# Engine advancements from Japan

Although hybrids have gotten much of the media attention recently, Japanese manufacturers have been constantly refining their conventional engines. Here are some worthy of note.

Honda's new 1.8-L inline four employs adaptive Atkinson cycle for optimum efficiency.

Honda's 3.0-L V6 engine features variable cylinder management and powers various car and minivan models, including the Accord Hybrid and Odyssey for North America, and the Japanese Inspire sedan and Elysion minivan.

The R18A 1.8-L i-VTEC inline four-cylinder engine is **Honda**'s global inline four, first introduced in the new Civic range. Intelligent VTEC technology is employed in the engine to vary intake charge volume. Unique to the 1.8 i-VTEC engine is that the FE (fuel economy) cam, engaged during low-load operations as steady cruise between engine speeds of 1000 and 3500 rpm, delays the intake valve closing timing by 63° (94° ABDC) vs. the HO (high output) cam (31° ABDC). In FE mode, the engine operates in the adaptive Atkinson cycle, taking full advantage of the superior fuel economy by greatly reducing pumping losses.

The R18A engine produces 103 kW (138 hp) at 6300 rpm and 174 N·m (128 lb·ft) at 4300 rpm on a 10.5:1 compression ratio, and is content with regular-grade unleaded gasoline. The output is 7 kW (9 hp) and 19 N·m (14 lb·ft) higher than the previous 1.7-L VTEC unit. More significant is an increase of 22 kW (30 hp) at the frequently used 3000-rpm zone, greatly enhancing on-road performance. On fuel economy, Honda cites a 6% improvement over its predecessor.

VCM is the acronym for the variable cylinder management technology that deactivates one bank of Honda's J30A 3.0-L VCM V6 engine. The engine powers Honda's upscale models including the North American Odyssey minivan, the Japanese Elysion minivan and Inspire sedan, and is combined with the IMA hybrid system in the U.S. Accord Hybrid.

The VCM V6 is still the only one of its kind, and its switching between full-six and partial-three cylinder operation is almost imperceptible, thanks to the active engine mount system and acoustic noise suppression.

In the North American-exclusive Accord Hybrid, the SOHC four-valves-per-cylinder, 2997-$cm^3$ engine produces 190 kW (255 hp) at 6000 rpm and 315 N·m (232 lb·ft) at 5000 rpm on a 10.5:1 compression ratio, combined with the 12-kW, 136-N·m (100-lb·ft)—at 840 rpm—electric motor, and driving the front wheels via a stepped-gear, five-speed automatic transmission. **EPA** mileage estimate is 29 mpg city and 37 mpg highway, vs. the gasoline-engine-only Accord EX V6's 21/30. VCM accounts for about 15% of the improvement in fuel consumption in city mode, and as much as 57% in the highway mode.

**Daihatsu**'s new Topaz KF is unlikely to find its way outside of its home country, Japan. However it is significant that the mini- and small-vehicle specialist has pursued and achieved its objective of a low-mass, low-friction, fuel-efficient, mini car engine. The aluminum inline three-cylinder engine displaces all of 660-cm³, the Japanese light vehicle limit, and produces 43 kW (58 hp) and 65 N·m (48 lb·ft).

Daihatsu's 660-cm³ inline triple is combined with a 9.4-kW electric motor and a four-speed automatic transmission in the Topaz KF.

The Super Intelligent three-way catalytic converter cleanses exhaust gas from the Topaz KF engine. The catalyst is the latest development of the Intelligent Catalyst that was first adopted in Daihatsu's light cars in October 2002, and the aggregate number of units installed now exceeds 1.5 million. The Intelligent Catalyst can regenerate one of its precious metals, Palladium, as well as greatly reduce the amount of all three precious metal contents.

The Super Intelligent Catalyst further reduces precious metal contents, by 50% vs. the Intelligent Catalyst, and 70% vs. the conventional three-way catalyst, according to Daihatsu, and it now regenerates the other two precious metals, Platinum and Rhodium. Daihatsu, **Japan Atomic Energy Agency**, **Hokko Chemical Industry**, and **Cataler** have jointly conducted the Super Intelligent Catalyst research.

