electric & hybrid vehicle technology international

July 2018

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July 2018

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NEXT-GENERATION GENIUS

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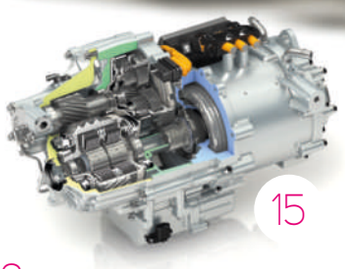

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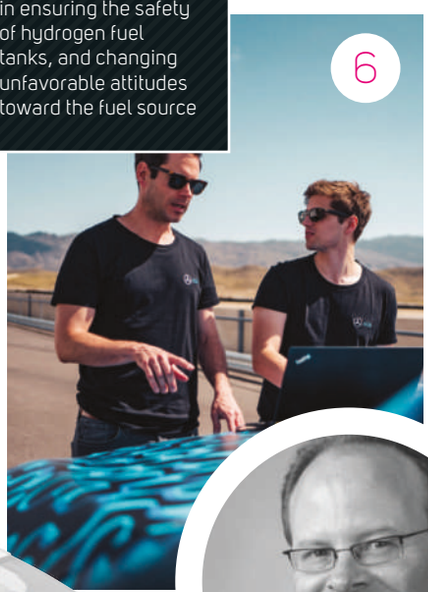

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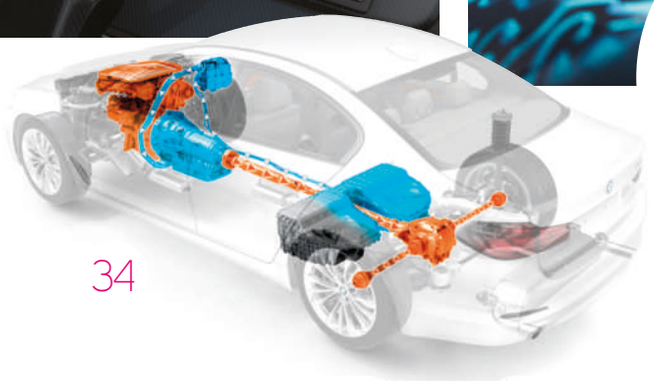

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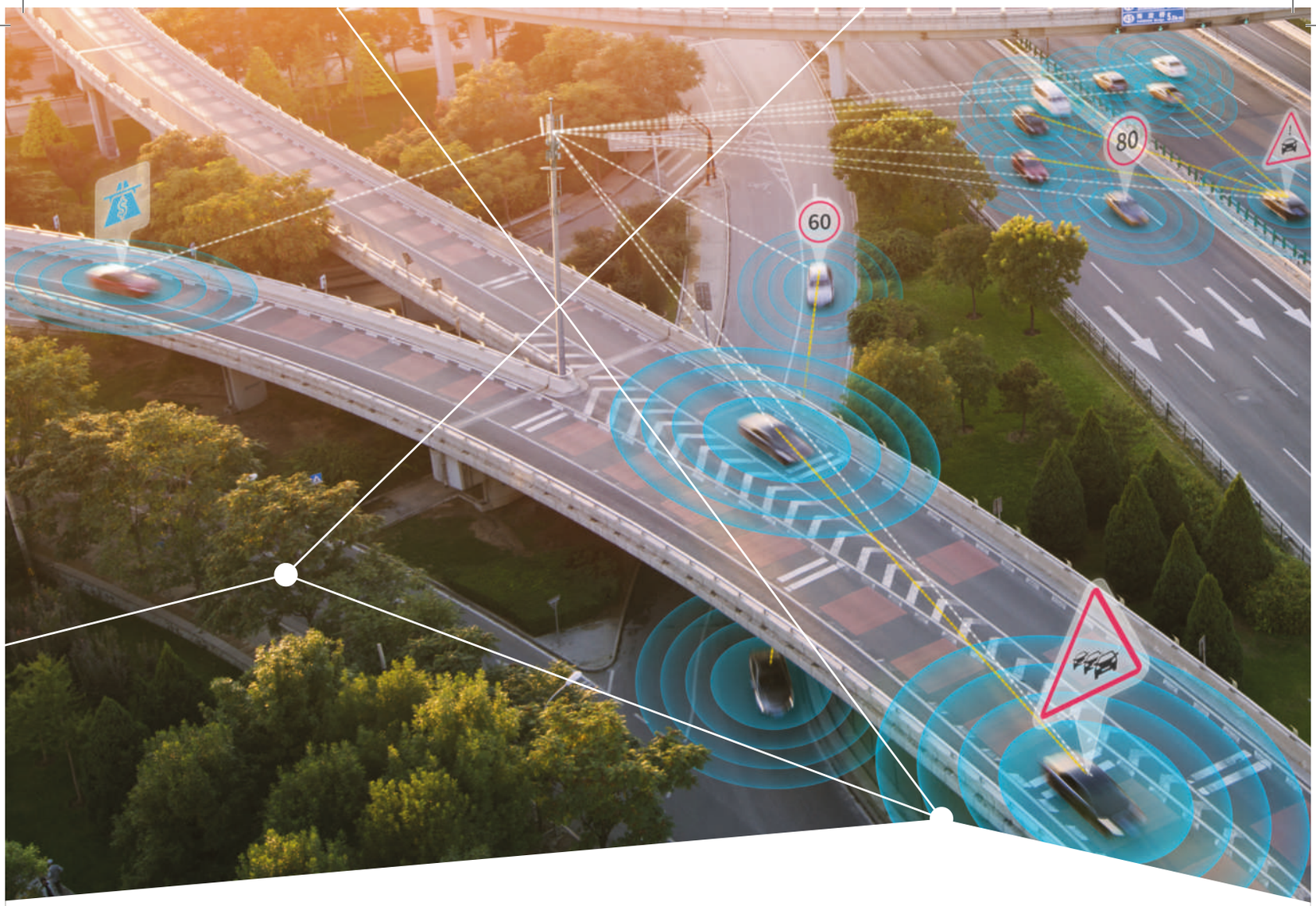

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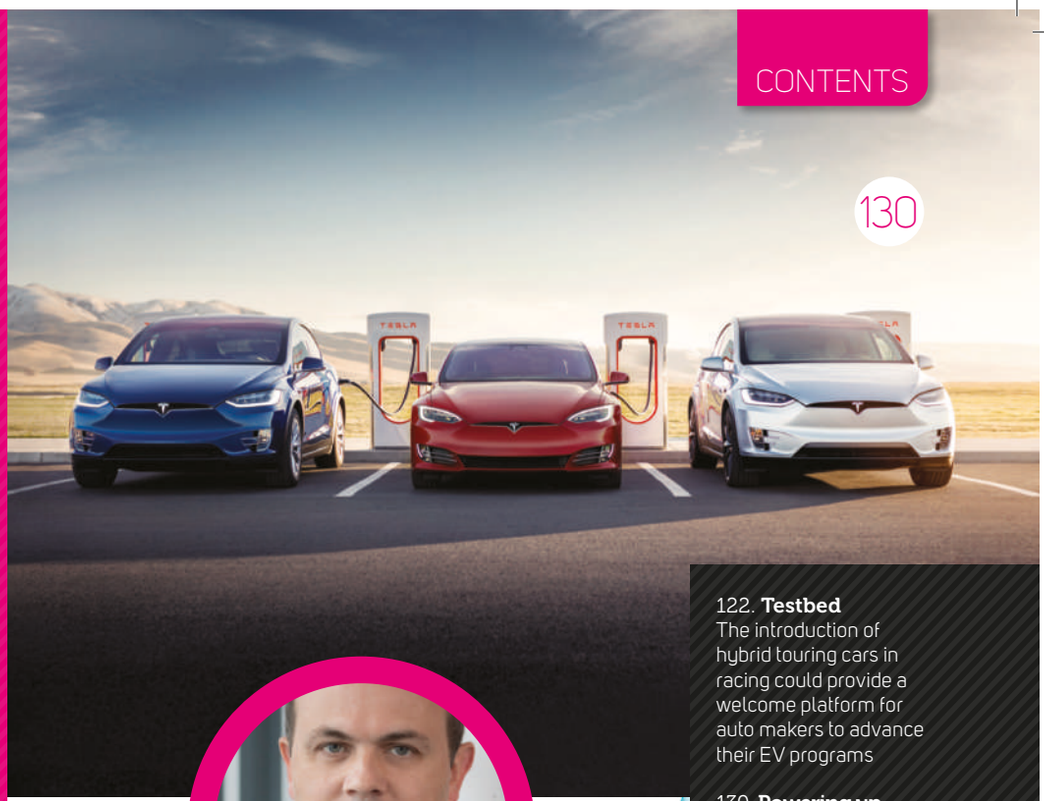

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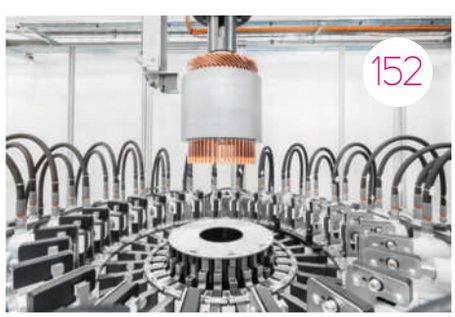

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PRODUCTS & SERVICES

EDITOR'S NOTE

I've often said that the best thing about being a journalist is that you get paid to listen to interesting people talk. I was at an event in London earlier this year and was lucky enough to hear Lars Thomsen, founder of Future Matters, speak on the trends that will dominate electrification in the coming years. Ordinarily, this would be where I summarize what he talked about, but I'm happy to report that I managed to convince Lars to pen a column for this issue – turn to page 40 rather than let me spoil the surprise.

In what has been a busy first half of the year, I also had the chance to interview Jochen Hermann, the vice president of CASE and eDrive development at Daimler. Aside from talking about the OEM's multipronged approach to vehicle electrification, manufacturing flexibility and a host of other issues facing the automotive industry, Hermann also raised an interesting point. For an established brand like Mercedes-Benz, customers want more from an electrified vehicle than just the knowledge that it sports a pure-electric, hybrid or fuel cell powertrain – there's a need to alter perceptions. For Mercedes-Benz, it's important that products such as the recently announced diesel hybrid range, the GLC F-Cell and the all-electric EQC not only showcase new propulsion technologies, but that they also deliver the quality and innovation that customers expect from the badge on the hood.

Earlier this year, I saw first-hand that there's still some way to go in terms of convincing people of the benefits of electric and hybrid vehicles. I was road-testing a BEV, and when I parked at home, a neighbor of mine commented on the fact that I'd done so almost silently. They asked a little about the car's range, what it was like to drive and whether people stepped out into the road if they couldn't hear it coming, before, as a throwaway comment, they remarked that I'd never catch them "in one of those silly electric things". I was a little stunned. After all, I'd just been extolling the virtues of instant torque, quiet operation and never having to visit a gas station, only for the car to be dismissed out of hand for no discernible reason other than it didn't burn hydrocarbons.

I do believe, however, that perseverance is key. As time goes by, fewer people are surprised by the sight of a Nissan Leaf, BMW i3, an electric Smart, or VW's E-Golf (to name just a few). And more are coming. The increasing proliferation of electrified models from established OEMs will go a long way to changing the situation, with the aforementioned EQC and GLC F-Cell, Audi's e-tron, Jaguar's iPace, Porsche's Mission E (now known as the Taycan), Hyundai's Nexo, and a host of others creeping ever closer to the showrooms. Perhaps electric and hydrogen vehicles will be more palatable if they are adorned with badges that everyday consumers recognize.

But that's not to say that only the major car makers you've heard of hold the key. After all, the pages of this very magazine serve to illustrate that innovation comes from companies old and new, and from all corners of the world. A few years ago, not many people had heard of Tesla. These days, the company (particularly its charismatic CEO) is never far from the headlines. The startups of today could be the major players of tomorrow, and news of technology breakthroughs and exciting vehicle developments seems to emerge on an almost daily basis.

Which leads, rather tenuously, to an exciting development of our own. Part of the reason that the first half of 2018 has been so busy is that we've been working to launch *E&H Vehicle*'s new website. Given how quickly news tends to break in this industry, www.electrichybridvehicletechnology.com is the place to not only find out about the latest developments from the OEMs, suppliers and innovators you *have* heard of, but also the most exciting breakthroughs from those you haven't. You'll also find opinion pieces from leading industry figures, exclusive features, details of industry events, job listings and access to online copies of the magazine. Enjoy the issue.

Matt Ross

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Character

building

The EQC will be the first **Mercedes-Benz** all-electric production model. But although its powertrain and technology might be new, designers had to ensure it retained the spirit of the brand

WORDS: **KYLE FORTUNE**

When the company that claims to have invented the automobile adds a new electrified brand to its portfolio, it's a solid indication (if one were still needed) that the traditional automotive world is fully embracing electrification. Mercedes-Benz EQ was introduced to the world in 2016 at the Paris Motor Show, with the Generation EQ concept, and while EQ Boost mild hybridization is being used with the OEM's newest combustion-engined vehicles, it'll be 2019 before a fully plug-in EV is realized.

The vehicle in question will be the EQC, an SUV-proportioned car that will be very close to that 2016 Paris concept in its execution. Following the automotive zeitgeist for SUVs is sensible on two counts as it's what buyers want, and their packaging suits an electric powertrain.

Michael Keltz, Mercedes-Benz chief engineer, explains that the EQC is spun

The Mercedes-Benz EQC undergoing summer testing in Spain

"What we do not want to make is a combustion car with an electric motor"

Michael Keltz, chief engineer, Mercedes-Benz

off the same platform as conventionally powered Mercedes-Benz models, enabling it to run down the same production lines. "When we have the marriage, it works much the same way as with a combustion engine, otherwise we couldn't produce on the same line."

The synchronous motors are mounted to suit, the front in a cage with auxiliaries attached, the rear fixed in line with the axle itself. Both are 150kW, although with differing power delivery – the front is tasked with being as economical as possible, with the rear focused more on performance. Driving all four wheels, or the front only for maximum economy, power for the motors comes from a battery that (although he won't admit to specifics) Keltz does concede comes from parent company Daimler's wholly owned subsidiary Deutsche Accumotive, is in excess of 70kWh, and accounts for around 25% of the EQC's weight.

Despite the technological advances developed for the EQC, particular attention was also paid to retaining the Mercedes-Benz character

The vehicle's range was originally quoted at 500km (310 miles), although under the more rigorous WLTP tests it'll be less, Keltz says, during a test drive of one of the 190 Mercedes-Benz EQC prototypes that is undergoing testing before the 2019 launch.

Like any Mercedes-Benz, the EQC will see three summers and three winters as part of its development. The mechanical elements are at the off-tool stage now, with the core of the development focused on software, fine-tuning the drivetrain and the user experience inside via Mercedes-Benz's MBUX infotainment system. Overall, the split between digital and real-world testing is around 35:65.

Retaining refinement

From an engineering perspective, Keltz admits to enjoying the challenge of developing a BEV, concentrating specifically on achieving the elements that define it as a Mercedes-Benz. Crucially, he explains, that means refinement. The team has worked at eliminating any electrical sounds and movements generated by the drivetrain. "We have the engine mounts isolated with rubber – they're passive," says Keltz, adding that the team has worked extensively to remove any sound paths and isolate any movement from the engine's sizeable, and immediate, torque output.

Without an ICE to mask sounds, that refinement is even more crucial. There's a domino effect, Keltz says, explaining that the sound of the compressor filling the standard air springs on the rear axle when the vehicle starts up needs to be addressed. That detail is key, with even the air vents designed to minimize any sound, as is the HVAC system that feeds them. Keltz relishes that challenge,

though: "This is like if you lose weight and then you have to buy new jeans. It's a nice problem to have."

Integrating ideas

The EQC's all-electric drivetrain also presents new ways of thinking, says Keltz. Micro management of torque on the motors can be exploited for ESP functionality, while the immediate reaction of the electric motors enables better transition from sailing (coasting) mode to driving at cruising speeds than you'd get with an ICE vehicle. "The guys that had done ESP systems up to now say, 'I have a system that works; it's only a different engine, so why change it? It works well.' The guys doing the motor say, 'I'm not in charge of the ESP, I want to be efficient and lightweight and so on.' I have to get them together and say to them that things have changed, that there are areas you are now in charge of that you would have never imagined. You need to integrate the systems. It makes the whole story interesting."

There remain challenges to be overcome. The vehicle charging infrastructure, for one, needs to catch up – although Mercedes-Benz's CASE strategy, and its Ionity charging network joint venture with other OEMs should help to address this. With fast charging, the EQC should take a 50% charge in around 20 minutes, depending on the battery level and charger's output. "What we do not want to make is a combustion car with an electric motor," concludes Keltz. It's clear, though, that it has to be a Mercedes-Benz.

Commonality between the EQC and conventionally powered Mercedes-Benz models will enable the all-electric vehicle to be produced on the same manufacturing lines

The testing of the **Bollinger B1** has been thorough and extensive – as befits the development of a versatile zero-emission truck

WORDS: **LEM BINGLEY**

ROUGH & READY

While most EVs lean toward the swift and sleek, Bollinger Motors' B1 embodies a very different vision for electric mobility. Unveiled in July 2017, it is a boxy SUV that seems rustic and old-fashioned, despite its modern powertrain.

Like other EVs, the B1 carries its battery pack flat and low, creating a seamless interior floor from front trunk to tailgate. A hatch in the firewall exploits the lack of combustion engine to create a unique party piece – the ability to carry 12ft (3.7m) planks enclosed inside a truck measuring barely any longer.

Under the floor, a bespoke aluminum chassis carries two motors, one for each axle, driving through reduction gearboxes offering both high and low ratios. Added together, the motors provide 365ps (268kW) and 640Nm of torque.

Hub-mounted reduction gears and inboard brakes raise underbody clutter up, creating a belly as flat as an Everglades airboat. Hydro-pneumatic suspension gives 15.5in (40cm) of ride height, ±5in (13cm) of adjustment.

Engineered to meet US Class 3 regulations, the B1 boasts a 10,000 lb (4.5 ton) gross weight, at least half of which will be cargo.

Theory into practice

Since the B1's unveiling last summer, much has changed as a result of a busy testing program, although the initial vision of a tough, versatile EV truck is undimmed.

Real-world testing began in summer 2017, on the farm owned by founder Robert Bollinger in the Catskill Mountains, New York. "At that point, the truck was basically theory," he recalls. "Everything was calculated and simulated, but what happens when you really rock crawl? Are the wheels moving the full range, or are they holding up on things? Is anything breaking? Is anything rubbing?"

Initial shakedown completed, the B1 went to North Carolina for dyno testing, to measure chassis stiffness and assess the frequency response of the adjustable suspension.

Then, in autumn 2017, the only existing vehicle prototype embarked on two weeks of off-road testing on the sand flats and stone hills near Moab, Utah, and on rock trails in the San Juan Mountains near Ouray, Colorado.

"We had a Jeep Wrangler with us as a support vehicle and it was bouncing around all over the place, while our B1 just felt solid," Bollinger recalls. "I turned to the guys and said, 'Oh my God, this is so exciting,' but they were just like: 'Yep.' Because that's exactly what they'd engineered it to do."

Those tests led directly to a host of refinements, including redesigned rocker panels for better ground clearance, and software changes to the vehicle control unit (VCU) creating

a virtual transfer case. "Between the left and right, there are mechanical differentials that you can lock, but between front and back we didn't have that," Bollinger says. "We added code so the VCU knows what the motors are doing, and when it registers that one is spinning, it can adjust the power."

The engineering team also gathered data covering transient responses. "When you move your foot from brake to throttle, the in-between has to be engineered," Bollinger explains. "It's not until you build a vehicle that you can feel it, and measure pedal force."

The testing program then moved on to highway speeds, to check power flows, battery and motor performance.

Finally the B1 prototype was dismantled and reassembled, checking for physical damage, wear and leaks. "That first round with our prototype was very pragmatic, hands-on kind of testing," Bollinger summarizes.

"We can simulate hundreds of thousands of miles and engineer to those standards"

Sensing the future

In March 2018, Bollinger Motors announced a partnership with engineering consultancy Optimal of Plymouth, Michigan, which is helping with further testing and production optimization for the B1.

"We're putting sensors all over it and are putting it through a durability test," Bollinger explains. The vehicle will be repeatedly driven over punishing roads featuring potholes, cobblestones and washboard ridges. "With that data, we can simulate hundreds of thousands of miles and then engineer to those standards," Bollinger says.

Three benchmark rivals have been selected, covering both the utility and EV aspects of the B1's design. Bollinger aims to beat all three, with a margin in reserve. "We can see what trends are happening, where body stiffness values are going to be in a couple of years," Bollinger notes. "We're engineering to that level, so when the B1 comes out in another year and a half we're still ahead of the game."

The aim is to hit stiffness goals with minimum weight, which will require both further testing and CAD work – and of course more prototypes.

"We have just come up with our plan for how many full prototypes, partial prototypes and test mules we'll need next year," Bollinger continues. "Some can be used for more than one thing."

The second B1 prototype, a four-door version, is due to be fully assembled by the end of 2018, incorporating all the lessons learned from the two-door truck. As well as a longer body, there will be improvements to chassis, drivetrain, NVH quality and passenger positioning.

Going forward, the engineering team will focus fully on the four-door, now set to become the initial production variant. Other body styles including the two-door have been put on the back burner.

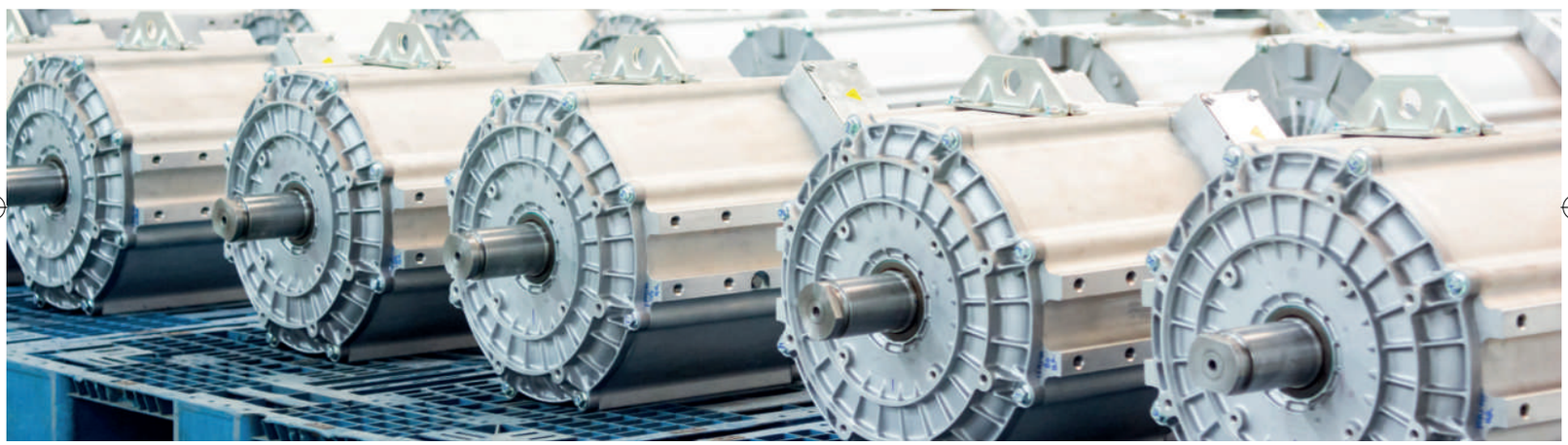
"Once we'd signed up Optimal we began re-engineering the truck to optimize it for production, and during those calculations decided we wanted a bigger battery pack," Bollinger explains. The B1 was initially envisaged with a 60kWh or 100kWh battery, but the team has now settled on a 120kWh, liquid-cooled lithium-ion pack. The four-door includes a 12in (30cm) wheelbase stretch, giving space to accommodate the extra cells.

The initial battery design was split either side of a central chassis compartment, but the new one stretches from axle to axle, door to door. "We moved around some of the electronic components to make room, because the new battery uses half the depth of the middle compartment," Bollinger says.

"The biggest piece of testing? Well, all of it is big, but a huge amount of testing that still has to happen is for the battery," Bollinger adds. "It's so crucial to get right. Most of that is bench testing, but we're testing tons of modules individually, then the pack together, and the welds where we attach wires to each of the cells. And then we have to take cells beyond their limit to see what happens, in a safely sealed laboratory. Then there's the BMS and the VCU. So there are months and months of testing still ahead of us."

The B1 makes the most of its electric powertrain architecture, and features unique front-to-back cargo space where a combustion engine would usually sit

sumo 300 million km of pure electric drive



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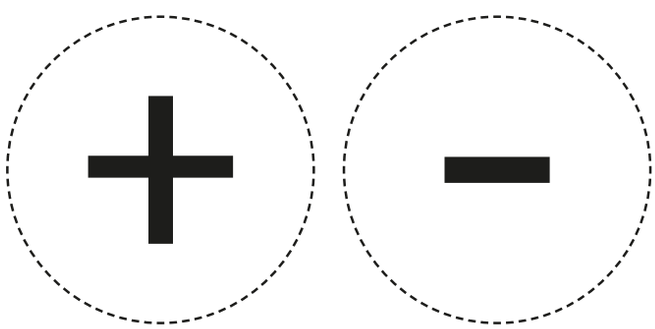

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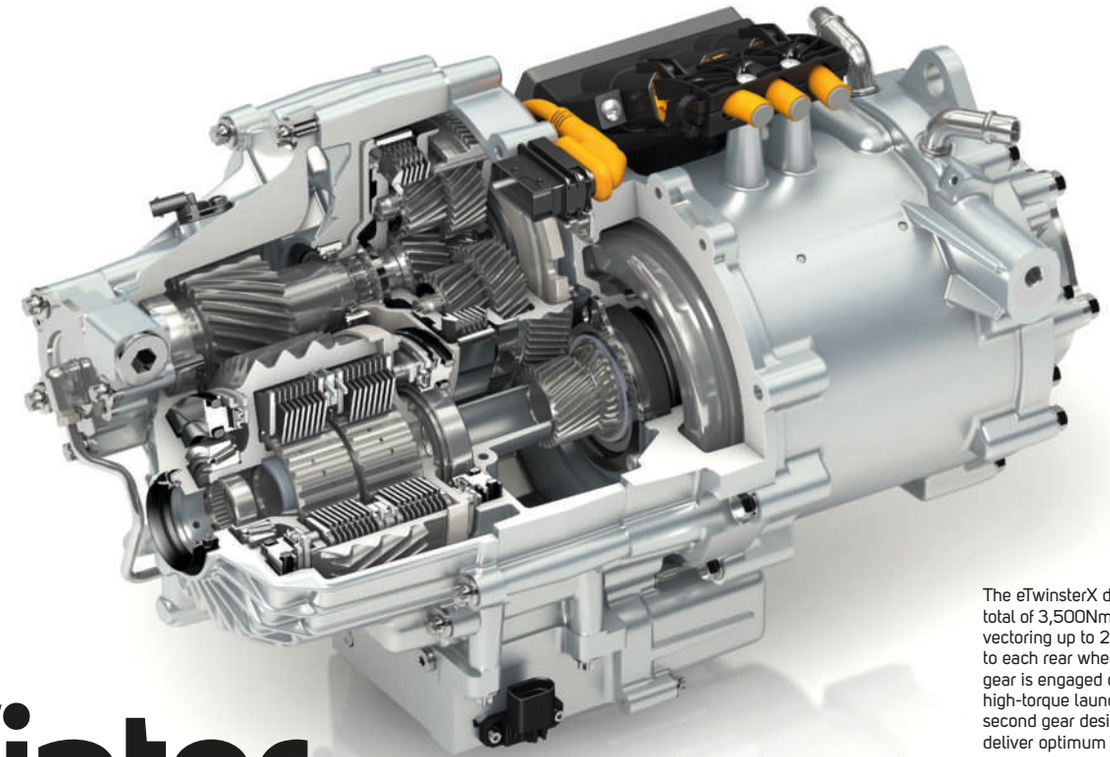

The eTwinsterX delivers a total of 3,500Nm of torque, vectoring up to 2,000Nm to each rear wheel. First gear is engaged only for high-torque launches, with second gear designed to deliver optimum efficiency

Winter wonderland

An all-new coaxial electric axle system marks the latest in technological development from **GKN Driveline**

WORDS: **MATT ROSS**

Held at the beginning of 2018, GKN Driveline's WinterTest engineering showcase demonstrated the global company's all-new coaxial electric axle system, the eTwinsterX. The prototype technology was showcased on a Mercedes-AMG GLA 45 vehicle, which was reengineered by GKN for use at its cold-weather testing facility in Arjeplog, Sweden. First revealed at the Frankfurt Motor Show in 2017, the eTwinsterX system features an integrated e-motor, efficient two-speed e-transmission and torque vectoring thanks to GKN's proven Twinster clutch pack technology. The modified GLA 45 was outfitted with the mechanical Twinster technology on the front axle and the eTwinsterX on the rear, transforming the gasoline-powered vehicle into a gasoline-hybrid with a zero-emission all-electric drive mode, and axle-split eAWD functionality that operates independently of the internal combustion engine.

Theo Gassman, vice president of advanced engineering at GKN Driveline, believes the eTwinsterX will be production ready by the start of 2019

Application of the Twinster unit to the front axle makes use of the vehicle's 381ps four-cylinder powertrain, integrating the Twinster directly with the gearbox, replacing the final drive and differential, and enabling GKN's software to control the torque distribution through the twin-clutch system.

At the rear of the vehicle, the eTwinsterX two-speed axle and a high-capacity, high-performance battery were installed, providing output of 163ps and 210Nm of torque in a package that, GKN claims, is smaller than similarly powered systems. The eTwinsterX also includes a GKN-designed two-speed transmission and full torque vectoring.

The testbed for eTwinsterX is GKN's Mercedes-AMG GLA 45 prototype vehicle. The car was reengineered by GKN for use at its cold-weather testing facility in Arjeplog, Sweden

This development from GKN Driveline marks the latest step in a series of drivetrain evolutions over recent years.

Driving change

"We have been in this business for quite a while," explains Theo Gassman, vice president of advanced engineering at GKN Driveline. "We have a lot of applications in the market, most of them using pretty straightforward single-gear fixed-ratio transmissions with a disconnect unit. And we have learned from our customers that this is okay for the first generation, but maybe not the best technology for the future.

"When you install more electric power, you don't want to disconnect the electric machine and lose the power at higher speeds. To us, it was an obvious trend that OEMs don't want to have a disconnect in the future. We also have a lot of business using normal drive systems with the Twinster technology, gaining a lot of momentum in performance vehicles, as well as in disconnect vehicles, traction-oriented cars and fuel efficiency-oriented cars. We learned a lot about using clutches to control the torque distribution between the wheels, and about how to control the clutches – it quickly became obvious to combine it with an electric machine as a secondary driven axle."

The result of GKN Driveline's technological developments in this area – the eTwinster – was showcased at WinterTest 2015.

"It was pretty successful," adds Gassman, "even though the car was not very refined at that time. We then spent another year improving it, presented it again at WinterTest 2016 and got a lot of positive feedback – and a lot of customer interaction. But at the same time we also realized that if you have all the great features of the Twinster and the torque vectoring, it would be great to have more electric power, because you can do even more good in terms of vehicle dynamics and performance."

Power struggle

Adding more power, however, means potentially losing those features – torque vectoring, electric boost, regenerative braking and potential CO_2 benefits – when disconnecting the electric machine at higher speeds.

"This wasn't really considered an option anymore," Gassman says. "So after WinterTest 2016 we decided that we needed to do more to make the system available for the whole speed range, up to maximum speed. If you have a high-performance hybrid, the cars are going faster than 200km/h and the electric system can't keep up with it. That's the conflict."

Gassman and his team looked to the lessons they had learned on other vehicle projects – not least a BMW i8 demonstrator vehicle they had worked on with a seamless shift two-speed – to develop a way to remove shift interruption.

"When you have a powershift, a seamless shift system, you can use the shift more often, have a more refined control strategy and even gain more performance, while still having a comfortable shift that does not frustrate or disappoint the driver."

Applied in prototype form in a Volvo XC90 demonstrator, the eTwinster unit takes GKN's coaxial eAxle and enhances it with its precision torque vectoring system

The shift uses only one clutch (using a free wheel overrunning clutch system to eliminate the second), producing a system that is more compact, lighter and with reduced clutch losses. "This was initiated in the summer of 2016," continues Gassman. "The first prototype units were on the bench in the summer of 2017. The system went through a mini validation exercise to make sure that it was robust enough for the demonstrator and for vehicle testing, installed in our Mercedes technology demonstrator at the end of 2017 and presented at WinterTest 2018."

The main challenge at WinterTest 2018 was to make the front and the rear of the vehicle work together. "We had to make the internal combustion engine and the electric motor work together, and develop our own GKN hybrid control strategy, because the car is essentially a conventionally powered vehicle that's been converted into a hybrid," Gassman says. "The core control had to be made from scratch for this car."

Work is continuing on refining the up and down shifts in different situations. "The shift needs to be coordinated and harmonized with the Twinster and the hybrid strategy," Gassman explains. "There is still quite a bit of work to do here. We need to explore the full benefit of the eTwinsterX in the car, which will probably take another couple of months. Then, I guess, at the next WinterTest, we'll have the perfect car."

Could this mean that the eTwinsterX will be production ready by the start of 2019?

"I would say so, yes," Gassman confirms. "We already have some application requests and we are working on concept phases for a few OEMs. From the bench testing we now feel comfortable enough to kick off customer application programs – to take the risk and go for application. In terms of the vehicle tuning and vehicle integration, it's going to take this year to really explore all the benefits, and all the performance."

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Split

The fourth collaboration between **Pininfarina** and **HK**, the GT concept pairs all-electric power with a choice of range extender options

The HK GT is the fourth concept vehicle developed by design house Pininfarina and Hong Kong-based tech company Hybrid Kinetic Group. The exterior design of the 2+2 configuration vehicle evokes classic Gran Turismo architecture, but blends it with modern design flourishes – the interior of the vehicle changes color depending on whether the car is in Race or Cruise mode.

The powertrain is also distinctly unique. As Hybrid Kinetic Group's name suggests, the GT draws its power from more than one source. Unusually, however, the concept is offered with a choice of range extender technology – pairing pure-electric propulsion with either hydrogen fuel cell, microturbine generator or ICE power.

PERFORMANCE

HK claims the GT will sprint from a standing start to 100km/h in 2.7 seconds, and on to a top speed of 350km/h (218mph)

TORQUE DISTRIBUTION

The vehicle's torque vectoring system provides torque distribution between the four wheels, each of which boasts its own motor, increasing control and stability

MOTORS

Four integrated, independent PM motors yield a combined power output of more than 800kW (1,072ps)

personality

RANGE

All-electric range is claimed to be in excess of 160km (100 miles), while use of the range extender will (reportedly) boost this figure to more than 1,000km (620 miles)

BATTERIES

The HK GT is fitted with 38kWh of Hybrid Kinetic's graphene super batteries

RANGE EXTENDER

The HK GT pairs its electric powertrain with a range extender, courtesy of a low-emission microturbine generator that can accept a range of fuels, a zero emission hydrogen fuel cell system, or an efficient internal combustion engine

Rules and the road

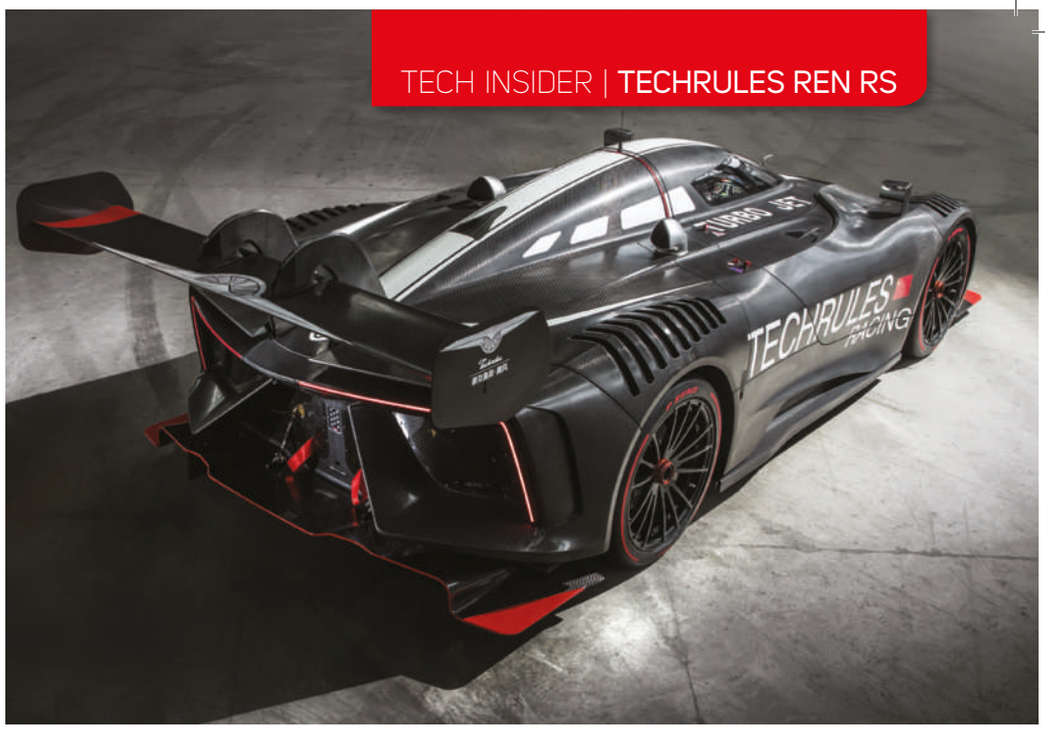
The first track car from **Techrules** sees the auto maker rework its hybrid diesel micro-turbine electric powertrain, and could spell big things for the passenger vehicle market

WORDS: **SAM PETTERS**

The push for electrification is changing the face of motorsport. As Formula E continues to grow in popularity and the World Rallycross Championship switches to an electric race series, a number of Chinese startups have come to the fore.

Formula E competitor NIO is the big Chinese name in racing at the moment, but it is little-known auto maker Techrules that is beginning to make a name for itself.

Now a regular at the Geneva Motor Show, the company has gone about electrification in a different



way from the rest. By using a diesel micro-turbine as a range extender, Techrules claims it can offer efficiency, ultra-low environmental impact and, most importantly, performance.

"An electric motor is used to drive the wheels, which effectively frees the combustion engine to exclusively convert chemical energy into mechanical energy and finally into electrical energy," explains Techrules's chief technology officer, Matthew Jin. "This unique powertrain design has enabled us to create a perfectly engineered high-performance electric track car."

Revisions were made to the Ren RS's powertrain, cooling and aerodynamics, and the battery layout differs from the road car model, with packs placed laterally to modify the vehicle's weight distribution

Track star

Unveiled in the AT96 and GT96 concepts in 2016, the system has since evolved, first for the Ren in 2017 and now for the car maker's first track-only supercar, the Ren RS. Co-developed with motorsport specialist LM Gianetti, the aerospace-inspired car is a lightweight, high-performance single-seat racer.

Equipped with the powertrain now synonymous with the brand, the RS has a modular chassis design to allow a variety of configurations. The flagship version – with a 28.4kW lithium-ion polymer battery and two axial flux, liquid-cooled YASA motors at the front and four at the rear – will deliver 1,305ps and a range of 1,170km (730 miles) from 80 liters of diesel on the NEDC.

The TREV will also generate 780Nm at the front wheels and 1,560Nm at the back, moving the racer from 0-100km/h in just 2.5 seconds, and on to a top speed of 330km/h (205mph).

Go with the flow

But it's not just the powertrain that has been reworked. "The main differences between the Ren and this RS is the job we did on the cooling and the aerodynamics," says Luisa Gianetti, general manager at LM Gianetti. "That was a huge job, to try and find the perfect balance on everything. And we think we found it, with distribution 50:50 front and rear."

