tech briefs

Edited by ***Darlene Fritz***

Siemens' wedge brake hits the ice

While the prospect of test-driving **Siemens VDO**'s electronic wedge brake (EWB) system on the ice of a frozen lake in Arjeplog, Sweden, may *sound* enticing, it's the danger of skidding into a 4-ft tall snowdrift and totaling a vehicle outfitted with one of only two advanced prototypes that enters my mind as I press the accelerator.

Let's try not to wreck, I think to myself.

The test vehicle, a **BMW** 5 Series sedan, is co-piloted by a Siemens engineer who acts as both driving instructor and onboard diagnostics technician.

"How do you like the feel of the brake pedal?" he asks.

"It's good," I say, as we motor along on the ice. "Could be a little more responsive I suppose."

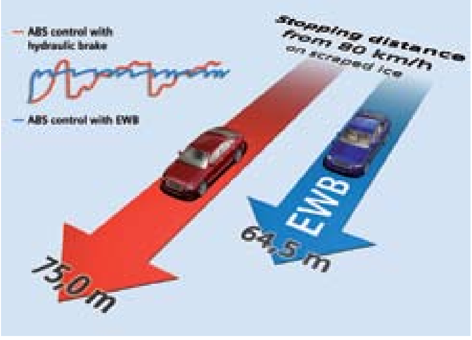
The engineer makes some minor adjustments on a dashboard-mounted laptop—which communicates with a bulky prototype ECU temporarily located in the trunk (which will eventually be shrunk to fit under the hood)—and asks me to do a hard brake. I indulge him and we come sliding to a rather quick halt on the ice, both of us lunging forward a bit in our seats.

"Is that better?" he asks.

My co-pilot then instructs me to accelerate the vehicle to 50 mph (80 km/h) and hard brake again, this time on the polished ice portion of the test track. We slide a considerable amount further this time, but the EWB remains smooth and quiet while the ESC keeps backend slide to a minimum. These contrasting scenarios, on both scraped and polished ice, are not only notable in performance, but in how different the EWB reacts when compared to hydraulic braking systems, like conventional ABS.

The EWB doesn't exhibit the noisy, stuttering sound that conventional ABS systems do on ice, and you don't get the choppy resistance in the brake pedal either. EWB, quite simply, just stops the car in a shorter amount of time and with less commotion. According to the company, the system operates 50 times faster than conventional brakes. The differences between brake-by-wire and hydraulic braking, I begin to realize, are rather significant.

The EWB system being tested at Siemens' frozen lake test track in Arjeplog, Sweden.



Siemens' wedge brake reduces braking distances at an average of 15%.

By electronically transmitting signals throughout the car (hence the term brake-by-wire), the EWB system bypasses the use of hydraulics altogether. This is good for several reasons, key among them is that the response time of an electric motor is far quicker than that of pressurized hydraulic fluid in a brake line. Instead, Siemens' system focuses on converting the kinetic energy created by the vehicle's own momentum into friction.

"We changed how we generate the braking force; everything else is the same," said Bernd Gombert, Chief Technology Officer of Siemens VDO's chassis and safety division, during a technical presentation preceding the test-drive.

Indeed, all the traditional disc brake components remain intact, from pads to rotors. But where the system differs is in its use of electronic actuators and an innovative caliper design. To engage the system's wedge-bearing mechanism, a caliper-mounted motor (one per wheel) controls a brake pad that moves over a roller bearing that the supplier describes as "a miniature saw blade with valleys and peaks." The "valleys" are the position where the metal rollers are at rest. When a brake signal is received, the electric motor moves the brake pad on the roller bearing in the vehicle's respective direction. The rollers then climb toward the "peaks" in the roller bearing. Once the brake pad touches the rotor, the aforementioned kinetic energy is converted to friction and the vehicle is slowed.

