problem. We have to look at all of the technologies, including better management of thermal energy in heavy vehicles, the topic that brings us here today.

We know that diesel technology is still the most efficient, convenient, and energy dense technology. Today’s heavy vehicle engines are not your daddy’s diesels; they are cleaner and quieter. The technical strengths of the diesel-cycle engines and the potential shown by advanced diesel engine technologies to use fuels made from alternative feedstocks and to reduce exhaust emissions to very low levels are encouraging. Our approach must be based not just on fuel efficiency, but on fuel flexibility.

Emissions are way down over the past few years, but not enough. Heavy vehicles must meet U.S. Environmental Protection Agency/California Air Resources Board (EPA/CARB) standards by 2002. The problem? When you reduce emissions, for example through exhaust gas recirculation (EGR), you reduce efficiency. Losing 4 efficiency points is enough to put you out of business. We’ve got to find a way to make EPA and your customers happy.

How Can We Help Each Other?

The goal of the OHVT program is to partner with industry and the national laboratories to make diesel engines more fuel-efficient, lower emissions, and explore the use of alternative fuels. The consensus of the trucking industry is that the time is right for assessing the state of the art in thermal management in large trucks and for developing and applying new thermal management systems. To implement these new systems successfully will require close cooperation among equipment suppliers, engine manufacturers, truck manufacturers, and researchers.

We need industry to guide our efforts; industry can tell us whether they’ve tried something already — you can keep us focused on the usable as well as the possible.

You are paying for our efforts. So we are asking you, our customers, how we can best team up to use the unique research capabilities of our national laboratories to address some of your most pressing problems. By leveraging our joint resources, we can solve these problems more quickly and at a lower cost.



Strengthening the Bond

DaimlerChrysler plant adopts weld monitor developed by ANL industry partnership

DaimlerChrysler's new state-of-the-art Indiana Transmission Plant (ITP) in Kokomo, Indiana, which manufactures and assembles transmissions for the Jeep Grand Cherokee, is abandoning its current laser weld monitoring systems in favor of a new infrared (IR) laser weld monitoring technology pioneered by researchers at Argonne. The switch to the new technology, which has been further developed and commercialized by Spawr Industries, is expected to be completed by March 2000, according to company spokesman Jack Evanecky, area technical manager at ITP.

Throughout the automotive industry, laser welding has been rapidly overtaking traditional arc welding technology as the state of the art in recent years, but an easy-to-use, cost-effective means of detecting bad welds has been lacking. At ITP, where the production rate for gear-train components is 1,600 per day, welds were monitored by means of a cumbersome, expensive process that required immersing bulky parts in dunk tanks for testing via ultrasound; the test units cost \$23,000 apiece for the equipment alone, plus another \$100,000 for probes and automation. The ultrasonic equipment also poses a maintenance challenge and is highly susceptible to false positives (identifying satisfactory welds as defective).

Enter the IR weld monitor, initially developed by then-Argonne engineer Keng Leong and his colleagues in cooperation with private industry and USCAR's Low Emissions Partnership (LEP). The monitor uses a passive sensor and related optics to detect heat from directly above laser welds as they are made ("real time" operation), so testing doesn't add to cycle time. It provides feedback in the form of ac and dc voltage traces that carry information about the weld's surface, penetration depth, uniformity, spattering, presence of impurities, etc. Spawr Industries (Lake Havasu City, Arizona) integrated the Argonne researchers' technology into a laser beam delivery system that permits better control of process variations. Spawr offers the monitor as an off-the-shelf commercial product for \$17,000 (with a personal computer and a scraper optic).

DaimlerChrysler bought two of the Spawr IR weld monitors for its ITP plant earlier this year. Over the summer, Evanecky and Spawr's owners shared their ideas for improvements, "playing with the technology, exploring the limits and trying to get a handle on a good process window." At present, four of the new units are in operation on the plant floor, and seven more will be installed (and process windows established) soon, entirely replacing the more expensive conventional units. "I have also purchased two additional units to be installed on our universal laser workstations," says Evanecky, "to act as production support for the 11 systems; this makes a total of

13 Spawr units that will be in operation by mid-summer of 2000." Cost savings, in equipment alone, are projected at well over a million dollars. In addition, by eliminating the need for destructive testing (once a routine operation) of welded components, the new technology is expected to cut scrap production by 10%.