To achieve that balance – a prerequisite to a good track car – the battery layout has been altered from the Ren. Packs are now placed laterally rather than centrally. And with a strengthened carbon-fiber monocoque chassis, a single cockpit layout and design changes that result in an aero efficiency of 3.36 and a drag coefficient of 0.43, the Ren RS is bred for racing.

There is an FIA-certified safety fuel bladder beneath the floor, an OMP-manufactured carbon-fiber race seat and lightweight 380mm carbon ceramic discs, fitted in conjunction with six piston calipers by AP Racing.

The suspension, designed and manufactured by LM Gianetti, comprises an unequal length wishbone design at the front and rear. Made from high-strength tubular steel and TIG welded, the wishbones are designed to withstand the forces that would be experienced by GT3 racing cars.

But while the Ren RS is completely capable of GT racing, its US$2.9m price tag is prohibitive. "It's a car that customers can buy and enjoy on the track or just have because it is an iconic object," says Jin. "The primary goal is to show what Techrules is capable of, and then we will look at the start of road car production."

And that is the next step for the auto maker. The Ren RS forms an illustration of what the TREV powertrain is capable of, and if Techrules's first track car performs as expected on the automotive testing ground that is motorsport, the turbine electric powertrain could be the next big thing in passenger cars.

WORDS: **ANDREW CHARMAN**

Bold ambitions

Few have heard of **Lvchi Auto**, but the Chinese startup intends to change that with its forthcoming electric vehicle range, starting with the Venere

At the end of a Geneva Motor Show press day featuring numerous car launches, the unveiling on the Lvchi Auto stand attracts only a small media crowd. In future years, however, the scene may be different, if the Chinese company's president Xiangyin Wang has his way. Taking the wraps off the Venere, a car he describes as "the world's first full electric limousine with supercar performance", Wang says that by 2023 the car will top an electric range selling in several sectors, produced by a well-known international brand with a 500,000 annual volume.

Bold words, particularly considering that Lvchi Auto was only established in Shanghai in 2016. And rivals such as Aston Martin, which unveiled its Lagonda electric luxury car hours before the Venere, might question the "world's first" claim. But in terms of technological know-how, the Lvchi newcomer certainly competes with the better-known European names.

Remarkably, *E&H Vehicle* heard, the Venere project began only in July 2017, as a joint program with the Institute of Development in Automotive Engineering (IDEA). Established in Italy in 1978, IDEA has extensive experience in design, modeling, engineering and prototyping.

Lvchi's stated aim is to "disrupt the EV market with innovative solutions, yet to be seen on such vehicles". Such innovation sees the Venere based around a carbon-fiber honeycomb composite tub, with the roof forming an integral stressed member. As a result, although it is a large car – 5,150mm long, 2,120mm wide and with a 3,040mm wheelbase – the Venere is also lightweight, tipping the scales at 2,100kg.

It is low as well, standing only 1,418mm tall with a frontal area of 2.4m². A drag coefficient of just 0.28 results from "innovative aerodynamic solutions" (about which neither Lvchi nor IDEA are more forthcoming).

A pair of aluminum subframes attach to the composite shell over the axles, each carrying two 185kW electric motors and a differential. The transfer box incorporates a two-speed gearbox and provides all-wheel-drive capability.

Total power is 740kW (1,006ps) at 13,000rpm, with 1,540Nm of torque. Lvchi quotes a 0-100km/h (0-62mph) time of 25 seconds and a 286km/h (178mph) maximum speed, while the NEDC range between charges is 652km (405 miles).

The 100kWh lithium-ion battery pack is incorporated into the floor and transmission tunnel. As a result, the Venere promises spacious surroundings for four occupants, and easy access – the composite shell dispenses with a traditional B pillar and employs rear-hinged doors.

A traditional-style steering wheel is fitted but the cabin is otherwise devoid of switches and knobs. All functions are accessed through touchscreens, including a large unit incorporated into the top of the transmission tunnel. Full autonomy will be part of the car's development.

Growing aims

Lvchi intends to start producing the Venere in Turin, Italy, putting it on sale in 2019 at a yet-to-be-revealed price. By that time the brand will be well into its ambitious growth plans.

A performance electric saloon, the Urano, was unveiled in Shanghai in January, and at Geneva Wang revealed that in September 2019 a two-seat EV will be launched into the Asian market on a new electric platform. From 2020 it will also underpin a three-door four-seater and a European five-door hatchback.

A mid-sized platform will form the basis of new MPV, SUV and saloon models to be revealed in October 2019, swiftly followed by an electric sports car and a hybrid coupe on a larger S platform. By 2023 Lvchi will be selling 500,000 cars a year, with its Italian plant joined by three in China and technology support being employed in Italy, the UK and the USA.

Wang describes the Venere as the future of electric cars. "We have a detailed plan to become one of the most recognized EV makers. Venere is how we present ourselves to the world," he says.

Equally, Domenico Morali, president of joint partner IDEA, sees the Venere as a bold indication of what the brand stands for. "We gladly shared IDEA's historic know-how and expertise to come up with this incredible car," he says. "First we prove, then we talk. This is why we are here with a performing prototype." ■

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Sharing is caring

With the Seven, **Iconiq Motors** aims to kickstart a vehicle program for chauffeur-driven customers as well as ridesharing applications

WORDS: **CRAIG THOMAS**

The explosion of the Chinese light vehicle market has accelerated the need for the automotive industry to address the implications it has for the country's (and the planet's) environment.

Iconiq Motors, founded in 2016 and with its HQ in China, is working on a low-emissions solution aimed at the chauffeur-driven and ride-hailing segments of the market.

The electric Iconiq Seven was unveiled at the Shanghai Auto Show in 2017, with an updated prototype receiving its European debut in Geneva this year.

"The Iconiq Seven has been designed to focus on the passenger first, because China has a big chauffeur-driven market," says Iconiq CEO Bruno Lambert. "At the high end of the market people have a car with their own driver, plus there's the shared mobility business. We're trying to offer the best solutions for this demand, which is very fast growing. The ride-hailing companies are hoping to get vehicles designed for their customers and there is also demand for this kind of concept in the luxury transportation sector, where the benchmark is the Toyota Alphard, which you see a lot of in China. We are aiming for individual customers, but we think that around 70% of our volume will be fleet customers, including ride-hailing companies. So we have a mobility variant, which is seven seats, a premium variant with six seats and the VIP with four seats."

Life expectancy

The Seven uses a new electric platform that has been developed over 18 months by Iconiq in conjunction with Austrian contract manufacturer Magna Steyr.

"The platform is a 78kW battery pack with a 165kW electric motor," says Lambert. "The focus is on delivering a solution for shared mobility, so that's why we're aiming for a range of 400km [NEDC], which answers the expectations of most ride-hailing companies today in terms of daily use. The powertrain is also designed with shared mobility in mind, so it's not focused on high performance but the right cost positioning.

"The 42-module lithium-ion battery pack, using a flat-floor layout with a standard battery tray integrated into the structural design of the vehicle, has also been developed with a focus on long life. The design and the BMS make sure that we can sustain 2,000 charging cycles with a degradation of less than 10%," Lambert adds. "If you compare that with some existing battery packs, you'll see that after 500 cycles there's already a degradation of 20-30%. You can have higher residual values, which is important for mobility suppliers, for example."

1

Iconiq has sourced the cells for the battery pack from Lishen, the second-biggest battery supplier in China. Lishen's location in the same economic zone as Iconiq means a guarantee of supply and technology access. The cells, Lambert says, are already in production, so Iconiq is currently testing at module level and pack level.

The motor – Iconiq is using one main motor for front-wheel drive, but is also considering an all-wheel-drive version with in-wheel tech – is also sourced from one of the larger suppliers in China, Jing-Jin Electric (JJE).

"It provides an integrated powertrain system [IPS], integrating a DC-DC converter, inverter and so on into one pack, which makes the weight-to-performance ratio better," says Lambert. "The controlling system, overall BMS and so on are our own design, but the system level is done by our supplier.

"Through the BMS we are integrating cooling for the whole battery, which we manage, but we'll get a solution from a supplier: we're choosing between two major international cooling and HVAC suppliers at the moment."

Production is slated to start in 2019 in Iconiq's factory in Tianjin, with a second location being sought to meet its target of 70,000 cars a year. The primary focus is China and the Middle East, but there are also ongoing discussions with European importers and interest from North America. Iconiq is also working toward Level 5 autonomous capabilities, which could see the Seven offer the kind of shared mobility solution that could be commonplace in the future.


2

1. Targeted at the chauffeur-driven and ride-hailing markets, the Iconiq Seven is planned to begin production in 2019

2. The Seven uses a main motor for front-wheel drive, but Iconiq is considering an all-wheel-drive version using in-wheel motors

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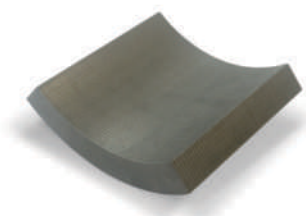

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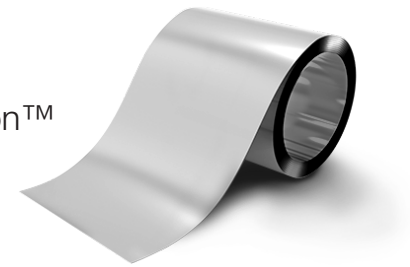

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Efficiency is at the heart of the Luka EV's vehicle platform, which includes a brand new architecture

Reinventing the wheel

A retro-styled sports car from **MW Motors** is a platform for the latest in-wheel motor technology

WORDS: **MATT ROSS**

The last issue of *E&H Vehicle* revealed details of how Jaguar's E-type Zero was combining the iconic sports car's chassis with a state-of-the-art, emissions-free powertrain. Coupling the latest in battery electric drivetrains with vehicle designs from the past, it seems, remains a popular trend.

For Czech Republic-based MW Motors, the pairing of past styling and present technology has resulted in the Luka EV, a production-ready electric vehicle that sports four in-wheel motors, yet looks like the classic GT cars of the 1950s and 1960s. Under the skin, however, the Luka EV couldn't be more different. The four 12.5kW brushless motors power the Luka from 0-100km/h (0-62mph) in 9.6 seconds (and on to a top speed of 146km/h (91mph)),

The Luka EV uses four 12.5kW in-wheel motors

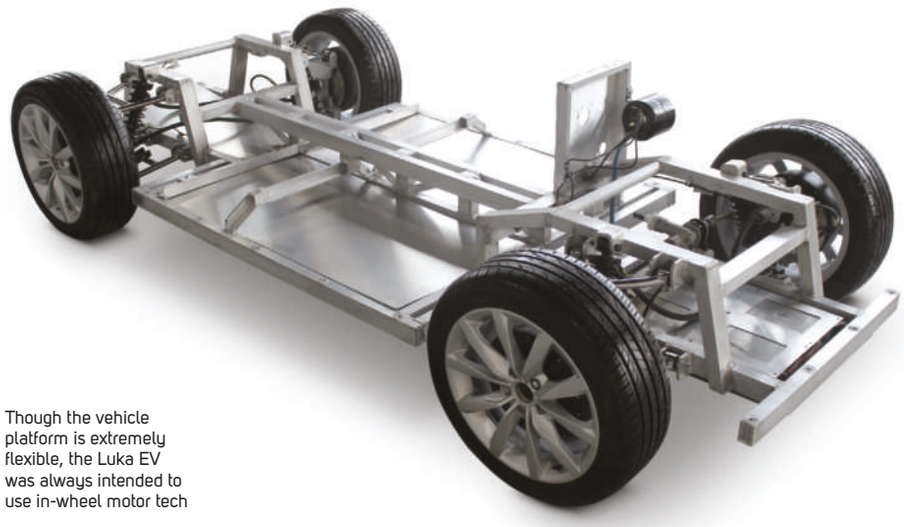
while strategic lightweighting yields a current curb weight of 815kg. Four battery packs, distributed across the floor of the vehicle, contain a total of 60 $Li(NiMnCo)O_2$ cells, which are good for an estimated 300km (186-mile) range.

Despite the retro styling, the Luka team – which began work on its first prototype in 2014 – always intended to design a brand-new car that was, first and foremost, efficient.

"Efficiency is at the core of the platform," says MW Motors owner Maurice Ward. "The market for fast and powerful is well served by other producers – the aim was always to create an efficient car.

"The architecture is entirely new – there are no elements from any other vehicle. Luka EV is entirely different in all aspects to any other M1 class production car."

Key to the Luka EV's range and performance figures is its light weight. Achieving 815kg was the result of three major factors. The use of in-wheel motors eliminates the need for many heavy powertrain components, such as an engine, gearbox, exhaust, differential and axle, among others – "If a part is no longer required," Ward says, "you don't need to worry about how heavy it is" – and the Luka EV uses aluminum



Though the vehicle platform is extremely flexible, the Luka EV was always intended to use in-wheel motor tech

for key components such as the chassis and motor mounts. Finally, the vehicle's body is made from lightweight FRP.

First choice

In addition to reducing weight and increasing interior space, in-wheel motor technology was at the heart of the vehicle's very design.

"No other drive system was ever considered," says Ward. "However, the platform is flexible and there is no particular reason why it can't be tweaked to accept other systems, such as an e-axle or traditional electric drive. This is not an area we are focused on, but some partner institutes are toying with this idea."

Although he doesn't name names, Ward reveals that his company has two suppliers for the motors. They are based on off-the-shelf units, but customized by MW Motors to suit the Luka EV's requirements. Due to the use of in-wheel technology, torque vectoring coordinates the motor controllers. "In essence, our master control unit knows some basic, fixed data about the car (overall mass, distribution of mass, architecture, and so on). Additional live inputs are gathered (steering wheel angle, specific brake/throttle info, other motor controller data). The master control unit crunches data in real time, feeds an algorithm and sends data back to the motor controllers, essentially transforming the open differential into an active electronic differential."

The battery pack architecture – front and rear mini-packs contain 12 cells each, while two central packs have 18 cells each – has been specifically designed to enable future expansion.

"There are large gaps between cells," Ward explains. "We haven't just crammed as many cells as possible into the smallest possible space. The height of the pack is 6cm [2.4in] and we have allowed an additional 6cm of space in case we wish to double the pack size. However, the basic pack is perfectly okay for the target market. Adding extra batteries adds weight, reduces efficiency and adds cost. Efficiency and cost are things we wish to keep under control.

"There are plenty of car makers simply adding more and more batteries to achieve a range similar to that which the Luka EV already achieves."

Balance of power

In terms of adding more powerful motors, Ward and his team are satisfied with the Luka EV's current specification.

"Today, we limit the motor output. Without electronic limitation, each motor has a peak power of 24kW; 96kW will always be enough for an 800kg car. The car is designed to be enjoyed, not as a vehicle to be raced."

In other areas of the vehicle design and powertrain, Ward notes, "As a small company, we have much more flexibility in the engineering changes we can make. Many companies and institutions wish to test novel technology on our platform – should any of this new tech prove itself, we are open to adopting it.

"Additionally, Luka EVs are equipped with a 'flight recorder'. This sends all drive data back to our central servers. This data is critical to the continuous improvement of both the vehicle and the platform."

Vehicles are assembled at MW Motors' campus in Štenovice, Plzen (which the company owns), and the car maker also has an R&D center in Zhongshan, China. Ward plans to build 100 cars in 2018 – although options to ramp up production could be easily put into place, particularly if early discussions to sell the vehicle in the USA (the Luka EV will be available in all EU markets) prove successful.

When it comes to additional models, Ward remains open-minded. "The project is as much about the platform as it is about the specific car. In effect, assuming the driving chassis platform is successful, we have the ability to add different body shapes and styles – these can all be produced at a very low cost using FRP tooling. If demand exists, we can, in theory, replace the FRP body shape with a stamped aluminum body for mass production. However, we need to focus on Luka EV now – that will tell us all we need to know about the platform."

Aesthetically, the Luka EV bears more than a passing resemblance to Tatra's JK 2500

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Power trip

The **Envision** and **GFG Style** Sibylla is not your average concept vehicle, but a portal into the future where connected digital energy powers our transportation system

WORDS: **LEON POULTNEY**

Automotive manufacturers regularly reveal striking concept vehicles at motor shows,using these typically future-thinking concoctions to show changes in upcoming design language or demonstrate technological advances.

However, it is slightly less common for a concept car to exist purely to highlight a concept, as was the case with Envision and GFG Style's Sibylla at this year's Geneva Motor Show.

Automotive designers Giorgetto and Fabrizio Giugiaro penned the sleek silhouette of this luxury saloon, which aims to paint a picture of future all-electric, highly autonomous transportation, but it is the connection with smart energy management expert Envision that makes the design study intriguing.

The Sibylla represents a vision of an all-electric, highly autonomous transportation system that makes use of smart energy management

"There are huge changes taking place in the automotive industry and the trend toward ever greater electrification of powertrains isn't showing any signs of slowing down," explains Felix Zhang, group executive director of Envision Energy. "But the big issue facing the industry is the lack of infrastructure. How do we bring renewables into the equation so we can run truly emission-free vehicles?"

Envision is already touted as a leading digital energy company, owning the world's largest Energy IoT platform, EnOS, which currently manages 100GW – or about the same as the UK's entire generating capacity – of energy assets globally.

"EnOS is an open platform – think of it as the Android of the energy industry – and it allows a seamless and harmonious shift from generation to demand," says Zhang. "There are a lot of OEMs that are talking about the energy system in a very traditional silo sense. EnOS is a completely open solution and we think the industry needs to break down the barriers if truly efficient and renewable e-mobility is to be realized."

Proactive partners

Envision has also teamed up with Sonnen, the German company that connects people who produce, use and share energy, creating a community that looks to benefit from a decentralized and clean energy source.

"Electric mobility for the masses cannot happen with the current setup we have," says Philipp Schröder, managing director of Sonnen and former head of Tesla in Germany and Austria. "Any OEM that's planning on bringing hundreds of thousands of vehicles to the market will find that it just won't work in the current state.

"It is clear we need to introduce intelligence into the system that will allow for staggered charging times and the smart movement of energy," he adds.

The company's SonnenCharger aims to achieve just that, and once plugged into any OEM electric vehicle, it becomes part of Sonnen's virtual powerplant, meaning that customers can make the most out of surplus wind, solar and other renewable energy, effectively translating into free all-electric miles.

"The solution we have does not need to have access to the proprietary system of the OEMs. You simply have the intelligence built into the charging box," says Schröder. "A customer allows us to intelligently charge their battery and in return, they get free electricity. They are not involved in managing it or processing; it's as simple as it can be."

From concept to reality

GFG Style's Fabrizio Giugiaro reveals that most of the Sibylla concept's underpinnings are largely fashioned from easy-to-obtain parts, with the 100kWh battery and four-electric-motor powertrain following a similar layout to that found in the Tesla Model X.

Figures released by Envision and GFG Style suggest that a production vehicle would boast a 450km (280-mile) all-electric range and a top speed that would top out around the 200km/h mark (125mph).

Although Envision is keen to point out that the Sibylla is purely conceptual for now, it hasn't completely ruled out moving into EV production in the future.

"In Germany, EV sales are actually in decline because the infrastructure can't catch up," says Zhang. "We want to see further growth of EVs going forward, so we are providing tools to help to accelerate this growth. We will watch the market and certainly see what happens."

Both Zhang and Schröder feel an innovative approach to energy management will have a greater effect on the industry than any new EV possibly could.

"Everybody is looking at the hardware, but nobody is looking at the infrastructure," says Schröder. "When Daimler was creating the first car, there was no infrastructure. There were no oil refineries, no filling stations, but these were developed.

"As soon as the industry wakes up and realizes that a virtual powerplant means the vehicle becomes far more than just a method of transport – it becomes a mobile energy storage device – the closer we will get to a real renewable future," he adds.

Route master

The developer of a new route-finding algorithm aims to give EV drivers the ability to optimize travel across the public charging network

WORDS: **MATT ROSS**

One stressful journey in a Model S has led a UK-based technology developer to create an EV route-finding algorithm to meet the navigation and trip-planning needs of electric vehicle drivers. During a 200-mile (320km) road trip, David and Jane Morgan-Brown found themselves subject to crushing range anxiety – and at the whim of a contrary in-car navigation system.

"It was the most terrifying, stressful journey," explains David Morgan-Brown, tech director and creator of EVNaviQ. "There was this tirade from the car, it was telling us that we weren't going to get there, that we had to drive below 60mph [97km] and so on. And then, as we were getting closer, it was suddenly telling us that everything was going to be absolutely fine."

Following several conversations with Tesla – "The impression I got was that they thought it was down to how we were using the satnav" – the couple, who are the founders of software development house Morgan Brown Consultancy, decided they could develop a route-finding solution that took into account the location of public charging stations.

"My background is in technology, and I'm fascinated by optimization problems," explains Morgan-Brown, whose résumé includes work with global companies such as BP, HSBC and Barclays on technology delivery programs. "It was an attractive problem. It was the first time we'd built software without a customer sat there ready to pay something. This was our idea, and we were building something based on what we saw as a need, rather than somebody coming to us with a problem."

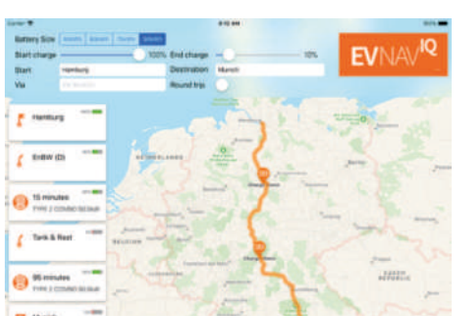
Morgan-Brown disappeared into what he describes as his "shed at the bottom of the garden, where I tinkered".

"There was lots of swearing. At the beginning it seemed like a relatively easy problem. Then I found out it was a surprisingly difficult thing to do – there were no precedents. There was some academic research on it, but it was very limited. Everything seemed to miss the key things you needed to accurately predict range, lacked really essential features, or simply couldn't perform well – there was some academic research that developed a system for a state in the USA, but that algorithm took 47 hours."

EVNaviQ, the result of Morgan-Brown's labors, enables drivers to quickly plan an optimal route. Running the system on an iPad, he demonstrates some of the variables that can be programmed in – battery capacity, current SoC, waypoints, desired charge at the end of the journey and so on – before calculating a route in seconds. And, unlike some in-house OEM systems, the algorithm draws data from Open Charge Map, which aggregates charging point information on public fast chargers from several sources.

High performance

The algorithm runs on Amazon Web Services in the cloud. When Morgan-Brown presented EVNaviQ to one industry expert, they insisted that the performance was so impressive that "he thought we must be running it on a supercomputer. He didn't believe us..." But Morgan-Brown explains that it's actually running on the smallest unit of computing power he could buy.



EVNaviQ will plot an optimized route that can even ensure a specified finishing state of charge

Morgan-Brown presented EVNaviQ at Electric & Hybrid Vehicle Technology Expo in Hannover in May, which has led to "early conversations with two car makers". The benefits of working directly with OEMs seem obvious, as building the software into a vehicle would mean real-time information regarding battery capacity, SoC and usage would be available to the algorithm. Morgan-Brown is also in conversation with a large manufacturer in India, which is trialling electric buses.

EVNaviQ is patent pending, with possible applications for hydrogen power, ships and drones included, and though Morgan-Brown is keeping his feet on the ground, he has a good idea of what he'd like the software's next steps to be. "If I had it with an OEM, ready and lined up to go into vehicles in 2021 or 2022, I'd be absolutely over the moon. And especially if that OEM could help me, in partnership, go to the CPOs to get real, live usage and availability data. I genuinely think that [a vehicle equipped with EVNaviQ] would have an advantage in the showroom over one that wasn't. My dream expectation is that we're in the development proving stage for the next generation of EVs."

And those people who still believe that the route planning he's demonstrating must be 'performance enhanced' by a secret supercomputer? "I'm happy to share this with anyone," Morgan-Brown says. "There's nothing up my sleeve."

ELECTRIC POWERTRAINS **ON TEST**

Our thoughts on cars we've tested recently, all of which feature some sort of advanced powertrain electrification

NISSAN LEAF

When releasing the second generation of a vehicle hailed as the best-selling EV in the world, there's no room for half measures. So perhaps it's no surprise that the second-gen Nissan Leaf looks a world away from its predecessor, and that the technology underpinning the all-electric hatchback has been given a substantive overhaul, too. Nissan has specified the new Leaf with a 40kWh battery, which takes up the same space as its predecessor but increases range by around 40%. The lithium-ion battery is mounted in the vehicle's floor to reduce body roll in the corners and smooth out handling. The spec sheet claims a total driving range of 270km (168 miles), though, as always, such figures should be taken with a grain of salt, and *E&H Vehicle* left the office after charging with a range closer to 225km (140 miles). The new 110kW front-mounted motor produces 150ps, which is enough to make the Leaf feel sprightly and agile for a car that is actually quite sizeable.

The headlining technology is the new e-Pedal. Selecting this drive mode essentially makes the brake pedal redundant, as the car's regenerative braking is turned up enough to bring the vehicle to a complete stop and even hold on a slope. It makes for an efficient drive, stretching out the range by smoothing acceleration and deceleration. But more than that, it's a lot of fun. There's an initial period of driver adjustment, but the e-Pedal is surprisingly intuitive after just a few minutes and, coupled with the satisfying throttle response, makes for a car that is not only frugal (though the remaining range will still yo-yo if you crank up the ancillaries) but entertaining as well.

HYUNDAI IONIQ ELECTRIC

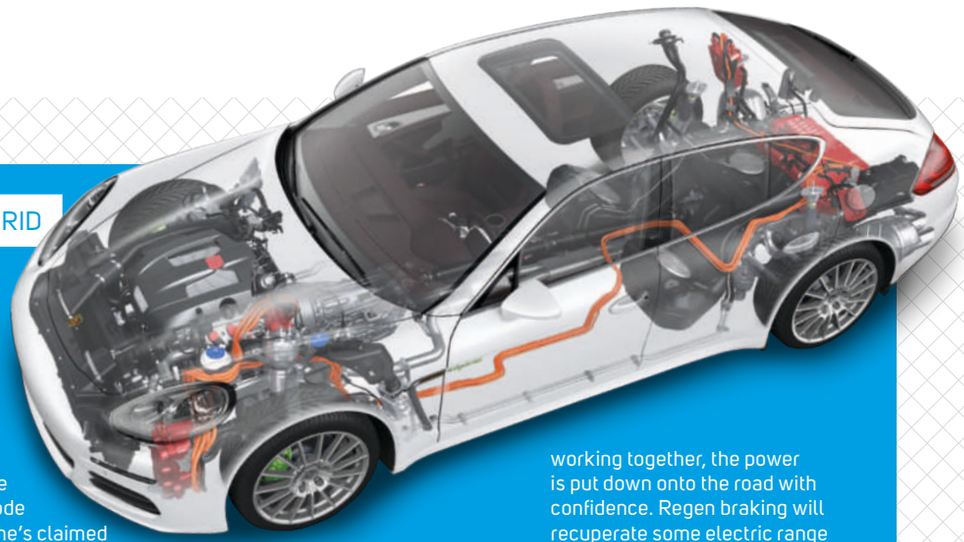
In the previous issue of *E&H Vehicle* we were impressed with the quietly competent plug-in hybrid Ioniq, so when we took delivery of the all-electric variant (which, along with a mild hybrid version, makes up the OEM's three-pronged Ioniq strategy), we were fairly confident of what to expect.

But it is always nice to have one's expectations surpassed; the Ioniq BEV is an impressive vehicle. Powered by a high-voltage electric motor that develops 120ps and 295Nm of torque, it accelerates smartly from a standing start – not the kind of seatbelt-tightening performance you'd expect from the likes of Tesla, but then that's not really what the Ioniq is about. And because it's not worried about forcing you backward into your seat at every opportunity, the Ioniq's 28kWh lithium-ion polymer battery (placed low in the chassis for better handling) holds its charge in a way that had us double-checking the range meter on a regular basis. The official figures state that the car has a range of 280km (174 miles) – though we started most journeys after a day of standard, three-pin charging with closer to 209km (130 miles) on the dashboard – and that figure will creep down far more slowly than you'd expect.

Hyundai's powertrain is, quite simply, remarkably efficient, and though it's not a performance vehicle, the Ioniq's dynamics and handling are sufficiently lively to keep you from becoming bored – even if the low-resistance tires mean the vehicle can get a little twitchy. What's more, the car boasts a number of other impressive features. The shift-by-wire buttons for drive selection sit on the center console, while the strength of the regenerative braking can be adjusted by paddles behind the steering wheel. On its strongest setting, the regen braking makes it almost possible to enjoy one-pedal driving similar to that in the Leaf (though the speed drop off when letting up on the accelerator is a little more severe than in the Nissan) – and the in-car navigation system keeps a constant eye on the location of the nearest charging point, even noting which may be restricted to private users and which are for public use.

The matt-gray panel on the front of the car's exterior is a little more divisive, and is certainly a... distinctive element. But given that the Ioniq has a drag coefficient of 0.24, which contributes to the efficiency of the powertrain, the aesthetics seem less important than just what a practical EV this is.

PORSCHE PANAMERA TURBO S E-HYBRID



The Panamera Turbo S E-Hybrid is a car with impressive stats. It sports a 4-liter V8 gasoline engine that creates 558ps, a 14.1kWh liquid-cooled lithium-ion battery and a 138ps electric motor, for a combined system total of 850Nm of torque and just under 690ps. But an equally important number is that this hybrid Porsche weighs in at 2,310kg. That extra heft makes for an assured ride – though deplete the battery and you'll notice that weight, particularly at low speeds. When it's in full flight from a standing start, however, the Turbo S E-Hybrid has an air of excitement about it – it employs the same boost strategy as the 918 Spyder and will race to 100km/h in just 3.4 seconds.

When the battery is fully charged it offers short, sharp response times in EV mode (though Porsche's claimed 50km [31 mile] electric range was difficult to achieve when we tested the car) and, unlike some hybrids, the pedal feedback when under electric power feels as responsive as when the ICE engine is at work.

After a set pressure threshold on the accelerator, or if the battery capacity drops below a certain point, Hybrid Auto mode kicks in, with both engine and electric motor power available. On occasion it seems that the ICE is doing the lion's share of the work, if only because the growl of the V8 is more noticeable after the eerie quiet of the e-motor's initial dominance. With both systems working together, the power is put down onto the road with confidence. Regen braking will recuperate some electric range (there's also an E-Hold mode that will enable you to maintain a set reserve) though for anything but the shortest journeys you're better served by plugging in when possible – not least because having both powertrains at your disposal means you'll get to enjoy the Turbo S E-Hybrid at its best.

BMW 530e iPERFORMANCE

Stefan Juraschek, BMW's head of alternative powertrain, told *E&H Vehicle* that we would be "supremely impressed" by the 530e iPerformance. Keen to see if he was right, we eagerly anticipated the arrival of the OEM's hybrid sedan, which combines a 2-liter four-cylinder turbo gasoline ICE (that produces 186ps) with an eDrive synchronous motor (integrated into the eight-speed Steptronic gearbox and producing 114ps) for a combined output of 255ps. The system also includes a 9.2kWh Li-ion battery under the rear seats.

Where the BMW sets itself apart from a number of other hybrids is the smooth and unassuming manner in which the two powertrains interact. Capable of a claimed zero-emissions range of 47km (29 miles), the 530e gets close to that on a full charge – assuming you don't call on the car's top electric speed of 140km/h (87mph) or make the powertrain work too hard. Careful driving will see short commutes completed without bothering the ICE, but when the two systems are working in concert the various driving modes offer a smooth integration of combustion and electric propulsion.

Sport, Comfort and Eco will be familiar to regular 5 Series drivers, but the three modes specifically relating to the electric-ICE interaction yield a high level of flexibility. Auto mode is as it sounds; Max eDrive will lean on the e-motor for as long as you have sufficient charge; and Battery Charge means you can set a threshold power level that the car will maintain. On occasion it's genuinely tough to spot the transition between propulsion technologies, and the vehicle's architecture, layout and weight distribution go some way to avoiding the feeling that you're simply carrying around batteries and a motor when they're not in use. It's a smooth, refined driving experience with a sophisticated powertrain that doesn't need baby-sitting. Impressed is right.

LEXUS LC 500H

Arguably Lexus's most visually striking model to date, the LC 500h takes many of its exterior design cues from the 2012 LF-LC concept. Sharp, angular lines cut through the luxury sports coupe's voluptuous sheet-metal body, while a large spindle grill has also been retained, adding to the car's futuristic aesthetic.

As impressive as the LC 500h looks, its drivetrain is even more interesting. An all-new direct-injected, Atkinson-cycle 3.5-liter V6 gasoline engine (type 8GR-FXS) with dual variable valve timing (producing 299ps) is coupled to two e-motor-generators and an 84-cell, 310V lithium-ion battery pack that produces 44kW (equivalent to 60ps) for a combined power output of 359ps. In fact the LC 500h represents the first use of lithium-ion batteries in a Lexus hybrid, replacing the previous nickel-metal hydride pack and reducing battery weight by over 30% and volume by 20% in the process.

However, it's the LC 500h's Multi Stage Hybrid System that really marks a vast change for the Japanese OEM's flagship coupe. An all-new CVT transmission couples the electronically controlled planetary power-split device that has been at the core of every Lexus hybrid with a new 4-speed planetary automatic final drive to simulate a 10-speed automatic transmission.

While all this technology helps the car to switch effortlessly between gasoline and electric power, it also contributes to the LC 500h's rather hefty 2,012kg weight. Inevitably, this does impact on the responsiveness of the powertrain, but the 0-100km/h sprint time of 4.7 seconds and 250km/h (155mph) top speed still manage to satiate performance cravings.

PROFILE: **RICHARD FARQUHAR**

Job title: Director of powertrain
Company: McLaren Automotive

What career did you want when you were growing up, and what was your first job?
Engineering or design was pretty much all I wanted to do – so choosing a career was easy! I always used to ask 'why?'. I wanted to know how things work and I would make little wooden go-karts and take things apart and put them back together again; I've always had a fascination for mechanics. I did a degree and a master's in mechanical engineering and then started my career working for Takata Corporation, although my first real engineering projects as such were at Lotus.

What are the best and worst elements of your job?
I believe I have the best job in the world, engineering the powertrains for some of the top supercars and hypercars – so by far the best element is being associated with those products, being able to drive them, and seeing other people's reactions when they drive them. The worst part is that inevitably at some point, the engineering process has to come to a stop, despite the fact that at McLaren we believe in continuously improving.

In your opinion, what is the best powertrain that's ever been produced?
I'm a massive fan of the V10 Formula 1 engines. As an engineer, whenever you hear those powertrains at a track it's exhilarating. Then when you think about what's inside, the components are a work of art. Those engines can rev to 20,000rpm and beyond! I really admire the engineers who built them.

Which other OEMs do you have engineering respect for?
I'm still inspired by the F1 engineers; the technologies combined in those [powertrain] units and what has been achieved are very special. I also think the German OEMs are producing fantastic powertrains to meet a breadth of applications and ever-demanding legislation. And the Californian companies developing next-gen EVs are truly pioneering.

What could legislators do to make your working life easier?
Introduce more standardization. Across the world we're all trying to achieve the same goals in terms of air quality and control of

> "It's all about optimization, so to create the best engine, the core is one thing, but we need to consider all the variables – whether it be the thermal management systems, variable compression ratio, or electrification"

greenhouse gases, but the legislation, the timing of it and the drive cycles differ. Standardization would make it much easier for us to optimize our vehicles to meet those specifications and ultimately spend more time improving their performance.

What will be powering the typical family sedan in 2030?

We are rapidly seeing the introduction of electric vehicles and particularly in the family sedan market, the industry is well on its way to providing the range that those vehicles need. The architecture lends itself to a family sedan and the charging network is being put in place.

I think there are a number of other technologies that will be developed further, but there's more momentum now than ever in the EV segment.

Does downsizing work in the real world?

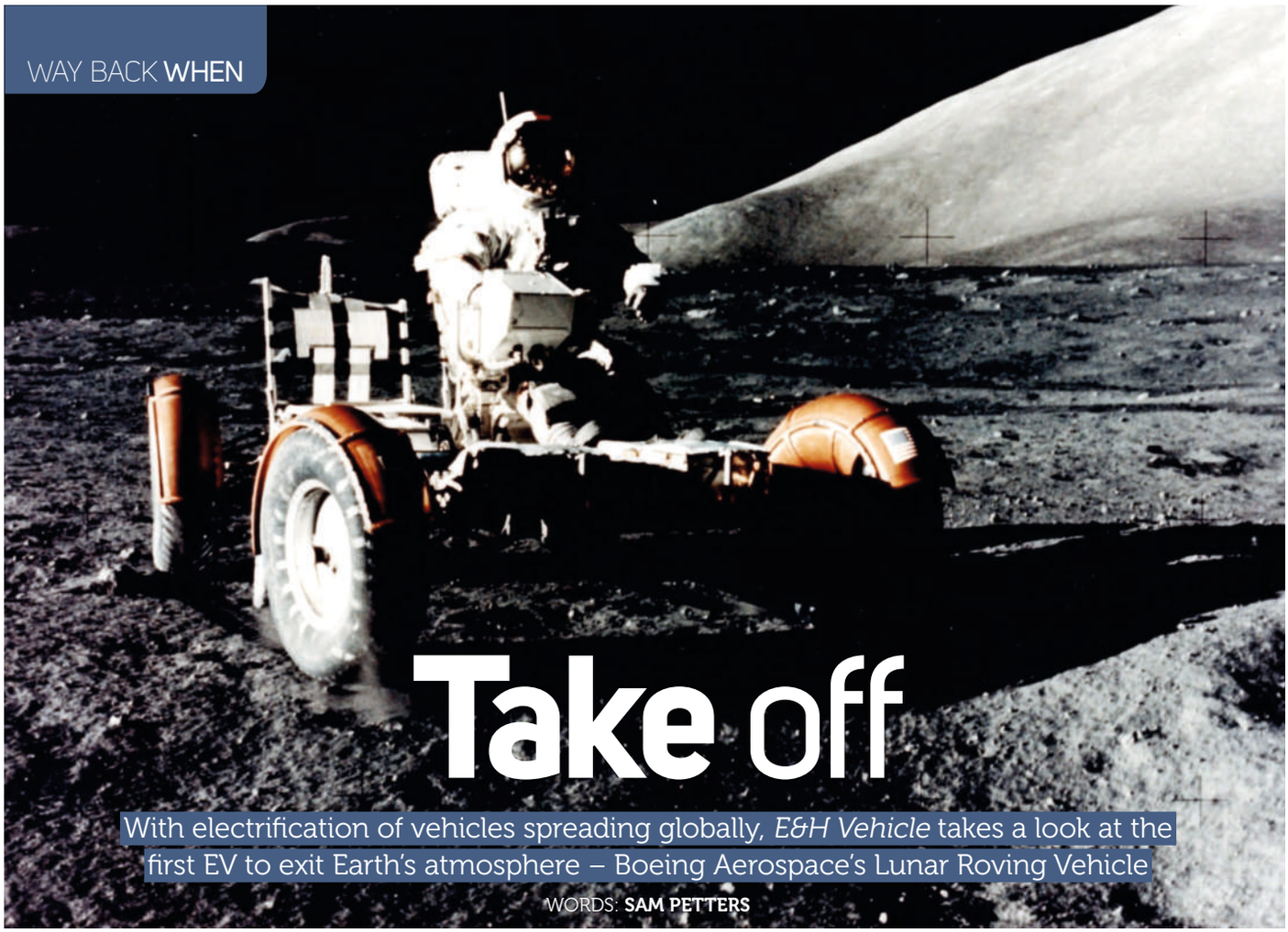
When McLaren first went to market with the M838T engine, relative to our competitors we were able to achieve 700hp from an engine that's generally normally aspirated, and typically 6 or 7 liters, but yet we did it with a 3.8-liter and it was the most fuel-efficient car in the segment for its performance – so the laws of physics tell us that downsizing has its advantages! And then applying that to different vehicles, if you look at the combustion process, the air path, the fuel path and the developments that are happening there to achieve the torque and the driveability with it, it's a really good foundation.

What would your dream engine specification be for today's eco-friendly world?