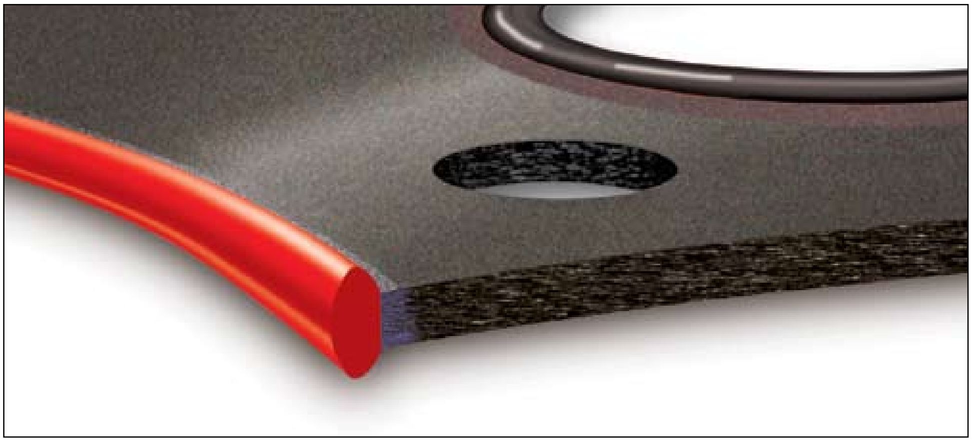
Several days prior to media arrival in Arjeplog, **DEKRA**, an independent automotive testing firm based out of Germany, concluded that Siemens' EWB-equipped vehicles provided 15% shorter stopping distances than their conventional ABS-equipped counterparts—an average difference of about 33 ft (10 m) when clocked at 50 mph (80 km/h).

While this improvement in stopping distance is obviously a key feature of the EWB when compared with hydraulic sys-

ISS Meets the Need for Technically Reliable, Cost-Effective Sealing

OEMs and OEM suppliers face two relentless business challenges: to constantly improve their products' lifespan and performance, while controlling and even reducing costs wherever possible. It takes a unique solutions provider to meet both challenges.

We're equipped to meet those challenges. Interface Sealing Solutions (ISS) is a new Tier One supplier of technically reliable, cost-effective sealing solutions for the heavy-duty diesel, automotive drive-train, and other key markets. ISS enters the market with roots in a company known for its technical innovation, TS 16949 certification, and a powerful new product called Select-a-Seal® Generation II.



Diesel Sealing Solutions

Much of our work centers on meeting the demanding requirements of world-class diesel manufacturers in applications including oil pans, bearing covers, fuel pumps, oil pumps, thermostats, water and hydraulic pumps, and gear cases.

We know, and have helped solve, many of the challenges you face. From providing long-term durability, to meeting ever-increasing warranty expectations, to developing sealing solutions for engines that are smaller, lighter, and run hotter, we know that a "solution" means more than just filling a spec.

It means satisfying demanding requirements with technical reliability. It means an integrated supply chain to ensure product availability and dependable delivery. It means containing costs and speeding time to market through rapid prototyping and a customer-focused process.

And, most importantly, it means unique, innovative products engineered to provide the affordable durability that today's global automotive and heavy-duty diesel markets expect from a Tier One supplier.

Proven Product Portfolio

The ISS product portfolio includes a range of advanced sealing solutions used in thousands of applications, with millions of miles of high-volume, usage-proven performance.

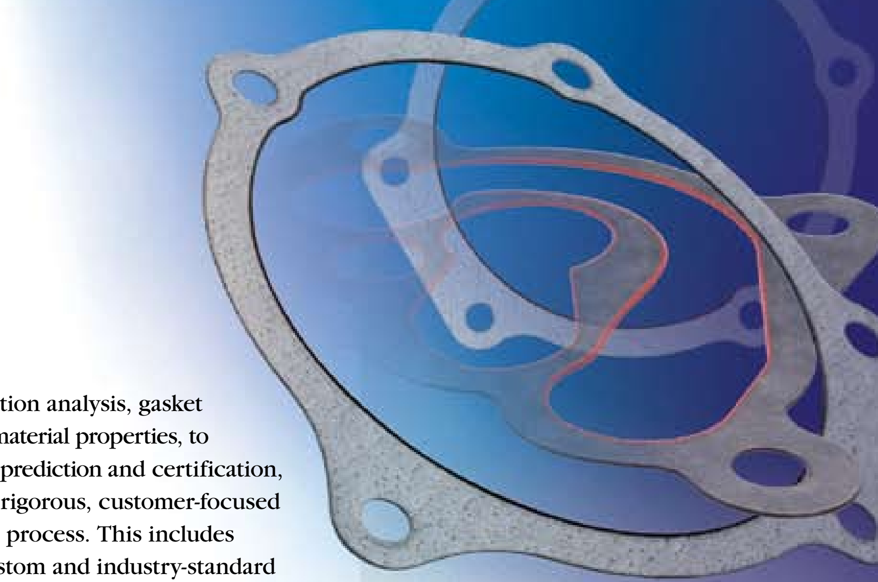
With Select-a-Seal rubber-edged composite (REC) gaskets, ISS offers an innovative category of sealing technology that combines an elastomeric edge with a compressible base.