*Jack Yamaguchi*

# Interior innovations en route

Mechanical-only technologies are gaining favor in one supplier's portfolio as a way to offer automakers a low-cost alternative for bringing innovations into vehicle interiors.

**Johnson Controls**' EZaxis Seating only requires a handle pull to automatically bring the seat bottom up to the seatback while at the same time rotating the seat. The patent-pending technology deals with the "functionality of handle to cables and the rotation off a single axis," said Ornela Zekavica, lead engineer for the U.S.-developed EZaxis Seating.

The mechanical seating concept, shown during North American International Auto Show media days, means "rapid accessibility for passengers getting into and out of third-row seating areas," said Keith Wandell, Executive Vice President of Johnson Controls and President of the Automotive Group. When the seat is in the stadium-style upright position, EZaxis also provides added storage space. EZaxis Seating will be available for mid-year 2009 vehicles.

Johnson Controls' active head restraint system will be offered in two versions:

Johnson Controls' Ornela Zekavica demonstrates EZaxis Seating.

one relying on an electrical signal from the vehicle's crash sensors to trigger the system's activation, and the other using the force of the occupant on the seatback during a crash to trigger the head restraint. "When the occupant goes into the seat at impact, the occupant loads an actuator that pulls on a cable to release the head restraint," said Scott Donegan, Product Manager for JCI's Automotive Group, describing the mechanical process.

Both the electrical and mechanical approaches "have proven to be very effective in testing [in terms of keeping] the head aligned with the torso and preventing the forces that cause whiplash," said Wandell, adding that both active head restraint configurations will be available for model year 2009 vehicles.

To prevent an occupant from sliding underneath a loose-fitting seatbelt, Johnson Controls' engineers in Europe have developed an anti-submarining seat. It uses the same sensor technology and electronic signal associated with airbag deployment to activate the movement of a ramp to change the angle of a person's legs on the seat in order to keep the knees from colliding with the vehicle's dashboard. "During a front-end collision, the ramp rises quickly in the front section of the seat, restraining the forward movement of the pelvis," said Wandell. The

Johnson Controls' active head restraint is designed to reduce the risk of whiplash in low-speed, rear-end collisions.

patent-pending technology will be available for model year 2009 vehicles.

Last year, Johnson Controls showed its Perimeter Overhead System, but this year the system is a "bit of an evolution" in terms of the engineering and development work that was done to reflect the system's integration aspects, according to Rick Arnold, General Manager of Overhead Products. The Perimeter Overhead System uses an injection-molded plastic trim to frame the headliner.

Johnson Controls' next-generation headliner would be shipped pre-assembled—including such items as sunvisors, overhead consoles, grab handles, lighting, and side-curtain airbags—to the automaker. The concept "enables designers to mold parts directly into the overhead system, which reduces the number of overall parts in the assembly process as well as mass and cost," said Wandell, who noted the system is slated to be production-ready in 2010 across all vehicle segments.

A product gaining production seat applications is a proprietary, vibration-damping material known as VibraTech Foam. Research studies conducted by Johnson Controls showed that "VibraTech Foam provides a 40% improvement in road vibration and improved noise absorption, and a 15% improvement in long-term durability. It also provides for improved packaging and long-term craftsmanship when compared to conventional foam seat pads," said Paul Lambert, Group Vice President and General Manager for Johnson Controls' North American seating business.