It's all about optimization, so to create the best engine, the core is one thing, but we need to consider all the variables – whether it be the thermal management systems, variable compression ratio, or electrification, for example – being able to control these elements without any boundaries in terms of cost, weight and package would bring out the best in any ICE.

Have engine developers learned lessons from the development of high-output small capacity engines that are transferrable to other units?

Without a doubt, the operating conditions of the downsized, pressurized, high specific output engines that we produce at McLaren, which mechanically have higher cylinder pressures, are tough. To maintain speed with downsizing, we need to make the core of an engine better and the application of that is very relevant to different market segments.



Take off

With electrification of vehicles spreading globally, *E&H Vehicle* takes a look at the first EV to exit Earth's atmosphere – Boeing Aerospace's Lunar Roving Vehicle

WORDS: **SAM PETTERS**

Main image: NASA; Inset: The Boeing Company

Earlier this year Tesla Motors and Elon Musk made headlines after the company sent a first-generation Roadster into space atop SpaceX's Falcon Heavy rocket. But though images of the car drifting through the darkness were met with bemusement, it wasn't the first EV to make it out of Earth's atmosphere.

Between 1966 and 1969, Boeing Aerospace and Bendix Corporation were in the midst of a design battle to win a contract to supply the Lunar Roving Vehicle (LRV) for the Apollo 15 mission to the Hadley Rille area of the moon.

When Boeing was awarded the contract, the company had just two years to prepare its concept. After undergoing enough development, qualification and acceptance testing to qualify the EV as a manned spacecraft, the LRV was ready.

And on July 31, 1971, it became the first vehicle to drive on another world.

Designed to carry two astronauts in conditions of vacuum and extreme temperature variation during lunar surface exploration, reliability was the number-one priority. It was achieved through simplicity in design and operation.

This philosophy meant that failsafes were implemented throughout. So while the LRV would normally steer with both front and back wheels, if one steering mechanism failed it could be disconnected and the vehicle could complete its mission with the remaining system.

That same idea was built into the powertrain, which was equipped with two 36V silver-zinc batteries designed and supplied by Eagle Pitcher Industries' electronics division. Each one was sufficient to power the vehicle.

The batteries were non-rechargeable, but the technology inside was advanced. Constructed of monobloc plexiglass, each battery contained 25 cells and featured silver-zinc plates operating in potassium hydroxide electrolyte.

This would give a 78-hour life and a distance of 56 miles (90km). This can't be considered great by today's standards, but where the LRV excelled was in management of battery health.

The batteries needed to be kept between 40°F and 125°F (4°C and 52°C) from lift-off to touchdown, so temperature losses due to the coldness of space had to be controlled. Boeing Aerospace achieved this through insulation and reflective coating.

When the lunar rover was in operation on the moon's surface, a multilayered aluminized Mylar and nylon netting with a Beta cloth coating provided temperature maintenance through both heat reflection and insulation.

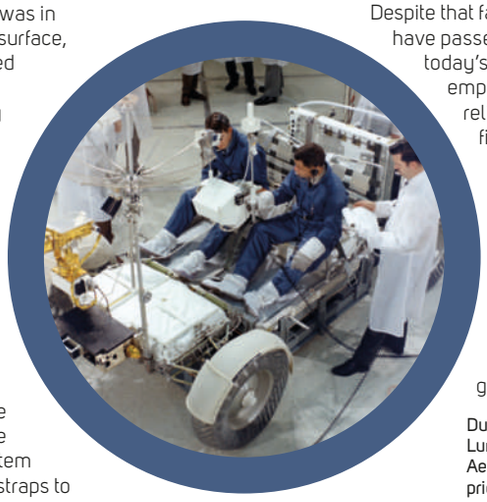
The EV's semi-passive thermal control system also came into play. During exploration, when the LRV would carry up to 1,140 lb (517kg) – more than twice the vehicle's weight – the intelligent drivetrain system used aluminum thermal straps to transfer heat from onboard electronic equipment to the batteries and fusible mass heat sinks.

Once the trip came to an end, the LRV could dissipate accumulated heat via radiation. The astronauts would open fiberglass dust covers to expose fused silica thermal mirrors that were mounted on top of the batteries, electronic components and heat sinks, forming a radiator to cool the equipment.

Used for the last three crewed lunar missions, the electric LRVs traveled between 11km and 20km (7 to 12 miles) on each trip and secured a lunar speed record of 18km/h (11mph). But the most significant achievement was the technology that was introduced.

Despite that fact that over 45 years have passed since Apollo 15, today's production vehicles employ electronic and reliability tech that were first seen in the LRV.

And with Elon Musk and SpaceX now plotting a route to Mars in the not-to-distant future, Tesla Motors will have a new pool of aerospace technology to draw from for the next generation of EVs.



During development of the Lunar Roving Vehicle, Boeing Aerospace built eight test units prior to the first flight model

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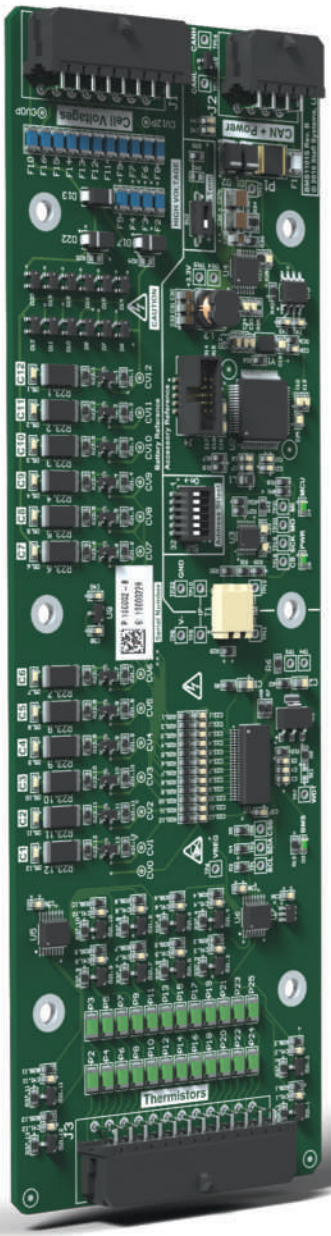

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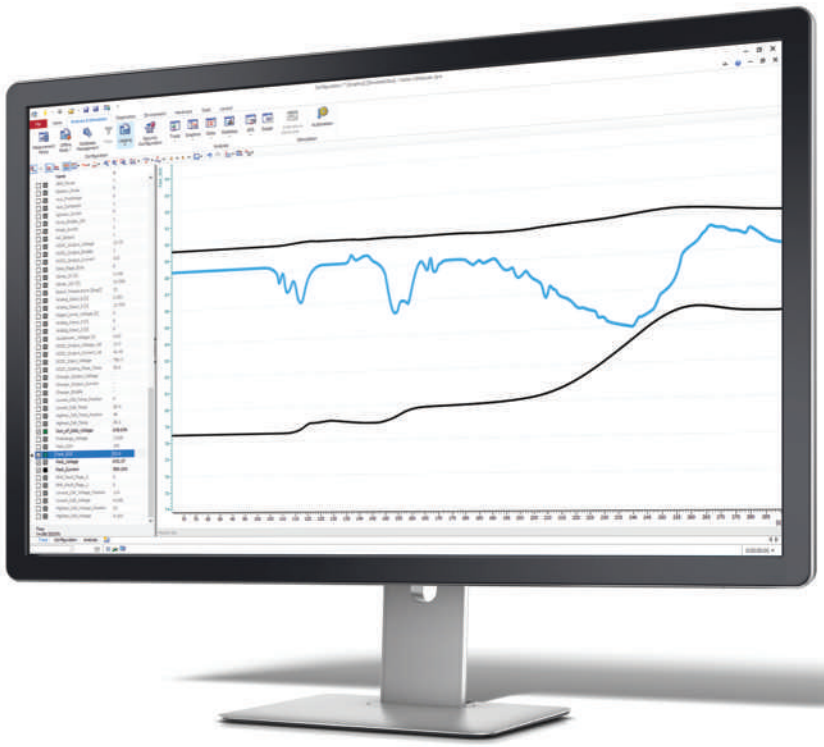

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STAFL SYSTEMS

Lars Thomsen

Tesla took a gamble on a then-non-existent market, and has gone head-to-head with the automotive industry's premium, luxury vehicle brands

When we are predicting the future, we are actually looking at what we call tipping points. Those are points in time when a new technology or paradigm takes the lead over the old. There was a time when a horse and carriage was more convenient than a car, because a car wasn't reliable, and you couldn't get petrol – there were no filling stations, you had to go to pharmacies to get the fuel you needed. When you look at electric mobility, we are at this kind of tipping point right now.

The price for batteries has come down even further than everybody predicted – even us at Future Matters. We were predicting a battery price of US$150/kWh about six years ago; now we are below US$100/kWh. We are at a very interesting time in history, and I often compare that to making popcorn – you put the kernels into the pot, you heat up the oil and, for a long time, the only trend you see is that the pot is heating up. The number of popped kernels is staying at zero. But once you reach a certain threshold, they pop – and they pop exponentially. That's where we're at now. China is producing more electric buses than diesel buses, which was unthinkable five years ago.

> "It takes a lot of courage to do what Tesla has done – to bet on a non-existent market"

Car manufacturers like Tesla, with a limited production Model 3, will be looking to outsell the incumbents such as the Audi A4, the BMW 3 Series, or the Mercedes C-Class. Many parts of the old industry are scared at the moment.

It takes a lot of courage to do what Tesla has done – to bet on a non-existent market and compete head-to-head with premium, luxury brands from the beginning. I have a lot of respect for the courage that Elon Musk has shown. And he is also a pretty strategic thinker.

Right now, there is no doubt in the industry that the future will be electric – for cars, for buses, for logistics. It will be highly automated or autonomous, but no other car manufacturer (besides BYD in China) has its own battery factory. When you want to disrupt an industry, it's not enough to come up with a good product – you also have to think about infrastructure, about energy, about the main components that you need to source.

I have met Elon Musk a couple of times. Many people call him a marketing genius or a guru. From my experience, he is actually a rather shy person. The first time I met him was at a store opening in Munich, and he was standing there with nobody talking to him. He's not the one in the middle of every party, or at the center of the universe. I don't think he founded Tesla to become rich or to be a big car manufacturer. His ambition is to change the way we use energy. For him, we need to have sustainable transportation, and he's just the one who said, "Okay, it seems like nobody wants to do this job, so I have to do it." And he's taking a lot of fire for that – from the media, from politicians, from many people who are afraid of change. It's quite interesting to see that, even among people that I talk to everyday, half of them are really scared of change and try to find every argument they can to say that electric mobility should not happen. He's up against people who don't embrace change as much as he does.

Lars Thomsen is chief futurist and founder of Future Matters. As a researcher of future trends, he is considered one of the most influential experts in trend forecasting in energy, mobility and smart networks

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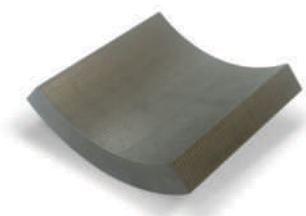

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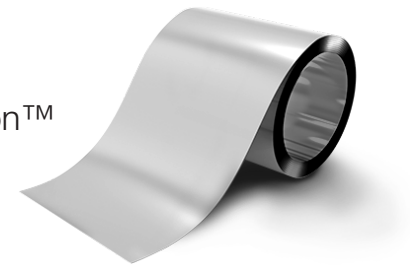

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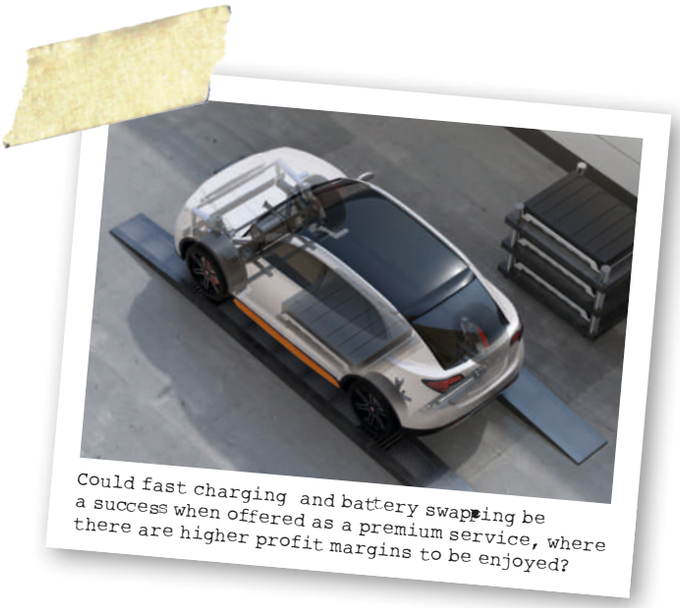
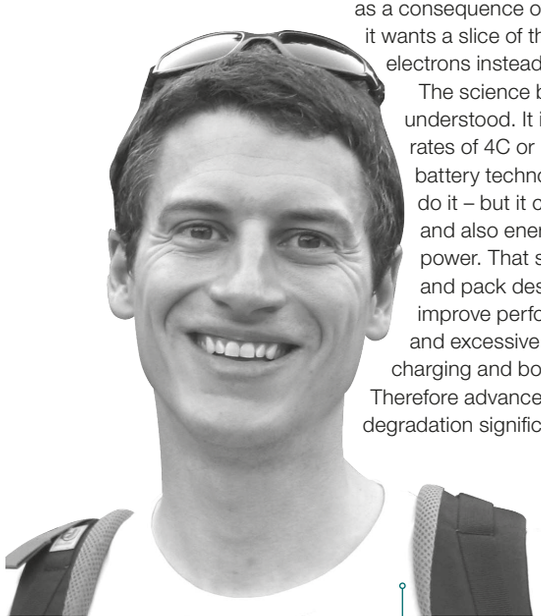


Could fast charging and battery swapping be a success when offered as a premium service, where there are higher profit margins to be enjoyed?

Fast charging is one of the hottest topics in the EV industry at the moment. But what exactly is it? For the uninitiated, charging is described in C rates, which is power over capacity, giving units of time^{-1}. A battery that is fully charged in 1 hour charges at 1C, in 30 minutes at 2C, in 15 minutes at 4C, and so on. Tesla superchargers, even at 135kW, are probably not fast chargers because of the size of the packs. It takes around 40 minutes to charge from 0 to 80%, hence the average C rate is about 1.2. If you charge to 100% the average C rate drops to 0.8. That said, there is no industry standard for fast charging, but most would consider it to be between 2C and 4C.

The standards instead define power delivered, such as the 50kW CCS or CHAdeMO systems. If you want more power, Porsche has announced an 800V, 350kW charging rate for its Mission E battery pack, which will go to 80% in 15 minutes, which would be a C rate of 3.2. It aims to install 500 of these across the USA by mid-2019. In Europe, Shell has been on a spending spree, buying NewMotion – the largest charging point operator – and collaborating with Ionity to install 400 350kW chargers by 2020. Shell has clearly decided that, if sales of gasoline and diesel begin to fall as a consequence of EV uptake, it wants a slice of the pie selling electrons instead.

> "Today, there are EVs and customers. Is now the time to revive battery swapping?"



The science behind fast charging is reasonably well understood. It is already possible to achieve charging rates of 4C or probably even 6C with existing Li-ion battery technologies. The engineers know how to do it – but it comes at a price, both in terms of cost, and also energy density when a cell is optimized for power. That said, material advances and new cell and pack designs could help bring down the cost or improve performance. We know that lithium plating and excessive heat generation can be caused by fast charging and both lead to higher rates of degradation. Therefore advances in these areas, if they can reduce degradation significantly, could be disruptive. However, equally challenging is infrastructure cost. Having just a few chargers at 250kW would require new transformers and local distribution networks to be strengthened – at great cost. This is why companies such as Leclanché and ABB are using batteries in shipping containers, which can be slowly charged but can dump power quickly to reduce the cost of grid upgrades.

Others are betting on battery swapping, an idea pioneered by Better Place 11 years ago. Back then, there were few cars available (and most were not compatible), which meant no customers. The company went bankrupt after six years – but not before a lot of investors had their fingers burned. I was advising the UK government at the time and could see that Better Place's business plan was fatally flawed, so my advice was to stay well away.

Today, however, the EV world is different. There are cars and there are customers. So is now the time to revive the idea? NIO Capital in China thinks it is, and has been making investments in the area, particularly for taxis and car-hailing services, where the vehicles are in almost constant use and payback times are much shorter.

In contrast slow charging is likely to constitute the majority of power supplied, but with little profit to be made. Fast charging or battery swapping, offered as premium services, might only make up a small fraction of electrons supplied, but with higher margins will probably be where the money is to be made.

Dr Gregory Offer is a senior lecturer in mechanical engineering at Imperial College London. His research focuses on fuel cell, battery and supercapacitor technologies, mainly in transport

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Answering the critics

Though many are convinced that electrification is key to lowering automotive emissions, dissenting voices remain. *E&H Vehicle* asks if EVs are really as green as we think

WORDS: **CRAIG THOMAS** ILLUSTRATION: **ALEXANDER WELLS/FOLIO ART**

One of the go-to arguments leveled against electric vehicles is that, despite the absence of on-the-road emissions, the 'whole story' of an EV – from bolting together the first panels, to fitting the battery, manufacturing the motor and even producing the electricity needed to power the vehicle – isn't as environmentally friendly as it first appears. The issue is not quite that simple – not least because there's a grain of truth in such an argument. For example, a November 2017 article in the *Financial Times* (*Electric cars' green image blackens beneath the bonnet*) commented on a report by scientists from the Massachusetts Institute of Technology (MIT) called *Personal Vehicles Evaluated against Climate Change Mitigation Targets*, which examined the costs and carbon intensities of vehicle models in the USA. The *Financial Times* cited a comparison of a Mitsubishi Mirage supermini and the Tesla Model S that concluded that the Mirage's lifetime emissions of 192g/km of CO_2 were, in fact, lower than the Tesla's 226g/km. When compared on the road, however, the Tesla produces no CO_2 from the tailpipe (it doesn't even have one). Depending on how you consider environmental impact, either vehicle can be held up as the 'greener' of the pair. Indeed, there are examples in the MIT report of EVs whose lifetime emissions are lower than those of some ICE vehicles. Similarly it stands to reason that, as the industry continues to mature, there will be some EVs whose production processes have been sufficiently


FUEL

"We can recycle 95% of all materials used in the production of our cars"

Tony Whitehorn, president and CEO, Hyundai UK

optimized and streamlined to undercut those of the Tesla. The point is that a better system of benchmarking is needed, not one that is simply based on roadside CO_2 emissions.

After all, as Colin McKerracher, lead advanced transport analyst at Bloomberg New Energy Finance, points out: "Whenever you make hundreds of millions of something as big as vehicles, there are undoubtedly environmental impacts."

Rare sightings

One of the most common barbs directed at EV production is the mining of metals for batteries and motors, with its accompanying environmental impact. Mining and processing metals such as lithium, copper and nickel not only uses energy but can also release toxic compounds, so mineral exploitation can lead to locals being exposed to toxic substances through air and groundwater contamination.

> "It's not all a story of new materials being needed – there are also some materials that we don't need anymore"
>
> Colin McKerracher, lead advanced transport analyst, Bloomberg New Energy Finance

However, Paul Morozzo, a campaigner for Greenpeace, puts these concerns into context: "The amounts of cobalt and lithium that are required, even at very large EV penetrations, are absolutely minuscule compared with the amount of oil that is drilled to fuel our vehicles. The oil industry is one of the most destructive on the planet. It's absolutely vast, spans the world, and drills in oceans, tropical forests, remote places, wild places…"

And the amounts of those materials used could decrease even further, as Tesla CTO J B Straubel explains: "Reducing cobalt use, for instance, is something we've been working on for several years. This has been extremely helpful in the overall cost per kilowatt-hour, especially with recent commodity price movements." CEO Elon Musk has even suggested that Tesla has reduced the amount of cobalt used to "almost nothing".

Above: OEMs are putting in place initiatives to reduce the environmental footprint of their factories as well as their vehicles

Left: Audi's Brussels plant, where it will produce e-tron, runs on renewably generated hydroelectric power

MAKING A DIFFERENCE

Not only are most major OEMs now committed to substantial programs of electrification, but many are making conscious moves toward reducing the environmental impact of vehicle production.

For example Volvo, which is committed to climate-neutral operations by 2025, has reduced CO_2 emissions per manufactured vehicle from 0.12 tons to 0.08 tons for the period 2012-2016. The company also has its first climate-neutral manufacturing plant, having switched to renewable heating at the engine factory in Skövde, Sweden, as of January 1, 2018.

Toyota is also focusing on lessening the impact of its vehicles on the environment through its Life Cycle Zero CO_2 Emissions Challenge, which covers not only driving, but the entire life of the vehicle, including materials and parts manufacturing, assembly, disposal and recycling. It also has an Eco-Vehicle Assessment System (Eco-VAS) to set and achieve environmental targets, a recovery network to collect end-of-life batteries to be recycled, and is investigating the possibility of using hydrogen fuel cells for production.

BMW's environmental initiatives include the methods it uses to mine metals for its batteries. As well as being part of a Responsible Cobalt Initiative (RCI), it is also increasing the transparency of its cobalt supply chain, releasing information on smelters and countries of origin for raw materials.

Nissan's environmental initiatives include addressing the recycling of batteries used in EVs. The OEM partnered with Eaton and The Mobility House on xStorage Buildings, an energy storage system to provide backup power for the Amsterdam Arena. A 10-year deal at the 55,000-seat stadium sees 280 repurposed Nissan Leaf batteries stored in racks and Eaton's bidirectional inverters providing backup power for major events, assisting utilities during periods of high demand, and grid stabilization.

Bloomberg's McKerracher also points to other gains, saying, "It's not all a story of new materials being needed – there are also some materials that we don't need anymore. We will need a lot less of the platinum and palladium used in catalytic converters, for example, as we move to electric vehicles."

Green manufacturing

OEMs are also working to reduce the environmental impact of vehicle production. Volkswagen's Think Blue.Factory program, for example, aims to reduce the environmental impact of all Volkswagen plants by 25%.

"Since production started in 2018, e-Golf assembly at the Dresden plant has been entirely climate neutral," the company said in an official statement. "Thanks to buying power from Naturstrom [a German supplier of renewable energy], supply to the plant is already carbon neutral, saving some 3,600 tons of CO_2 per year. VW Kraftwerk will be cooperating for three years with the South Pole Group (SPG), the world's largest developer of climate protection programs. The 400 tons of CO_2 produced by heat generation from fossil sources will be compensated for by reductions in other places."

Patrick Danau, managing director of Audi Brussels, describes what the brand is doing to minimize the effects of building its e-tron models, saying: "As the first plant in the Audi Group purely for electric cars, sustainable and environmentally friendly production is particularly important to us. Audi Brussels installed a photovoltaic system with a total area of 37,000m² [400,000ft²] at the site, generating more than 3,000MWh of electricity and reducing CO_2 emissions by around 700 metric tons per year."

Above: Individuals from numerous sources have expressed concerns about the recycling of EVs – in particular the batteries

Below: Stepping up its effort to increase its green credentials, Volkswagen produces the e-Golf in Dresden on entirely renewable energy

Mining of metals for EV batteries and motors has also been underlined as a key concern due to the toxic compounds released during the process

Power play

The other stick that is commonly used to beat EVs with is the cleanliness of the electricity generated to build and power them. There is evidence, however, to suggest that even in countries with a heavy reliance on coal-fired power stations, EVs are still cleaner than ICE vehicles. Poland, for example, leans heavily on carbon-intensive power generation, but a study conducted by VUB university in Brussels for the European Federation for Transport and Environment found that a Polish EV emits 25% less CO_2 over its lifetime than a diesel car. In Sweden, which has one of the cleanest energy mixes in the EU, an EV emits 85% less than a diesel car.

And as grids increasingly rely on renewable energy, so EVs make even greater gains over ICE vehicles, as McKerracher explains: "The grid is getting cleaner at a remarkable rate and that is driving down both the emissions from using an EV and also the emissions from manufacturing it."

Second life

Another commonly cited argument against EVs is the end-of-life recycling of the materials used to build them, especially the batteries. However, learning from the electronics industry, the car industry is already putting plans in place to deal with them.

"It took a while to get recycling of consumer electronics batteries to the point where now you can just get an envelope and mail off your old phone, tablet or laptop and parts of the battery can be recycled," say McKerracher. "This will also take time for EV applications. What we're seeing right now is auto makers trying to get ahead of that, and trying to have a plan to take back all of their batteries at the end of their life.

"Recycling will play an important role in increasing the supply of some other raw materials and also, in some cases, reusing those batteries for scale applications can also provide some residual value."

Hyundai has a recycling program that is already proving successful. "We can recycle 95% of all materials used in the production of our cars," says Tony Whitehorn, president and CEO of Hyundai UK. "We recycle up to 75% of all solvents used in the paint shops and 88% of all manufacturing waste is being recycled."

However we look at EV manufacture and use, there's a strong argument that they have less impact on the environment than ICE vehicles – to the extent that Greenpeace's Morozzo tells *E&H Vehicle*: "Every time someone buys an EV and not an internal combustion engine there's an environmental gain."

> "Every time someone buys an EV and not an internal combustion engine there's an environmental gain"
>
> Paul Morozzo, campaigner, Greenpeace

Nissan Leaf batteries have been repurposed at the Amsterdam Arena to provide backup power during busy times

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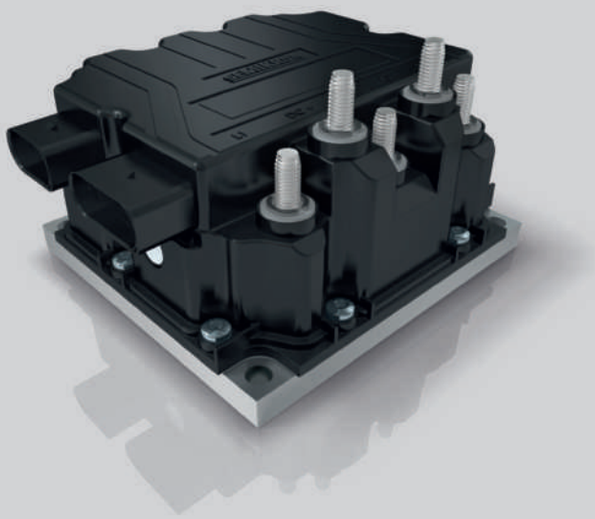

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Heavy hitter

It's an exciting time at Nikola Motor Company as the startup prepares to begin prototype testing of its hydrogen-electric truck at the end of 2018. But for **Jesse Schneider**, recently appointed vice president of hydrogen and fuel cell technologies, the new vehicle and its powertrain are just one aspect of the company's ambitious plans for the future of emission-free heavy-duty commercial vehicles

WORDS: **MATT ROSS**

ILLUSTRATION: **MITCH GEE**

What was it about the opportunity that attracted you to take the position at Nikola Motor Company?

Light-duty vehicles are getting started in fuel cells, but it looks as if the first market that will really take off is heavy duty. This is an opportunity in a startup that has put some thought into not just the fuel cell and the suppliers for the powertrain, but also the infrastructure needed. It's a big opportunity to make the leap into zero-emission trucks with hydrogen.

Can you tell us a little more about what your new role will involve?

Essentially it's the hydrogen powertrain and the R&D to make that happen, the hydrogen storage, and giving guidance for infrastructure. We have a director of infrastructure and we'll be hiring others to help focus on certain areas. Right now you're speaking to me when I'm in Stuttgart, because in the near-term I'm working full-time with Bosch on our first-level prototype vehicles. Next week I'll be in Denmark with NEL, helping to coordinate the build out of our first generation of stations for the customers that have already been announced. So it's quite a coordination, and it's drawing on a lot of the background that I have in both vehicles and stations. When I go to Arizona in December, we'll be kicking off our R&D center, which is going to be pretty comprehensive, to validate the fuel cell.


NIKOLA ONE
NIKOLA

The powertrain for the Nikola One uses the company's unique motor layout, which takes much of the unsprung weight out of the wheels

Is your work with Bosch focused only on the prototype vehicle, or are there already plans being made for future powertrain iterations?

With any vehicle program, and especially when you're kicking something off, you focus on one vehicle at a time. That's all we can say. We're bringing a fuel cell truck to market and right now our partner is Bosch. We're going to have multiple levels of research in Arizona, including future vehicle programs, and right now we can't guarantee how much of that will be done in house and how much with suppliers.

Will the powertrains in the Nikola One and Two be the same?

Yes. Right now we're working on one powertrain. I can tell you that there are some really interesting synergies.

"We can give the fuel experience of today for the truckers, with about the same range. That's the simple answer"

What's not really talked about in the press is that the motor layout in the Nikola is actually our intellectual property, and we're just asking Bosch to build it. The motor philosophy is… well, it's incredible. It allows torque vectoring of all four wheels without having a motor inside the wheel. There are a lot of advantages because we don't put the motor in the wheel – we have a center frame that holds the motor and a driveshaft that goes to each wheel. It sounds simple, but what it does is allow a better center of gravity and takes almost all the unsprung weight out of the wheels.

What sort of production volumes are you aiming for?

We're going to have hundreds of vehicles in 2021 and 1,000+ vehicles in 2022 as we start to ramp up.

What are the principle focuses for the work on the powertrain right now?

We're in A sample. That's about getting the functionality right. Sometime next year we'll be in B sample, which is when you start on the durability. In terms of our focus right now, the good news is that we have a stack that's been developed, from PowerCell – which was originally

founded by Volvo and later spun off. It was a heavy-duty stack, made by a heavy-duty manufacturer, and we've got new components that are going into it – the compressor, the cooling. What you do in the first phase is shake that out. That's what we're planning in the near term. My goal is to get the R&D center up and running by the middle of next year. We're ordering equipment right now, where we can have the temperature chambers for testing all types of scenarios under low and high ambient temperatures, which are challenging for batteries and fuel cells. At -40°F/°C we call the battery a brick and the fuel cell takes over. Essentially, right now, we're getting the basic controls down and working on the basic components. Next year is when we start to get more sophisticated and start the durability and different ambient condition testing.

So the plan is to do some of the testing in house?
You can't do everything in house – some of the EMF testing, and some of the really huge chambers… it simply doesn't make sense to buy everything. But we will have the capability to perform a good portion of that in Arizona. We're lucky. Every auto maker has a proving ground in Arizona, because right outside the city is the desert. And for a lot of the proving ground work we're going to be working with others.

"[Our motor philosophy] allows torque vectoring of all four wheels without having a motor inside the wheel"

What's next in terms of the powertrain development?
We're going to show the public something about the truck in February or March next year. So we're preparing the truck so that it can show the public what it can do. The goal is to show it can do everything a conventional truck can do, and more. And with a whole lot more horsepower.

How many vehicles are you thinking of prototype testing, and will the powertrain be tested on a complete prototype?
I can tell you that we have a chassis builder – this is not a carrier vehicle – making our first vehicles, and we have

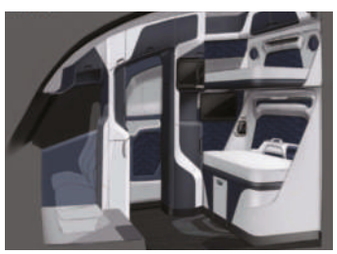
"The goal is to show it can do everything a conventional truck can do, and more. And with a whole lot more horsepower"

our own aerodynamic body that goes around it. It's a unique build, so a lot of it is custom. I can't tell you numbers about our fleet of test vehicles. When you invest in development, you don't have thousands of vehicles in the beginning – you have enough to get the validation that you want. The purpose is to prove the concept of the powertrain, the fueling, the driveability, the functionality and so on. We're going to be testing in hot conditions in the summer, and arctic conditions in the winter. The goal is not to show off how many prototypes we have. That's never the goal. It is to validate the vehicle so that the customers have something to see, and something that works.

Why is the hydrogen-electric combination so suitable for this kind of application?

The higher up you go in mass, the more a fuel cell makes sense. The 1.3GW charging that is being proposed by other battery truck auto makers is very close to insanity. No grid could support that sustainably. What I don't want to say, and what others have said, is that batteries or fuel cells are better. For light-duty vehicles it makes sense to have battery propulsion, and it makes a lot of sense to have charging. But the higher up you go in mass – and don't forget that we have around 120-130kWh of battery on our vehicle – the fuel cell is the range extender. It's very fast fueling, because if you want to carry freight across the country you want to have fueling of around 15 to 20 minutes. If you want to compare it with current heavy-duty vehicles, the fueling rate is around 20 gal/min, which is around 15 to 20 minutes depending on the size of the tank. And we can do that today with hydrogen. We can give the fuel experience of today for the truckers, with about the same range. That's the simple answer. You can't imagine having lots of megawatt chargers – there aren't enough windmills around to do that. That's why hydrogen is better for heavy-duty semis.

Schneider believes that, for heavy-duty commercial vehicle applications, hydrogen is the most viable solution



Nikola is currently working with Bosch on the powertrain for the One and Two hydrogen-electric trucks

You've targeted your teams with accomplishing a 600- to 800-mile range and a hydrogen refueling time of 10 to 15 minutes. What are the challenges of meeting those kinds of targets?

Nikola is working alongside other heavy-duty auto makers that are looking into the same area. When you're thinking about infrastructure you can't just think about yourself if you're looking at wide-scale. The hardware for fueling today gives around about a 20-minute fueling time. To get it down to 10 to 15 minutes, we're going to have to modify the fueling hardware, the compressor and the cooling.

1

1. Anheuser-Busch has selected Nikola for its future North America fleet

2. Nikola's vehicle developments also include full-electric sports UTVs, such as the four-seater NZT

That is something we're working on with NEL and a few other partners to evaluate. That's really the challenge before 2020 and that's our goal – to get down to under 15 minutes.

Refueling gives a lot of people pause when it comes to hydrogen...

You're talking to the guy who helped standardize a lot of the fueling for light-duty vehicles. And [the stations] are few and far between. If you have general customers who live at home and want to get to where they need to go, it's challenging. But the fueling time for light-duty vehicles is five minutes. The technology is there. The advantage of having fleet customers is that we will be putting stations where they want, and where it's most advantageous for their fleets.

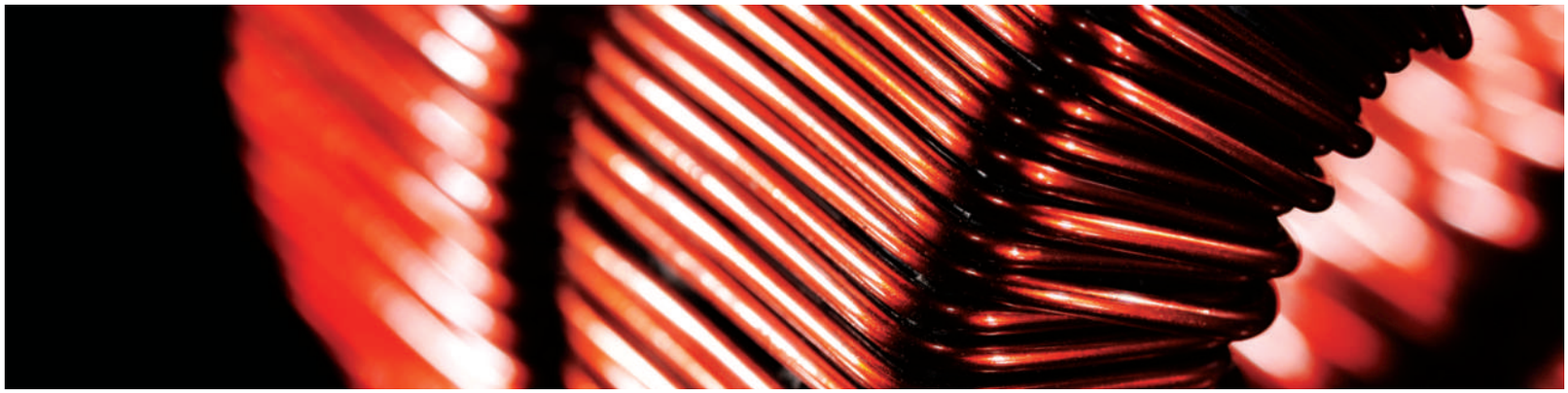
2

Is it a priority for Nikola to be at the forefront of developing standards for heavy-duty fueling?

I'd like to say that it's a collaborative effort. We have already started discussions with other bus and truck auto makers in terms of trying to get the interface to something that would make sense. Because it's also part of Nikola's business model to sell the fuel. We need to make sure that a Nikola truck can fuel there, that a Toyota and a Volvo truck can fuel there. That's something we do plan to be a part of and help lead.

Anheuser-Busch has recently put in an order for up to 800 Nikola vehicles. How big of an endorsement is that for what you and your colleagues are trying to achieve?

The big picture is that there are 9,000 orders right now, and the largest of them is that deal. And it really is a big deal, because what's not said in the press is that that is all their trucks in North America. They're fully in. I'd call it a huge commitment from a major company. And it's also a huge challenge. We're working with the individual customers that have made their pledges to by our trucks, but having Anheuser-Busch on board is a big motivator. We're committed to making sure that everybody has enough hydrogen, and has a reliable powertrain to meet their needs.



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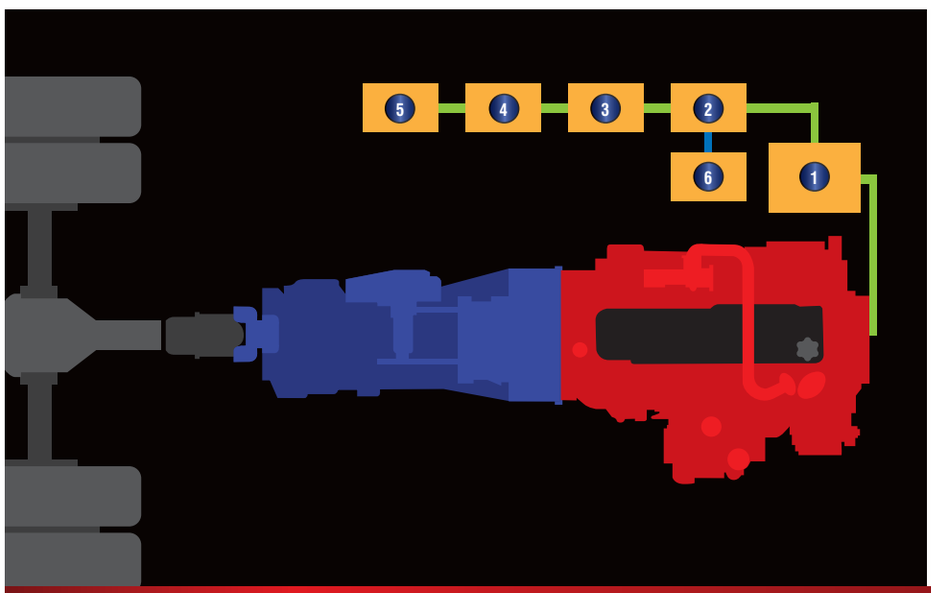

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Sound

With external sound synthesis rapidly becoming mandatory for electric and hybrid vehicles, just what should they sound like?

WORDS: **CHRIS PICKERING**

choices

There's a growing debate about the sound of electric vehicles. While nobody disputes the fact that their near-silent propulsion can be beneficial at times, there's also a general consensus that it may be counterproductive or potentially even dangerous in other circumstances. This has opened up a vast can of worms – one far more complex than the already contentious issue of what a combustion engine should sound like.

The default option would be to embrace the silence, but that is already outlawed in several key markets, including Japan. Next year the USA and Europe are set to join that club, with legislation requiring new electric and hybrid vehicle models to emit an audible warning signal at speeds up to 20km/h (12mph).

There's strong anecdotal evidence to suggest this is justified. In Japan there was outcry when an electric vehicle with its alert system deactivated reversed over a guide dog and its owner, killing both of them. Meanwhile, research carried out in the UK by the Guide Dogs for the Blind charity concluded that

GOING VIRTUAL

Designing a synthesized or enhanced sound for an electric powertrain is a complex task – one which requires extensive testing in a representative environment.