REC gaskets provide stable bolt-load retention (BLR) and an adhesion-based sealing mechanism that can improve gasket reliability, reduce warranty expense, and achieve a Lower Total Cost (LTC).

Select-a-Seal Gen II builds on that value: it's a durable sealing solution with the unique adhesion advantages of the first generation of REC seals, with an improved performance profile that delivers stable BLR at 175° C.

Like other Select-a-Seal products, SAS Gen II can consistently outperform other sealing technologies such as RTV silicone, molded-rubber seals (i.e. press-in-place seals), and rubber-coated metal gaskets.
It is well suited for:

- Out-of-flat flanges
- Non-uniform loading
- Rough or non-machined flange-surface finishes
- High shear stresses
- Wide bolt spans



The TS certified Select-a-Seal manufacturing process uses a proprietary coating that forms an edge on the inner aperture(s) of each gasket, eliminating the need for molding or costly and time-consuming tool-and-die production. This speeds prototyping and reduces overall production costs compared to many competitive sealing solutions.

SAS Gen II is the first of several proprietary next-generation sealing technologies that will be available exclusively through ISS. In addition, ISS also offers a range of other sealing products to match specific application requirements.

UL REGISTERED FIRM ®

REGISTERED TO ISO 9001:2000
AND ISO/TS 16949:2002
FILE NUMBER A10517

Certified Innovation

ISS offers both certified excellence and proven expertise. The Lancaster, Pa. production facilities and Technical Center have been registered by Underwriters Laboratories, Inc. to the International Organization for Standardization (ISO) 9001 management system standards and TS 16949, the Harmonized Standard for the Automotive Supply Chain, the automotive industry's highest quality standard.

From application analysis, gasket design, and material properties, to performance prediction and certification, ISS follows a rigorous, customer-focused development process. This includes extensive custom and industry-standard validation capabilities. The result: solutions that precisely match your unique performance and cost requirements.

For ISS, a successful solution is one that yields the greatest value in end-use. This typically involves reducing costs associated with maintenance, repair, and warranties. It is achieved through our unique combination of engineering experience, rapid prototyping, VOC for proof of concept, and responsive onsite and virtual onsite engineering resources.

ISS—Affordable Durability

As global requirements for performance improvement, cost control, and certainty of operation become more aggressive, and as the demand for advanced "green" diesel grows, ISS focuses on what matters most: technically reliable, cost-effective sealing solutions.

Integrated Supply Chain

ISS is equipped to be a cost-effective, integrated sealing solution supplier at the Tier One level. A new, lean production facility provides sufficient capacity to accommodate broad swings in market demand, while satisfying customer needs for contingency planning.

The new site is equipped to complete all required manufacturing steps for SAS Gen II, including coating, curing, and inspection, and can house additional production modules to keep pace as manufacturing requirements expand.

This new facility augments SAS production at a nearby location. Both facilities, as well as manufacturing plants in Croghan, NY and Marshalltown, IA, are TS-certified. In addition to these resources, manufacturing plants in Beaver Falls, Fulton and Hoosick Falls, NY are registered to ISO 9001, as is a Research and Development Facility in Lancaster, Pennsylvania.

ISS is also building a network of global resources, with offices in Europe and Asia and a gasket manufacturing facility in China scheduled to be added soon.

For more information, visit www.interfacesealingsolutions.com, or call 1-877-9GASKET (1-877-942-7538.)