Two more of the new IR weld monitors are being evaluated at Kokomo Transmission Plant (KTP), a sister facility to ITP. According to Evanecky, KTP is also very interested in replacing its existing ultrasound systems wherever possible; that switch could mean buying 20 more of Spawr's monitors. And after that? Evanecky doesn't hesitate to predict that the applications will go well beyond their present efforts. "There's a whole lot of welding required in DaimlerChrysler's manufacturing operations," he says. "I really don't see any limit to the potential for using this technology."

Initial development of the IR laser weld monitoring technology at Argonne was supported through cooperative research and development agreements between DOE and Delphi Energy & Engine Systems and the LEP (consisting of General Motors, Ford, and DaimlerChrysler).



This weld monitor, developed at Argonne, is now being used in DaimlerChrysler's manufacturing operations.

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Mapping Hybrid Territory

A tiny torque sensor helps leverage testing of Toyota Prius

This fall, Argonne engineers spent several months coaxing a Toyota Prius — the first mass-produced hybrid-electric vehicle — into revealing its technical secrets. Their main quest was to understand the car's 4-cylinder, 56-hp gasoline engine, the first designed from the ground up for a hybrid vehicle. Their data will help researchers improve computer models for designing and evaluating new hybrid vehicles.

The goal of the testing was an engine map — the set of data that relates an engine's fuel consumption, power output, and emissions. Mapping an engine is generally a straightforward task; the engine is removed and connected to a dynamometer, which measures the engine's torque. In the Prius, however, "getting an engine map is difficult because the engine is so highly integrated with the drivetrain and computer control system," said Bob Larsen, manager of the Advanced Powertrain Test Facility. "Getting the engine to work outside the vehicle is almost impossible."

Instead, the Argonne team hit on a clever way to get the engine map with the engine still in the car. They had heard about a new kind of torque transducer, made by HBM Technologies of Germany, that measures about 5 inches in diameter but is only 1.5 inches thick. "To our knowledge, nobody has ever used this type of transducer to measure engine torque directly in an intact drivetrain," said Argonne engineer Mike Duoba.

First, technicians at Argonne encased the transducer in a housing the size of a small snare drum. Then they squeezed this housing into the already cramped engine compartment of the Prius. "We basically made the transaxle grow," said Duoba. "Our shops did an amazing job of shoehorning it in." Staff from HBM Technologies helped test the sensor before the final welds marked the point of no return.

The "enhanced" car was put through rigorous engine testing at General Motors' Vehicle Emissions Laboratory and at

Prius Powwow

In October, Argonne hosted a data exchange workshop for engineers from U.S. automotive and government laboratories who have also tested the Prius. According to Bob Larsen, "The meeting allowed us to pool our knowledge, see if we're getting the same results, and discuss a common interpretation of the Prius' control strategy." He added, "We believe our innovative approach can add insights to the U.S. auto industry's work and provide a knowledge base for the government. This facility can provide benchmark data to the industry as a whole."



Argonne technicians squeezed an ultra-slim torque transducer into the drivetrain of a Toyota Prius to gather data while the engine was fully integrated with the control system.

Argonne. Argonne also conducted detailed testing of the hybrid control strategy, collecting up to 16 streams of data on all aspects of power train operation simultaneously. They even instrumented a second Prius for mobile testing during on-road city and highway driving.

The engine map obtained by Argonne showed that the control system of the Prius succeeds in keeping the engine in a very narrow operating regime. In fact, it was difficult to get the engine to operate outside this optimal pattern. "We had to trick the engine into running under abnormal conditions, such as at very high speeds or very low battery charge" said Duoba.

The resulting data show that the engine efficiency is about 36%, an extremely high value for a gasoline internal combustion engine. The efficiency of an average car in normal operation is 25%. "The key to this efficiency is the way Toyota chose to configure the flow of power among the engine, the motor and generator, and the braking system, which recaptures energy that would otherwise be lost," said Larsen.

The Prius research program is sponsored by the U.S. Department of Energy's (DOE's) Office of Advanced Automotive Technology. Toyota provided guidance in understanding the vehicle. The testing and data are part of a larger research effort involving several national laboratories and the Partnership for a New Generation of Vehicles, which includes the major U.S. automakers. Argonne plans to use the same testing approach on forthcoming hybrids.