"You really need to experience sound in context. You also need a simple way to classify the sound and identify its favorable qualities," says Professor Paul Jennings from Warwick Manufacturing Group in the UK.

One solution is to use a driving simulator, which provides repeatable testing and infinite adjustability. With state-of-the-art sound hardware, these are now capable of providing a very realistic audio environment, as well as the other cues necessary to create an immersive vehicle driving experience.

Volvo's David Lennström notes, "Until now we have been investigating sound quality through subjective evaluations and also acoustic measurements of our own cars and competitors' vehicles. We are also considering evaluating more in a driver simulator in the future."

pedestrians were 40% more likely to be hit by an electric or hybrid vehicle than its combustion-engined equivalent.

And it's not just a safety issue, either. The sound of a car has always been a key part of its brand perception. Plus, it can also provide meaningful acoustic feedback to the driver, conveying subtle changes in the car's behavior.

"There is a marked difference in brain activity when sounds are combined with other stimuli," says Dr Duncan Williams, a research fellow at the University of York's Digital Creativity Labs. "Sound can help give context to visual or haptic cues, and create feedback mechanisms that do not require other sensory processing to occur – so the driver can keep their eyes on the road."

Of course no car is truly silent, and that brings us to one of the other major issues facing electric vehicles. Factors such as road noise and transmission whine are already important considerations for sound and vibration engineers tasked with dealing with comparatively noisy internal combustion engines. The switch to electric propulsion

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1. The limited edition Mercedes SLS Electric Drive sports a specially developed control unit, playing sounds through interior speakers

2. Driving simulators provide repeatable scenarios, which are key to development of synthesized sound for electric powertrains

3. Harman has developed a number of tools to measure sound inside and outside the cabin of the vehicle

2

means that those challenges will become greater still.

"There are two ways to address noise – you can cancel it out or you can mask it with something more appealing," explains Rajus Augustine, director of Halosonic Technologies at Harman. "With EVs you generally have very little powertrain noise to obscure unwanted sounds, so that means you need an alternative solution. As a result, electric vehicles are already one of the biggest application areas for road noise cancellation."

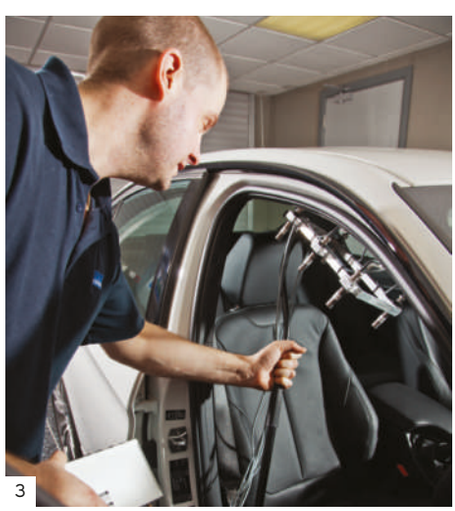
Less is more

With acoustic vehicle alerting systems (AVAS) set to become mandatory in most markets, the majority of EVs will soon have to have at least basic sound synthesis hardware. So should manufacturers expand this capability further? It's a dilemma that most of the major OEMs have already been grappling with for some time. And the consensus seems to be that less is often more.

"In general we aim for as little sound as possible while fulfilling legal requirements,"

"We don't aim to mimic the ICE as [these are] electric cars and we aim for a different sound"

David Lennström, technical expert, driveline NVH and sound quality, Volvo Cars



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comments David Lennström, technical expert for driveline NVH and sound quality at Volvo Cars. "We don't use any throttle-dependent sound and we don't aim to mimic the ICE as it is an electric car and we aim for a different sound. The sound character [of our AVAS system] simply mimics the moving car in respect to wind and tire noise."

This type of noise should render the vehicle relatively inconspicuous, yet it also has the benefit of being highly directional, making it easy to pinpoint the source. That's not to say the sound isn't carefully tailored, however. And Volvo isn't ruling out the possibility of sound enhancement, either.

"Primarily we strive to make the high-frequency tonal components – those over 1kHz due to electromagnetic forces originating from

1

"One of the great things about synthesized sound is that it can be context-dependent"

Dr Duncan Williams, research fellow, University of York's Digital Creativity Labs

the e-motors and inverters – inaudible inside the car," says Lennström. "We're also looking into possibilities for using audible sound in the low- and mid-frequency range to enhance the sensations of power and fun in sportier variants of electric cars. Ideally we would like to achieve this without adding synthesized sounds."

Mercedes-Benz is thinking along the same lines. "Electric cars are inherently quieter than ICE vehicles, and of course this positive characteristic should be preserved," an OEM spokesperson told *E&H Vehicle*. "However, it's important to have a characteristic sound that indicates that an electric car is approaching. The source should be locatable and the sound still be pleasant to perceive – just a new drive concept with a new, characteristic sound."

Some manufacturers have already produced electric cars with sound synthesizers on board.

2

1. In-car measurement of vehicle sound being conducted by experts from Brüel & Kjær

2. Harman Halosonic technology installed on a Tesla Model S vehicle

Mercedes was one of the first with the SLS Electric Drive, which featured a specially developed control unit, playing sounds through the interior speakers. Numerous suppliers now offer systems along these lines – often originally developed to enhance the sound of combustion-engined vehicles.

One of the more intriguing solutions has been put forward by Ricardo. Instead of generating purely synthetic signals, it uses an accelerometer to pick up the electric motor's natural sound signature. A series of filters and audio effects are applied, but the resulting sound still samples direct from a physical source. As a result, Ricardo claims it provides a more faithful reflection of the changes in speed and load than is possible with a synthetic sound generation system.

Conflicting requirements

While it's likely that we will see an increased use of sound enhancement inside the car it's harder to balance the requirements of information and brand perception when it comes to external sound.

"The type of sounds that you would typically use to alert pedestrians to the

1

1. Alerting pedestrians to the presence of electric vehicles is of particular importance in urban areas

presence of a vehicle, and those that are likely to enhance the experience for the driver, fall at two contrasting ends of the spectrum," comments Williams.

"One of the great things about synthesized sound is that it can be context-dependent", he points out. "Theoretically motion tracking could be combined with machine learning to monitor the movement of pedestrians and decide whether they need to be alerted to the vehicle's presence. Similarly GPS data could be used to geofence these alarms to pedestrianized areas."

Both of these ideas raise the prospect of the vehicle alert system going off intermittently, which could be irritating or distracting for those located inside the car, but there is a potential solution.

"You could theoretically play the alarm sound in anti-phase inside the cabin to attenuate it," Williams points out. "The exterior sound will still be subject to occlusions and reflections, so you won't be able to cancel it completely, but you could do a pretty good job of attenuating it, which means you could potentially use the sounds quite differently inside and outside the car."

That said, there are other possible pitfalls to intermittent vehicle warning signals. Sudden noises can startle people or cause them to look round involuntarily, potentially leading to cyclists or pedestrians swerving unexpectedly. "Where the head goes, the body often follows, especially on two wheels," Williams notes.

"You could potentially use the sounds differently inside and outside the car"

Dr Duncan Williams, research fellow, University of York's Digital Creativity Labs (above left)

This suggests that a fixed, yet relatively unobtrusive sound, along the lines of the current AVAS regulations, may be hard to beat. Several studies have concluded that sounds associated with transportation tend to be the most effective alert signals for pedestrians who have grown up with these stimuli. Interestingly, it was noted in one report that sounds inspired by vehicles in science fiction were very nearly as effective as those that set out to mimic conventional combustion engines.

Ultimately, however, EVs are a blank canvas. The technology exists to enhance the sound digitally, as does a wealth of acoustic expertise to damp out some frequencies or enhance others. Whether it's the whisper-quiet interior of a luxury saloon or the growl of a passing sports car, sound will always be one of the defining aspects of a vehicle's character.

2

2. York University carried out a study with taxi company LEVC using brain monitoring. It observed lower stress in drivers of electric vehicles, potentially due to the creation of a less fatiguing acoustic environment in the car

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While Tesla's factories are outfitted with the latest production equipment – such as these KUKA robots at the Freemont facility – other car makers have had to decide whether to retrofit or build new plants

Building the future

As auto makers prepare for the increase in EV demand, they are facing a manufacturing choice: to build new production plants or refit existing facilities. And with predictions of vehicle uptake varying, flexibility is vital

WORDS: **RICHARD N WILLIAMS**

OEMs are making all sorts of pledges toward the production of EVs. Daimler has stated it will electrify its entire portfolio by 2020, while PSA, which has as yet only dabbled in electric vehicles, has promised the same by 2025. Others are making similar statements. This commitment has meant huge investments in new facilities, renovations of older plants, as well as acquisitions and partnerships to meet a rise in EV production.

"They're all investing billions in plants to redefine their entire assembly line," says Axel Schmidt, strategic management consultant to leading auto makers and managing director of Accenture's Global Automotive Practice.

"At the moment, these production lines can build only petrol and diesel. Hybrid and electric cars are just so different. You have to dismantle your entire production line so you can build both. You have to construct a high level of flexibility," he says.

The 3,200-acre (1,295ha) site in the Nevada desert is estimated to be costing US$5bn

1. After a hold-up on expansion, Tesla has begun construction work on its Gigafactory in Nevada, where it will produce batteries for its product line-up

2. The PSA plant in Trémery is currently being prepared for electric motor production

1

BIG AMBITIONS

One of the main barriers to EV uptake is price – and much of that cost is down to the batteries. Tesla has certainly put a shot across the big car makers' bows with its Gigafactory, which could see the cost of Tesla batteries fall dramatically.

The 3,200-acre (1,295ha) site in the Nevada desert is estimated to be costing US$5bn, most of which is being supplied by Panasonic. It promises to be the biggest building in the world when it is finally completed, with a footprint of 5,800,000ft² (538,840m²) – more than 100 football fields.

While already in operation producing the Tesla/Panasonic designed and engineered 2170 cell which, according to Tesla, offers the best performance metrics for an EV at the lowest production cost, completion of the plant has been hampered by delays.

However, Tesla says production for Model 3 cells starts this year, so the factory could help the company achieve the economies of scale needed to bring down the price of its cars and also achieve the capacity demands that have seen the company refund deposits for the Tesla 3.

Renovating assembly lines

This is the approach most OEMs are taking, retrofitting production lines to accommodate new EV and HEV variants of existing models.

GM is manufacturing the Chevrolet Volt alongside traditional ICE vehicles at its Detroit-Hamtramck plant, and has adopted a very similar approach for the Bolt EV at its Orion Assembly Plant.

The company says this enables it to draw on standardized work processes across the entire manufacturing enterprise, installing, for instance, batteries instead of gas tanks, while the drive units are assembled on the traditional engine line.

PSA, which so far has only dipped its toes into electrified vehicles, is taking a similar approach. The group, which includes Peugeot, Citroën and now Opel, has partnered with Japanese electric motor specialists Nidec, and is preparing the Trémery plant in France to produce electrical motors from 2019 onward.

"We have had some electric cars, such as the Berlingo VP and LCV and now the Opel e-Ampera," says Alain Raposo, senior vice president of powertrain and chassis engineering at PSA. "But we are planning seven new EVs and eight PHEVs by 2021."

2

To achieve this, he says, the OEM is drawing on Nidec's technical knowledge of e-motors. "Combined with our experience, this means we can do this two to three years sooner than if we were alone," he says.

The company has also pledged an electrification push that will see 100% of the group's vehicle range to include an electrified offering by 2025.

"Trémery will be the first plant to produce electric motors, but we will build the electric motors in the same plant as ICE powertrains,"

> "Electrical cars will be the future of the market regardless"
>
> Axel Schmidt, strategic management consultant and MD, Accenture's Global Automotive Practice

3. Upgrades implemented at the GM Hamtramck facility have enabled it to manufacture the Chevy Volt alongside ICE cars

explains Raposo. "So the same people can work on ICE or electric motors. They are assembled on the same vehicle production line, so one car may be gasoline, the next electric. You have to have a high flexibility rate so you can adjust capacity based on the demands of the market."

Future flexibility

Exactly what this demand turns out to be still requires a "crystal ball" admits Raposo, so why all this investment?

"Electrical cars will be the future of the market regardless. It is just a question of how big," says Schmidt. "No one knows how big the market share will be, but they cannot

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1. Mercedes has pooled expertise from various partners in the production of the F-Cell. EDAG for example, which provides support with the integration of the drive system, is located in the vicinity of the factory

SEEING OFF THE UPSTARTS

The trend toward electrification has created an opportunity for fresh blood to enter the car manufacturing industry.

The likes of Tesla have taken large shares of what is still a small but burgeoning market. But if EV sales numbers approach the numbers that some are predicting, can these startups meet the capacity demands to survive?

"The automotive industry has always been a mass production industry," says PSA's Raposo. "We have the facilities and people to handle the demand. It is going to be really difficult for new companies and startups.

"Sure, companies like Tesla have done well with small volumes and a small number of models, but they are going to find mass production very different," he claims. "We have the experience in our plants to get the right level of quality, production and efficiency."

Global Automotive Practice's Schmidt agrees, and thinks mass production will make or break a company like Tesla.

"Tesla is a loss-making company, but can it go from zero to 100% overnight?" he asks. "Well, Tesla is Elon Musk, so if he can do what he says he can, and produce the Tesla 3 in the volume required, and get the price down, then yes. If not, then he will need a nice investor, and you'll have to ask how long is he willing to carry on rather than go off and do something else?"

do nothing – it takes time to build the production lines, so the OEMs have to invest now, and I think the number most people are basing their assumptions on is 25-30% electrification by 2025."

Daimler certainly anticipates this sort of sized demand in the market. The OEM is electrifying its entire portfolio based on an assumption that electric models will make "somewhere between 15% and 25%" of Mercedes-Benz sales by 2025.

To accommodate this demand, the company is expanding its Sindelfingen plant in what has been dubbed Factory 56 (named after Hall 56, the internal name for the position and location of the area at the plant).

Mercedes-Benz is heralding the facility as the "first factory of the future" and it will encompass all the technologies and systems of so-called Industry 4.0.

However, beyond the collaborative robots, digitized and connected production line, and driverless transportation systems inside Factory 56, what makes the facility special is its flexibility. As with PSA's Trémery plant, the state-of-the-art facility will produce electric vehicles alongside conventional passenger cars (and indeed, autonomous 'robo-taxis').

The company has also started construction of its Full-Flex Plant in Kecskemét, Hungary, about 90km to the south of Budapest, where various vehicle architectures, including EVs, will be produced on the same line.

2

2. VW has opted to convert its plant in Zwickau, Germany, to build only electric vehicles – unlike numerous other OEM factories where both EVs and ICE cars are produced

Going all-in

But not everybody has chosen to take the flexible approach. Volkswagen is investing US$1bn at its facility in Zwickau, Germany, converting it to produce only electric models over the next five years, including the all-electric ID, and SEAT's first EV, both of which use VW's newly developed MEB (Modular Electric Architecture), designed for creating new EV models.

"They now know they can meet the volume, whatever it is," says Schmidt of the German car maker's decision to move all electric production to one facility.

"If you have existing facilities, you convert them. That is efficient behavior. If you don't, you build new facilities," says Raposo.

Price is right

"The market is already here and it is growing," says Schmidt. "If the OEMs don't stand up, new players will. Even the players that don't have the money are investing in this, because if they don't they are vulnerable.

"How big the market gets is going to be as much based on the price of the electric vehicle, bringing it down, as well as government intervention, how they steer electrification demand through regulations and penalties."

However, he has this warning for auto makers in how they are implementing electrification: "Electrification can mean a number of things: it can mean 100% electric cars or hybrid. I think it would be a mistake to invest too much in hybrids. Building cars with two different powertrains is extra investment. I don't see hybrids as being the future of automotive."

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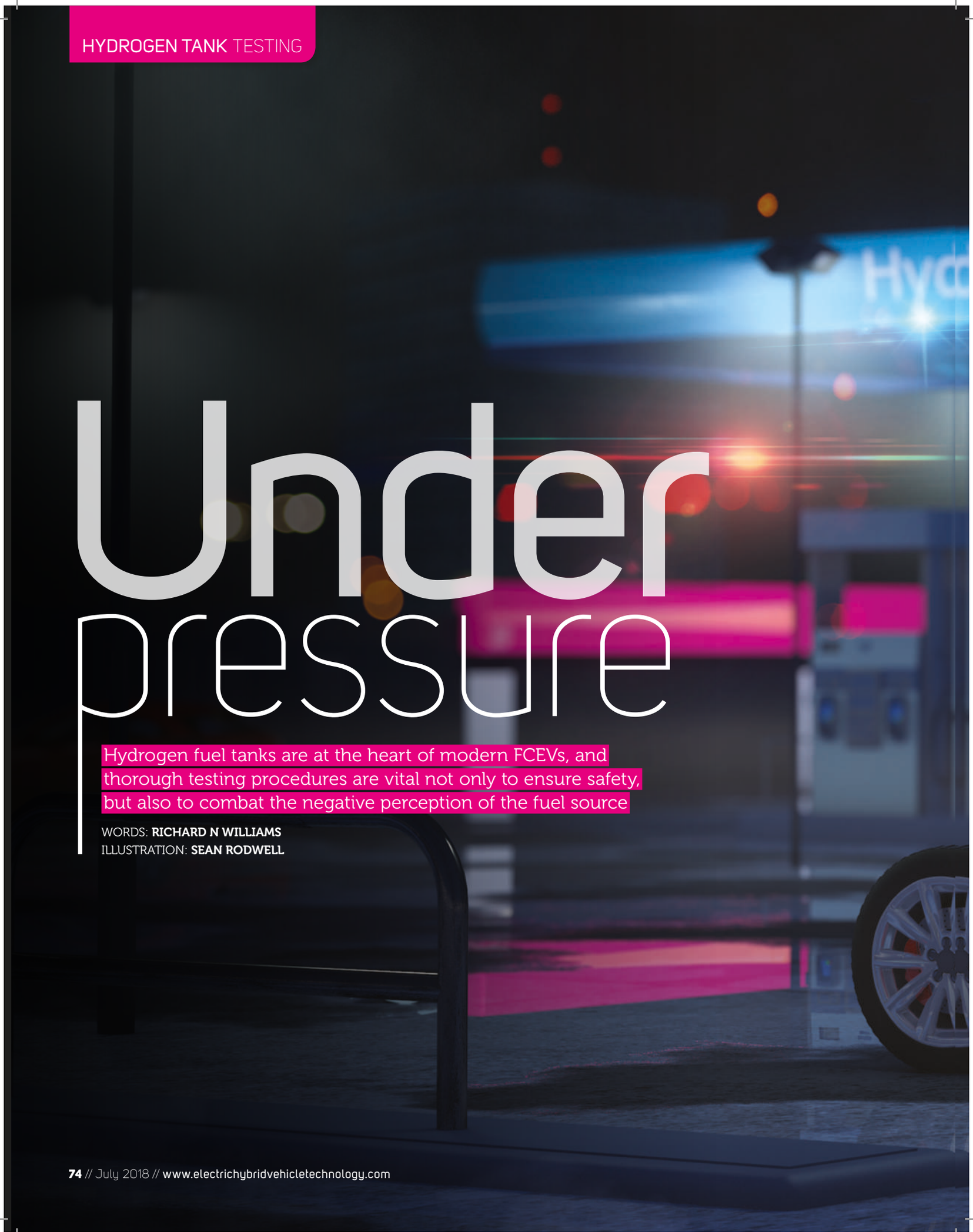

Under pressure

Hydrogen fuel tanks are at the heart of modern FCEVs, and thorough testing procedures are vital not only to ensure safety, but also to combat the negative perception of the fuel source

WORDS: **RICHARD N WILLIAMS**
ILLUSTRATION: **SEAN RODWELL**


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Hydrogen
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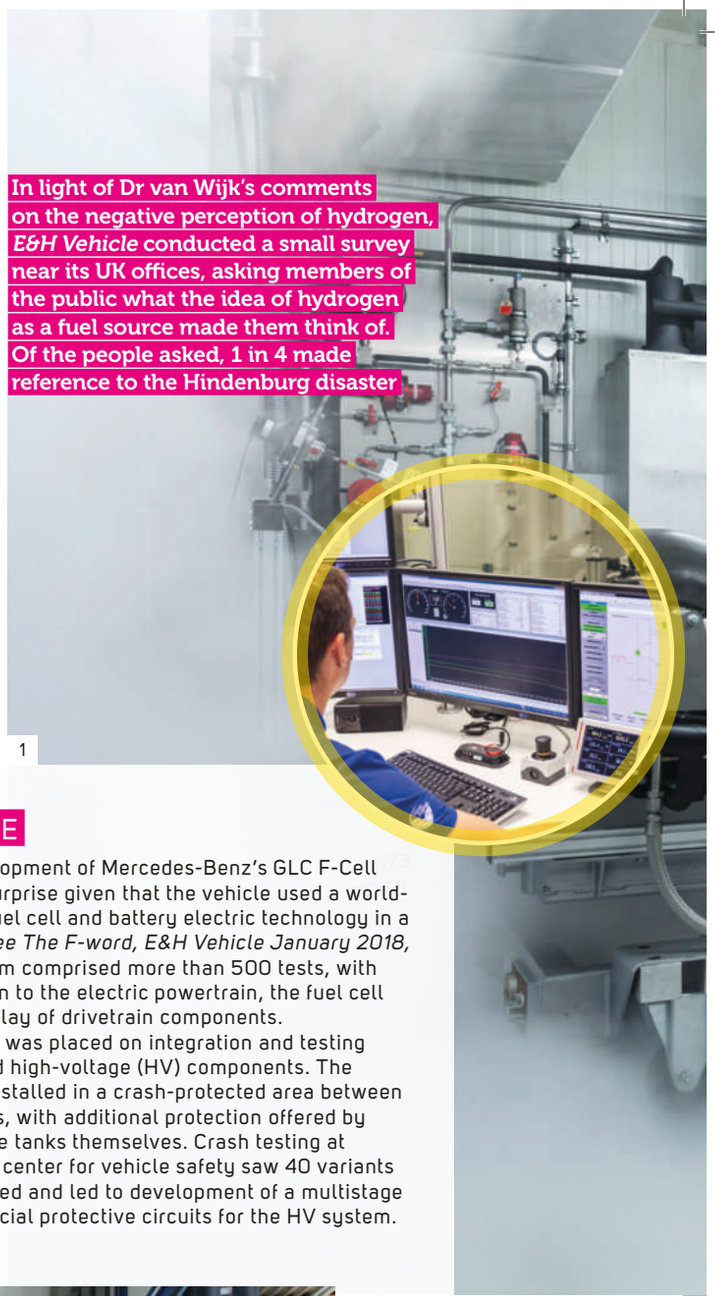
In light of Dr van Wijk's comments on the negative perception of hydrogen, *E&H Vehicle* conducted a small survey near its UK offices, asking members of the public what the idea of hydrogen as a fuel source made them think of. Of the people asked, 1 in 4 made reference to the Hindenburg disaster



1. The GLC F-Cell was subjected to a series of intensive functional and fatigue tests to ensure the system's reliability

The FCEV has the potential to be a game changer. With its ability to be refueled in minutes, much like a gasoline car, combined with the fact that the only thing to come out of its tailpipe is water, hydrogen fuel cell technology could be a key element in the future of motoring. But a specter sits on the technology's shoulder – one that has unfairly tainted people's perception of its safety.

"It goes back to the Hindenburg," says Dr Ad van Wijk, professor of future energy systems in the Mechanical Engineering Department at Delft University of Technology, referring to the 1937 disaster in which a hydrogen airship exploded, killing 36 people. "That is the reason for it being perceived as an unsafe fuel.

"The truth is that [hydrogen as a fuel source] is safer than gasoline. Hydrogen is under pressure. You don't get leakages because the gas comes out at force and disappears up into the atmosphere." Because of hydrogen's low density, and the fact it is stored in a gas tank under high pressure, van Wijk believes fires and explosions are far less likely than with a gasoline fuel system.

"A flame can't get into the fuel tank because it is under such pressure," he explains. "Any fire will just blow out. It is not like gasoline that can pool under a car. Hydrogen is the lightest gas, so it will just go up into the atmosphere."

Storage solutions

It may well be the lightest element, but hydrogen still packs a substantial punch, with an energy density that's considerably higher than gasoline – one kilogram of hydrogen (compressed at 700 bar) has a potential energy

CRASH COURSE

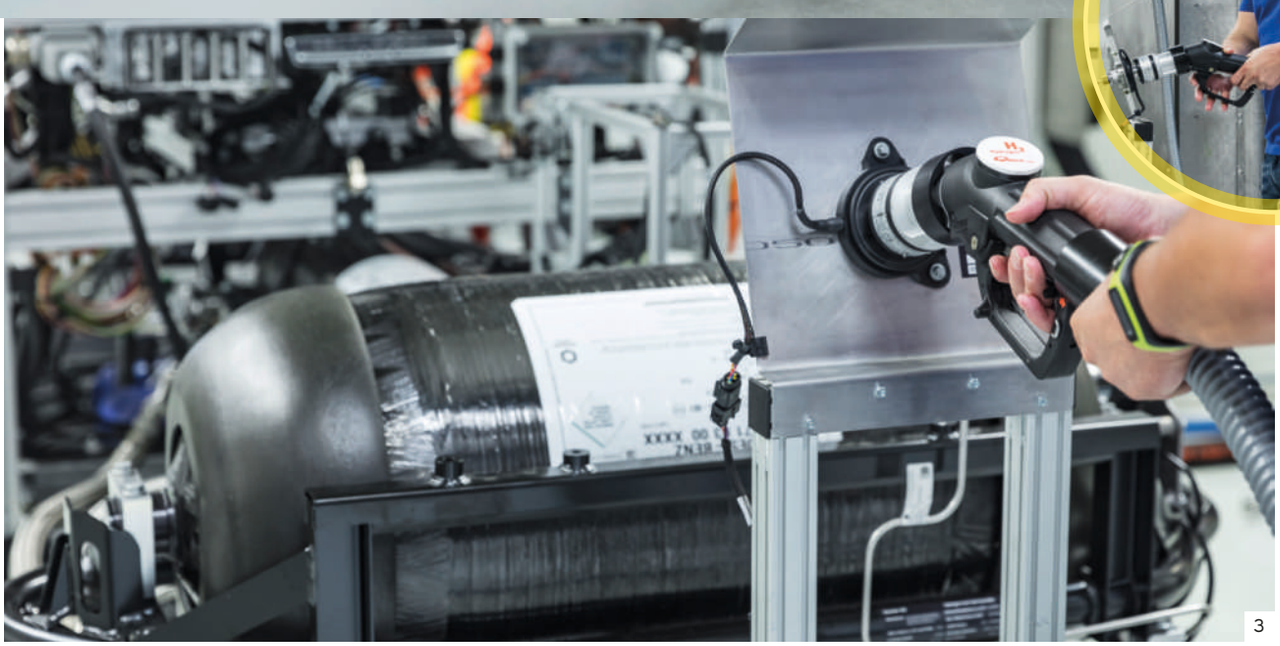
The testing and development of Mercedes-Benz's GLC F-Cell was extensive – no surprise given that the vehicle used a world-first combination of fuel cell and battery electric technology in a production vehicle (*see The F-word, E&H Vehicle January 2018, p114*). The test program comprised more than 500 tests, with special attention given to the electric powertrain, the fuel cell system and the interplay of drivetrain components.

Particular emphasis was placed on integration and testing of safety-relevant and high-voltage (HV) components. The hydrogen tanks are installed in a crash-protected area between the GLC F-Cell's axles, with additional protection offered by a subframe around the tanks themselves. Crash testing at Daimler's technology center for vehicle safety saw 40 variants of the vehicle evaluated and led to development of a multistage valve system and special protective circuits for the HV system.

2. F-Cell engineers paid special attention to the integration of the safety-relevant components such as the hydrogen tanks, the gas seals and valves, as well as the high-voltage components

"As far as the storage tanks go, they are probably the strongest component on the vehicle"

Jerome Gregeois, senior manager for powertrain, Eco Technologies Department, HATCI



3. In a two-year period of developing the GLC F-Cell, about 200 tons of hydrogen was used

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of around 140MJ, while the same weight of gasoline has approximately 46MJ.

"The hydrogen has more energy, and also has better combustion efficiency," explains van Wijk.

This potential force, combined with the negative perception of hydrogen, has meant car makers have been rigorous in the design, safety and testing of hydrogen fuel tanks. After all, one picture of an FCEV in flames could do irreparable damage to the reputation of hydrogen-powered vehicles.

"As far as the storage tanks go, they are probably the strongest component on the vehicle," says Jerome Gregeois, senior manager for powertrain at the Eco Technologies Department at Hyundai Kia America Technical Center (HATCI). "Hyundai's fuel cell development started in 1998," says Gregeois.

1. In the F-Cell, the hydrogen tanks are installed in a protected area between the axles. A subframe wrapped around the tanks provides additional protection

2. Hyundai hopes the Nexo will open a new chapter for FCEVs, and has been researching and developing the technology for 20 years

Since then, the OEM has experimented with different types of tanks as it developed its Tucson and Nexo fuel cell vehicles.

"You have Type I, Type II, Type III tanks, and so on, [see *Pressure to develop* sidebar], but mostly now it is carbon fiber with a plastic or aluminum liner."

The same design is adopted by Toyota, which has been working on its fuel tank since 2000. "The hydrogen that powers Mirai is stored at a high pressure (700 bar) in two compact, ultra-tough tanks," explains Yoshikazu Tanaka, chief engineer and manager of development of the Mirai Project.

"The tanks' main source of strength is their carbon-fiber shell, over which there is a further layer of glass fiber," explains Tanaka. "The whole tank is lined with plastic to seal in the hydrogen."

Putting it to the test

Both Toyota and Hyundai put their tanks through severe testing, ensuring they can withstand up to 225% of their operating pressure.

"And they go through the same processes and crash tests as other fueled vehicles do," notes Gregeois. "The vendors who supply the fuel tanks also put them through their own strength tests: drop tests, leakage tests, bonfire tests and so on."

"Hydrogen is under pressure in the tank,so the tank has to be strong, which gives it more structural integrity"

Philip Horacek, senior manager, Powertech Labs

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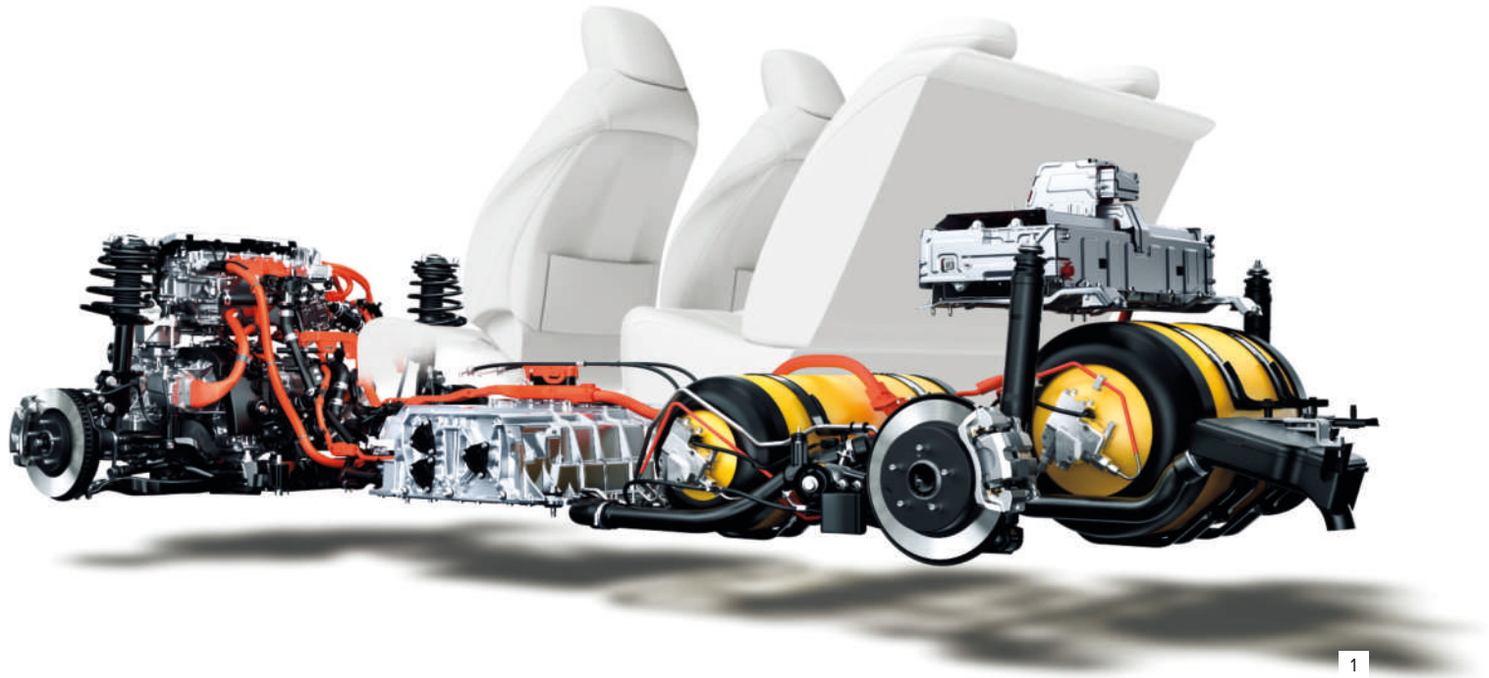

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1. Special sensors in the Mirai can detect tiny amounts of hydrogen should a leakage occur. The high-pressure tanks (below) have been tested rigorously to ensure they can endure up to 225% of their operating pressure

Working with auto makers and fuel tank vendors is Powertech Labs in British Columbia, Canada, which has carried out extensive testing on hydrogen fuel tanks. "We have dropped them from a great height, shot them with bullets, subjected them to fire and put them under half-ton loads," says Philip Horacek, senior manager at the testing center.

"The technology is all borrowed from the compressed natural gas industry," he explains. "So it is completely different from the fuel tank used in a gasoline car. A gasoline tank is just a metal or plastic container, as there is no reason for it to withstand extreme stresses. Hydrogen is under pressure in the tank, so the tank has to be strong, which gives it more structural integrity.

PRESSURE TO DEVELOP

The current hydrogen fuel tank owes much of its design to the CNG storage industry, which has four classes of compressed gas cylinder: Type I – all metal; Type II – metal liner with a hooped wrapped composite; Type III – metal liner with fully wrapped composite; and Type IV – plastic liner with fully wrapped composite.

Most automotive OEMs have opted for Type IV fuel tanks, not just because of their lightweight nature and toughness, but more crucially their ability to handle ultra-high pressure.

"The CNG industry has always favored steel cylinders as it is very cost driven, and natural gas pressure is only 200 bar," explains Horacek from Powertech Labs, which has been testing CNG storage systems since 1983.

"When the hydrogen industry came along, initially tanks were at 350 bar but then there was a big push for it to go to 700 bar as auto makers wanted to store enough hydrogen to allow a similar range to a gasoline car," he recalls.

While consumers have been used to carrying high-pressure LPG tanks for some time, with hydrogen stored at nearly double that, could this level of pressure be dangerous?

Horacek doesn't think so. "You are doubling the pressure of the tank, so you have to have the same factor of safety. A 700 bar tank will be considerably stronger than a 350 bar tank," explains the expert. "And if hydrogen does get out, it dissipates into the atmosphere."

"The primary concern is this high pressure," admits Horacek, explaining that while the gas is under pressure in the fuel tank, once it leaves and enters the fuel cell it is no longer pressurized, so the integrity of the tank is what is important.

And he has certainly put them through their paces, even firing armor piercing rounds into fuel tanks. "They had to be armor piercing because normal bullets would not pierce the tank. The bullet made a hole and the gas came out, but the tank remained intact."

Venting pressure

This ability to just vent gas makes Horacek and others believe the hydrogen fuel tank is as safe, if not safer, than conventional fuel tanks. "If there is a release of gas, it just escapes into the atmosphere," says Horacek. "Ironically, the biggest vulnerability would be in a crash with a gasoline-powered car. Hydrogen just escapes, but gasoline can pool under a vehicle and burn."

Because of this, hydrogen fuel tanks are fitted with a venting system, usually heat activated, that deliberately releases the hydrogen if the tank gets too hot. Other sensors and safety valves have also been added.

"In the unlikely event of a leak, Mirai is fitted with highly sensitive sensors that will detect minute amounts of hydrogen," explains Tanaka. "They are in strategic locations for instant detection. Should a leak occur in the fuel system, the sensors will immediately shut down the safety valves and the vehicle itself."

"It goes through the same battery of tests as gasoline vehicles, and even has its own specific tests," Gregeois adds. "There is less chance of an explosion with a hydrogen car than a gasoline vehicle."

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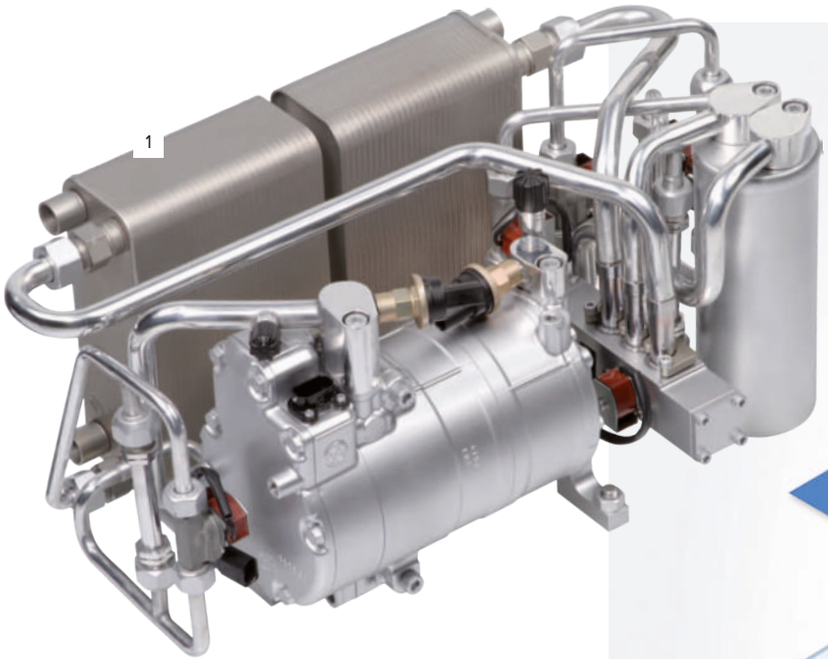
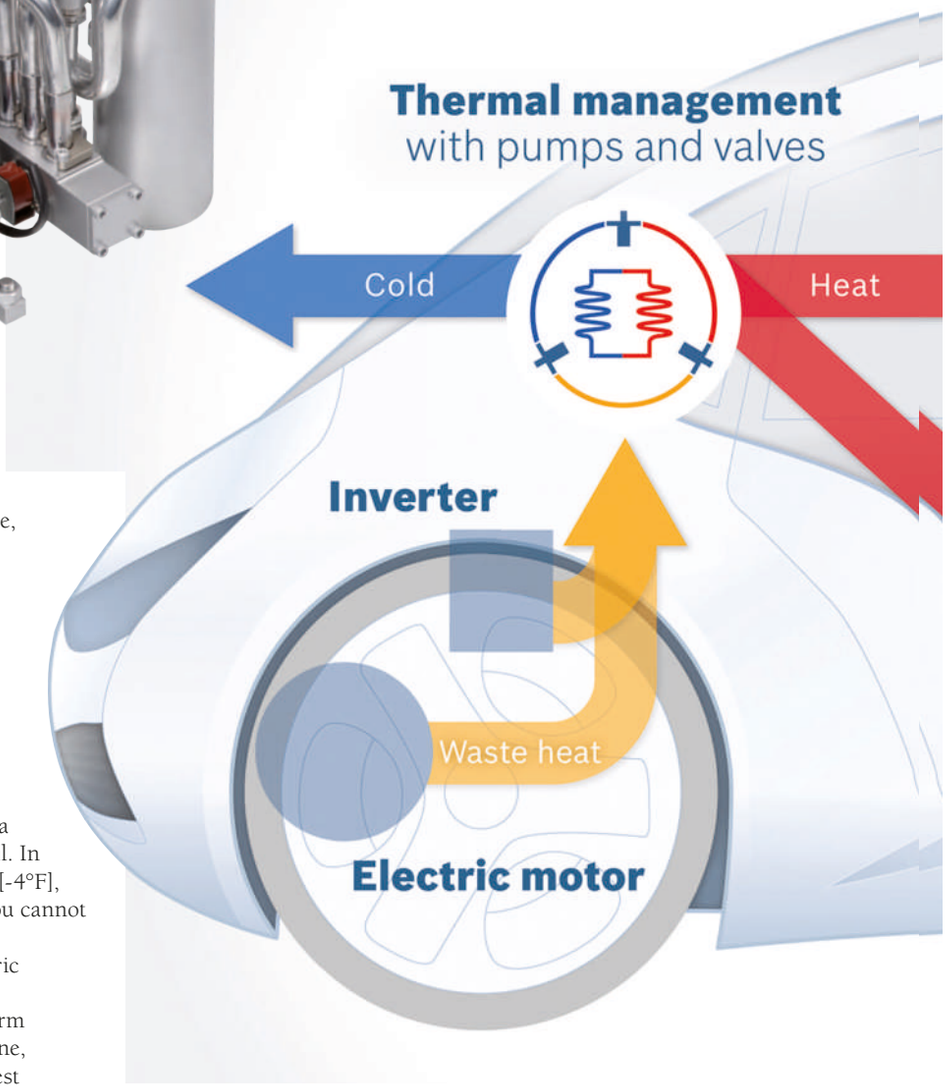
Temperature affects all cars, but it has an even bigger impact on electric vehicles. Cold impedes range, and batteries, motors and power electronics all require cooling, consuming much-needed energy. But new developments in thermal management are helping extend the range and lifetime of EVs

WORDS: **RICHARD N WILLIAMS**



1. Rheinmetall is one of several companies to develop a heat pump, which can greatly extend EV range by controlling the battery temperature



Decades ago, when cars were less reliable, cold mornings would often lead to a dawn chorus of starter motors futilely trying to crank engines into life. Thankfully, most cars have no trouble starting in cold weather these days, but temperature does affect a car's performance. This is especially true of electric powertrains.