InterFace
Sealing Solutions

Technically Reliable, Cost-Effective Solutions

The EWB's braking mechanism takes advantage of the wedge principle's self-energizing effect.

tems, there are several other benefits as well. Some benefits include: longer brake pad life; use of standard 12-V architecture; increased crash safety via adjustable e-pedal; wheel-specific braking (torque vectoring); no brake fluids; decreased fuel consumption as a result of system's light weight; reduction of parts; and 78 ft^3 (22 L) more space under the hood thanks to a small package ECU.

While Siemens would not disclose which of its OEM customers were interested in the system, the supplier did announce that the wedge brake will enter series production in 2010.

Matthew Newton

Clock ticking for new A/C refrigerant selection

Engineering top management at most U.S. and Asian car companies is being urged by the **SAE** Interior Climate Control Committee to become aware of a too-close-for-comfort deadline to find and validate a new A/C refrigerant.

Engineers in the trenches understand the problem: the European Community's legally mandated phaseout of R-134a starts in 2011, and no low-global-warming replacement has been identified yet. However, the level of concern has to reach management to spur the industry into a coordinated effort, explained SAE ICCC chairman Ward Atkinson of **Sun Test Engineering**. The EC regulation limits the global warming potential (GWP) to 150 (as a multiple of carbon dioxide, which has a GWP of 1.0).

The EC has just rejected a request for an extension from several European auto industry representatives. All manufacturers export to Europe, and European makers export to the U.S. and Asia, so a European regulation requires a worldwide solution, despite the non-European decision to stay with R-134a—for now.

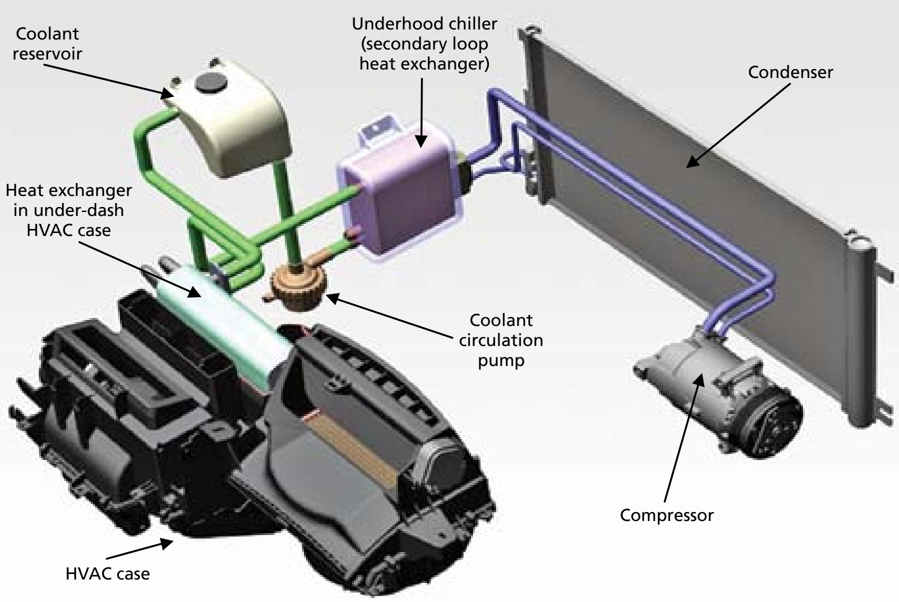
There are several proposed refrigerant choices, none obvious, none proven, and all raising long-term complex engineering challenges greater than the 1990s switch from R-12 to R-134a, which took place at a cost of $8 billion in 1990 dollars, according to a United Nations study estimate. Without coordination to sort out the choices and make a pick, multi-billion-dollar mistakes are possible, warned Atkinson.

The EC regulation timetable means auto manufacturers need to issue contracts for new components within the year to have them ready for 2011 new-car introductions. "Continuing production" cars can use R-134a until as late as 2016.

The 1990s changeover from R-12 to R-134a, both single-compound refrigerants, dealt with stratospheric ozone layer depletion. R-134a was well known, yet problems took years to solve.

Atkinson noted that some work is underway in Europe and Japan, and that an SAE Cooperative Research Group (CRP 150) has U.S. **EPA** support here, but engineering resources are stretched thin.