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A Solid Idea

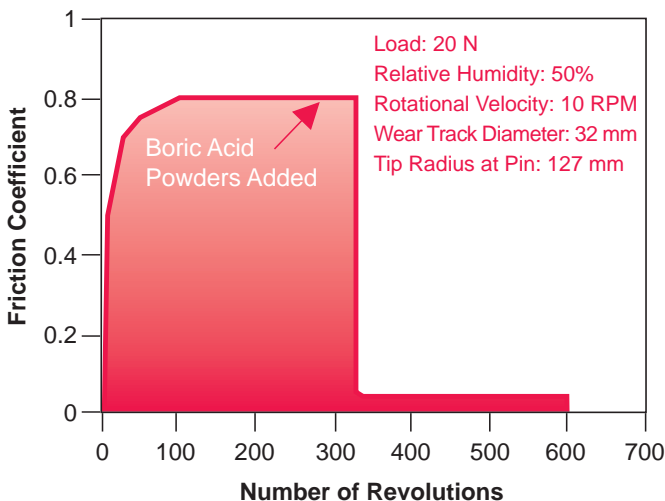
Argonne finds an environmentally friendly lubricant for automotive metal forming

One of the best ways to increase fuel efficiency in today's vehicles is to reduce their overall weight by using lightweight aluminum- or magnesium-based alloys. But forming these alloys into automotive body parts is very difficult, mainly because of the high friction of the alloy surfaces, the extreme pressures required for metalworking operations, and the inability of conventional lubricants to prevent wear under the extreme conditions encountered during metalworking. Also, most conventional lubricants are flammable and contain chlorine, phosphorus, and sulfur-bearing additives that are potentially hazardous: removing these lubricants from finished products and treating them for disposal is difficult and costly.

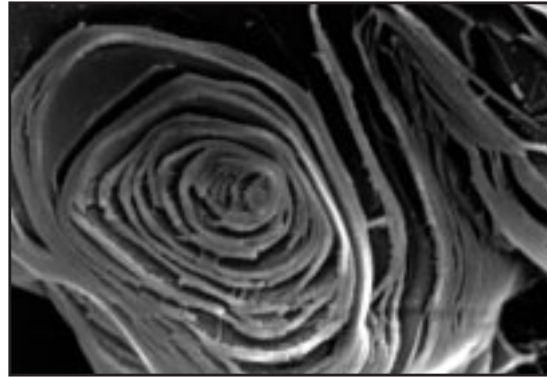
Several years ago scientists at Argonne National Laboratory discovered that boric acid, used as a lubricant, is one of the most slippery solids around. Tests show that boric acid can provide friction coefficients as low as 0.02 to 0.05 — one-fourth to one-sixth the value of other, more expensive solid lubricants. Its exceptionally low friction coefficient prevents the aluminum- and magnesium-based alloys from sticking or transferring to the die or roll surfaces.

The lubricating mechanism of boric acid is controlled by its special structure. The compound is crystallized in layers in which the atoms are tightly bonded to each other. The layers themselves are weakly bonded; when stressed, they shear and slide over one another easily, so friction is low. The strong bonding between the layers prevents direct contact between sliding parts, thereby minimizing wear.

“Boric acid is a cheap, abundant, and environmentally friendly substance that greatly reduces friction and wear of dies and



Friction decreases dramatically when boric acid powder is placed between two sliding steel components.



Photograph shows the layered crystal structure of boric acid.

molds and at the same time provides an ultrasmooth surface finish on final products. After metal-forming operations, parts can be rinsed in water to remove the excess lubricants — no toxic or flammable solvents are necessary,” said Argonne principal investigator Ali Erdemir. He also pointed out that use of boric acid decreases the unit cost for automotive parts because the near-perfect finished products don't require secondary machining or grinding.

Other potential automotive applications for boric acid include its use as a lubricant for gears and bearings. Boric acid may also be mixed with existing liquid and solid lubricants; if the conventional lubricant is inadequate, boric acid becomes active and acts as a backup.

The discovery of boric acid as a solid lubricant was an R&D 100 award winner in 1991. The awards recognize “the most significant technical products of the year” as selected by R&D magazine on the basis of importance, uniqueness, and usefulness. Now Argonne is working on identifying specific lubrication problems in aluminum-forming operations and testing a series of boric acid formulations under shear and stress conditions typical of cold-forming operations (using actual dies and rolls). We are coordinating our efforts with aluminum manufacturers who are interested in employing boric acid lubricants for large-scale industrial use. We also recently licensed the technology for use as a grease additive.