*Kami Buchholz*

# A fuel cell with a dual purpose

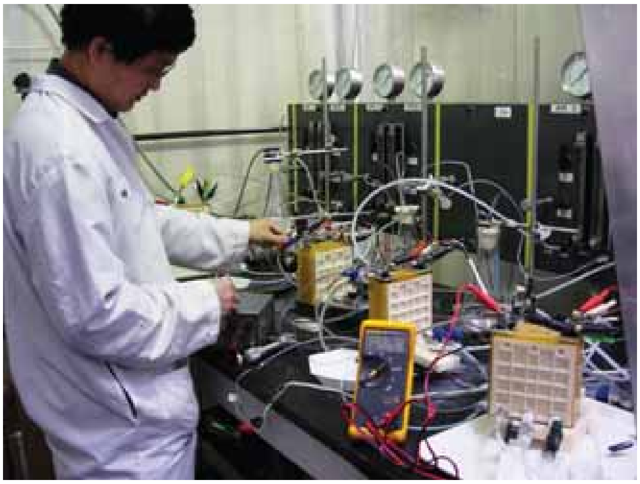
An atypical fuel cell would use metal hydride as a substitute for precious metals. The design would employ injection-molding equipment, and the system would function as its own energy storage unit. But is the resulting fuel cell ready for prime time?

"It is difficult to get new concepts accepted, particularly when there is a mainstream movement in place, which is the Proton Exchange Membrane (PEM) fuel cell for low-temperature applications such as automotive propulsion. But we think the Ovonic Metal Hydride Fuel Cell has more promise for a lot of applications, including automotive," said Dennis Corrigan, President and Chief Operating Officer of the **Ovonic Fuel Cell** Company, a subsidiary of **Energy Conversion Devices**.

Designed as a low-cost alternative, Ovonic's fuel cell bypasses precious metals usage. Instead, metal hydrides that consist of disordered multi-component alloys of transition metals and rare earth elements as well as graphite powders and Teflon are the main materials. No proprietary membranes or bipolar plates are part of the package, but plastic meshes and nickel screens and tabs outline the landscape. The hydrogen electrode active material is an electrochemical catalyst layer—made of the metal hydride, carbon powders, and Teflon.

The fuel cell operates with hydrogen entering on the metal hydride side, while air passes through the metal oxide side. In between the catalyst sheets is an alkaline electrolyte. "It's a simple three-part design with the electrolyte being sandwiched between metal hydride catalysts and metal oxide catalysts," said Corrigan. Ovonic's fuel cell has received more than 12 patents, and there are 20-plus pending patents covering aspects ranging from fundamental use of hydrogen storage and oxide materials to construction and design aspects.

In the prototype presentations, fuel-cell stacks are encased in an epoxy-sealed ABS housing, but injection-molded containers welded by laser or vibration technique are envisioned for production application. "Instead of a Silicon Valley type of approach where manufacturing is done in an environmentally controlled area, we plan to produce and seal the pieces together using conventional automotive manufacturing methods," said Corrigan.



Hong Wang, Senior Research Scientist, tests fuel-cell stacks in a laboratory at the Ovonic Fuel Cell Company.

One aspect that really differentiates the Ovonic metal hydride fuel cell from other fuel cells is its ability to store energy, thus eliminating a separate storage battery for startup and for capturing regenerative braking energy. "It's the first fuel cell that can run backwards and store electricity in the fuel-cell stack with the potential also to replace the hybrid battery in a fuel-cell vehicle," said Corrigan.

Because the unit also functions as an energy storage portal, there is instant startup without hydrogen. Early testing has shown that the initial operational state can continue at peak power without hydrogen for approximately five minutes. The Ovonic metal hydride fuel-cell stack also can operate below -20°C (-20°F). Early product prototype in-house testing demonstrated that an eight-cell stack lasted more than 2000 h at constant power. Single electrode tests showed the potential for more than 5000 h.

Ovonic's present prototype fuel cell is still well shy of the 1000 mA/cm$^2$ output of typical PEM fuel cells. "We feel with continued engineering that a substantial power boost is possible by optimizing the gas flow patterns, improving the current collection, establishing better spacing of the electrodes, and designing more efficient packaging," said Corrigan. Ovonic researchers have realized a 250 mA/cm$^2$ power output, and the prototype has exceeded 500 mA/cm$^2$ in pulse mode operation.

Company officials recognize that the near-term production application is centered on the stationary market. "We have a good technology for UPS (uninterruptible power supplies)," said Corrigan. Several potential customers have indicated an interest in Ovonic's metal hydride fuel-cell technology. "We're working to provide prototype samples over the next several months," said Corrigan.