"There are two main problems," says Stefano Longo from Cranfield University's Advanced Vehicle Engineering Centre. "When it comes to batteries, people think all you have to do is cool a battery down, but warming it up is just as crucial. In some locations, when temperatures are at -20°C [-4°F], it is going to be impossible to operate an EV if you cannot warm up the battery."

Of course, you also have to warm up the electric vehicle's passengers.

"Extracting excess heat from the battery to warm the cabin isn't as easy as with a combustion engine, which produces a lot of heat. Batteries operate best at 20°C [68°F], which isn't a lot of heat to start with and there will always be losses," says Longo.

Warming up

In cold conditions, Longo adds, battery power is used to both heat the occupants and get a battery up to temperature. This, of course, affects range.

This problem is one that EV manufacturers are familiar with. Many OEMs are now using liquid heating systems for their batteries, ensuring they can get up to temperature, and automatic heater systems that warm cabins before the cars are unplugged.

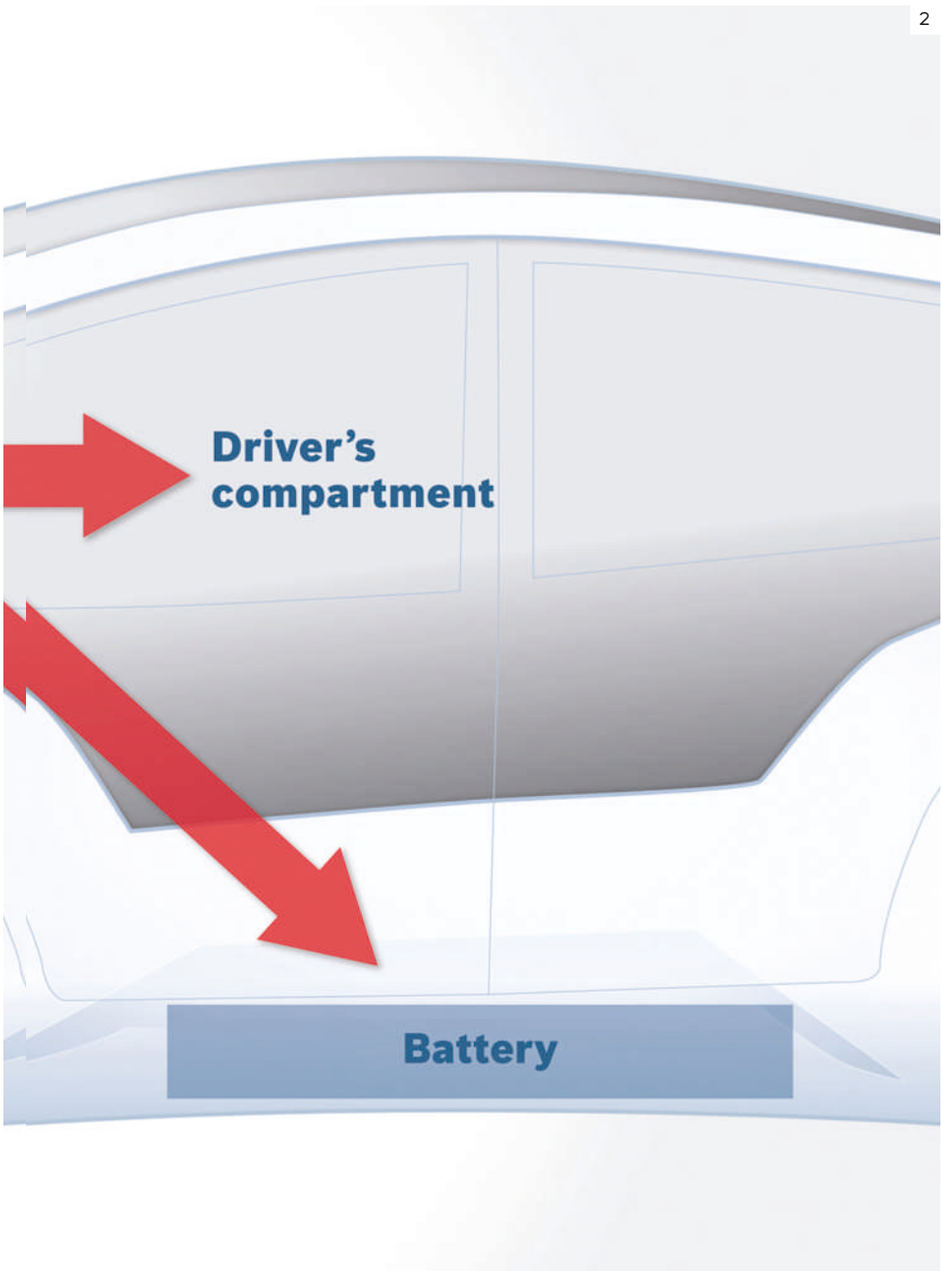
"Using a liquid-heated battery system allows Ford to keep the Focus Electric battery at a moderate temperature and improve performance whether you are charging or driving in a cold climate," says Sherif Marakby, Ford's director of electrification programs and engineering.

On cold days, heated liquid warms the batteries, gradually bringing up the system's temperature for good vehicle performance.

"Even when you're parking in cold temperatures, as long as the vehicle is plugged in, you will warm up the battery," explains Marakby. "Basically, customers will have the capability they need right off the bat. They won't have to wait for the car to warm up."

"Manufacturers want to create more powerful electric vehicles, and have faster recharging times"

Lieven Vervecken, chief executive officer, Diabatix



2. Bosch claims that its heat pump technology has the potential to extend EV range by up to 25% in winter

Cooling down

A warm battery is also able to accept more charge energy, enabling faster recharging, but critically, if batteries get too hot, it can damage the battery life.

"When you think of lithium-ion batteries, a few years ago the fear was them exploding if they got too hot; now the focus is on improving recharging time, so keeping them at the correct temperature range is crucial, and this also means cooling," says Longo. "When they exceed this range, not only will batteries not deliver the same power but more importantly, they degrade quicker. Batteries are the most expensive component, so extending their life is important."

Different cooling methods have all been tried in EVs – from water and glycol, to refrigerants and oil cooling – but EV batteries require delicate thermal management.

CABIN FEVER

One disadvantage EVs have in comparison to ICE cars is the lack of heat from an engine to warm the occupants, so on a cold day, range is going to be diminished by the energy needed to power the vehicle heater.

Saving energy in this area could enable engineers to extend range, and a new type of heater system is generating huge gains.

Heat pumps harvest heat energy in even cold air and distribute it to the cabin using the refrigerant in an AC system. The Nissan Leaf has had one for several years, and now several manufacturers, such as Bosch (main image) and Rheinmetall Automotive (top left), are building compact, modular systems that can be fitted to new and existing vehicle models.

"The heat comes from the ambient air. It can be -5°C [23°F] outside, but this is still warmer than the refrigerant," explains Florian Wieschollek, senior manager of thermal systems at Rheinmetall Automotive.

Refrigerant, warmed by the ambient air, is squeezed to high pressure, and then condensed, and the heat is extracted to warm the cabin.

"The energy saving is considerable compared with an electric heater," continues Wieschollek. "At -5°C, to warm the cabin and keep it at equilibrium, you need 4kW of electrical energy. You could perhaps travel 50km [31 miles] with that power. "Our system uses only 2kW, so it is a 50% saving. Instead of going 50km, you could go 80km [50 miles]," he claims.

Indeed, Nissan says its cabin heater has cut heater energy consumption by up to 70%, which must dramatically improve cold weather performance.

"Uniformity is really key in battery cells," says Ryan Maughan, CEO of UK-based Avid, which manufactures a range of electrified powertrain components, including cooling systems. "The touchpoints get hot, where you connect the charger and the thermal layers in the battery itself. Controlling the direction of heat is just as important because you don't want areas of battery at different temperatures."

As OEMs attempt to extract more energy out of batteries, Maughan explains, thermal management will be even more critical going forward.

"The trend is for higher power density but lighter. This is going to mean more electrons, which will mean more heat, and denser cells also mean thinner cells so they become more susceptible to heat damage. The challenge is going to be managing and getting the heat out."

> "The trend is for higher power density but lighter. This is going to mean more electrons, which will mean more heat"
>
> Ryan Maughan, chief executive officer, Avid

Management strategy

It is not only batteries that need to be kept in the right temperature ranges. Motors and power electronics all require thermal management to keep cool, and there are plenty of ways of doing it.

"Most people are familiar with radiators and fans, but there are other components such as heat sinks, and how you connect your devices in the first place," says Maughan.

Thankfully, new technologies are making the role of thermal management much easier for engineers, and this could also lead to greater efficiency, helping with the unending task of extending EV range.

"We use AI," says Lieven Vervecken, CEO of Belgium-based engineering firm Diabatix. "Our software understands the laws of physics and of heat transfer, and the AI, starting with nothing, creates the solution."

Vervecken says the three main areas of electric vehicle cooling – batteries, power electronics and electric motors – all use geometric shapes to remove heat, whether to channel liquid coolants or air, and the geometries of these channels are vital for both uniformity and cooling efficiency.

"Liquid cold plates are used in batteries," explains Vervecken. "The geometry on the bottom creates a channel for the water to dissipate the heat. Typically, these shaped channels do not always make cooling even, so some areas experience warmer conditions. This is a problem, as part of the battery will degrade quicker than other parts.

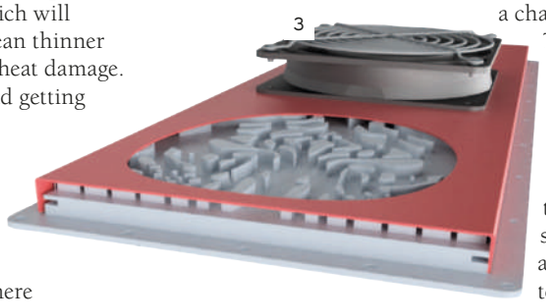
"Power electronics are also very susceptible to heat, especially during recharging. Heat sinks are used to draw away the heat, but again, the geometry of these is important to ensure uniformity.

"Electric motors use cooling fins and channels to dissipate heat," he adds. "The design of these can mean you can dissipate more heat and make the design more compact."

Diabatix's AI software creates the most efficient geometry for uniform cooling in these components, increasing the cooling efficiency.

"We start with just a description of the problem. The AI analyzes the information and creates and modifies the design of components – it is in full control of the design process," explains Vervecken. "It may look like the AI has placed metal in random places, but it is done to make the cooling as efficient as possible. It is very complex. No engineer could come up with it."

Like Maughan, Vervecken believes cooling is the next big challenge for EV production. "Manufacturers want to create more powerful electric vehicles, and have faster recharging times, but the cooling doesn't follow yet, so this needs to be cracked."



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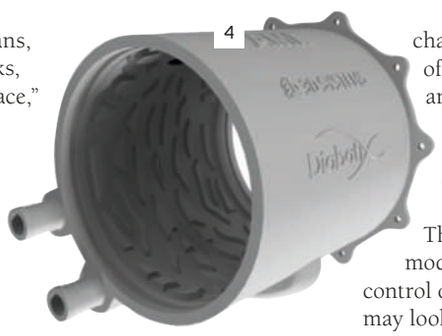

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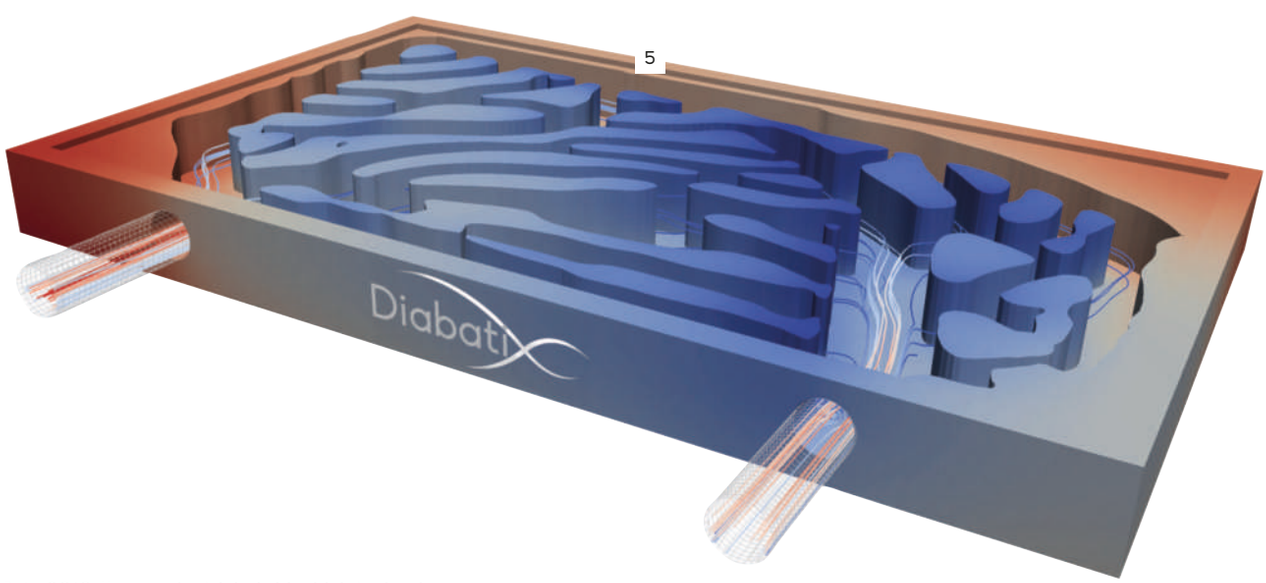
3 & 4. Diabatix's software uses AI to optimize the geometry of cooling components



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5. Liquid pathways are automatically defined within the system

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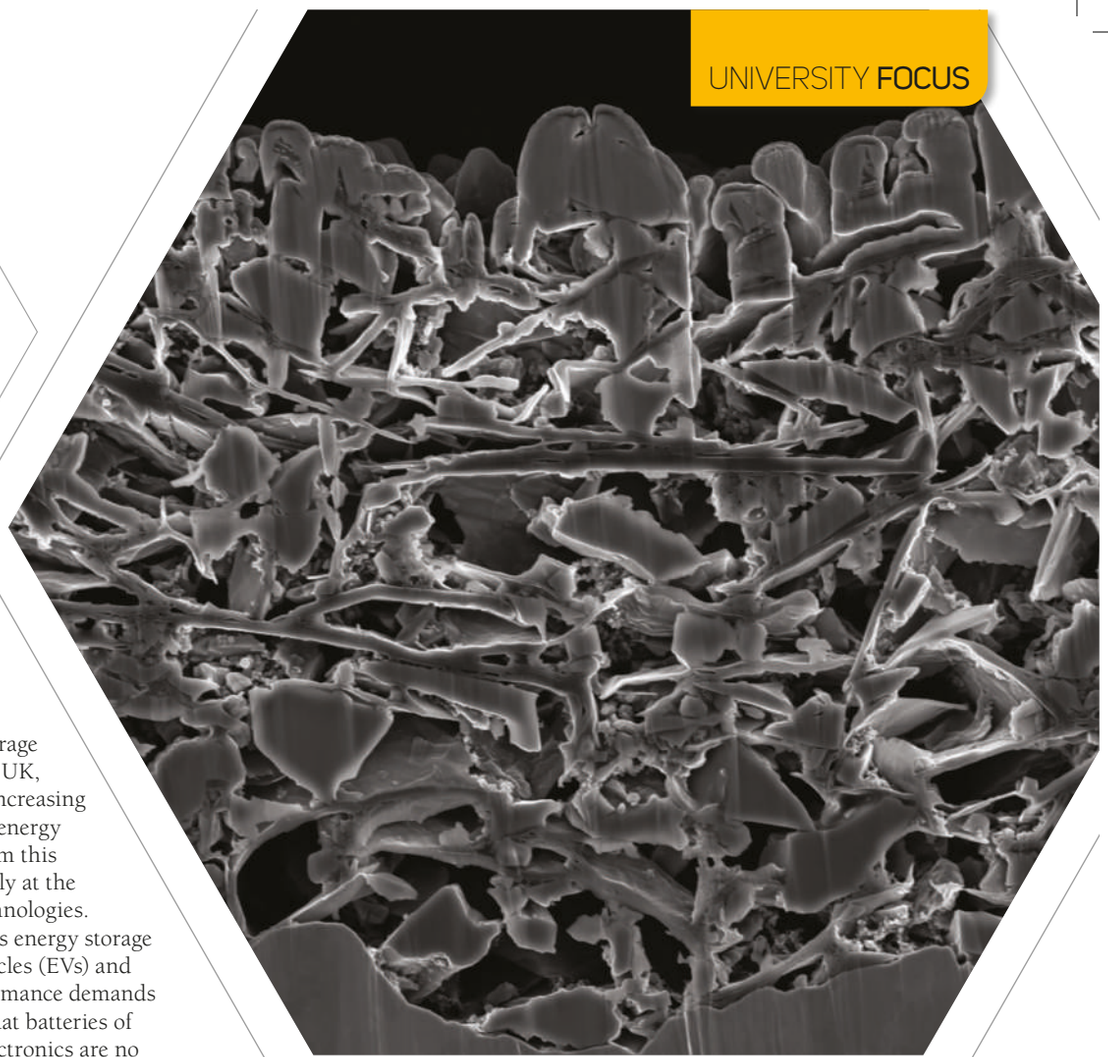
Research into 2D materials, led by the University of Warwick's Energy Innovation Centre, could have significant implications for the lifespan of rechargeable lithium-ion batteries in electric vehicle applications

WORDS: **MELANIE LOVERIDGE AND ROHIT BHAGAT**

Life-changing experience

"One of the new material avenues being focused on is 2D materials"



A cross-section of the silicon and FLG together in an anode. Much like graphene, polymers incorporating silicon nanosheets are particularly well suited for application in nanoelectronics

The creation in October 2017 of The Faraday Institution, an independent center for electrochemical energy storage science and technology in the UK, was a timely reminder of the increasing focus on the need to improve energy storage. Research growing from this initiative will put the UK firmly at the forefront of global battery technologies. Two prime areas requiring this energy storage improvement are electric vehicles (EVs) and grid storage. The higher performance demands of these applications means that batteries of the kinds used in portable electronics are no longer 'good enough' (in homage to their inventor, John Goodenough).

Longer operational lifetimes with higher power requirements and less hazardous chemicals all contribute to an energy-storage quadrilemma (meaning it must meet four criteria: cost, safety, environment, and performance targets). In this light, continued effort is required to research new materials and manufacturing approaches for lithium-ion batteries. This was the driving force that led Automotive Council UK – an independent organization established in 2009 to enhance dialog and strengthen cooperation between the UK government and the automotive sector – to conceive and fund Warwick Manufacturing Group's (WMG) Energy Innovation Centre at the University of Warwick in Coventry.

Opened in 2013, the Energy Innovation Centre was – and still is – the only facility of its kind in UK academia. A national facility for battery research across the R&D process, from electrochemistry and materials through to application integration and recycling/reuse, the Energy Innovation Centre supports the testing, development and scaling up of new battery chemistries from concept to full proven traction batteries, produced in sufficient quantities for detailed industrial evaluation in target applications.

A material synthesis facility is one of the more recent extensions of the original facility, enabled by the UK government's Energy Research Accelerator (ERA) program in 2017. This capability enables researchers to synthesize lithium-host materials via solid-state or solvothermal methods in addition to using commercially sourced materials.

WMG's electrochemical testing capability has more than 1,000 test channels spanning the 1,000A ranges. This means researchers there can perform charge and discharge cycling tests on various sized cells, from coin cells (such as those found in watches and calculators), to full packs (such as those found in EVs). There is also a new forensic laboratory that enables researchers to look at the root cause analyses of the modes of battery failure and capacity fade.

Building blocks

One of the new material avenues being focused on is 2D materials. This is to augment the performance and specific capacity of anodes made of such materials compared with those made of graphite, the anode material used since the lithium-ion battery

was developed by Sony in 1991. One high-profile 2D material that has made many headlines in the last decade is graphene, the 2D building block layer of graphite. Graphene possesses several desirable properties, notably planar conductivity and mechanical strength. Why would such properties be required in battery electrodes?

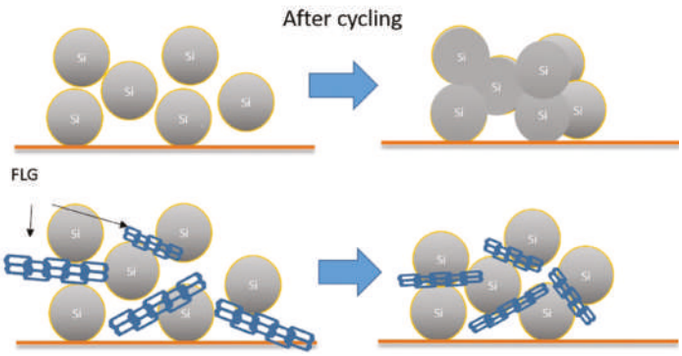
Battery electrodes are composite films consisting of the active material particles (lithium host), conductive additives and a polymeric binder. Conductive additives are required to transfer charge through the electrodes to the current collector substrates. The polymer binder holds all the materials together and adheres the composite film to the metal foil current collectors.

When the energy demands on lithium-ion batteries increased in parallel with EV development, it became clear that new battery chemistries would be needed to meet these demands. Tesla addressed this by enlisting the help of Canada's Natural Sciences and Engineering Research Council and Dalhousie University's Prof. Jeff Dahn, to embark on a five-year program in 2015. In 2017 Tesla unveiled its latest research on battery chemistry, to enable more cycles without significant degradation. Dahn has focused on improving the cathode electrode properties to limit gassing of the organic electrolyte (used in most lithium-ion batteries).

Silicon valleys

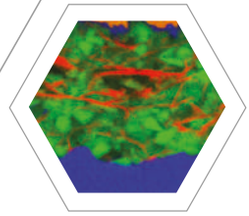
In parallel, on the anode side of the battery, Tesla began to introduce silicon into the graphite coating. Its CEO and product architect Elon Musk described the move as "a baby step in the direction of using silicon". Tesla achieved this using Panasonic's NCR18650BF, NCR18650GA and NCR1860G cells (3,400, 3,500 and 3,600mAh capacity, respectively). Other Li-ion cell manufacturers also focus on the incorporation of silicon into carbon anodes.

However, the trouble with silicon is that it suffers from deleterious volume expansion when lithiated in a battery. This causes macro degradation phenomena at the electrode level, resulting in continual capacity fade. This is why researchers and manufacturers are using silicon in combination with graphitic materials (which only experience around 10% volume expansion following the intercalation of lithium ions).



FLG flakes can prove very effective at preserving the degree of separation between the silicon particles with each battery charge cycle

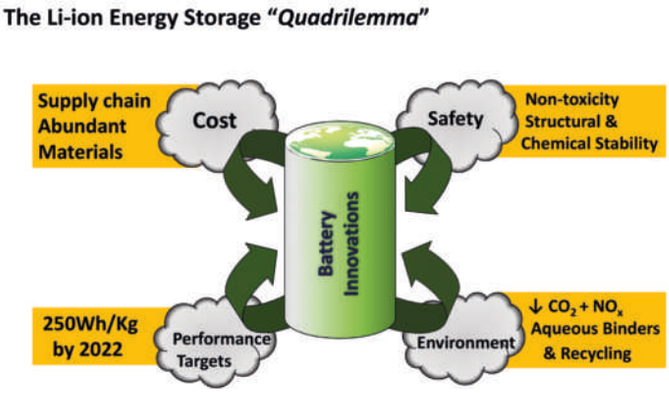
> "Researchers and manufacturers are using silicon in combination with graphitic materials"



WMG's current research with silicon investigates combining the material with few-layer graphene (FLG), to exploit the aforementioned properties of this material. In one study, researchers demonstrated reversible charge-discharge behavior at almost five times the capacity of graphite. The researchers attributed this to a number of combinatorial physicochemical benefits that the presence of the graphene confers. These include reversible lithiation capacity of few-layer graphene to around 600mAh/g; augmentation of tensile strength; chemical bonding to other components through functional groups and defects; and mitigation of the electrochemical fusion of silicon particles by way of volume expansion.

The follow-up paper focused on the electrical conductivity improvements that graphene can introduce to a silicon-based anode. By having graphene in the anode coating, the series resistance of the electrode is maintained at a lower level. Additionally, as outlined above, as the active silicon particles avoid fusing together, being kept apart by the graphene, this allows better electrolyte permeation. The effect of this is to maintain electrolyte channels throughout the anode's architecture to maximize lithium-ion access and help to retain the battery's capacity.

Such 2D materials are generally proposed to be an attractive class of new materials that exhibit outstanding energy and power densities. They also bestow operational performance benefits as versatile additives, as outlined in the case with silicon host materials. So, with materials research in lithium-ion batteries at an all-time high, could graphene (and other structural 2D analogs such as phosphorene) cause revolutions in the battery world, as is often reported in the mass media? To paraphrase William Shakespeare: 2D or not 2D? That is the question. Whether 'tis nobler in the mind to suffer the slings and arrows of outrageous hype, or to take arms against cells of troubles, and by opposing, end them.



Energy storage solutions must balance factors such as cost, safety, performance targets and the environment

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Your Perfect Climate

Daimler is approaching an electrified future with a wide array of propulsion technologies, and armed with an ambitious plan for new vehicles. **Jochen Hermann**, VP of CASE and eDrive development, reveals why the OEM has opted to keep its options open, and what it says about the brand's ambitions

Multiple choice

WORDS: **MATT ROSS**

ILLUSTRATION: **MITCH GEE**

Daimler is taking a multidisciplinary approach to the future of powertrains – not opting for a single technology alone. Why is this the best strategy?

I think the only certain thing in this uncertain, volatile environment that we are currently facing across the industry – and the whole world – is change. The thing that you can do to be prepared for all the things that might happen in the future is to have a broad portfolio to deal with all the challenges. Especially if you are an OEM dealing with worldwide market requirements. It makes sense to invest in conventional powertrains, such as diesel and gasoline engines, but also in electrifying those powertrains. And going from fully electric vehicles through to the fuel cell means that whatever is needed in other markets – and sometimes those needs are different from one market to another – is a good approach.

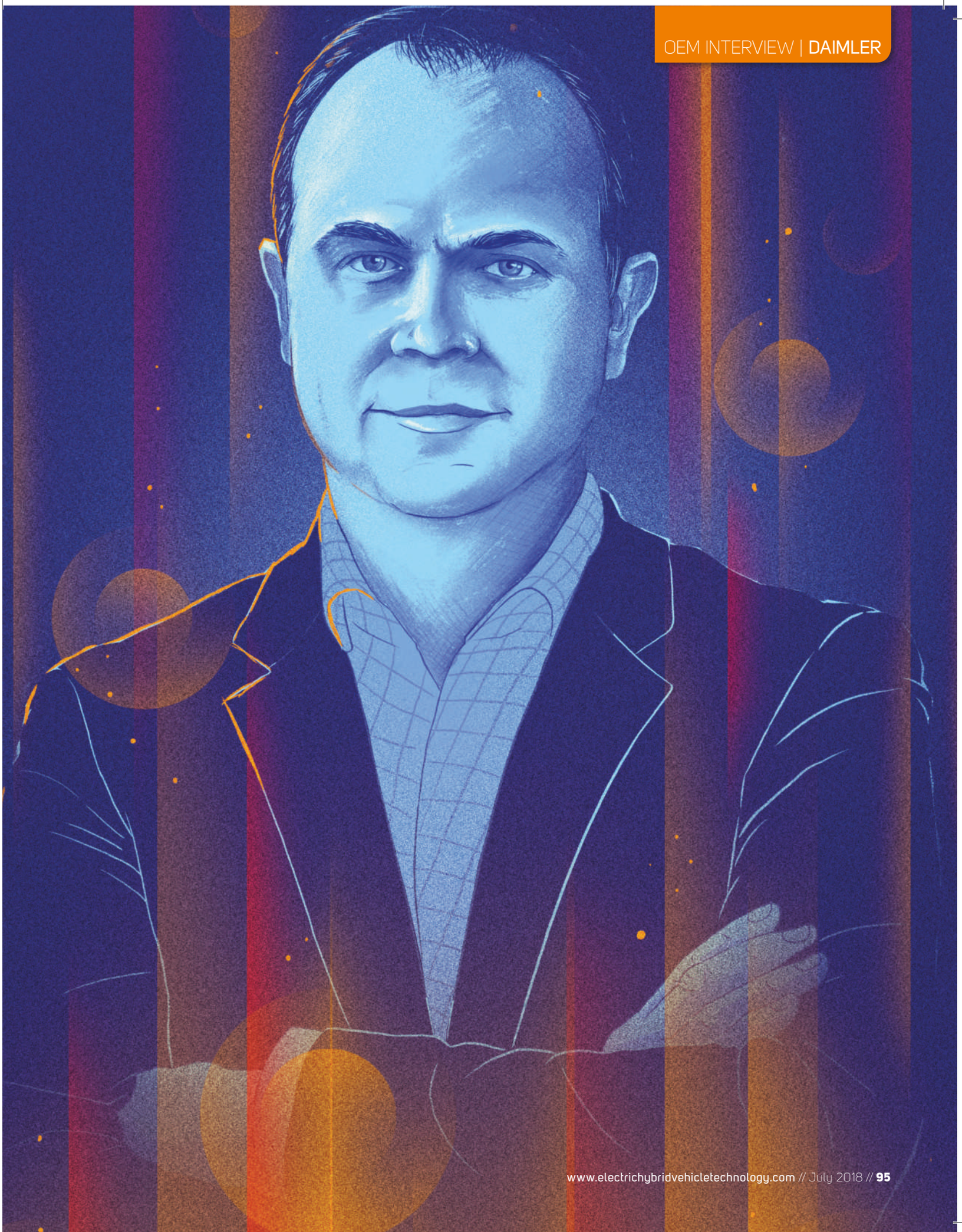
Does having such a wide-ranging propulsion strategy help you avoid worrying about some of the more hyperbolic proclamations about certain technologies being 'doomed'?

That's exactly what I mean. If you follow all of the weekly rumors, announcements, re-announcements, redirections and so on, you'd go crazy. The only thing you can do is rely on your own strengths – ultimately we have to offer our customers a wide variety of powertrains so that they can make their choice. If they want a diesel engine, all we can do is offer the best diesel possible. We want to offer our customers whatever they need in their market, and to make sure that whatever they need is the best they can get if they get it from Mercedes.

> "Mercedes customers like the brand, and have certain expectations of the quality, design and performance of the car"

Investing in your manufacturing plants must be fundamental considering you're opting for such a variety of powertrains. Is that why Daimler places such emphasis on flexible, modular architecture?

That's the flexibility you need on the production side, but it starts in development. Whether the cars are very different or very similar, if we use modular components – such as an HVAC, a seating structure or whatever – then it is the same for an EQ model and a combustion engine model. This modular strategy is very important as it's where you get your scale effects, where you can bring down the costs and offer the most benefits, and the most secure technology, to the customer. On the other hand, the drivetrain and the whole vehicle build of a fully electric car is very different from an ICE car. Nevertheless, if you are able to put the electric car on the same line as a combustion engine vehicle, then you get the flexibility of such a broad portfolio of powertrains. If you are able to keep that flexibility in your production plant, then that's the moment when you are really flexible. Looking into the future, you may be able to make some guesses. What will be the electric share in 2025, for example? I'd say nobody really knows at this point in time, but what we can do is be prepared for the uncertain situation in a very flexible way. Making sure that an EQ car or a non-EQ car

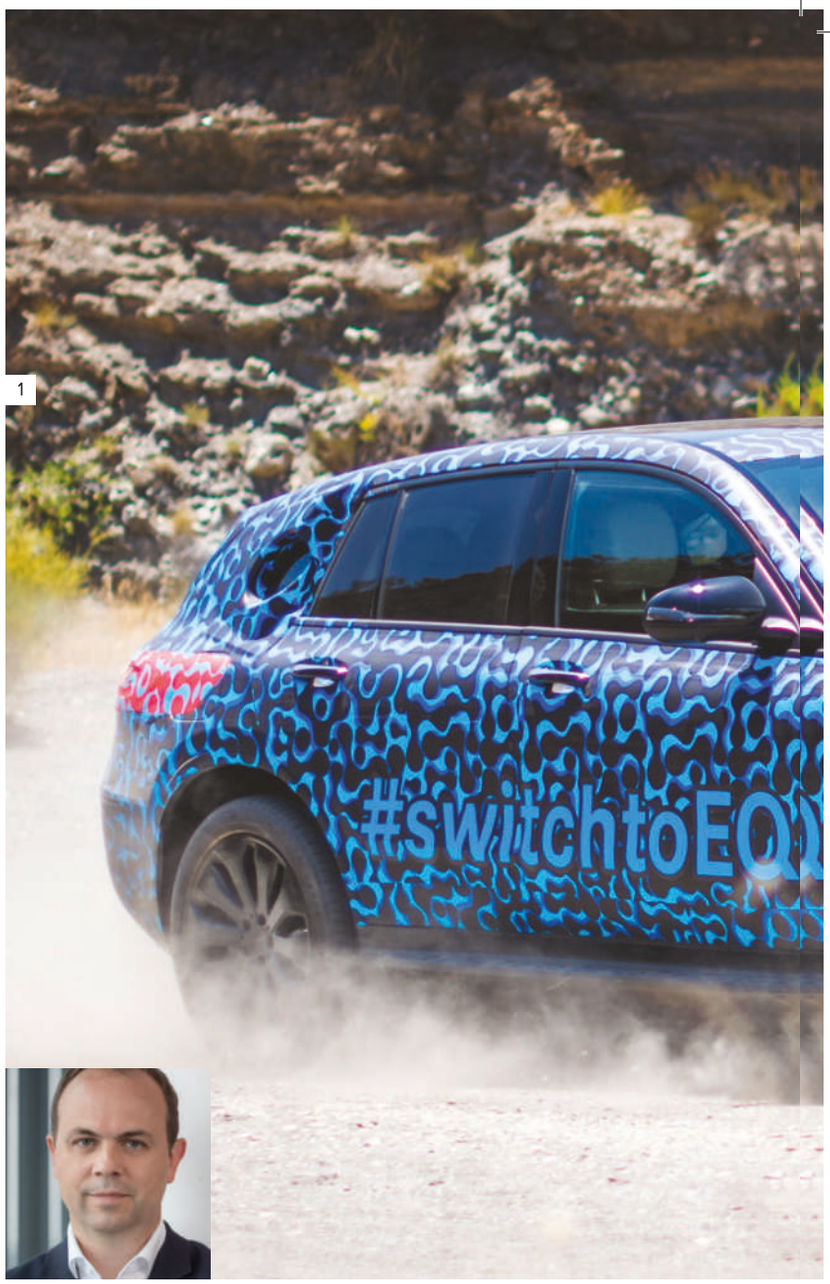


can go through the production line in whatever plant it's going to be built at is a very important task for us right now.

Does a fuel cell program make that more challenging, given the specifics of that powertrain architecture and the fewer commonalities with other technologies?

What you have to do is look at your architecture. For example, look at the ICE car and the fuel cell car that we are bringing to market this year. The powertrains in both cars are actually very similar in terms of the boundary conditions. If I show you a fuel cell and a four-cylinder engine, you wouldn't see a massive difference. The new concept we have for the fuel cell means it fits into exactly the same engine compartment as the combustion engine. You need some additional parts because, for example, you're missing the gearbox, but that can be replaced with a metal structure so that you keep your structural stiffness for crash applications.

Looking at the powertrains, and at the cars that are the basis for the two models, they will go through the same production line. But that wouldn't be the case, say, for a fully electric battery vehicle. Sometimes you may have changes in your production application for the car lines if you look at the powertrains. So the fuel cell vehicle fits very well into the plant where you are building combustion engine cars. The electric vehicle could fit into another plant – perhaps one where you wouldn't initially think it would, but then you look at the wheelbase, the overall dimensions of the body and so on, and you look at what plants you have, and what flexibility you have. It's important to offer customers a choice between, for example, an electric car or another powertrain. If you can bring these two cars into the same manufacturing line then your flexibility will contribute to the decisions that your customers can make in the future. There are some cars that fit together perfectly, there are some where it's a bit more of a challenge.



1

1. Launching in 2019, the Mercedes-Benz EQC will be the car maker's first all-electric production model

"If you are able to put an EV on the same line as an ICE vehicle, you get the flexibility of such a broad portfolio of powertrains"

2

2&3. The Mercedes-Benz GLC F-Cell is powered by a new fuel cell/electric hybrid powertrain, but uses a tried and tested vehicle architecture

And yes, some cars won't fit with others. Then you have to make some risky decisions, but at least you can keep them to a minimum.

When a lot of startup companies were first emerging, many OEMs cited their greater experience, more diverse product offerings, and superior capabilities in terms of reacting to market trends. Is this an example of how established car makers may have an advantage over some of these newer companies?

I get goose bumps when you describe it. Because when I was head of AMG engineering for the sports cars, we were building the GT, and at that time we had our own production site – and when you start a project like that, it's a nightmare. You're finding all the problems that you've put into the car during the design phase, and at the production stage you're saying to yourself, 'Oh god, if we had known XYZ before, we would have done things differently.' But then the production line starts and you have all the usual problems you encounter when starting a new plant. But even though it's a tough time, and I was forever in engineering meetings, driving to the plant, seeing the production issues over there, I was able to call my colleagues in Sindelfingen, near Stuttgart, and ask for two or three experts from their plant. And that was no problem. With that kind of expertise we got three lots of 30+ years of experience walking through the door – and four-to-six weeks later a lot of those problems had been solved. There's a strong heritage in companies like Mercedes, like BMW. Sometimes it's

Daimler will invest around €500m (US$788m) in its Hambach plant as part of its EV manufacturing infrastructure. Hambach has been manufacturing the electric Smart vehicle in series since 2012

referred to as the old economy, but it's a very strong one with a lot of experience. It's about production capabilities and experience that will ultimately help you to have a car emerge from the production line that fulfills your company-defined quality requirements – a car that is what you think a Mercedes, BMW or whatever should be. We have more than 130 years of experience in building cars.