European manufacturers know how cost, performance, and durability issues hampered efforts to make carbon dioxide work as a refrigerant, despite the appeal of its global warming potential, which is just 1.0. Carbon dioxide has not been ruled out completely, but the manufacturers asked refrigerant producers for alternatives, and blends were proposed by **Honeywell**, **DuPont**, **Ineos Fluor**, and **Solvay Fluor**. Flammability can quickly be determined, but toxicity testing takes



R-152a could be used in a secondary loop system, in which the refrigeration system is confined to underhood, where it chills a liquid coolant in an additional heat exchanger. The chilled coolant then is circulated by a pump to another exchanger in the dashboard HVAC case.

years, although preliminary results for go/no-go decisions may be ready later this year. However, without final toxicity results, any choice is a gamble. The SAE ICCC hope is that coordination would bring the broadest-possible industry expertise to the subject.

If just one refrigerant maker has favorable early results, the industry might have to hope that its long-term toxicity test results are good. That would not be known until late 2009, when car manufacturers would already have invested in components, integration, and durability testing. With coordination, better information would be available faster, enabling industry to set the best course, Atkinson said.

If there are more refrigerants to evaluate, and no coordination, a company might have to work with all of them, a potentially costly solution without a clear-cut result.

Atkinson said that despite industry's obvious preference for one worldwide refrigerant, variable performance across different climates likely means there would not be one global choice.

Any blend introduces new problems for automotive A/C. There are two types of blends, one of which is an azeotrope, which vaporizes and condenses at the same temperature at constant pressure, similar to a single-compound refrigerant like R12 or R-134a. However, the one proposed azeotrope has raised concerns.

The second type of blend is a zeotrope, which goes through a composition shift during vaporization and condensation at constant pressure. This affects component design and system calibration. Because higher-pressure ingredients normally leak out at a greater rate, the composition could shift beyond the system's ability to maintain performance. That puts a premium on making the system even more leak-tight than in the newly enhanced R-134a systems. The auto industry has never dealt with a blend refrigerant before, and would likely face a steep and potentially expensive learning curve.

The U.S. EPA requires recovery of all refrigerants, as no venting is allowed under the Clean Air Act. Blends cannot be recycled at garages, unlike single-compound refrigerants such as R-12 and R-134a. Blends would thus require more-complex service systems, perhaps including off-site reprocessing or destruction, at unknown cost and energy consumption.

To provide additional choice, EPA revived **Delphi**'s R-152a "secondary-loop A/C" project and enlisted support from **Fiat**, **General Motors**, **Ford**, and **Volvo**. R-152a is a highly efficient refrigerant, but it is also mildly flammable. However, EPA has said it would be approved with the appropriate safety systems.

The secondary-loop system confines R-152a to underhood, where a heat exchanger chills a coolant, which then is circulated to an under-dash heat exchanger. The second (underhood) heat exchanger reduces system efficiency, but R-152a's greater cooling efficiency helps to minimize the loss. If it is engineered to provide enough cold storage, the system could provide A/C cooling even with the engine off, without the added cost of an electric compressor. Secondary loop with liquid cooling also would simplify a rear A/C installation.

However, production development of secondary-loop R-152a components would require financial commitments, and solving inherent packaging difficulties.

Refrigerant changeover also is on California's Air Resources Board (**CARB**) agenda. CARB has proposed a replacement of R-134a in medium/heavy-duty and off-road vehicles in 2015. And where California goes, the Northeastern states generally follow.

Paul Weissler

Battery breakthrough on the horizon?

A joint venture between **Nissan**, **NEC**, and NEC subsidiary **NEC TOKIN** could bring significant advances—with the potential for a breakthrough technology—in the development of future battery systems for automotive applications. The joint venture company, **Automotive Energy Supply** Corp. (AESC), is to focus on lithium-ion systems for wide-scale application by 2009.

A statement by the companies revealed that AESC would focus on the development, production, and marketing of advanced lithium-ion batteries designed to power future generations of electric-powered vehicles. It added that AESC would produce batteries with what it termed "a set of unique properties."

AESC will produce lithium-ion batteries for a wide range of high-technology electric vehicles, including fuel cell.