Although an automotive production application may be years away, Ovonic officials have an optimistic view about what they consider game-changing technology. "We offer a way to eliminate the battery and associated weight, volume, cost, and complexity penalties from a fuel-cell vehicle while offering key advantages in efficiency and heat rejection," said Corrigan.

*Kami Buchholz*

# The cost of piracy

The U.S. automotive industry is probably losing billions of dollars a year to product piracy. Since counterfeiting is illegal, there are no sales reports showing actual dollar amounts, but the bottom line is that the fake parts business is a very costly fact of life.

"This problem is not going to go away," said Mahesh Lunani, Partner at **Roland Berger Strategy Consultants**. The consulting firm's 2004 study, "Intellectual Property Protection in China," underscores a pervasive problem that automotive suppliers and vehicle makers are encountering.

Counterfeit components produced in China are popping up in Africa, Europe, South America, and North America. The fake aftermarket parts are "visually very similar to the real product, and the quality of the packaging has improved—virtually no more misspellings or wrong addresses," said Scott Emmer, Brand Protection Manager for **Federal-Mogul**.

The country posing the biggest piracy-related headaches is also the country predicted to have the biggest automotive sales gain in the coming years. "By far, China is the biggest infringer out there," said Emmer. North America's largest association for automotive and truck parts makers, the **Motor & Equipment Manufacturers Association**, notes that fake parts are also coming from other emerging markets such as Brazil, India, Taiwan, Turkey, Malaysia, and Russia.

Even though Emmer is focused on anti-counterfeiting initiatives for products like spark plugs, wiper blades, gaskets, lighting as well as engine and chassis components, the Federal-Mogul official knows that engineering efforts suffer a fallout from counterfeiting tactics. "In a general sense, it stifles innovation," said Emmer, who points out that many companies in the automotive industry must fight counterfeiting and that requires money. At times, cash for protecting intellectual property comes from research and development budgets.

For example, **X-Rite**, a producer of color measurement instrumentation and software, usually invests 10 to 14% of its annual sales into research and development efforts, with a portion of that going toward intellectual property initiatives. "We want to protect our investments in the future," said Shannon Gary, Category Director of the Industrial Group for X-Rite.

To illustrate that point, the company's X-Rite Color Master version 7.0 software—for assessing color control and formulation data in automotive and other manufacturing environments—has a protective mechanism in place. "Once you patent something, it can be disclosed to the public," Gary said, referencing why the patent addresses the usage process because that "represents a stronger intellectual property position than patenting the algorithms."

Like many companies, **Delphi**'s name is vested in the technical attributes of its products. "We're very diligent about data and product security," said Delphi Vice

Officials conduct a seizure of a facility in China that was producing counterfeit air filters.

Chairman David Wohleen. The company has had a presence in China since 1993, and its manufacturing ventures produce more than 40 products, including wiring harnesses, batteries, drum brakes, and automotive electronics.

In the fall of 2005, Delphi opened a technical center in Shanghai to provide an additional outlet for engineering and product development. But regardless of where product development occurs, the safety of the company's intellectual property remains a big concern. "It's an issue," said Wohleen, adding, "We're a target for having our technology utilized or shared inappropriately."

Doug Halliday, Director of Product Development for **AutoWeb Communications**, a global provider of engineering data exchange services, agrees that intellectual property crime is a major threat to the automotive industry. One of the more insidious crimes is information stealing. Even though there is an obvious danger to transmitting data over unsecured networks, not all companies are dispersing information that way. "There are still too many people using physical media (*i.e.*, tapes and CDs) to exchange data, and that's highly risky," said Halliday, noting that a CD could be lost, stolen, or copied.

Should the information contained on the CD need to go a great distance—such as U.S. to China—there is also a time delay vs. sending the data over a secure network. Halliday cautions that engineering information should be provided on a need-to-know basis. "Share only what's required," said Halliday.

AutoWeb has realized an 1882% increase in its Asia-Pacific business since 2003. "A lot of that has followed the automotive industry's growth into that part of the world. There's a lot of movement of sourcing to the region," said Halliday.