How much crossover is there between the teams working on the different powertrain technologies?

This is one of the key questions being asked inside every OEM. I think there are two ways of answering it. It's worth talking about them both, before I explain how we've decided to address it. If you are in a situation like the traditional car manufacturers are, where you come up with a completely new powertrain idea – fully electric versus combustion engine – you can put all the people into one powertrain department and say that they are responsible for everything, no matter if it's electric, diesel, gasoline or anything in between. That keeps all your expertise together, but it also always involves a fight between old and new, which can be tricky.

The second way is to say that, with fully electric vehicles, you can go into new architectural layouts, and in that case it makes sense to put the electric vehicle architecture layout together with the new powertrain. Then, of course, the advantage is that you put the new powertrain together and you can come up with new architectural layouts for the car, or new structural designs. On the other hand, you're missing out on all of the experience of the non-electric powertrain experts.

What did Daimler decide?

Both ways have disadvantages. What we did was opt for the second approach because in the beginning it's very important to take all the advantages created by having a new powertrain in terms of how it can affect

"People will want to choose a vehicle because of what it gives them – it's not only because it is powered by a battery and electric motors"

vehicle layout, for example. But we took an additional step. We combined the efforts of both teams. So my counterpart on the ICE side and I have a common strategy – we put people together, we exchange people and we have cross-functional responsibilities in his and my departments. We bring people together on the powertrain department so that we can put all the effort into that development, but on the other hand we need a strong connection to the electric architecture of the future. Because it makes a difference. If you build a new car with only an ICE, it doesn't matter if there is a hybrid or not. The overall principle architecture of the car stays the same. But for future cars, the new approach involves asking what the benefits are for the customer – besides the fact that the car drives under electric power. It's not about forcing people to drive electric – that isn't a good strategy. But with electric power, other advantages can be brought into a car. And if you want to make the most of these advantages, it's a very good idea to put the powertrain people and the architecture people together at that early stage. You have to make sure that expertise is exchanged between conventional powertrain and electric powertrain.

There is a lot of mechanical engineering in a battery design. It's not only chemists putting together a cell – you have to look at factors such as cooling, stiffness and so on. And that kind of expertise is found throughout conventional powertrain departments. It's good to exchange the know-how.

We made the decision to bring the new architecture to the powertrain people, because it's there that we see a lot of change in the future.

Diesel hybrid is just one of the many powertrain technologies that Daimler offers its customer base

"By 2022, when all the models have been released, people will understand what we did"

What can you tell us about the future architecture, due to be revealed in 2019?

It will begin in 2019, but it will take until 2022 for us to bring out the 10 models. You will see the whole architecture, maybe not with the first car, but as the models are released. And by 2022, when all the models have been released, people will understand what we did.

Is an OEM like Daimler being so committed to electrification an important step in continuing to convince consumers of the benefits of alternative propulsion?

That's exactly what we see and feel. Let's take a startup like Tesla. The cars are nice, and the company has done a lot to change the perception of electric vehicles. But it's not the case that we are losing X number of customers to Tesla. Why? Because customers of BMW or Mercedes like the brand, and have certain expectations of the quality, design and performance of the car. And the moment we bring out an electric car, we have to fulfill those expectations. This is one of the advantages we have. But it's also a huge challenge to fulfill those expectations. And with the ideas we will bring to the electric car in the future, people will want to choose a vehicle because of what the car gives them – it's not only because it is powered by a battery and electric motors.

What's the next big thing you and your teams are building to?

For this year, it's making sure that our fuel cell vehicle gets into the market. Because that's a new technical approach that hasn't been seen before. And also because it gives us some opportunities within Daimler, not only on the passenger vehicle side, but also on the truck and bus side in terms of fuel cell applications. That's the short-term goal. We will show the car to journalists and I think that it will give people the idea that sometimes we can go in different ways, and that they will be surprised with what they see and experience.

This car, even if people are familiar with fuel cell technology, will surprise people in terms of its performance. And that's kind of the surprise I would like to see in the next few years, until 2022. Some other surprises may be bigger or smaller, but this is the kind of change that we need to bring into our portfolio and into the acceptance of our customers. We can only change people's attitude to the future of technology if they like it, and if they see the benefits. It's not just about CO_2 or whatever. It's a very emotional market that we are dealing with, especially if you are a premium brand. But it's also a big opportunity, and that's what we are striving for.

Next-gen geniuses

Vehicle powertrains and the skill sets required to work on them continue to evolve at a rapid rate, resulting in a shortfall in the next generation of automotive engineers. Are the auto makers taking charge of their education, or are they taking direction from academic institutions?

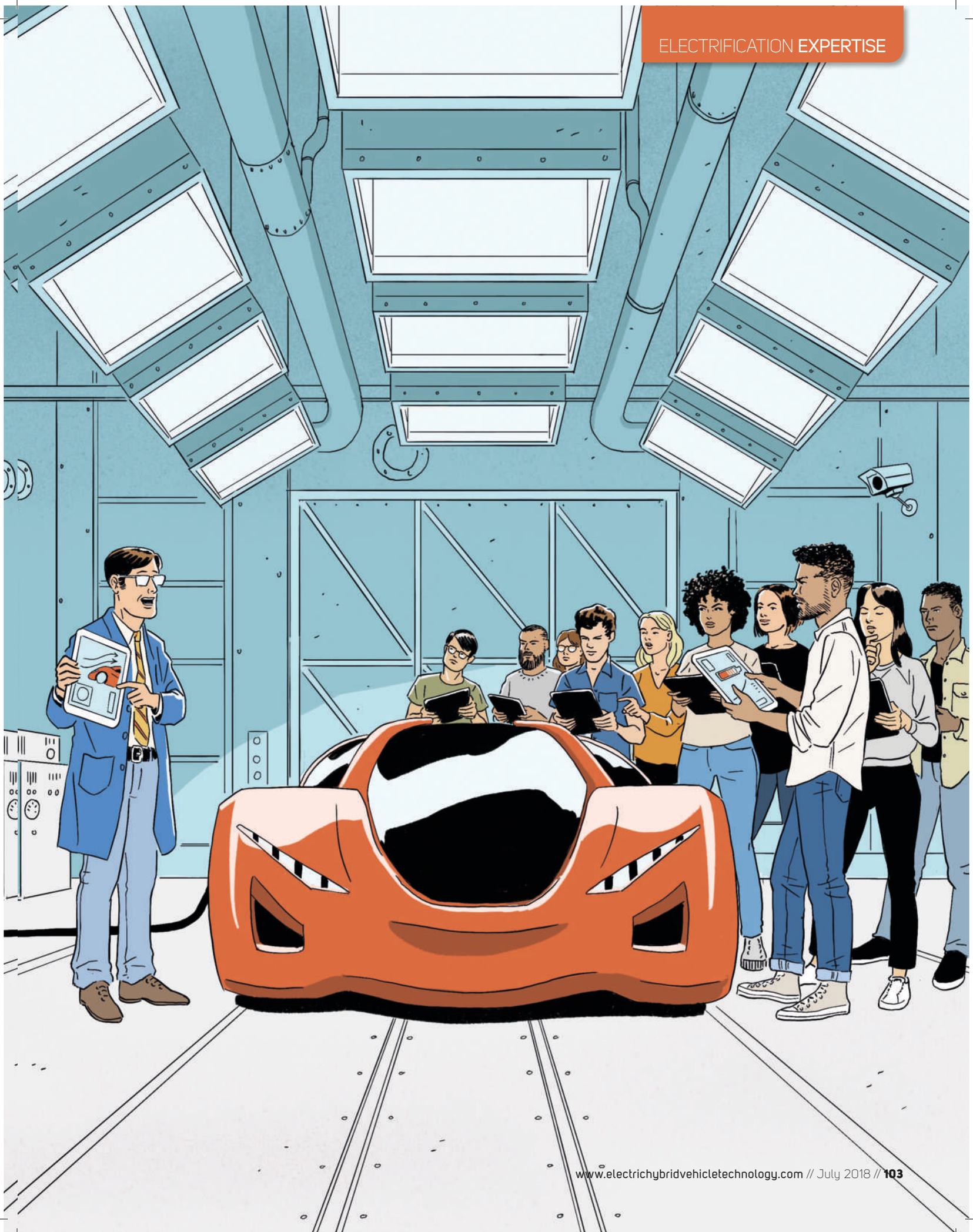
WORDS: **SOPHIE WILLIAMSON-STOTHERT**
ILLUSTRATION: **JACK RICHARDSON**

Although the particulars vary from one country to the next, the majority of zero-emission automotive strategies tend to agree on one thing – in the coming decades, we could be mourning the loss of the internal combustion engine. It won't be plain sailing though. Targets for the demise of petrol and diesel engines still give many pause for thought, not least because range anxiety remains a deal-breaker for many car buyers. And that's not the only problem to ponder. Not only are issues such as charging and fueling infrastructure big hurdles to be overcome, but training and developing the engineers and mechanics required to build and maintain alternatively powered vehicles must be addressed.

With the ICE, hybrid and all-electric powertrains in the mix, there's a growing need for expertise in integrated technologies, which begs the question: do the designers and engineers of the next generation need to come from an automotive background at all?

Back to the classroom

Tesla Motors is one of a handful of vehicle manufacturers that has decided to take the matter of education into its



RECOVERING THE SPARK

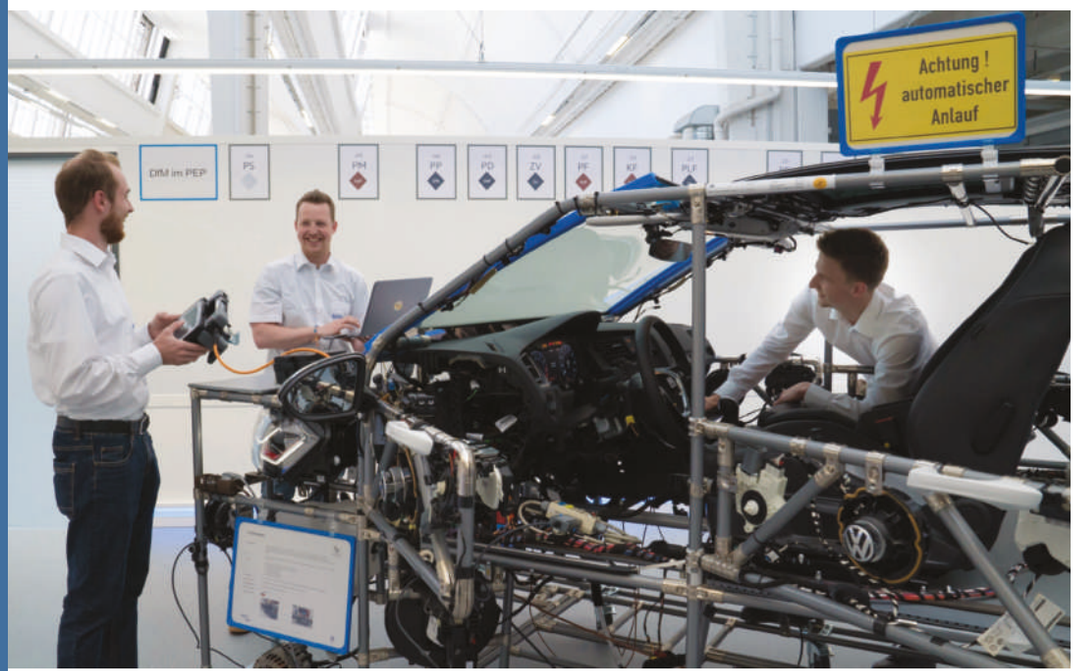
As more pure-electric and plug-in hybrid vehicles filter onto the roads, it is becoming increasingly likely that recovery services such as the UK's AA will encounter a broken-down vehicle powered by batteries rather than petrol or diesel. That's why AA patrols have already undergone intensive training in how to deal with any breakdowns involving electric or hybrid vehicles using a specialized rig at the patrols' training center.

Speaking at the 2017 Energy Savings Trust conference in London, AA president Edmund King revealed that one-third of AA members aim to make the switch from diesel and petrol for their next car purchase, according to an AA-Populus survey of 19,308 drivers.

The AA's partnership with Chargemaster allows the firm to use the Polar network – the UK's largest public EV charging network, which provides access to more than 5,000 charging points nationwide – to provide an emergency backup charging solution for its patrols in the event that an EV driver runs out of power.

AA patrols also carry Polar RFID fobs. If an AA member is stranded with an empty battery, they will be recovered to the nearest Polar network charging point and provided with a complimentary charge to get them back on the road as soon as possible.

"We have always been at the forefront of motoring innovation and, as our member surveys show, the number of plug-in vehicles on the roads is going to increase quickly," King said in his keynote speech. "So we want to ensure that all of our members are supported on the road, no matter what vehicle they drive."



Above: Young engineers performing analysis as part of the development of Volkswagen's ID family

Below: Engineers at work at Nissan's state-of-the-art battery plant in Sunderland, UK

own hands, by launching a new automotive training program called Tesla START. The 12-week program is designed to train a new generation of electric car technicians to specifically work on Tesla vehicles – the first class of 10 students has already graduated from Rio Hondo College in Whittier, California, and another 13 at Central Piedmont Community College in Charlotte, North Carolina.

Until now, Tesla has recruited technicians who have a background working with the ICE and trained them in-house – but while electric cars share similar components to conventionally powered vehicles, their powertrains are polar opposites. With more than 100 service centers across the world, the Tesla START program allows the technicians to qualify before entering the workplace, placing graduates at service locations across North America within a month after they finish the program.

Tesla also lists more than 150 service technician jobs on its careers website, many of which are for mobile technician roles, as part of Tesla's growing mobile service program. Its mobile service fleet, which includes a custom Model S, is designed to phase out the use of petrol- and diesel-powered ICE commercial vehicles. The company says that the Model S could fix more than 80% of the issues a Tesla vehicle could develop.

Speaking with *E&H Vehicle*, a Tesla spokesperson says, "We're working with some of the best automotive education programs in the country to educate students on electric vehicle technology, and our unique

approach to customer service, to prepare them for a career at Tesla. Students graduate with a full-time job, certification and the skills necessary to succeed in the growing electric vehicle industry."

Electric offensive

Volkswagen Group, meanwhile, is moving ahead with preparations for its electric offensive – it plans to release 27 electric cars within three years across four brands – by launching a comprehensive e-mobility competence program. The three-year Future Electronic Engineer Program (FEEP) will see 100 young engineers and skilled workers throughout the world trained specifically to support the run-up phase of the ID family and the modular electrification toolkit (MEB) that will underpin all future VW Group electric vehicles.

As qualified production specialists, the engineers will occupy future-oriented positions in planning, the pilot hall, the e-mobility model group, the pre-series center and electronics development. The new program, supported by the brand's volunteering initiative and local universities, has been managed by the VW brand pilot hall in Wolfsburg, Germany, with plants in China, Brazil, Argentina, the USA and Mexico also participating. The first ID model is scheduled for production in November 2019, with 100,000 ID vehicles to be made annually in Zwickau, Germany from 2020.

Oliver Wessel, head of the pilot hall, is responsible for the product creation process of all Volkswagen models together with his team, ensuring that series production of the models starts in the optimum way. He aims to provide one of the most comprehensive specialist training schemes in the industry with the FEEP. "This year and next, we will have to master about 80 starts of production," he explains. "The vehicles have more digital intelligence on board than ever before. We need specialists who can provide local support at our plants when the need arises."

According to Volkswagen, the successful FEEP trainees will act as "midwives" for the new electric cars. Thomas Ulbrich, member of the board of management and responsible for e-Mobility, outlines the dimensions: "Within three years, Volkswagen will be starting production of a total of 27 electric car models for four brands in three regions of the world. At the Zwickau plant alone, models of three Group brands will roll off the production

Above: Volkswagen's FEEP initiative is a three-year program intended to train the engineers and workers vital to the ID range

Left: Volkswagen's IT Symposiums showcase R&D areas in which the auto maker wishes to develop its expertise

AN IGENIUS PLAN

In 2013, BMW employed artificial intelligence to promote its new electric vehicles through an automated information service for UK customers – the first ownership package of its kind.

The iGenius system uses specially developed software to interact with potential customers in a live question and answer format that works on a mobile platform – users simply text in a question relating to BMW i and iGenius will instantly respond with a detailed answer.

The adaptive system is capable of interpreting words, the context of those words, and the sentiment behind each question in order to respond, enabling customers to have a real-time conversation with a robot. As a concept that works well as a promotional tool, it has been pondered as to whether iGenius could evolve to understand the workings of battery technology and act as a diagnosis system for both owners and technicians, or replace the latter altogether.

lines. In the future, our MEB plants throughout the world will need young engineers who are thoroughly conversant with the requirements for production of the new vehicle architecture and also have considerable practical experience."

Participants entering the program in fields such as vehicle informatics or data logistics will usually have completed a practically oriented course of study. Initially, they will be provided with basic training on commissioning at the Volkswagen brand pilot hall in Wolfsburg and will work on current vehicle projects such as the first ID hatchback. Following this, they will receive intensive seminars – during specialist training as programmers, for example – and will work on projects with gradually increasing requirements. They will then complete an assignment to another country, where they will work on starts of production and benefit from practically oriented support by highly qualified mentors and senior experts working on a volunteering basis.

An economical proposal

It is not just manufacturers who are taking a keen interest in the education of future automotive engineers and battery scientists, as research institutions team up with academic centers and universities to provide education opportunities to invigorate workforce development in electrical battery storage.

Founded in October 2017, The Faraday Institution is the UK's independent institute for electrochemical energy storage science and technology, supporting research, training and analysis. Bringing together expertise from universities and industry, The Faraday Institution, based in Harwell, Oxfordshire, endeavors to make the UK the go-to place for the research, development, manufacture and production of new electrical storage technologies for both the automotive industry and the wider relevant sectors, thanks to a new government-supported economical proposal for higher education and research institutions.

"We will play a vital role in the education and training of future engineers and scientists in the automotive sector," says Matthew Howard, head of engagement and education at The Faraday Institution. "We have been awarded £78m [US$104m] of government grant funding over the next three years, from the Engineering and Physical Sciences Research Council, to commission and manage research in energy capture, conversion and storage.

"The UK EV and Battery Economics Project addresses questions such as 'What is the maximum opportunity for electric vehicle and battery cell production to be based in the UK by 2030, 2040 and 2050, and what actions need to be taken now, and by who, to ensure that this opportunity is captured?' The project also considers what it will take to attract battery manufacturers to the UK, providing us with data and conclusions that will influence our understanding of job demand for the automotive industry during its transition from the ICE to electrification.

"Our plants will need young engineers who are conversant with the requirements for production of the new vehicle architecture"

Thomas Ulbrich, member of the board of management, responsible for e-mobility, Volkswagen

Above: Tesla's START program is designed to train a new generation of electric car technicians

"We anticipate the transition from the ICE to electric power is going to create a cresting wave of varied needs and, by working in partnership with the automotive industry and academic centers such as Zero Carbon Futures at Gateshead College [in the northeast of England], we hope to launch a training program for the national curriculum in 2019."

Howard concludes, "We will sponsor a national curriculum in energy storage science and provide technology education opportunities to invigorate regional and national workforce development. This will provide new models of education and training for skilled workers, while creating new and expanded employment."

The call for proposals to participate in The Faraday Institution's economics project closed in June 2018. The proposals will be reviewed by the Faraday Institution Expert Panel with the final funding decision to be made by the Institution's Board of Trustees.

Producing approximately a quarter of Europe's low emission vehicles and being home to a battery factory in Sunderland, UK authorities hope the country is well positioned to become a lead developer and producer of electric vehicles and the batteries that will drive them as the national 2040 target (banning sales of new petrol and diesel cars) approaches. However, the UK is in a global race, with countries such as China, the Netherlands and the USA. It is likely that electric car manufacturing will gravitate toward the presence of battery manufacturing, so it is vital that the UK secures contracts from large-scale battery manufacturers and investors in order to future-proof its jobs in the automotive industry.

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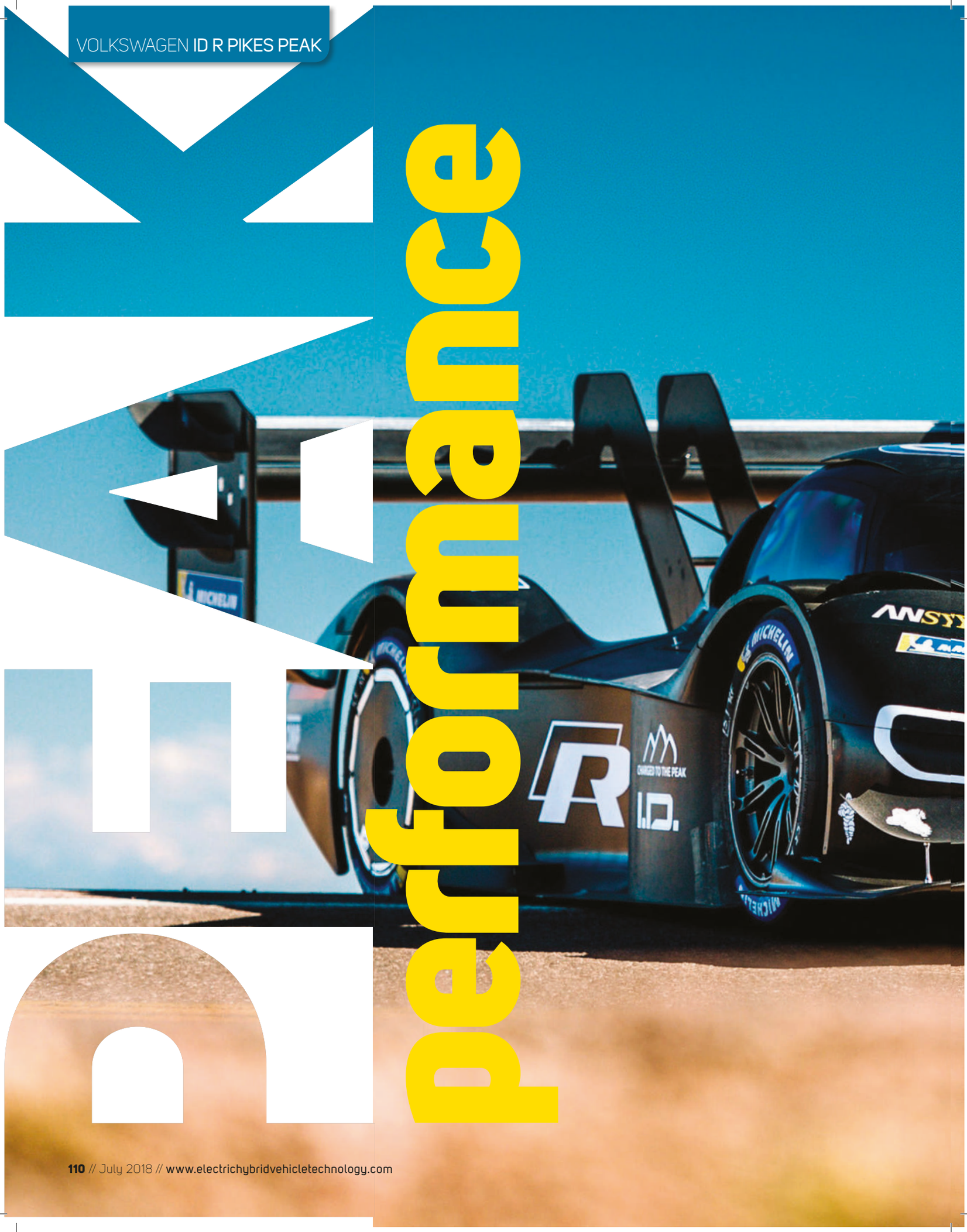

Targeting an electric record in the Race to the Clouds: Volkswagen has taken on the famed Pikes Peak hill climb in Colorado with an all-new prototype

WORDS: **ANDREW CHARMAN**

It's a fascinating combination – the ultimate hill climb event and a global car manufacturer, with the latter smarting from recent controversies over emissions manipulation and bidding to showcase its electric powertrain technology.

The result is the Volkswagen ID R Pikes Peak, a prototype race car built as an ambassador for the German giant's ambitious ID electric road car program. The first ID cars are expected on sale before 2020 and Volkswagen intends to offer more than 20 fully electric car models by 2025.

The brand argues that the importance of electric power in motorsport will also grow as such powertrains become more

Left and below: The engineering and design teams worked together closely in development

commonplace on the road, and as in the past, development for motorsport can benefit future road cars.

Taking on the Pikes Peak hill climb provided an acid test for such development. Held annually since 1916, the event pitches competitors against a 20km (12.4 mile) route in the Rocky Mountains in Colorado. The start is 9,200ft (2,800m) above sea level and the finish at 14,100ft (4,300m) – little wonder it is known as the Race to the Clouds.

Aiming high

And at this year's event, VW made quite the impression. Setting out to beat the current course record for an electric car – 8 min 57.118 secs – set in 2016 by Rhys Millen in the eO PP100, the ID R rolled home in 7 min 57.148 secs. Not only besting Millen, but going 16 seconds quicker than all-time-record-holder Sébastien Loeb and his 887ps Peugeot 208 T16 from 2013. The ID R Pikes Peak competed in the unlimited class of the hill climb, its open regulations primarily focused on safety. This is effectively a rally stage on a course set among stark, mountainous terrain.

Visually the car looks much like a Le Mans LMP1 prototype, but Volkswagen Motorsport director Sven Smeets insists that the prime design consideration was not maximum performance, but a balance between energy capacity and weight, requiring input from many parts of the VW Group. "The cooperation within the group really helped us, particularly given the tight schedule. For example, we received support from the Volkswagen battery plant in Braunschweig and worked with the technical development department in Wolfsburg."

Below: A half-scale model was used to test different variants in the wind tunnel. The final touches were then refined on a full-size chassis in a rolling road tunnel

The car was essentially a clean sheet design, developed in just seven months. Measuring 5,200mm long, 2,350mm wide and 1,200mm high, it is built around a carbon composite monocoque with a steel roll cage. But, according to Volkswagen Motorsport technical director François-Xavier Demaison, the weight saving does not extend to extensive use of composites: "The chassis, suspension and safety structure of the ID R Pikes Peak are almost completely made of steel and aluminum."

Despite this, overall weight has been kept to 1,100kg – significantly lighter than previous electric Pikes Peak competitors. Aiding this is the compact format of the battery packs, mounted adjacent to and behind the driver to help provide a perfect 50:50 weight distribution.

Peak power

Greater electric capability normally means larger and heavier batteries, but for this car

VW was not concerned about range between charges. Power generation was the priority, with energy management regarded as the key to a record time on the mountain. Twenty percent of the energy required is generated during the run, recovered under braking.

The batteries feed two Integral e-Drive-sourced advanced SPM electric motors, one on each axle, resulting in an all-wheel-drive powertrain – essential for the Pikes Peak course. Power is quoted at 500kW (679ps) with 650Nm of torque, resulting in a 0-100km/h time of 2.25 seconds – quicker than a Formula 1 car.

One area in which the open regulations suit Volkswagen's engineers is in overcoming the unique aerodynamic challenges of the course. The winding route has 156 corners, putting a premium on grip rather than outright speed; maximum speeds are not expected to exceed 240km/h (149mph). But as the course climbs 1,400m (4,590ft), the air becomes 35% thinner, compromising aerodynamic downforce.

An electric powertrain offered some advantages to the designers, not requiring anywhere close to the amount of cooling air that a traditional combustion engine would. Powertrain temperatures cannot be completely ignored, but the traditional cooling ducts on the car's nose can be largely dispensed with, along with the aerodynamic compromise they create.

The compact drivetrain also allows greater freedom with aerodynamics. ID R Pikes Peak employs a large front splitter, further aero body sections either side of the cockpit, and a rear wing much larger than on a typical circuit race car to ensure it remains effective toward the end of the climb where the air is thinner.

Top: The all-electric prototype showcases technical elements of the future production cars in VW's ID family

Middle: Driver Romain Dumas prepares for the event in Colorado

Above: Dumas smashed the record, finishing the climb in 7 min 57.148 secs

Calculating the aerodynamic and cooling requirements required much time in the wind tunnel, with various configurations tried initially on a 1:2 scale model and then on a full-size chassis. Each configuration experimented with employed 3D-printed parts. "We printed about 2,000 parts, and in doing so saved a lot of time," says Dr Hervé Dechipre, the CFD engineer heading the aerodynamics team.

However, the wind tunnel could not replicate the thinner air on the upper stretches of the course, so simulation software supplied by technology partner Ansys was also employed.

Pre-event testing and development also proved challenging – the Pikes Peak course is a public road, and was not available to the team until the start of June, and then only for restricted, three-hour sessions.

The car was shaken down at the Ales circuit in the South of France on May 23, before the team relocated to a bespoke facility set up in Colorado to test, when permitted, at Pikes Peak.

Testing went well, but the final Race to the Clouds went even better, with the ID R and driver Romain Dumas exceeding even the company's own high expectations. Following the drive, he said: "Since this week's tests, we have known that it was possible to break the all-time record. For it to come off, everything had to come together perfectly – from the technology to the driver. That everything ran so smoothly is an incredible feeling."

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Game changer

Mike Carcamo, Nissan's global motorsport director, believes the OEM's entry into the fifth season of Formula E will provide a welcome platform to further its electric road car program and spread the message of Nissan Intelligent Mobility

WORDS: **BRUCE NEWTON**

Below: The Japanese OEM will provide electric motors, gearboxes and software for the e.dams racer in the 2018/2019 season of Formula E

If Nissan's global motorsport boss, Mike Carcamo, is in any way apprehensive about the company's return to top-flight international competition, he's doing a very good job of hiding it. But then he's doing an equally good job of avoiding bullish forecasts about Nissan's new Formula E program, even though the Japanese manufacturer is uniting with what has been proved to be one of the best operators in the category – the French e.dams team.

"The competition is going to be incredibly tight in Formula E and we have to do our homework and work hard just like everyone else," says Carcamo.

Carcamo's low-key stance is understandable, because the last time Nissan made a high-profile commitment to motorsport, it turned into an utter shambles.

We're talking about the World Endurance Championship program that was to take on Toyota, Porsche and Audi in LMP1 racing – and especially the Le Mans 24 Hours – back in 2015. Carcamo didn't create that program, but he inherited it in late 2015 and has been Nismo global motorsport director since April 2016.

Left and below: In 2015, Nissan's LMP1 entry raced Le Mans without its hybrid system engaged after it was found that the GT-R LM gained no benefit from hybrid power

Designed by the USA-based British designer Ben Bowlby, the GTR-LM featured a radical front-wheel-drive design but it was never competitive. And although it raced at Le Mans in 2015, it did so without its hybrid system engaged. It was pulled out of subsequent 2015 races and was redesigned for 2016, but the program was canned before the new version of the car was built.

The resulting bad publicity for Nissan was massive. Now it is back on the international stage and, according to Carcamo, lessons have been learned.

"Whatever mistakes were made [in LMP1] were clearly discussed and we talked about them and found ways to overcome them," he says. "We have been planning this [Formula E] for two years now, so it's not as if today is the first day we are jumping into this. The planning is the most important step. That and finding the right resources to execute the program."

Looking back, Carcamo can see positives from the LMP1 experience.

"It was fascinating," he insists. "I love motorsport – this is what I do – and I am trying to drive the company forward in that direction. It was really exciting, with lots to learn – a highly intense situation. I expect Formula E to be no different."

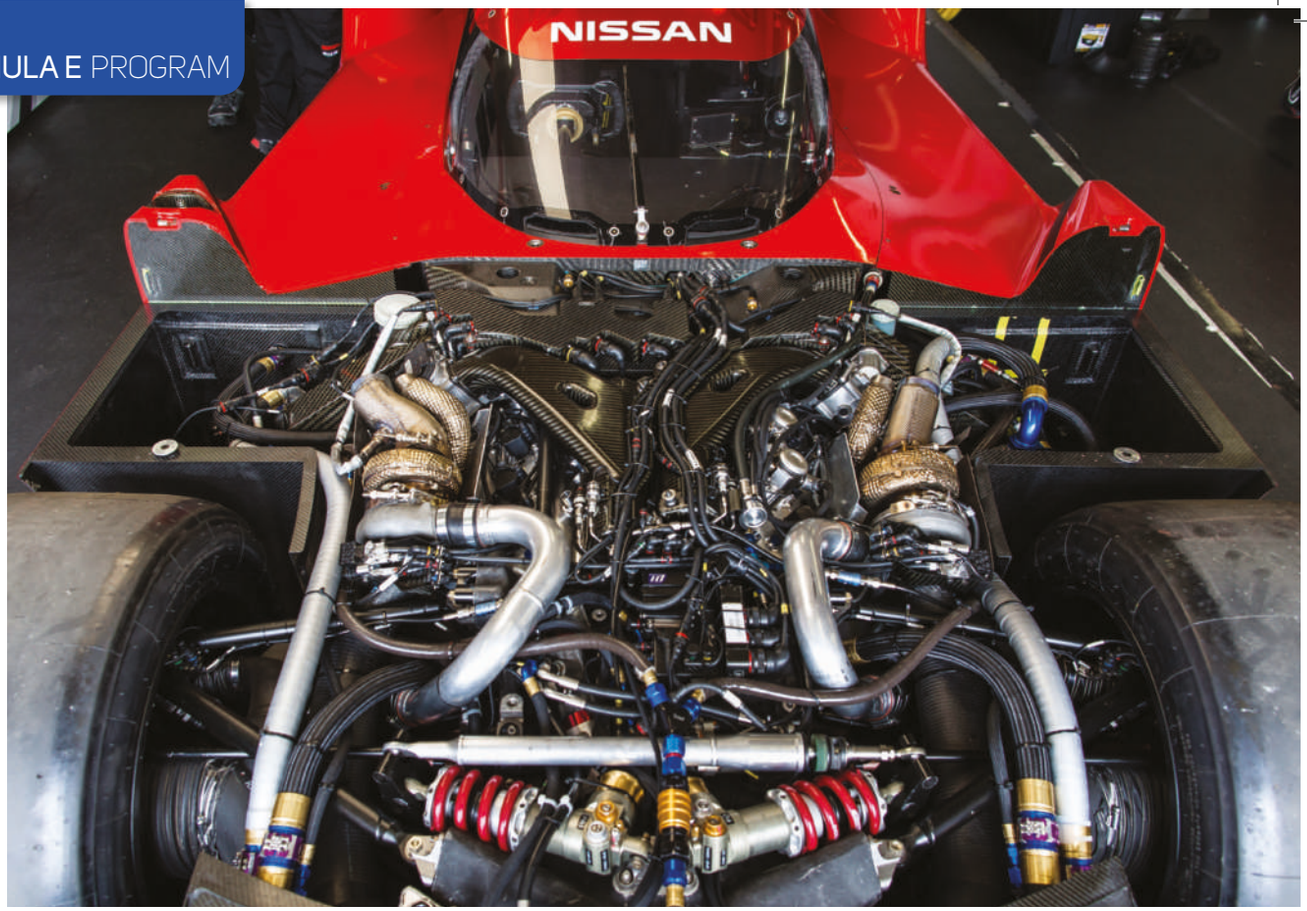
"The planning is the most important step. That and finding the right resources to execute the program"

Mike Carcamo, Nissan's global motorsport director

Nissan's black, silver and red Formula E racer was revealed at the Geneva Motor Show back in March. Other vehicle manufacturers on the grid in 2018/2019 for the fifth season will include BMW, Jaguar, DS, Mahindra and Audi, with Mercedes-Benz and Porsche joining in the 2019/2020 season.

Nissan will become the first Japanese manufacturer to participate in Formula E, replacing alliance partner Renault, which will be focusing on Formula 1. e.dams has won three team titles, two of them with Renault.

This is very different from Nissan's LMP1 program, an in-house operation. The radical second-generation Formula E chassis, physically revealed at Geneva, is identical



The drive system in the GT-R LM comprised a twin-turbocharged 3.0-liter V6 petrol engine and a mechanical flywheel KERS

for all teams, as is the battery pack supplied by McLaren.

Individual manufacturers will provide electric motors, gearboxes and software for battery and energy management systems.

Efficiency drive

"When you buy an EV road car, you may be concerned with how far and how fast you can go. This is the process we are accelerating with Formula E," Carcamo notes.

"Getting the maximum efficiency for the longest period is what will concern most people if they buy an EV. How far and how fast can I go? This is what we are addressing with the racing. We can accelerate that learning process 100 times."

For the first time in the 2018/2019 season, extended battery life means the drivers won't have to swap cars halfway through races. Maximum power also bumps up to 250kW from 200kW, while top speed could reach 300km/h (186mph), up from about 225km/h (140mph).

Blast from the past

Carcamo says a combination of the auto maker's production of electric vehicles, such as the second-generation Leaf BEV, and its racing heritage, made the transition to Formula E a logical move.

"It's the right time and platform for us to get our message out about Nissan Intelligent Mobility," he says. "We have a lot to talk about in the electric vehicle world and we just want to find another way to communicate that to people."

"Getting the maximum efficiency for the longest period is what will concern most people if they buy an EV. How far and how fast can I go? This is what we are addressing"

He points out that Nissan has a strong history in the development of EVs, stretching back 70 years, and that the company has sold 300,000 Leaf electric cars.

"We have freedom [with Formula E] to work on both hardware and software," adds the former Nissan LMP1 program director. "With all the knowledge we have in our company, putting some of that knowledge to work in battery and energy management systems is critical.

"This is vital for Formula E, a key component of electric road cars, and we can teach people about it."

Carcamo refuses to speculate about what Nissan's move into electric motorsport might mean for a potential Nismo hybrid or EV performance road car. However, a concept Nismo version of the new Leaf was revealed at the Tokyo Motor Show in 2017.

"I can't comment on the full product portfolio of Nissan Nismo, but you can definitely see the concepts we are working on, such as the Nismo Leaf. You can see there is a link; there is a not a gap anymore," he says.

While the Formula E program is a key focus at this moment in time for Carcamo, it isn't the only motorsport responsibility he has on his plate. Nissan's involvement in GT racing with the GT-R, engine supply deals in sports car racing, the GT Academy and Australian Supercars are all part of his business, too.

While Nissan has evolved the GT-R GT3 for 2018 – with Carcamo overseeing improvements in aerodynamics, fuel economy and weight reduction – there are signs of a new direction for the car manufacturer. The Academy has paused its new driver search and Nissan Australia recently announced its withdrawal from Supercars. It seems all attention has turned to Formula E ahead of the new season.

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Auto Race

RACING

As the number of new electric racing series continues to rise, could hybridization represent a more realistic route to electrification for established ICE motorsport stalwarts?

WORDS: **ANDREW CHARMAN**

The automotive landscape is changing, with the rise of the electric car now firmly underway. Automotive OEMs are queueing up to adopt the technology across their road car ranges, whether full electric, plug-in hybrid, or traditional hybrid systems, and are pushing the development of electric-based powertrains. Many promise some form of electrification in every new model launched from as early as 2020.

Those same manufacturers are also abandoning traditional motorsport categories to increasingly pour budgets, and technological development, into what they see as the one game in town – the FIA's Formula E electric single-seater series. Recent OEM recruits to the standard-bearing international championship have included Mercedes-Benz, dumping its German DTM program,

AHEAD

1. The Jaguar I-Pace will compete in a single-make series from late 2018

2. Could electrification make its way into racing series such as the British Touring Car Championship?

1

2

ELECTRIC EXPOSURE

Hong Kong-based FRD Motorsports, which hosted the world's first-ever E-Touring Car Challenge in 2016 on the same weekend as the inaugural FIA Formula E Hong Kong ePrix, has announced its second E-Touring Car Challenge, to take place by October 2018 around Hong Kong's Central Harbourfront. Sanctioned by the Hong Kong Automobile Association, the original 2016 event involved 16 e-race cars, with five celebrity drivers competing against 11 veteran Hong Kong drivers.