Nissan and NEC Group are to invest around US $4.1 million in the partnership, with AESC operating as an independent company. By the middle of next year, the partnership will be expanded to include mass production and sales. The new joint venture will become a leading company in mass production of lithium-ion batteries for the global automotive community using pioneering technologies developed by Nissan and NEC group, according to the companies' statement. Nissan will focus on the cell stack for real-world application in electric-powered vehicles.

Nissan's partnership with NEC represents a key component of its "Nissan Green Program 2010" mid-term environmental action plan, announced in December 2006.

"As a 'Sincere Eco-Innovator,' Nissan continues to develop forward-looking 'green technologies' that contribute to sustainable mobility," said Carlos Tavares, Executive Vice President of Nissan. "Nissan will introduce our own original hybrid vehicle by 2010, followed by our next-generation electric vehicle in the early part of the next decade.

"Together, Nissan and NEC's engineers have addressed the key challenges of cost, performance, safety, and reliability; we believe that we have a breakthrough technology in the lithium-ion battery product we will produce. Through AESC, this battery will be made available to all automakers, and we expect this could further accelerate the development of future generations of eco-friendly vehicles," explained Tavares.

He added that NEC brought to the partnership many years of knowledge, expertise, and resources in lithium-ion battery technology through NEC TOKIN's experience in producing batteries for industrial use.

The first AESC battery would be available quickly to meet the eco requirements of customers, said Konosuke Kashima, Executive Vice President of NEC, adding, "Moreover, the alliance with Nissan guarantees Nissan as a prospective customer of AESC. We will also strive to accelerate growth by expanding marketing to auto manufacturers worldwide."

In their joint statement, the companies also noted that the evolution toward cleaner powertrains would lead to the proliferation of a wider mix of consumer-ready electric-powered vehicles including hybrids, plug-in hybrids, hydrogen fuel-cell vehicles, and electric vehicles. Establishment of AESC demonstrates that both Nissan and NEC firmly believe that lithium-ion battery technology will become an important energy-source solution to achieving a sustainable mobile society. Both companies are confident of a ready and growing market for lithium-ion batteries in the next decade and beyond.

Stuart Birch

Ford delivers fuel-cell demonstrator in 100 days

In January 2007, **Ford** unveiled a plug-in hybrid electric (PHEV) demonstration vehicle, the HySeries Edge. The purpose of the $2-million demonstration vehicle, developed under a 50/50 cost-share program with the U.S. **Department of Energy** (DOE), was to demonstrate a PHEV with a 25-mi (40-km) range from plug-in power and a total range of 225 mi (362 km) on a hydrogen fuel cell.

Two 65-kW (87-hp) electric motors, fed by a 130-kW (174-hp) lithium-ion battery, power the car. The 35-kW (47-hp) fuel-cell package is a "range-extender" that charges the battery—it is not connected to the electric motors. This series hybrid reduces the size of the fuel cell and the complexity of the powertrain, according to Mujeeb Ijaz, Manager for Ford's Fuel Cell Vehicle Engineering unit.

The Ford team's major achievement may not have been simply demonstrating innovative automotive technology, but demonstrating that technology in just 100 days.

"On September 1, 2006, we started building the vehicle," said Ijaz, who noted that this stage was preceded by some design work and powertrain component development that had started in June. On November 5, 2006, the team drove the vehicle's first mile, and on December 8, 2006, the team delivered a vehicle to Gerhardt Schmidt, Vice President of Ford Research, for a test-drive. They built their previous demonstrator in eight months.

The Ford team created a working series hybrid fuel-cell demonstrator in just 100 days.

The HySeries Edge design included a central hydrogen cylinder with the fuel cell and battery pack on either side. Future HySeries powertrain architectures should allow more design freedom.

So what was the rush? "One of the key things we saw in 2006 is that the lithium-ion battery was starting to look quite attractive," said Ijaz. The new battery could hold enough charge to give the plug-in concept the potential to become commercially viable. That is when the hybrid-series architecture came together as more than an idea. Turning it into a working reality—quickly—became vital. Ijaz and his team at Ford felt they needed to display their fuel-cell powertrain at a key meeting in Washington, D.C., in January 2007, and at the Detroit Auto Show where the same powertrain was on display supporting the **Air Stream** concept vehicle. As it turned out, **GM** revealed the **Chevrolet** Volt gasoline-battery series hybrid at about the same time.