At present, AutoWeb is providing secure data-exchange services to more than 19,000 users at 2500 companies, including **DaimlerChrysler**, **Ford**, and **General Motors**. Before joining AutoWeb, Halliday was Director of the Global Enterprise Collaboration for General Motors, which included responsibility for global data sharing among the company's groups, suppliers, joint ventures, and alliances to support GM's product development activities.

"I can tell you from my previous work experience that you have to be able to do things globally," said Halliday. He knows that more companies will realize the importance of having a secure means of protecting engineering and product development data. Otherwise, those companies could be among next year's grim statistics for having monetary and information losses attributed to piracy.

*Kami Buchholz*

# Handling hydrogen

The mere mention of the word hydrogen as a fuel source for cars may excite researchers and engineers, but equally it can cause the general public concern or even alarm. The hydrogen-filled Hindenburg airship exploding as it docked at Lakehurst, NJ, in May 1937 remains a searing lesson of what may happen when safety—or security—precautions fail. Although the technology link between the airship and the emerging generation of hydrogen-fueled vehicles almost 70 years later is arguably tenuous, the use of hydrogen in any form presents particular safety systems challenges.

Two key aspects of its use in fuel-cell vehicles are carriage and handling. **DaimlerChrysler** (DCX) is committed to the development of fuel-cell vehicles and has some 60 F-Cell cars based on the regular production A-Class in use in several countries. They form part of a research program that DCX believes will lead to production on a large scale—although just when remains an imponderable.

An important dimension of the program concerns safety. "Hydrogen does ignite very easily, and what is more, if it is confined within a solid container during the ignition process, it reacts very violently," said Erwin Wuchner of the DaimlerChrysler Research Center at Nabern, Germany. "One has to understand the special characteristics of hydrogen and act accordingly; then it is just as safe an energy carrier as gasoline or natural gas. So we focused early and systematically on the question of what faults are possible, even in theory. For every conceivable fault, we develop a safety concept that is subsequently subjected to further testing and improvements." If a safety problem is encountered, modifications and/or development work continue until a solution is found.


DaimlerChrysler's F-Cell research and development car is based on the A-Class.

One of these has concerned the possible effects of slow leakage of hydrogen into a vehicle's exhaust system after the fuel cells are shut down, particularly if the vehicle were to be left unattended in a confined space such as an underground car park.

Normal operating pressure of the aluminum, carbon fiber-coated hydrogen fuel tanks of the F-Class fuel cell cars is 350 bar (5075 psi), but they have been tested at pressures exceeding 800 bar (11,600 psi).

Normally, the amounts migrating to the exhaust are small and dissipate quickly, said Wuchner. But what if they do not dissipate? To find out, DCX filled an exhaust system with hydrogen and ignited it. Although there was a loud bang described by Wuchner as approaching the pain threshold, the exhaust system remained intact. However, such events are hardly acceptable in a production car. The solution was to fit a fine mesh flame arrester in the tailpipe similar to the type installed in gas pipelines. It demonstrated that the problem was "manageable."

Escaping hydrogen could also accumulate in some cavities within the underbody. To deal with this on the research cars, hydrogen sensors have been installed. These are linked into the fuel-cell system and shut it down automatically, closing the gas valves if a leak is detected. They are set to react at 2% by volume or above; the ignition limit is 4% by volume. The F-Cell's two aluminum hydrogen tanks, which are carbon-fiber coated and operate at 350 bar (5075 psi) are also monitored and have undergone extensive tests and certification. They have been designed to withstand pressures up to 800 bar (11,600 psi). When the vehicle is parked, the valves of both gas cylinders are closed and sensor-monitored to ensure they remain so.

The F-Cell's hydrogen-related components including pressure tanks, lines, valves, and seals underwent extensive endurance tests covering shake, shock, vibration, and temperature, and the propulsion system is separated from the passenger cabin by an airtight partition. The hydrogen lines of the fueling system are monitored for pressure fluctuations to check connector integrity. A control system records the pressure when the ignition is turned off and then compares the value with pressure at the next start.

DCX states that other potential sources of faults may occur in the stack and the membranes that separate hydrogen from oxygen in the fuel cells. Because a defect could result in an oxy-hydrogen-gas reaction, the housing containing the stack is constantly ventilated during operation and even minimal amounts of hydrogen dispelled.