According to FRD, the China Electric Touring Car Challenge will combine "street e-car technology alongside new design aero parts and electronic enhancement, to bring the best e-race cars to the series". FRD is already cooperating with factories in Europe on "research and development".

"With zero emissions and low noise pollution, the China Electric Touring Car Challenge will be able to host races in city centers, bringing the exciting races close to the public, while expanding the level of exposure for the car makers. The first race will be hosted by October 2018 and the second race will be wrapping up by December 2018."

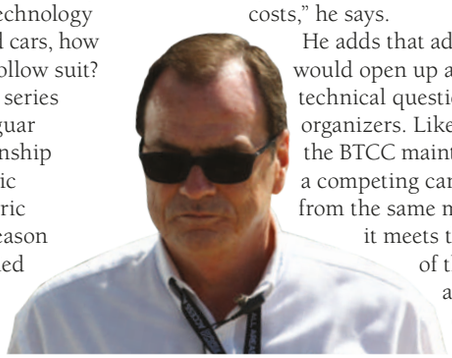
Founded in 1997, FRD is a motorsport promoter headquartered in Hong Kong, China. It has organized and promoted several Asia- and China-based championships, such as the Asian Formula Renault Championship, China Formula Campus Championship, Clio Cup China Series and Asia GT Race Series.

> "Touring car racing has to reflect what is happening on the road"
>
> Alan Gow, series director BTCC (below)

and Audi and Porsche, both manufacturers selecting Formula E over the World Endurance Championship, where they had been running hybrid-engined cars.

What, however, of touring cars, the circuit racing category most closely allied to the daily drivers of its audience? As electric technology looks set to become the norm in road cars, how soon before the racing equivalents follow suit?

There are already electric 'tin top' series close to launch – from late 2018, Jaguar will organize a supporting championship at Formula E races for its new electric family car, the I-Pace. And the Electric GT Series plans to contest its first season in 2018 with 20 Model S cars supplied by Tesla – the OEM most closely associated with electric performance road cars.



Hybrid challenges

Both the Jaguar and Electric GT initiatives are one-make series based on identical electric cars – although the latter states that it will accept entries from other manufacturers following its initial season. Bringing electric power to mainstream touring car racing, contested by a wide variety of competing models from many different manufacturers, throws up a host of new challenges.

Peter Riches has been technical head of the world's best-known touring car series, the British Touring Car Championship, for more than 20 years, and has overseen four generations of BTCC technical categories, from the FIA-derived Super Touring and Super 2000 specifications, to the series' in-house-created BTC Touring and currently highly successful NGTC formats.

Riches' personal view is that the prospect of electric cars in touring car racing is still several years away, with even the adoption of hybrids posing many technical and budgetary challenges. "At national level, the cost of electrification would be prohibitive – it would need to be a bolt-on plug-and-play hybrid system – and still teams would baulk at the costs," he says.

He adds that adopting such a system would open up a whole new range of technical questions for championship organizers. Like most touring car series, the BTCC maintains a free engine rule – a competing car can employ an engine from the same manufacturer so long as it meets the technical regulations of the championship. Could a hybrid unit be suitably designed to ensure equal performance across

multiple engines, or would a 'one type for all' spec engine rule be required?

Another major challenge, according to Riches, will be weight. Hybrid and electric cars require substantial, and heavy, battery packs. In a steel-bodied touring car, these would create significant tire issues. "Touring cars suffer from enough tire challenges already," he says.

BTCC series director Alan Gow is in no doubt, however, that the next generation of BTCC technical regulations, which are likely to emerge in 2022, will involve a degree of electrification, in the form of hybrid systems.

He agrees with Riches that full electrification is many decades away, both on the road and on the track, but argues that bringing hybridization to touring cars is inevitable. "By its very nature, touring car racing has to reflect what is happening on the road, the type of cars we drive every day, so some form of electrification, i.e. through a hybrid system, is definitely coming over the horizon," Gow says.

He believes hybrid systems are becoming more attractive to series such as the BTCC because the cost of fitting them is steadily decreasing and the actual fitment is becoming easier to carry out. He argues that by the time series come to introduce hybrids as a mandatory measure, the costs will be quite low – certainly in comparison with today.

"Cost is a crucial factor, but like all technology it comes down in cost quite rapidly," he says. "We looked at the cost of doing it two or three years ago, simply to begin the thought process, and it was eye-wateringly expensive. Now it's not, and in another three or four years' time it will be less expensive still – the cost/benefit analysis becomes much better as time goes on."

Leveling up

Some argue that any electric future for touring car racing will start at World Championship level, with manufacturers developing such powertrains, as is currently happening in the Formula E series. And the introduction of such technology will, it is argued, be delayed by the current lack of a manufacturer-contested World Touring Car Championship.

1

In 2018, the WTCC adopts the regulations of the TCR touring car category that launched in 2015 and which has since spawned several regional and national series across the globe. The FIA has licensed TCR's regulations for three years in a bid to arrest sliding entries in the WTCC and the series will be known as the FIA WTCR – effectively the World Touring Car Cup.

TCR's business model, however, is based on manufacturers building runs of race cars to sell to teams on a customer basis, and specifically prohibits full works teams competing directly against each other on track. In adopting these regulations, the FIA has removed significant manufacturer-funded technical development from front-line touring car racing.

Gow, however, believes this will make little difference to the advance of hybrid systems, as such technology does not need to cascade from international to national level. He expects some domestic championships to adopt hybrids before their international equivalents. "Hybrids are a subject on everyone's lips and can't be ignored," he says.

"Today you can buy many plug-and-play hybridization systems off the shelf, to fit to the flywheel, gearbox, or whatever, and you don't need OEM manufacturers funding development – the systems exist and are quite reasonably priced.

"You also have to remember that a hybrid system that a manufacturer would use on the road will be totally different and far more complex to one used in racing. Road systems have to do so much more than a race unit, so are far more complex and expensive."

2

3

1. Thanks to its zero emissions and low noise, the second E-Touring Car Challenge can be staged in city center locations

2 & 3. The full-electric TCR car was unveiled at the Geneva Motor Show

Easy electrification

The TCR category, however, appears to be much further along the electric road than many might think. The Geneva Motor Show on March 6 saw the surprise unveiling to the press of a ready-to-go full-electric TCR racing car, in the form of a SEAT León Cupra.

1

2

1. The E TCR could be part of a standalone electric championship in 2019

2. A rear-facing camera in the Cupra electric car removes the need for drag-sensitive mirrors

"For us, it is important to go to full electrification when the opportunity is there"

Marcello Lotti, WSC head and TCR creator (below right)

The car has been developed by the new E TCR subsidiary set up by TCR-owning company WSC, and SEAT Sport, a staunch supporter of TCR since it launched in 2015. However, the unit has also been designed as a drop-in system, enabling any of the dozen different brands that are currently represented in TCR to be easily converted to full electric propulsion.

E TCR plans to test and develop the Cupra E-Racer throughout 2018, then to race it for promotional purposes in a TCR regional series event in October, before launching a standalone electric championship – hopefully in 2019.

WSC head and TCR creator Marcello Lotti tells *E&H Vehicle* that electric is a natural direction to take. "We expend all our energy on developing touring cars, but we need to look at what is happening in the world around us," he says.

"Manufacturers like series that allow them to do research and development, especially in this area that is becoming more important. We can recreate the interaction that used to be seen between manufacturer R&D departments and motorsport, developing new technology that can progress to production cars."

Lotti foresees E TCR one day progressing from a separate championship to the norm in TCR, but he does not anticipate a period with hybrid engines. "For me, hybrid is already a reality, but we are offering manufacturer R&D departments the chance to work directly with us on the next big step for automotive. For us, it is important to go to full electrification when the opportunity is there."

So it appears that the arrival of electric power in touring car racing could be much closer than many might expect, with national series such as the BTCC showing the way via the adoption of hybrid systems, and the internationally represented TCR planning a full-electric route.

To rule makers such as Marcello Lotti and Alan Gow, a direction involving electric propulsion is obvious because of the place touring car racing occupies in the motorsport arena, and its close affinity to everyday driving. "What we race is what you see on the road," Gow says, adding that he believes every major touring car series around the world will be thinking in similar terms.

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POWER TRIP

Charging rates and infrastructure provision continue to be a major talking point for the EV industry. *E&H Vehicle* looks at some of the dominant areas of development

WORDS: **CRAIG THOMAS**


TESLA

1

LIFE AFFIRMING

As rapid charging rates become more common, should vehicle owners be worried about a detrimental effect on the life of an EV battery?

"We're not really seeing that," says David Martell, founder and chief executive of Chargemaster. "It seems to be a bit of a myth. We've seen people rapid charging cars twice a day and have ended up with over 150,000 miles on them."

"There is nothing in the chemistry that prevents recharging at rapid rates," agrees Subhash Dhar, an expert on battery technology and founding president of Ovonic Battery and most recently CEO of Xalt Energy.

"If we are talking about lithium-ion chemistry, which the majority of EVs have, then it is possible to rapid charge. It makes a difference what your battery charge is. It is better to charge batteries at high rates when they are between 10-90% charged."

After 80% of charge, Dhar adds, battery efficiency is dependent on age and internal resistance, with newer batteries being more efficient.

WORDS: **RICHARD N WILLIAMS**

Electric and plug-in vehicles are increasing in popularity all around the world, with sales volumes rising nearly four-fold since 2014. Specialist consultancy EV-Volumes estimates that, if the present rate of adoption continues, plug-in cars will account for approximately half of global car sales by 2027.

However, the big question is whether the charging infrastructure will also grow to keep pace with the expansion of EVs. The number of public charging locations has doubled in the past two years and, according to Colin McKerracher, lead advanced transport analyst at Bloomberg New Energy Finance, there were close to 600,000 public charging points installed globally at the end of 2017.

That increase looks set to continue, McKerracher explains: "You're seeing a big increase in spending right now, in places like the USA, where Volkswagen is spending a billion dollars on charging infrastructure as part of the diesel emissions scandal settlement. Big electric utilities have another billion dollars' worth of spending they're putting toward that, both in California and New York."

Research by Swiss bank UBS has estimated that US$360bn will have to be spent by the end of 2025 to build a global charging infrastructure to keep pace with electric car sales.

Need for speed?

Super-fast rapid chargers providing 150kW and 350kW are being rolled out, but these are unlikely to become a common part of the street furniture.

"Not all cars are going to need charging in 10 or 15 minutes, rather than, say, 20 or 30 minutes," says David Martell, founder and chief executive of UK charging supplier Chargemaster (which was acquired by BP at the end of June 2018). "But some will, some of the time. A small proportion of drivers and for a smaller number of journeys. The average person with a 20- to 30-mile journey per day can make it work pretty sufficiently as things are."

This view is supported by UBS's research, which found that 81% of respondents do no more than two trips per year with a driving distance greater than 300 miles.

Martell also points out that the cost of establishing 350kW technology is in the

2

1. Qualcomm has demonstrated dynamic wireless charging at a test track in France, transferring power at a speed of 100km/h

2. Chargemaster's Ultracharge 500S rapid charger technology

1. BMW's fully integrated inductive charging facility for the high-voltage battery in a plug-in hybrid

2. Wireless charging technology has yet to be rolled out on a significant scale, with plug-in points currently the dominant form of public charging

1

"Not all cars will need charging in 10 or 15 minutes, rather than 20 or 30 minutes. But some will, some of the time"

David Martell, founder and chief executive, Chargemaster

millions of dollars per charger, which is prohibitive for many sites. The cost is therefore likely to limit the roll-out to highway rest stops.

But there are cases where the investment could be worth it. "There's a business model in energy storage," Martell says. "If you can wrap energy storage into the mix, then the quick connection cost looks more sensible, because you can actually start using that grid connection for things like demand response."

No strings attached

After super-fast chargers, the next most talked-about development is wireless or inductive charging.

Technology company Qualcomm is among the leaders in the field, with its Halo program established eight years ago and targeted at making wireless charging a reality.

Graeme Davison, vice-president of development and marketing for Halo, believes the technology is just around the corner: waiting for OEMs to launch cars that can be charged without the need for cables.

In addition to customers with off-street parking having OEM-branded charging units

2

– BMW has announced that its wireless technology will start production in July 2018 – there will be numerous opportunities for destination charging, says Davison: "We've been talking to anybody who could be a charging provider – shopping malls, car parking area providers, large department stores. Anybody who's got space where a vehicle's going to sit stationary for a couple of hours is a charging infrastructure player."

Inductive charging will operate at speeds of up to 22kW because, as Davison points out, it's all about dwell time – how long the vehicle will be stationary. Locations such as shopping malls, therefore, don't need expensive DC charging solutions that charge a vehicle in 20 minutes and then sit idle and occupied for another two hours while drivers are shopping – in these instances, speeds such as 7kW or 11kW are more sensible solutions.

Losses are relatively minimal, too. "If you look at the end-to-end loss, we expect our system efficiency to be in the order of 90-92%. The actual efficiency through the air gap is around 99%. A plug-in solution is about 94-95% efficient," Davison explains.

Qualcomm has also demonstrated dynamic inductive charging at a test facility in France. "We were able to show that you could charge a vehicle in excess of 20kW of energy, transferred across the air gap, to a vehicle traveling at 100km/h," Davison says.

Although real-world applications of this technology are estimated to be 10-15 years away, for taxi ranks and commuter roads, Davison believes wireless charging could be a useful element of future charging infrastructure: "Instead of using punitive measures to control congestion and traffic in a city, you could actually give the city planners a new tool: wireless charging-enabled lanes."

Taking on Tesla

Ionity – established by a consortium of car makers including VW, BMW and Daimler – has declared its intention to launch a network of 350kW chargers across Europe, challenging Tesla's 120kW Superchargers.

However, while Tesla is improving its Supercharger technology, it believes that Ionity's proposition is flawed, with Elon Musk saying recently, "The thing about a 350kW charger is it doesn't make a ton of sense, unless you've got a monster battery pack or have a high C-rate. We think if you use 350kW for a single car, you're going to frag the battery pack. You cannot charge a high-energy battery pack at that rate, unless it's a very high kilowatt battery pack. So for us, something around a couple of hundred, 200-250kW maybe."

> "Instead of punitive measures to control traffic, you could give city planners a new tool: wireless charging-enabled lanes"
>
> Graeme Davison, vice president of development for Halo, Qualcomm

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1. Graeme Davison

2. The Ionity network plans to install a series of 350kW chargers across Europe, and aims to challenge Tesla's Supercharger network

Ionity's ability to charge numerous models – which makes it more appealing to any potential public subsidies or cooperations – also gives it an advantage over the Superchargers. But Tesla is meeting this challenge, with Musk saying, "We're happy to support other auto makers and let them use our Supercharger stations. They would just need to share the costs proportionate to their vehicle usage. And they would need to be able to accept our charge rate, or at least our connector, or have an adapter to our connector. This is something we're very open to, but so far none of the other car makers have wanted to do this. It's not because of opposition from us. This is not a walled garden."

Superfast charging might be a relatively small niche within the public charging infrastructure at present, but the technological prestige it offers to the market leaders makes it an important area for future development.

2

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Fuel cell flagship

Intended to be the vanguard of its eco-mobility vehicle range, Hyundai's second fuel cell vehicle, the Nexo, showcases the very latest in the OEM's research and development

WORDS: **CRAIG THOMAS**

The announcements are coming thick and fast. Whether that's manufacturers revealing plans for plug-in hybrids and battery electric vehicles to be added to their model line-ups, or governments laying down schedules for ending sales of cars powered by internal combustion engines, at the moment the auto industry can't move for announcements on future low-emission mobility.

But while electric vehicles are understandably seen as the way to lower CO_2 emissions, they have their limitations, with range being a particular concern to consumers. This will be less of an issue for urban drivers (by 2050, the UN projects, two-thirds of the world's population will live in urban areas), who should be able to access the necessary charging infrastructure, but what about the need for vehicles with greater ranges?

One solution is a complementary zero-emissions technology that can work alongside electric vehicles, which is where hydrogen fuel cell electric vehicles (FCEVs) come into the equation. Toyota and Honda have already invested in FCEVs and produced models that are

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available to consumers. But another major car maker is arguably making an even bigger bet on the future viability of hydrogen-powered vehicles.

Hyundai already has one FCEV on the market – the ix35/Tucson that went into production in 2013 and has been on sale in 15 countries around the world. Now it has Nexo, a brand-new FCEV launching in late 2018. It is the physical manifestation of Hyundai's plans for hydrogen as part of an electrification strategy that aims to have 38 models (bearing either Hyundai or Kia badges) on sale by 2025.

The Korean company sees Nexo as the technological flagship of its eco-vehicle portfolio, which is why it has developed an all-new, dedicated platform designed to give engineers more flexibility to cope with engineering challenges and maximize the strengths of the vehicle. The new platform has initially been developed exclusively for Nexo, but any electrified powertrain – and even internal combustion engines – can also be fitted to it (though Hyundai claims that it currently has no plans to introduce a Nexo BEV).

When questioned on whether this new platform has been developed with future-proofing in mind, Dr Sae Hoon Kim, director for Hyundai's Fuel Cell R&D division, says, "Hyundai is developing electrified vehicles of all types – HEVs, PHEVs, BEVs and FCEVs – to address the full breadth of customer needs and anticipate future trends. As environmentally friendly vehicle volume is expected to grow, we envisage that the volume of FCEVs will gradually increase as well. And as the FCEV market grows, we expect that the potential of the dedicated FCEV platform will be used for broader applications."

1. Hyundai sees Nexo as the technological flagship of its eco-mobility line-up

2. The OEM's plans for hydrogen vehicles see the technology as integral to its electrification strategy

Next in line

The focus of the platform development was to offer customers a practical car with a usable cabin (it's 260mm longer and 40mm wider than the ix35 FCEV), while the trunk has an 839-liter capacity. However, it's Nexo's hydrogen-fueled powertrain – the result of research and development that started 20 years ago – that's truly impressive.

Hyundai initially worked on the technology with US company UTC Power, which supplied fuel cells to NASA for the Apollo and space shuttle programs. However, the durability of the first stacks was limited to 800 hours, so in 2004 Hyundai started to develop its

"Hyundai is developing electrified vehicles of all types – HEVs, PHEVs, BEVs and FCEVs – to address the full breadth of customer needs and anticipate future trends"

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1. The Nexo's hydrogen powertrain is the result of a long-term research and development commitment

2. The vehicle's platform can be fitted with an electrified or even ICE powertrain, though the OEM does not currently have plans for a Nexo BEV

own FCEV program, with the first development vehicle being produced in 2006.

Since then Hyundai has learned a lot about how to produce fuels cells, as Kim explains: "There has been a lot of progress in durability development. We didn't understand, in the initial phase, why a stack dies, but we now have much better control thanks to about five years of operation in the Tucson ix35. And not only control but also hardware-wise: even if you have the same materials, how do you produce it in a manner that makes the durability significantly different?

"There's chemical degradation, mechanical degradation and physical degradation and we have to solve those problems. In the early days we used several hundred grams of platinum per car, which was really expensive. Now we use almost a tenth of that, with the same performance or better."

Innovative iterations

Hyundai has manufactured hundreds of prototype and pre-production vehicles as part of the Nexo program, and this constant development has resulted in a raft of improvements and breakthroughs in every aspect of the fuel cell's evolution. "We have changed our designs in every area," says Kim. "For example, we have 800 sheets of separator in the stack, each of which had a very expensive coating. But now we've developed with a local company a sheet without the coating that doesn't corrode, and even has the same electric conductivity as coated materials."

Kim also provides numerous examples of how his team has revised, rethought and reimagined the fuel cell, refining and even eliminating entire components. Hydrogen recirculation pumps, multiway valves, compressors that operate at 100,000rpm, air foil bearings that have previously only been used in jet aircraft – the list of technical innovations is extensive. And this development has also reduced costs.

"Some specific technology we develop on our own and almost all components are supplied by local Korean firms," says Kim. "When we started our FCEV development, some of the components didn't exist, so we had to develop them. But because we built only 10 units per year, each component cost about US$30,000 – which is why the car cost US$1m in 2003. Every valve, every pump, all cost US$30,000.

"There's chemical degradation, mechanical degradation and physical degradation and we have to solve those problems"

"But we've reduced costs and there have been so many improvements in so many areas because fuel cells aren't just about chemical engineering or mechanical engineering. We also have plastics, metals, power electronics and electrochemistry," he continues. "We use the same components from our battery electric cars because the fuel cell's motor and motor controller are the same as in an electric car, while the hybrid battery we're using is the same as in our hybrid car. We're adopting this technology from battery and hybrid vehicles, which have greater production volume. The hybrid and battery electric cars help support fuel cell development because we only need to focus on the fuel cell itself and the hydrogen storage systems."

Most of the development work for Nexo has been conducted at Hyundai's R&D center in Namyang, South Korea, with the vehicle subjected to one of the most rigorous global test regimes, undergoing some 10,000 safety and durability tests in North America, Korea and Europe – including gunshot tests, firing tests, drop tests, extreme environment cycle tests, hot/cold weather tests and altitude tests.

> "We use the same components from our battery electric cars because the fuel cell's motor and motor controller are the same as in an electric car"

Indeed temperature extremes – especially cold – are crucial tests. Starting the ix35 in temperatures between -10°C and -20°C (14°F to -4°F) created a big technical challenge, but Hyundai's engineers designed a new component to heat the stack in sub-zero conditions. This thermal management strategy means that Nexo can be started at -30°C (-22°F), comparable to ICE vehicles.

Hyundai's investment in FCEVs is a big bet on future mobility needs in the decades to come. But if other countries follow the lead of Japan – which is planning to invest billions of dollars in a hydrogen economy that will also replace its nuclear industry – that bet becomes less of a gamble and more of a canny investment. An investment that could help give Hyundai a significant lead over its OEM rivals.

1. Hyundai subjected the Nexo to extensive safety and durability testing in North America, Korea and Europe

2. Investment in hydrogen could stand Hyundai in good stead if similar commitment is shown to fueling infrastructure

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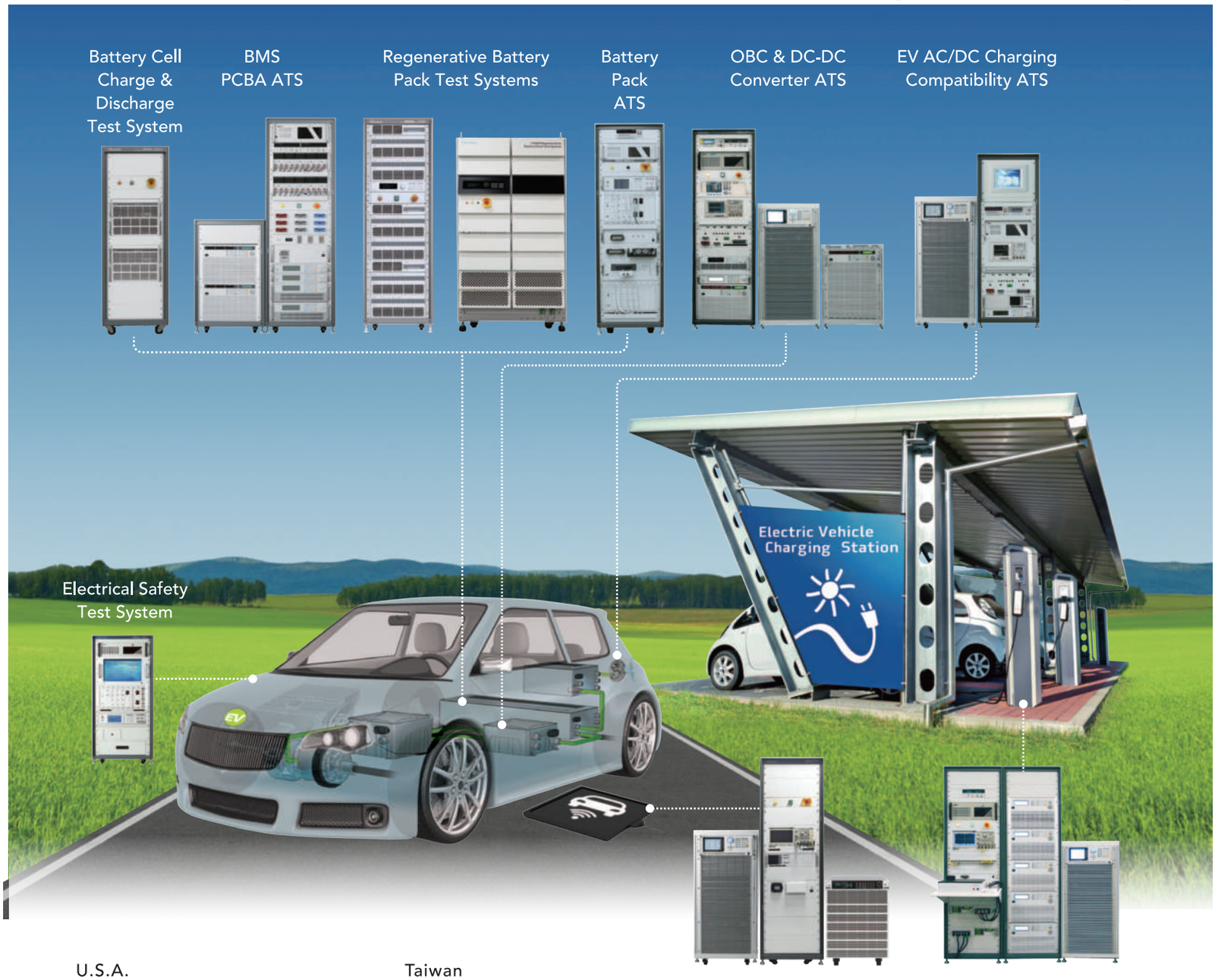

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Hit and miss

Xing Mobility is pushing the limits of electric vehicle powertrain systems with the development of extreme-performance on- and off-road cars, but its R&D projects go way beyond electrifying top speeds

WORDS: **LEON POULTNEY**

After a chance meeting at a 2013 TEDx event, former Tesla engineer Azizi Tucker and designer Royce Hong bonded over a shared love of high-performance cars and bleeding-edge technology.

The pair decided to pool their knowledge and embark on an electric race-car project that would go on to form the bedrock of Xing Mobility – a company that harnesses the power of its unique Taiwanese location, a dynamic approach to design and a left-field relationship with its supply chain.

Xing Mobility's current line-up of high-performance machines includes Miss E (a prototype electric racer that develops the equivalent of 405ps via a 350kW electric motor) and the 1MW, rally-inspired Miss R, which uses four electric motors to deliver an astonishing 1,360ps both on-track and off-road.

"You can trace our racing roots back to 2013," explains Tucker, Xing Mobility's CEO. "We started with a project dubbed Miss G, which was our first carbon-fiber body racing prototype.

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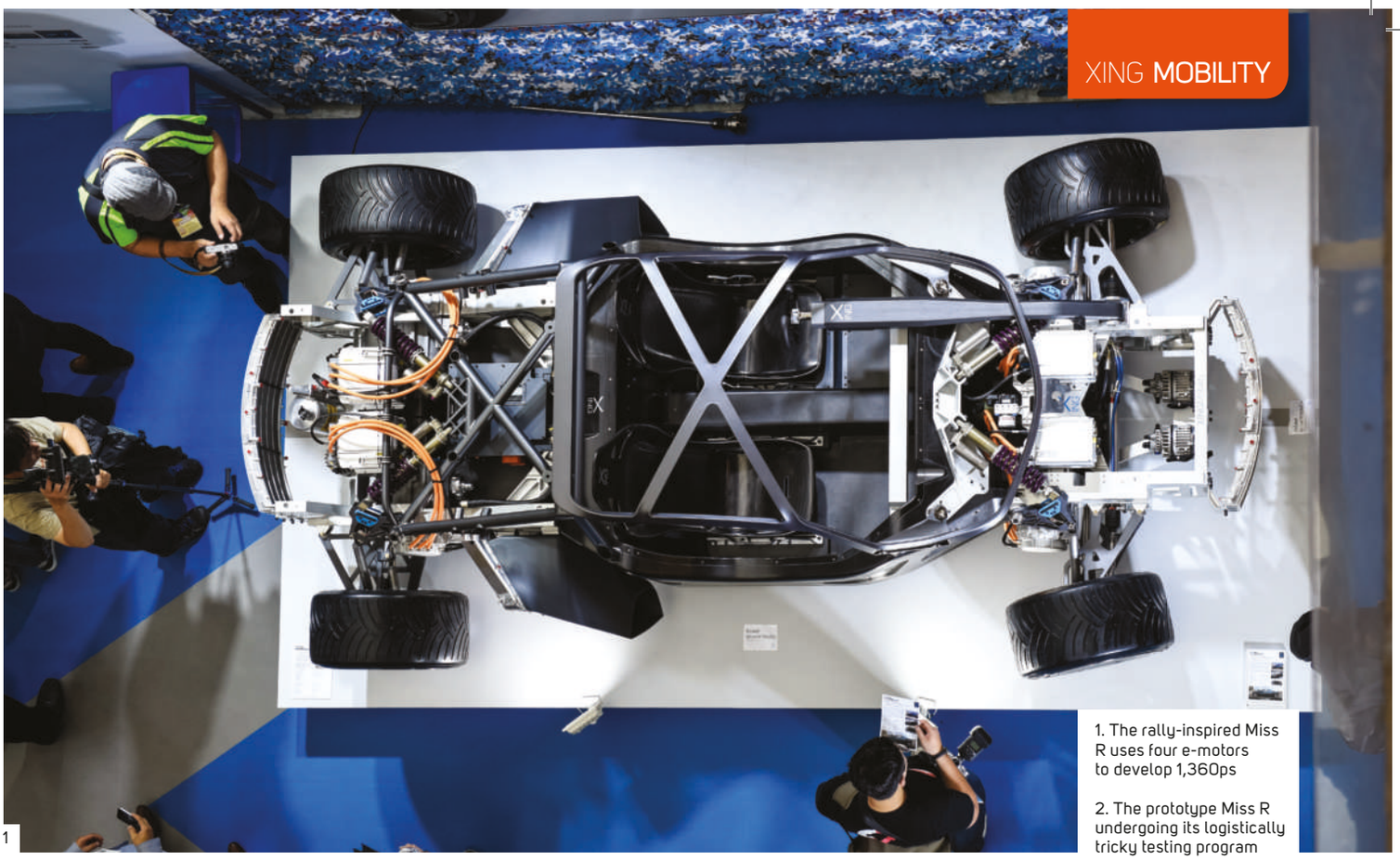

1. The rally-inspired Miss R uses four e-motors to develop 1,360ps

2. The prototype Miss R undergoing its logistically tricky testing program

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"We were a small startup, so to streamline the process we created two vehicles – one gas and one electric – with as many identical parts as we could. The gearbox stayed the same, the wheels, the chassis, even the bodywork. Only the gas tank and engine were different."

The pace of change

Setting this challenge naturally led to difficulties, not least the fact that if the battery pack was going to replace a gasoline engine, it would have to fit into spaces that hadn't been customized for its dimensions. It was solving this problem that resulted in Xing Mobility becoming an unlikely leader in immersive battery-cooling technology.

"Our Miss E electric racer is really an extension of our early research," Tucker explains. "It is a performance race car at its very heart. We have seen some impressive electric powertrains make an appearance in things like the Tesla P100D, but in my opinion they have been placed in the wrong vehicle.

"As cars have gone from analog to digital, they've become videogames or toys – driver feedback is missing. We wanted to make an analog electric car, a car that oversteers and understeers, would move under the driver and be faithful to what the driver asks for, notably excellent steering feel, feedback and brake performance."

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Miss E would become a rolling laboratory for Xing Mobility and spur the company to produce faster, stronger and more exciting things in the shape of Miss R, arguably the world's first all-electric supercar that also dabbles in a spot of rallying.

This impressive feat of engineering houses 4,116 lithium-ion cells in 98 configurable battery modules, four sets of 450V induction motors and patented immersion cooling technology that was created in conjunction with 3M. Projected performance figures see the 0-100km/h (0-62mph) sprint completed in just 1.8 seconds and the 0-200km/h (0-124mph) dispatched in 5.1 seconds.

"We will sell some of these cars in very low volume, around 10 a year, but that's not the sole purpose of this project," explains Tucker. "Our aim is to become the powertrain supplier of choice in the low-volume/high-mix arena. If we were talking in old-school terms, we would be a typical engine supplier, like Cummins or Detroit Diesel, but we want to be as recognizable as those names in the EV arena."

Testing times

Xing Mobility is based in Taiwan, a location which has both its benefits and drawbacks, according to Tucker.

"Testing a vehicle like the Miss R is tremendously difficult," he explains.

"One of the first issues we ran into was while testing the duty cycle of our battery packs and electric motors. Using our typical calculations for duty cycles, we realized that we just didn't have enough space."

Tucker goes on to explain that it wasn't just a problem in Taiwan, but finding an available facility with the required room was going to be tricky anywhere on Planet Earth.

"Accelerating to 200km/h in five seconds meant that we just didn't have enough space to have the car stopped and turned around to do another run," he says. "Luckily we have some facilities that are coming online soon in Taiwan that will allow us to achieve this and test our off-road capabilities."

Shocking the supply chain

A base in one of the manufacturing powerhouses of the world has given Xing Mobility a great location in which to be at the forefront of cutting-edge technology.

Tucker's background in manufacturing led him to a number of conclusions, including the observation that the link between design and manufacturing is, in his opinion, "too weak" in many companies.

"My desk here at Xing is meters from the CNC machine and all our engineers are in an open office that includes 3D printers, welding equipment and more," he explains. "Our design engineers are responsible for manufacturing their own prototypes. Clearly we buy in a fair number of components, but our manufacturing engineers carry out all the assembly. This is so that we can close the gap between our design and suppliers."

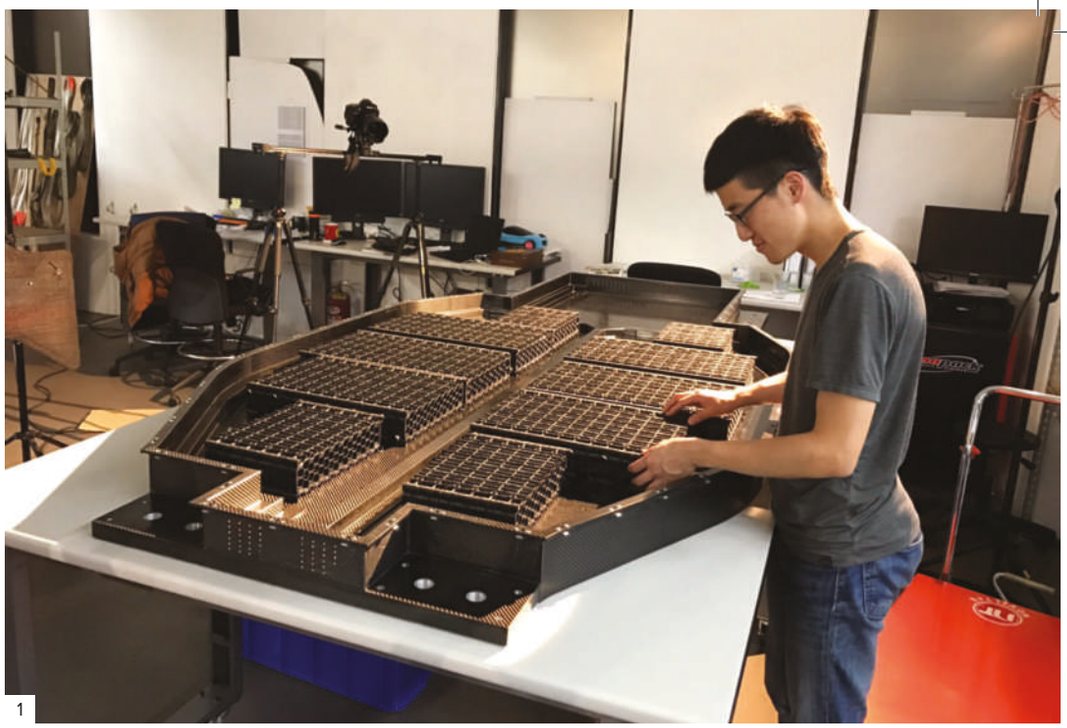
This approach has seen Xing Mobility adopt a cloud-based CAD system that enables its designers to be 'co-located' with manufacturing employees in order to make rapid or last-minute adjustments to designs.

On top of this, all of Xing's suppliers are within two hours of its facility, while the leveraging of small and medium factories has proved successful.

"I like to say we abuse the processes of a lot of local small and medium factories," explains Tucker. "They might make a consumer product for a refrigerator or a home appliance, for example, but we see that their manufacturing process matches those parts of ours that don't have a standard name.

"With Miss E, our first car, we used a high-end bicycle frame company to do the TIG welding on the chassis.

"It worked out that the tube diameter and wall thickness fell right into their sweet spot. We designed and made all the fixtures but they carried out the welding and it turned out beautifully."



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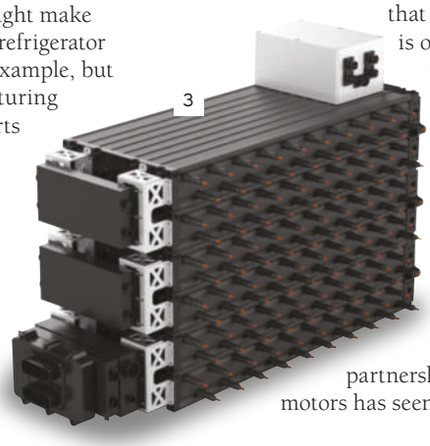

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1. Xing Mobility has adopted a cloud-based CAD system to streamline the vehicle design process

2. The car maker's motor and gearbox componentry

3. The Xing Mobility battery system. The Taiwanese company has won many plaudits for its approach to technology development

Fast charge forward

Xing Mobility might not currently be the most recognizable name in the automotive industry but it is already making waves with its approach.

Global engineering, environmental and strategic consultancy Ricardo has stated that the Taiwanese outfit is one of the world's leading names in immersive cooling technology, thanks to its joint venture with 3M, which sees battery packs submerged in patented Novec Engineered Fluid for high charge and discharge rates. Plus, Xing Mobility's partnership with Clean Wave motors has seen a demonstration of high peak and sustainable continuous power in an extremely lightweight and compact package.

Although not likely to become a big name in the high-performance electric car market any time soon, Xing Mobility believes its on-track and off-road experiments have enabled it to become an expert in the provision of electric powertrains to a vast array of commercial projects.

"Some of our first modular systems are going into Japanese construction vehicles as we speak," Tucker explains. "There are marine applications in the Middle East and we are currently looking at motorsport applications in Europe, but that project is very much under wraps."

It's an exciting time for any electric vehicle manufacturer, but Xing believe its bleeding-edge approach has given it a competitive advantage over traditional OEMs. It is poised to deliver bespoke modular electric drive systems that deliver anything from 4kWh to over 500kWh in any size and shape. Proof, if needed, that "playing with race cars", as Tucker puts it, can pay huge R&D dividends.