There were plenty of challenges, one of which was the fuel-cell management system. The fuel cell, supplied by **Ballard**, required a new control system for it to act as an auxiliary power unit (APU). The fuel cell, acting as an APU, feeds power to the lithium-ion battery, supplied by **Johnson Controls-Saft**, whenever the battery dips below 40% charge.

Another significant project-management challenge was putting this one-of-

a-kind powertrain architecture into a base vehicle, the 2008 model year Edge, which was simultaneously going through its own launch. "The documentation for the base vehicle was not really mature when we started this project," said Rich Scholer, Product Design Engineer responsible for all wiring on the HySeries Edge.

The central packaging of the hydrogen cylinder flanked on either side by the fuel cell and battery pack presented an entirely different weight distribution than the powertrain in the Edge. To stiffen the body for the extra weight, the team developed a unitized body-on-frame structure under the vehicle, according to Ijaz. It emulates a **Land Rover** design used in the LR3. **Roush**, working as a subcontractor to Ford, mechanically integrated the vehicle at its facility in Dearborn and provided some engineers as well.

With a small team of only 18 full-time Ford and 12 Roush co-located engineers, decision-making was fast. This reduced the communication overhead typical of a larger program. Meetings were few and mostly informal, with only one scheduled meeting each week.

Ijaz employed a parallel task structure. The vehicle build started while the design studio worked on what the vehicle would look like with a different tire/wheel package and trim. Design, build, and test of the key components, including the vital fuel-cell APU system, commenced at the same time.

At times, people worked around the clock. "It is a little like a race team," said Ijaz. "This was probably the most intense project I personally have ever worked on," said Mike Brown, a Senior Research Technologist for fuel-cell vehicles with over 30 years of automotive electrical design and development experience.

"We have become good at making battery-powered cars," said Jerry Amey, a Ford electrical engineer who has spent 15 of his 38 years at Ford building developmental electric vehicles. The fact that the HySeries Edge was the seventh Technology Demonstration Vehicle (TDV) in the series under the DOE cost-sharing program demonstrates this long-term commitment. The purpose of the TDV program is rapid technology evolution—building one focused success on another. One result of this commitment is the 100-day HySeries PHEV.

Simple human idealism is at work as well. "It is not just the excitement of building this one car," said Amey. "It is also the thought that you are doing something that could make a better world."

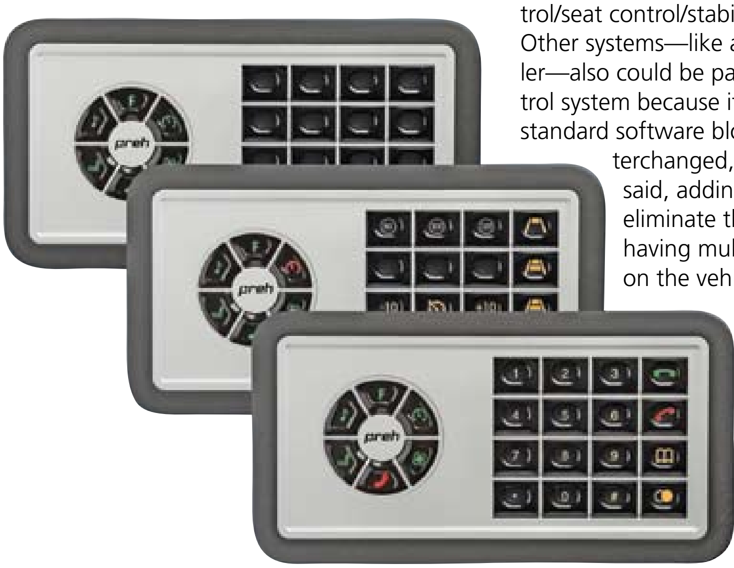
Ijaz agrees. "We are exploring technology that is for the first time looking to be on a path to commercializing a fuel-cell vehicle," he said.

The next step in the evolution of the Ford/DOE program is to build the TDV around the powertrain, rather than trying to shoehorn the powertrain into an existing vehicle like the Edge. The world waits.

Bruce Morey

Preh concept delivers multifunction versatility

The prospect of gaining new business is always appealing, but sometimes the route to getting contracts is not an exact repetition of what a company has done in the past.