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With more than 80 representatives from government, industry, and the national laboratories who are involved in the transportation field, I attended DOE's thermal management workshop here at the Laboratory in October (see story on page 2). The significance of the name, thermal management *workshop* — not conference, symposium, or presentation — was not lost on any of us. After the first 10 minutes of the opening presentation — by Dr. Jim Eberhardt, Director of DOE's Office of Heavy Vehicle Technologies — it was clear that we were there to work. By the end of the two-day session, DOE expected to have the basis for a multiyear program plan to focus its research and development efforts on viable technologies that will efficiently manage the heat generated by diesel engines and still meet EPA's 2002 mandate for emissions reductions. In four technical breakout sessions, representatives from the truck and engine manufacturing companies (Caterpillar, Navistar, Kenworth, Mack, Cummins, Freightliner, Western Star, Detroit Diesel), cooling system and equipment manufacturers (including Modine, Allied Signal, Borg-Warner, Valeo, Thermo King, American Cooling, Webasto), and many of the national laboratories worked together to identify the challenging issues of thermal management and to define and prioritize research needs. Even in this era of unprecedented cooperation between government and industry, these workshops are a milestone in DOE/industry efforts to collaborate on solving problems that affect us all.

Jim and the other presenters emphasized over and over that both industry and government have much to offer. Industry keeps the research focused on affordable technologies that will

be acceptable to consumers and offers the know-how to test the concepts we develop together. At the national laboratories, we have state-of-the-art facilities, innovative concepts, and some of the leading experts in the field. At Argonne in particular, George Fenske, Ali Erdemir, and their colleagues are conducting award-winning research in coatings and lubricants (see story on page 6); Marty Wambsganss heads Argonne's research in compact heat exchangers, nanofluids, and other thermal management technologies; Frank Stodolsky leads our efforts in life-cycle analysis of truck energy use and emissions for alternative fuels and technologies; and Raj Sekar's group has gained national recognition for their work in making diesel engines cleaner and more efficient (see *Fast Trax*). Argonne also has the CAVE, the Advanced Photon Source, and other unique facilities where government and industry can work together to solve transportation technology problems.

When it all comes together, we have success stories like the weld monitor described on page 4 — a concept developed in the laboratory, tested and commercialized by industry, then put to work to improve quality and safety and make products more affordable for everyone.



Larry R. Johnson
Director



Ali Erdemir, a materials scientist in Argonne's Energy Technology Division, recently received the American Society of Mechanical Engineers' Innovative Research Award, which recognizes his consistent and pioneering contributions to the field of tribology. Among his many achievements, Erdemir and two of his colleagues, **George Fenske** and **Osman Eryilmaz**, developed a coating with a friction coefficient that is 20 times lower than that of the previous record holder. Erdemir also received a 1999 Argonne Director's Award, two R&D 100 Awards, a Discover Magazine Award, and the STLE Edmond E. Bisson Award for his work with solid lubricants and carbon coatings.

Raj Sekar, of Argonne's Energy Systems Division, was honored at a banquet on October 19 by the Internal Combustion Engine Division of the American Society of Mechanical Engineers. Sekar received the Meritorious

Service Award, "For many years of loyal service and worthy contributions on numerous committee assignments within the Internal Combustion Division. For guidance and leadership in division activities to the benefit of the engineering profession and the ASME." Most of Sekar's career, spanning 34 years, has focused on internal combustion engines. He currently manages the Engine and Emissions Research Section in Argonne's Center for Transportation Research.

On September 9, **George Fenske**, of Argonne's Energy Technology Division, met with a group of representatives from Castrol Oil to explore collaborative research projects in the areas of tribology, molecular modeling, characterization of lubricants (and additives), and after treatment catalytic poisoning. The visit represents another step forward in Argonne's continuing efforts to establish mutually beneficial relationships with the transportation industry.



Argonne is seeking industrial partners to develop advanced transportation technologies. The following types of working arrangements can be made:

- In a *reimbursable R&D agreement*, Argonne's industrial partner pays the full cost of the research performed. The company generally takes title to any inventions, and proprietary information and research results are kept confidential.
- In a *cost-shared R&D agreement*, Argonne and its industrial partner share the costs of research. The company may obtain rights to intellectual property developed by Argonne. Proprietary information is kept confidential, and research results may be protected from disclosure for up to five years.

■ *Licenses* for Argonne inventions and software may be granted to companies that wish to develop them into marketable products or processes. Licenses may also be part of other agreements.

■ *Personnel exchanges* and *technical assistance* projects can be arranged with Argonne for short-term or rapid-turnaround work.

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