If hydrogen did accumulate in the stack box, a sensor is positioned in the area and a pressure test is made before each start to indicate whether hydrogen could have escaped into the exhaust system via membrane leaks.

Plans for further development of the F-Cell system include some detail changes: If any hydrogen escapes, instead of being channeled into the exhaust system to be dissipated, it will be piped into the intake system enabling it to react with atmospheric oxygen in the catalyst layer on the cathode in the stack, to form water.

Refueling systems for hydrogen-powered cars has been a technology of steady development for several years. The technique used by DCX is similar to that applied to gas-powered vehicles, with the gas hose and filler neck connected via an airtight coupling. The possibility of electrostatic discharge must be considered during the hydrogen refueling phase, just as it is with other fuels. As well as the basic precautions already found at regular gasoline stations via forecourt surface treatment and through the conductivity of tires, the refueling coupling at hydrogen filling facilities is automatically tested for an airtight seal, and the refueling line is tested for pressure before delivery can begin.

A further change is the development by DCX of a filler neck with integral data interface. An infrared diode on the filler neck transmits data to a receptor on the hose coupling. The refueling pump receives information on the operating pressure and temperature of the vehicle's fuel tanks, allowing more precise refueling. A problem when this had been attempted before was that the hydrogen gained heat during the refueling process, with the result that only approximate adjustments could be made for the temperature-related increase in pressure, according to DCX.

*Stuart Birch*

# Focused on the bigger picture

There are times when an automotive sealant or adhesive can satisfy a particular problem, but solving a more complex issue requires a more comprehensive approach. To facilitate broader thinking, a provider of sealants, adhesives, and surface treatments invested $8 million in a new under-one-roof technical center.

Prior to the opening of the center, **Henkel** had research and development experts spread among various locations, which meant face-to-face contact among the technical specialists was fairly infrequent. But with workers from three locales now in a single building—a new 65,000-ft$^2$ (6040-m$^2$) facility in Madison Heights, MI—the exchange of ideas and information for developing turnkey solutions is more commonplace.

The 70-person staff—shuffled from two closed Michigan facilities (in Auburn Hills and Plymouth) as well as several relocated workers from an Oak Creek, WI, site—is working in a facility stocked with computers and analysis tools, testing equipment, and validation rigs. "We have design, application, mechanical, electrical, and process engineers as well as research and formulating chemists working in cross-functional teams to deliver the best solutions at the lowest cost," said Chuck Evans, Senior Vice President, Automotive, for Henkel, adding, "There's an extraordinary benefit to working together in one area."

The joining of metals is just one of many applications undergoing further investigation at the technical center. "Structural bonding can replace welding, or reduce the need for welding, or enhance the performance of welding," said Rajat Agarwal, Technical Manager of Automotive Adhesives and Parts at

Rajat Agarwal holds a box beam that will be used in an energy management test to prove out a structural adhesive.

Henkel's new Adhesive and Sealants Technology Center includes crash test equipment, which allows company workers to test Henkel materials.

Henkel. Passenger vehicles already use structural bonding—mostly in floor and door sections. "The plan is to increase the usage," said Agarwal.

About five years ago, it was not uncommon to see a vehicle using 15 to 20 ft (4.6 to 6.1 m) of adhesives. Today, it is not unusual to see adhesive usage in the 300-ft (91-m) range on a large vehicle such as an SUV. The target, according to Agarwal, is to have every joint in a vehicle using structural bonding.

Widespread use of structural bonding could replace 200 lb (91 kg) of sheet metal on a passenger vehicle. "That's an estimate that we think is possible," said Agarwal, adding, "Weight savings is the next evolution for structural bonding."

The technical center also provides an interface point for client engineering teams as well as Henkel researchers and engineers. "This facility gives a different value proposition for customers," said Matthias Hofmann, Henkel's Vice President of Marketing & Business Development in North America, adding, "We're trying to take a systems approach to a customer's problem in order to arrive at a complete solution."

*Kami Buchholz*