Preh's FPB concept uses projection technology with LEDs, a fiber dye, and an LCD for each button. With the FPB system, ordinary switches handle intelligent, multifunction assignments.

"This is unique for us," said Nick Lontscharitsch, mechanical and industrial engineer and **Preh**'s Senior Vice President of Sales in Novi, MI. "All of our other products are evolutions of standard products, such as going from a manual climate control to an automatic climate control system, or going from a knob with a potentiometer to using a potentiometer in drive-by-wire applications, like a pedal-position sensor," Lontscharitsch said.

Preh will stray from its own product-evolution norm when it ventures into the arena of control systems. "We'd like to do everything in one electronic control unit, meaning a combination climate control/seat control/stability control system. Other systems—like a fuel tank controller—also could be part of that single control system because it would be built on standard software blocks that can be interchanged," Lontscharitsch said, adding, "This is a way to eliminate the complexity of having multiple control boxes on the vehicle."

At present, 60% of Preh's automotive business is from driver controls such as steering-wheel buttons, instrument-cluster controls, and other driver-control interface points. Preh's new Freely Programmable Button (FPB) format is a departure from the traditional presentation of driver controls. Instead of adding more driver-control buttons or creating unwanted complexity for simple operations such as changing the radio station or adjusting the seat, Preh engineers have devised a multifunction driver control system.

The FPB comprises 16 buttons, plus six main function buttons. Until the vehicle is started, the FPB grid remains black. Once the ignition is engaged, the six main function buttons illuminate. After a function button is selected, an array of 16 control buttons is highlighted. The icons that illuminate match the task at hand, so if seat adjustment is the requested function, the icons show seating positions; if an HVAC system adjustment is the requested function, the icons show fan speeds and fan-blower directions. "Ninety-six different commands can be done by this simple and intuitive setup," said Lontscharitsch.

Preh has a production-ready modular sensor. This technology would permit separate functions—such as rain detection, windshield defogging, and automatic headlamp activation—to be combined in one sensor. Future comfort-oriented electronics include a sunlight-detection sensor for in-vehicle climate enhancement. "We are using a capacitive technology for our current defogging sensor, and we'd use that same approach for the rain and sun sensors, although for the sun sensor, we'll also integrate an optical sensor," said Lontscharitsch.

Sales for the Preh Group in 2006 were $361 million, up 11.8% from 2005. "About 86% of our sales are from the automotive unit," said Lontscharitsch. Preh was founded in 1919 and is now owned by Germany's oldest private-equity firm, **Deutsche Beteiligung**. The automotive unit, which employs more than 1800 people, has assembly plants in Portugal, Mexico, and Germany. Romania is set to go online in early 2009 with a manufacturing plant for the production of driver control systems.

Kami Buchholz

Researching fuel and combustion technologies

The **UK University of Birmingham** has opened a new laboratory for work on fuels of the future and new combustion technologies, including hydrogen, and gasoline/diesel technology convergence. Industrial partners **Jaguar**, **Land Rover**, **Ford**, **Johnson Matthey**, and **Shell** support the facility.

Research work will also include vehicle exhaust emissions reduction, particularly CO_2, and enhancement of the security of energy supplies and bio-sustainability for transport.

The laboratory includes seven test beds, two single-cylinder research engines, a Ford optical engine with laser diagnostics, two multi-cylinder Jaguar and Land Rover prototype engines, and a Formula Student race engine. A dedicated biofuel engine is being prepared, and a Ford engine testbed is also being built.

A Jaguar-led consortium sponsored via a UK Government Foresight Vehicle program is working on a new combustion system combining gasoline and diesel engine technologies to achieve reduced fuel consumption and emissions for a future generation of power units.

Further research scheduled for the new laboratory includes optical diagnostics of flow and combustion engines; on-board hydrogen generation by exhaust gas reforming; diesel engine exhaust aftertreatment; determination of the chemical and physical properties of new fuels; analysis of fuels and emissions by mass spectrometry; modeling of fuel reformers and engine systems; and investigation of alternative fuels (biodiesels, diesels from methane and biomass, ethanol, biogas, natural gas, and hydrogen).

Stuart Birch