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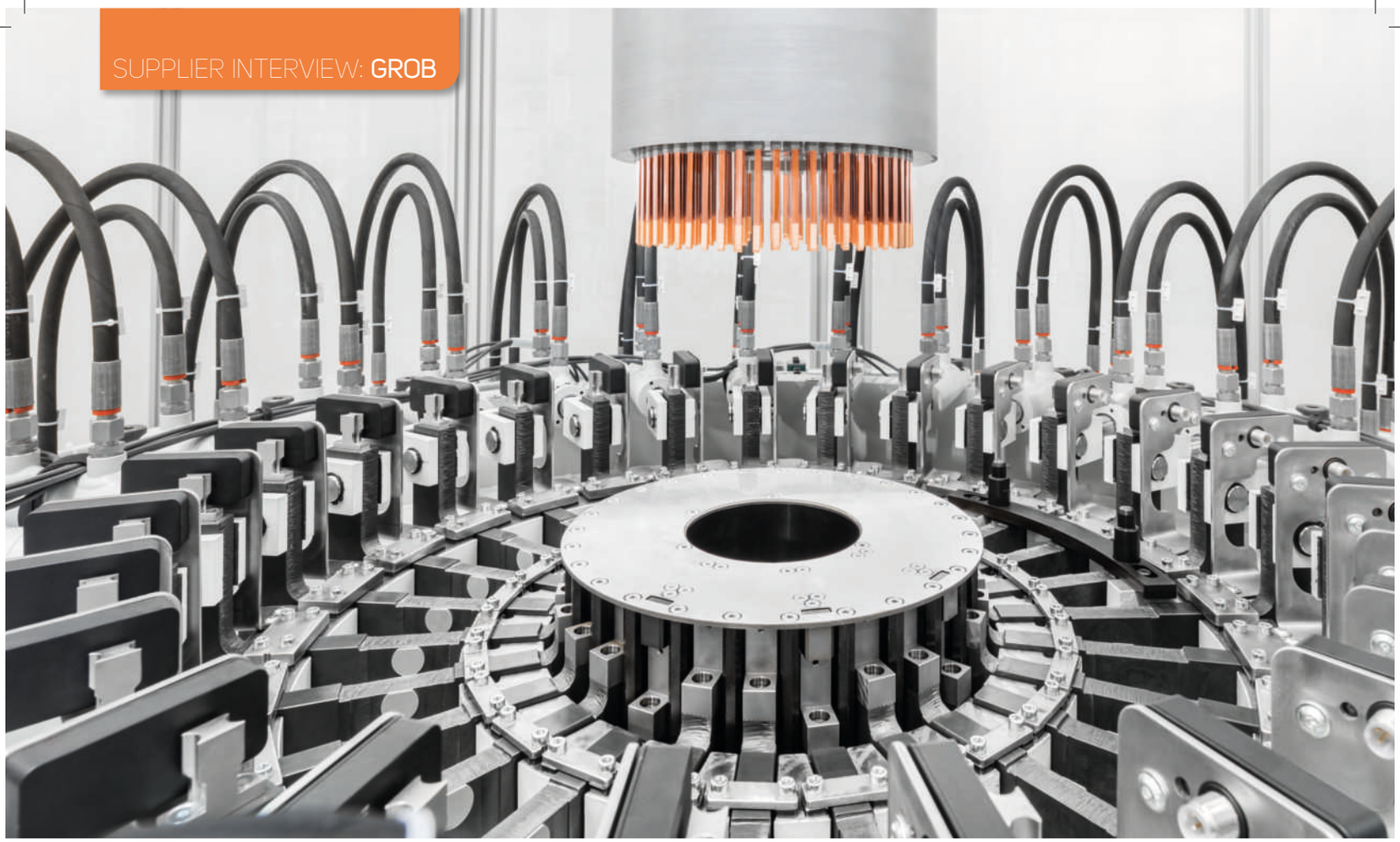


Rapid response

The key to future success is in embracing the rise of electromobility. Some companies have not been quick to do so, enabling others to take advantage

WORDS: **KARL VADASZFFY**

For over 90 years, Grob has developed and manufactured machines and production lines for its customers – including the world's most prestigious car makers and their suppliers. As part of the Grob Group, it has a workforce of around 6,600 employees and generates a worldwide revenue of over €1.5bn (US$1.8bn).

The company's portfolio ranges from universal machining centers to complex manufacturing systems with their own automation functions, as well as manual assembly stations and automated assembly lines. Furthermore, production plants for electric motors and assembly lines for batteries and fuel cells are included in the range.

Grob engineers also deliver solutions for the technology involved in spraying engine components, cutting high-strength turbine housings, and machining structural and chassis components. By developing Grob-Net4Industry, the company's proprietary industrial software for the digitization and networking of production systems, Grob is taking a giant leap into the digital future.

Grob's latest machine portfolio covers the entire production process for an electric motor, from winding and shaping processes for wires, to assembly and contacting. "One of the core processes in the production of a motor is guiding the copper wires into the stator," says CEO German Wankmiller. "We cover all processes, including wave winding technology, the hairpin process and fan-coil technology."

In February 2017 Grob purchased 100% of the shares of DMG Meccanica, a leading

The Grob Group's headquarters in Mindelheim closely coordinates the company's strategy and sales structure

Grob's hairpin process technology is just one of the company's many core competencies

manufacturer of electric motors. In 2018, DMG Meccanica was renamed Grob Italy. Grob Italy offers winding/inserting technology as well as needle winding, which means that "Grob can market and operate with ease all production processes required in the auto industry".

Customers are provided with the machines and system for the highly precise production of components in both mass production and large-scale production. These machines are highly standardized and modular, enabling expansion and modification in the future.

The main challenges in developing these machines have been analyzing trends and the resulting development tasks, including: development, engineering, the construction of prototypes in very challenging timescales, the development of new process technologies, and the verification of optimal processes.

Grob has broadened its product range by moving into electromobility. "After several years in installation and development, this new line of business is now well established," Wankmiller says, adding that Grob machines meet industry requirements and specific demands. The machines and systems are highly efficient and designed for production 24 hours a day, seven days a week.

With production plants in Germany, the USA, Brazil, China and Italy, the Grob Group and its service and sales subsidiaries are represented around the globe. This positions Grob to tackle future electromobility challenges, responding to individual customer requirements, which vary in each country.

Thinking ahead

Against the backdrop of the paradigm shift in the powertrain of the motor car, Grob set up an R&D team three years ago, tasked solely with working on electromobility. "In close collaboration with well-known representatives from the automotive industry, the team quickly realized that there was a great need for mass production installations in the auto industry, with a particular focus on key components, namely the electric motor and battery components," Wankmiller explains.

Grob is currently developing several electric drive projects for the international automotive industry. All these projects can be carried out at Grob, as it already has many specialists and development engineers working in this field. Furthermore, the company is in a position to take on additional large projects as a general contractor for complete powertrains in hybrid or pure-electric drives, and to provide machines and equipment for electric motors, battery modules and battery packs, as well as fuel cells, and to ensure series production in the future.

The company has increased its product range by moving into the field of e-mobility. Pictured above is a hall at Grob's Mindelheim facility

Wankmiller believes that while the processes used in existing company divisions form the basis and serve as models, e-mobility is still a relatively new concept in the auto industry. Therefore all market operators, he believes, have to adjust their approach.

Even though markets are reacting at different speeds, Grob has adapted to the new technologies. Within the Grob Group there is a uniform approach and sales structure that is closely coordinated through the company's headquarters in Mindelheim.

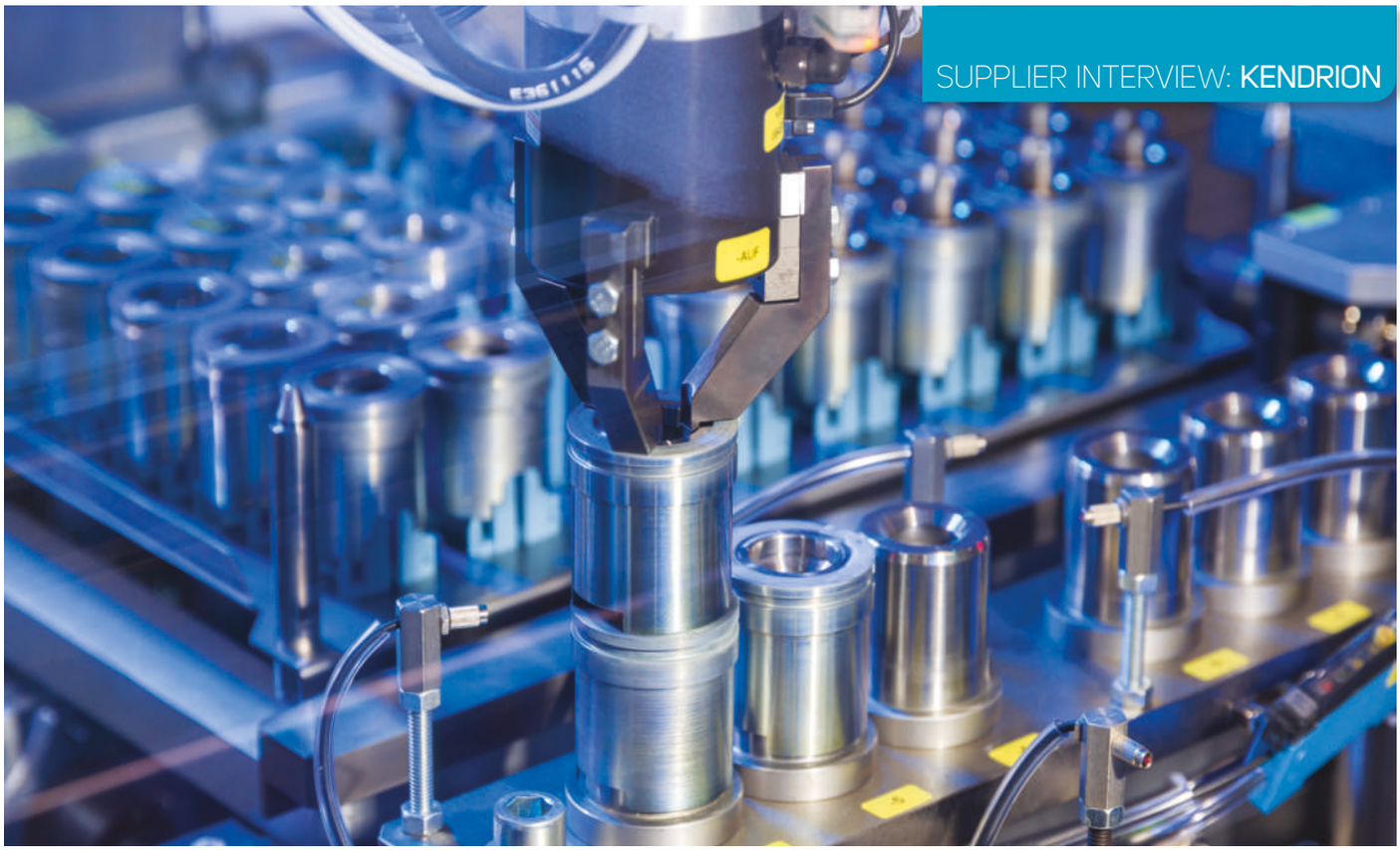
"Europe – especially Germany – and China are pioneers in the field of electromobility," comments Wankmiller. "Within the next few years, in China the number of electric vehicles will be fixed by law and consequently there is significant investment along with lots of opportunity there."

"The automation of machines and systems will forge ahead"

German Wankmiller, CEO, Grob

Global development of drive technologies and systems in motor vehicles is expected to keep pace in the coming years, explains Wankmiller, who also predicts that new advances will continue to emerge. "Software solutions and mechatronic systems will continue to influence and accelerate developments," he says, "and the automation of machines and systems will forge ahead."

Grob will continue to pursue and analyze technology trends and, while focusing on these, aim to increase its revenue and expand its worldwide sales and service activities.



Systems specialists

Advanced componentry plays an integral part in electric and hybrid vehicle operation, and ongoing development will also be vital to a future that includes autonomous driving

WORDS: **KARL VADASZFFY**

Electromagnetic solution specialist Kendrion develops, produces and distributes components and systems for automotive manufacturers and system suppliers. Contributing to reductions in fuel consumption and emissions, the company's solutions enable customers to achieve their economic and ecological goals.

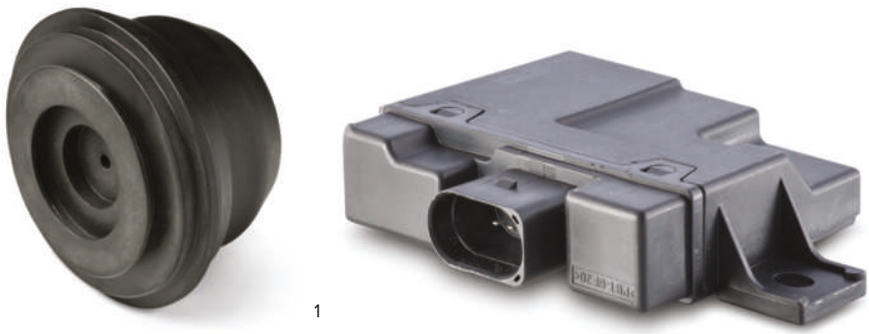
With headquarters in Germany, as well as engineering and production sites in China, the USA, Austria and Romania, the company has over 15 years of experience in diesel and gasoline injection systems. Its control valves enable flexible flow rates in the high-pressure pump and are able to withstand pressures of up to 3,000 bar. Now this experience is being put directly into use to benefit the electric and hybrid market.

Frank Zelano is Kendrion's head of advanced development, and believes that electric and hybrid vehicles are a natural next-step focus for the company. "We innovate to grow and live to innovate," he says. "Electric and hybrid innovations are enabling us to get involved in new projects as a development partner. Our customers are under a lot of time pressure to develop electric and hybrid cars, so we have taken our varied, relevant experience from the gasoline and diesel environments to support them in this."

Kendrion has developed a series of five valves that manage the hydrogen on fuel cells especially for the electric and hybrid market, with a first car in production using one of these valves. "We specialize in pressure controls for hydrogen," says Zelano. "When the hydrogen tank is open, it has to pass pressure reducers, on-off valves, and the final

"Our customers are under a lot of time pressure to develop electric and hybrid cars, so we have taken our varied, relevant experience from the gasoline and diesel environments to support them in this"

Frank Zelano, head of advanced development, Kendrion



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pressure control valve delivers exactly the right amount of hydrogen to the fuel cell to generate the required power."

Other recent developments, which the company has developed exclusively for electric and hybrid vehicles, are for water control. "When you put hydrogen and oxygen into fuel cells, water comes out," explains Zelano, "so we have developed a water drain valve that is responsible for the flow out. The water must not run out freely – it must be controlled because, as it can freeze, it can be dangerous to pedestrians on the street. Therefore, it can only be drained out in certain locations and in certain conditions, so our valve controls the open-and-close function and drains out the water."

The water exiting the system can be very corrosive as it is de-ionized, so ferritic steel is used because it is resistant against corrosion. In addition, the water can freeze in the system, so it must be possible to heat it up in seconds to make the car ready to drive. To enable this, there is electronic intelligence in the valve itself integrated for communication with the ECU and the car control unit. Furthermore, power control is included to handle up to 200W of energy. "We offer the complete system," explains Zelano, "with solenoid, water valve, electronics and the sensor."

Safe and secure

Aside from dealing with the high levels of corrosion, Kendrion is also addressing other challenges encountered when developing for the electric and hybrid market. A secure design is needed. "We must have solid tightness to prevent hydrogen getting out of the system," Zelano says. "And for pressure control that's especially challenging because the inlet that enables hydrogen to reach the fuel cell must be very linear with a very low hysteresis and tightness."

A secure design is also vital with diesel and gasoline valves, so the crossover offers Kendrion an advantage over competitors. Indeed, the company's experience includes laser vaulting to seal the system, and it does 100% of adjustment in the valve to get the specified characteristics, such as the precise pressure control. "We also do 100% of end-of-line testing to measure all specified characteristics like linearity and tightness," adds Zelano.

Looking ahead, there'll be more challenges to overcome. "From a technical standpoint, we need to ensure there will be very good thermal management for the battery, fuel cells, electric drive and electronics," Zelano explains. "Everything must be very well conditioned. As such, we are working on products for thermal management, especially valves for battery cooling and the regulation of water pumps on hybrid cars – part of which includes the requirement to handle water and fluids for climate control."

When it comes to a future of autonomous driving, Zelano reveals that Kendrion is developing a range of products, including those for feedback on the gas pedal. "When driving electrically," he says, "it's important that a strong and responsive solenoid is on the gas pedal to provide a signal that activates the combustion engine when it is needed. There also needs to be control that works with information about speed guidance, and it's vital that developments are made in the area of driver, or passenger, comfort – there's a definite trend about how to ensure comfort when the driver is not driving but rather engaged in a different task, such as reading a book or talking with others." Therefore, Kendrion offers high-performance valves for ride control, which are mounted on the suspension or are even integrated inside of the damper. These are fully proportional and can adjust the suspension to road conditions and driving mode.

Another trend relating to autonomous driving is acoustic design and the importance of ensuring pedestrian safety by controlling, or even manipulating, external sound emissions. "EVs are very calm at low speeds, especially in the city, which can be dangerous – our behavior is firmly linked to combustion vehicles," Zelano says. "External sound must be generated to signal an approaching car."

Kendrion offers customized sound system solutions, comprising an electronic control unit, a sound actuator and sound designer software, which generate brand-specific sound to the exterior and interior of the vehicle to create additional recognition value.

1. Sound actuators and ECUs play a key role in Kendrion's customized solutions

2. Secure design is essential when working with hydrogen systems

3. Water control valve for battery cooling in thermal management

4. Hydraulic valves can regulate systems reliably and accurately

2

3

4

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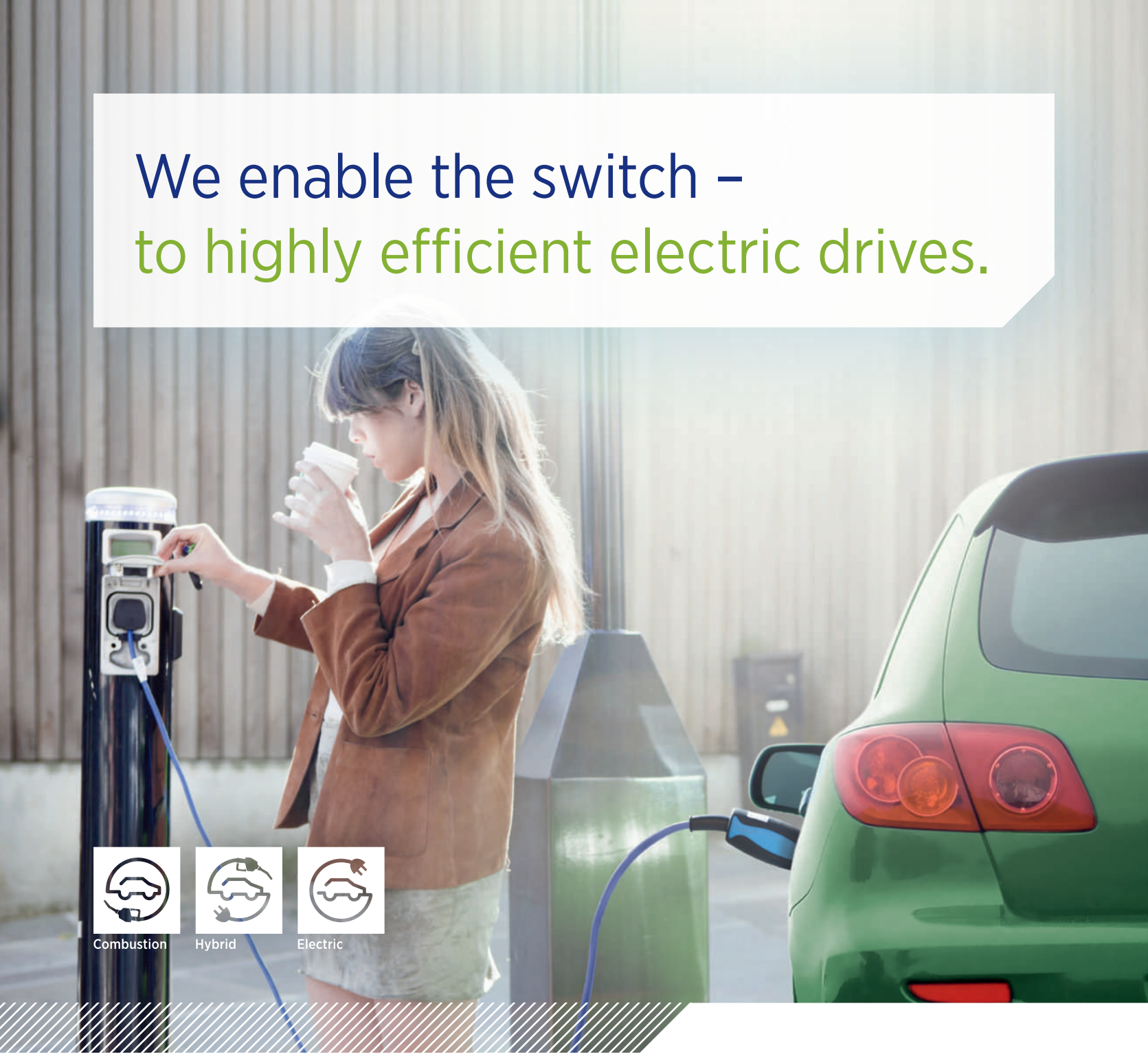

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Efficient driving dynamics

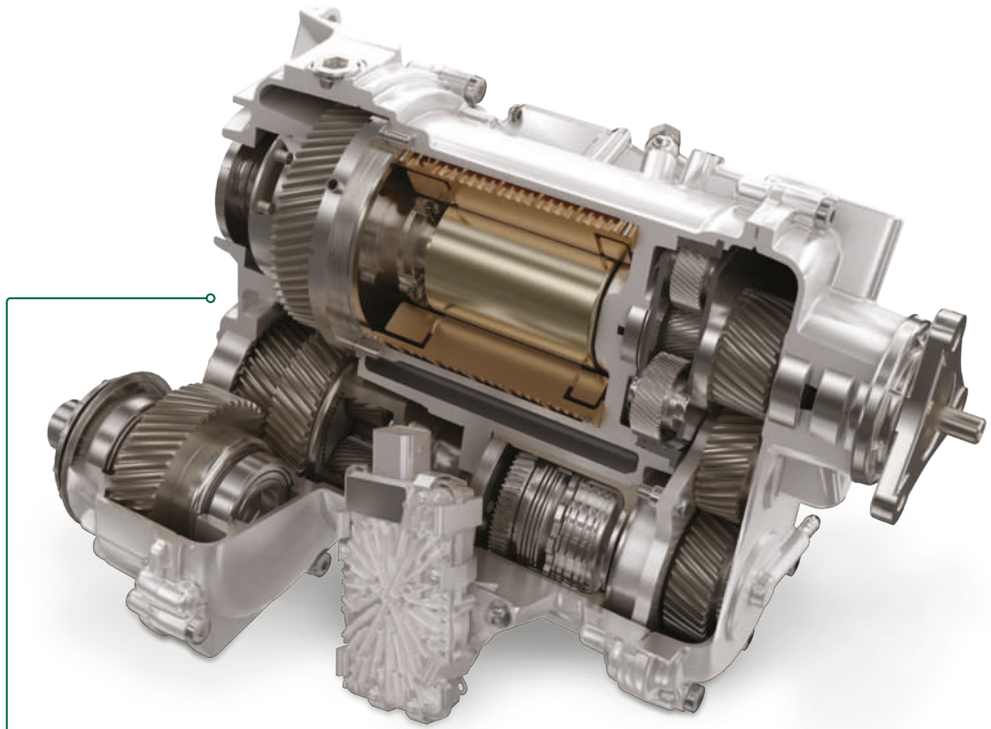
An electrified transfer case for four-wheel-drive vehicles achieves the fuel efficiency of two-wheel-drive models and improves driving dynamics for high-end vehicles

The requirements for all-wheel drives (AWD) are changing. Once, traction on snow and ice had been the focus of improvements; now safety and driving dynamics are overtaking those requirements, enabling sports cars and utility vehicles to benefit from greater lateral traction and improved cornering properties. Market researchers expect to see upticks in torque, acceleration, braking path and many other parameters by the mid-2020s.

But providing power to four wheels means more weight, more friction, lower fuel efficiency and, therefore, higher ICE emissions. Today, AWD vehicles still consume 9% more fuel in comparison with two-wheel-drive (2WD) models, despite advances in technology.

Car manufacturers are using disconnect systems, which interrupt the transmission of power to one axle when coasting in the city or driving on highways. The Flex4 by Magna Powertrain is one example of a solution for actively disconnecting from the secondary axle. Systems that enable distribution of the torque between the front and rear axles are the standard in vehicles in the top-end segment. However, they do not cover all possibilities in free torque distribution. In rear-wheel drive vehicles with four-wheel drive (4WD), for example, the rear axle is always engaged and the front axle only ever receives approximately 60% (or often less) of the entire available torque.

Magna Powertrain is developing a novel concept that improves the fuel efficiency of a 4WD vehicle,



The EtelligentDrive eTC 48V 4WD System is said to stand out from conventional systems in terms of driving dynamics and fuel efficiency

surpassing that of a 2WD. It is made possible by a transfer case with an integrated 48V electric motor mounted in a P3 mild hybrid topology. The system will suit vehicles in the top-end segment with torque up to 1,300Nm and top speeds of 300km/h (186mph). Developers are pushing to reduce CO_2 emissions, with savings of 10% in the WLTP cycle compared with 2WD vehicles. Magna Powertrain is developing the electrified transfer case and expects the prototype to reach maturity by 2019. It is currently undergoing testing on a testbed by Magna Powertrain in Lannach, near Graz, Austria. Initial results have been positive, and should be ready for series production by 2022.

In addition to the two partial transmissions, the electrified transfer case features a 25kW electric motor for 48V power supply. The rotor is designed as a hollow shaft and is compact enough that the entire transfer case fits into the available space of many top-end vehicles without major adaptation. The electric motor is powered by an inverter mounted on the casing, and supports the powertrain via power split. This planetary gear combines the total torque of the electric motor and the ICE. The torque is distributed to the axles mechanically, while the sun gear is connected to the electric motor, the planetary gear to the front axle, and the hollow shaft to the rear axle. It is possible

to vary the distribution of the torque between the front and rear axles from 0-100% with relatively low levels of electric power. The electrified transfer case is engaged by a mode-shift system, an arrangement of multidisk clutch, dog clutch, and actuation via ball ramp.

This system enables three driving modes: four-wheel drive with torque vectoring, two-wheel drive with recuperation and two-wheel drive with decoupling. This decoupled mode is particularly important for synchronization when the transfer case switches between 2WD and 4WD modes. This process takes less than 300ms. The driving modes are controlled with the integrated sensors – wheel speed, lateral acceleration, yaw rate, steering wheel angle, gas pedal position and so on. The control unit calculates the appropriate mode and the optimum torque distribution for the specific driving situation every 10ms.

The electrified transfer case offers a number of advantages, such as improved traction even when oversteering and true torque vectoring that covers the entire range from 0-100% on both axles. Distribution of the torque is free of wear and tear because the electric motor performs this function. Simulation tests demonstrate these advantages in various driving situations. For example, the time needed for stabilization in the electrified transfer case is much faster when cornering quickly than the transfer case of manufacturers, such as Actimax from Magna Powertrain. In simulated driving analysis, the electrified transfer case stabilized the vehicle after only 1.4 seconds by directing 100% of the torque to the front wheels and straightening the vehicle again when exiting the bend. This is nearly 50% faster than Actimax transfer case technology.

The electrified transfer case enables the vehicle to provide 48V electric drive performance in a P3 mild hybrid topology. It offers comfort functions such as fully electric driving when parking. Cruising speeds of up to 125km/h (78mph) are possible under electric drive. It also offers all advantages regarding the increased fuel efficiency of a hybrid drive. It is possible to manage up to 60% of the driving time without the ICE in the WLTP if the vehicle slows down and the energy is recuperated, or if it is powered by electricity only. The latter case is possible up to 47% of the time.

The EtelligentDrive eTC 48V 4WD System – the full name of the product – is the first 4WD concept that provides improved fuel economy compared with a 2WD architecture. It also reduces CO_2. Developers at Magna Powertrain are targeting fuel savings of around 10%, which is made possible by the recuperation of energy if the mode-shift system is in the coupled two-wheel mode and the support of the e-machine under certain driving modes.

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The layout of Magna Powertrain's 48V transfer case in the vehicle drivetrain

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Fast charging for e-buses

A recent installation at Amsterdam Airport Schiphol is the world's largest opportunity charging electric bus scheme, showcasing the latest in fast-charging expertise

As North American transit authorities adopt electric buses (with large-scale e-bus operations in Chicago and Los Angeles announced) Heliox has started US production of its SAE J 3105 /SAE J 1772- and Buy American-compliant chargers.

Heliox, founded in 2009 and with its headquarters in the Netherlands, is aiming to create a pioneering piece of 'green' history. Using its expertise and an innovative approach to power conversion, the company developed the world's first CCS charger for electric buses in 2013.

From there, Heliox continued to develop its unique fast-charging technology in partnership with leading European vehicle makers (such as Daimler, Volvo and VDL) and public transportation operators (Transdev, Deutsche Bahn Arriva). The company currently has installations in more than 20 countries, including the USA, Chile, Germany, Benelux, France, the UK, Sweden, Turkey, India, Singapore and New Zealand.

As a result of these large-scale operations, Heliox has been awarded numerous prizes for accelerated growth (from the likes of the *Financial Times*), while also growing to become the world's largest opportunity charger manufacturer. The most recent chapter in the Heliox story was written when private equity investment group Waterland gained a major shareholding in May 2018.

Heliox provided 109 fast chargers to power a fleet of 100 electric buses at Amsterdam Airport Schiphol

Heliox has illustrated what the company can offer to US bus manufacturers and public transportation authorities with the inauguration of the world's largest opportunity and depot charge network (13MW) in March 2018. At Amsterdam Airport Schiphol, Heliox supplied

The company's technology in operation in Eindhoven

109 fast chargers to power a fleet of 100 electric buses.

As the third-largest airport in Europe, Amsterdam Airport Schiphol made the commitment to become one of the most sustainable airports in the world. To achieve this goal, Heliox was selected by Transdev to charge 100 electric buses in 24/7 operation on six routes, providing public transport to some of the 68.5m passengers who visit the airport each year.

Heliox opportunity chargers offer charging en route, and recharge as passengers board and exit the bus. In total, 23 Heliox OC 450kW chargers have been placed in four strategic charging points as part of the operation, recharging batteries within two to four minutes. Overnight charging, using 84 Heliox Fast DC dual 30kW chargers, takes place in two depots, located in Amsterdam and Amstelveen. The 100 electric articulated VDL Citeas are expected to drive a combined 30,000km (18,640 miles) per day.

As Heliox's US director Bob Bouhuijs explains, "The e-bus market in the USA is growing, and with our open standards approach (OCPP and SAE J 3105 / SAE J 1772), we want to be the hardware provider to multiple US bus manufacturers and cities with an e-bus masterplan in hand. Our choice to open a US office and US production locations gives the market more choice [to be Buy American-compliant], creating competition and accelerating zero-emission bus operations, as we have seen in Europe. We will leverage our European experience to bring a proven product to the market with high reliability, flexible design and smart functionality for a competitive price."

Heliox will manufacture its electric vehicle charging stations in California and Minnesota.

Bouhuijs foresees a rapid roll-out of the company's V2G technology. V2G-technology works through bidirectional charging stations. These stations enable transit agencies to charge their fleet while also facilitating the balance of supply and demand within the electricity grid, effectively turning the agency's vehicle fleet into power service providers.

This results in better integration of renewable energy resources and more stability in the electricity grid. Together with its partners, Heliox shows that V2G is easy to implement and can make a huge difference to the electricity grid as well as investment reduction of e-bus implementation schemes.

Bouhuijs and his colleagues are also keen to assist customers, providing more information and advice, and helping to accelerate zero-emission operation plans. The company is also accepting requests to visit the Schiphol operation.

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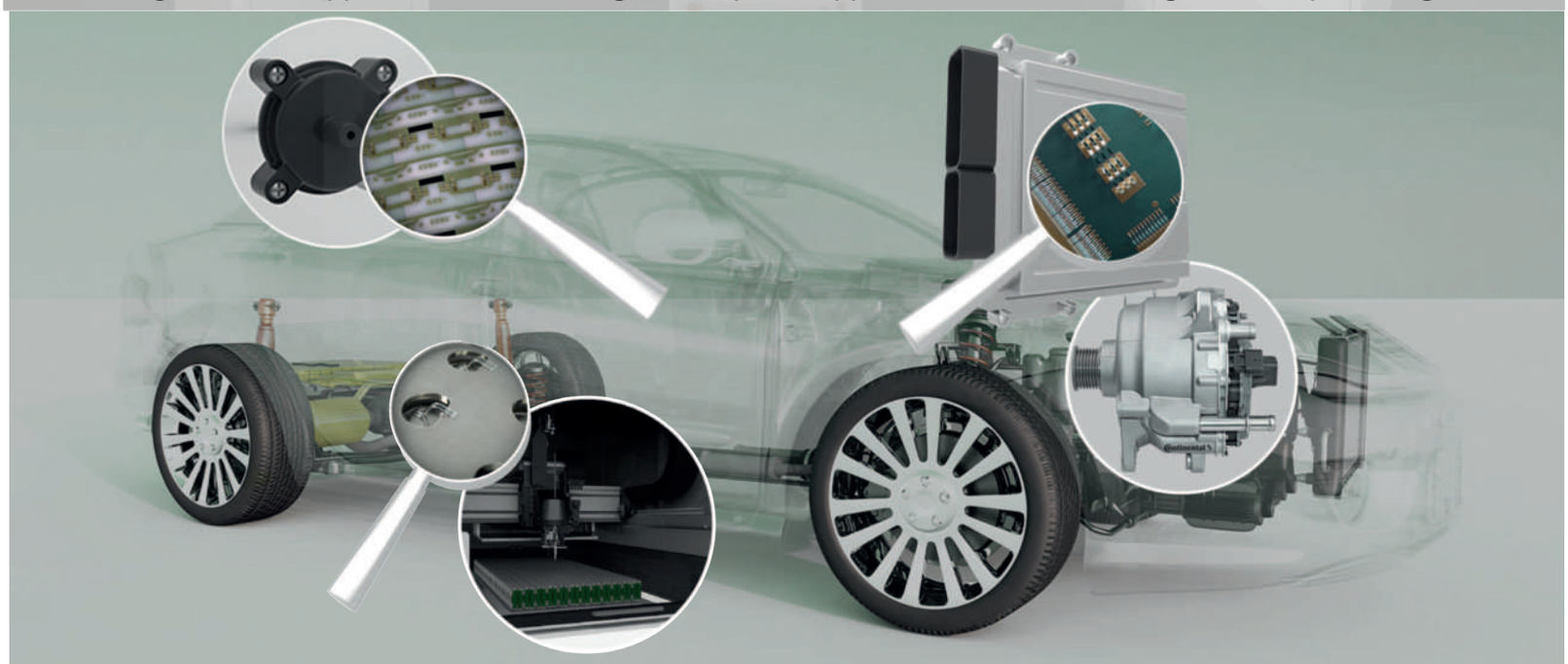

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Combining technologies

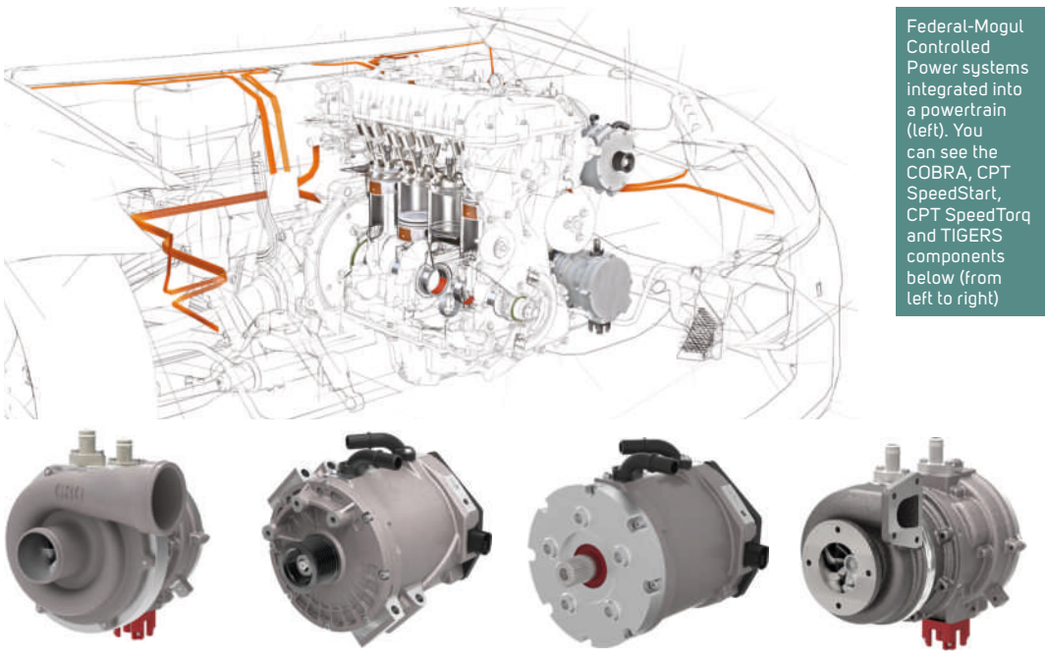
As the industry evolves to meet tighter emissions targets, combining improved combustion engines with driveline electrification presents an attractive solution

Powertrain technology has long been influenced by standardized drive cycles, but differing regional priorities mean there is no single optimum technical strategy. The relative importance of the major drivers – energy availability, fuel consumption, CO_2 and harmful emissions – varies regionally so the ideal powertrain solution also varies. However, one common theme does exist: the trend toward increasing electrification or hybridization of the powertrain in combination with further optimized ICEs.

One company at the forefront of this trend, Federal-Mogul Powertrain, recently acquired Controlled Power Technologies, in the process adding a suite of driveline electrification products to its portfolio.

Nick Pascoe, managing director of Federal-Mogul Controlled Power, believes there are important synergies that can be leveraged from combining the two areas of expertise. "The growing importance of real-world figures for emissions and fuel economy, stemming from increased public demand and new, more representative test cycles, is accelerating the electrification of conventional ICEs and drivetrains," he explains. "Even a modest level of hybridization leads to significant improvements in real-world vehicle emissions and fuel economy. At the same time, all levels of hybrid systems require the most efficient ICE to deliver their full performance advantage, so demand will continue for component technologies that reduce friction and weight and enable improved efficiency."

The random, transient conditions typical of urban driving result in a series of acceleration and braking events that are detrimental to ICE operation in two ways. Harmful emissions, such as particulates and NOx, peak during the transition from idle to wide open throttle and, once underway, the dynamic energy of the vehicle is wasted with the next application of the brakes. For heavily boosted gasoline and diesel engines, the transition from idle to high load often results in the greatest release of emissions.



Federal-Mogul Controlled Power systems integrated into a powertrain (left). You can see the COBRA, CPT SpeedStart, CPT SpeedTorq and TIGERS components below (from left to right)

Electrification of the driveline, by even a modest amount, greatly cuts those emissions by reducing the work done by the ICE. Energy can be recovered electrically during deceleration then released during subsequent acceleration, to reduce the demand on the ICE and the severity of the transition in demand.

Federal-Mogul Controlled Power's product portfolio enables integration of electric motor/generators for stop-start/recuperation/torque assist in several configurations, exhaust-driven electrification technologies, ICE e-boosting and fuel cell e-compressors. The products are based on SRM (switched reluctance motor) technology, which provides a robust, highly controllable, thermally managed, cost-effective solution with high efficiency, over a wide operating range.

CPT SpeedStart is a belt-driven integrated starter generator system for stop/start micro-hybrids and mild hybrids at 12V, 24V and 48V or above, enabling launch assist, power generation/regenerative braking and e-crawling. It also supports enhanced transient emissions control strategies.

CPT SpeedTorq is a gear- or shaft-driven integrated motor/generator unit for driveline electrification incorporating bidirectional motoring and generating, and advanced control capabilities for enhanced driveability performance and functionality.

TIGERS (turbo-generator integrated gas energy recovery system) integrates an exhaust-driven turbine with a liquid-cooled switched reluctance generator to harvest exhaust gas energy for storage as electrical energy, supporting increased vehicle electrical demands and other CO_2 and emissions reduction strategies.

COBRA (controlled boosting for rapid response application) is a liquid-cooled SRM directly driving a compressor for medium- to heavy-duty vehicle applications. It uses stored electrical energy to increase the supply of air to an ICE, enabling downsizing and downspeeding strategies and improvements in combustion to reduce transient emissions. It is also available as COBRA FC with lower flow, higher pressure ratio and higher duty cycle capability for fuel cell air supply.

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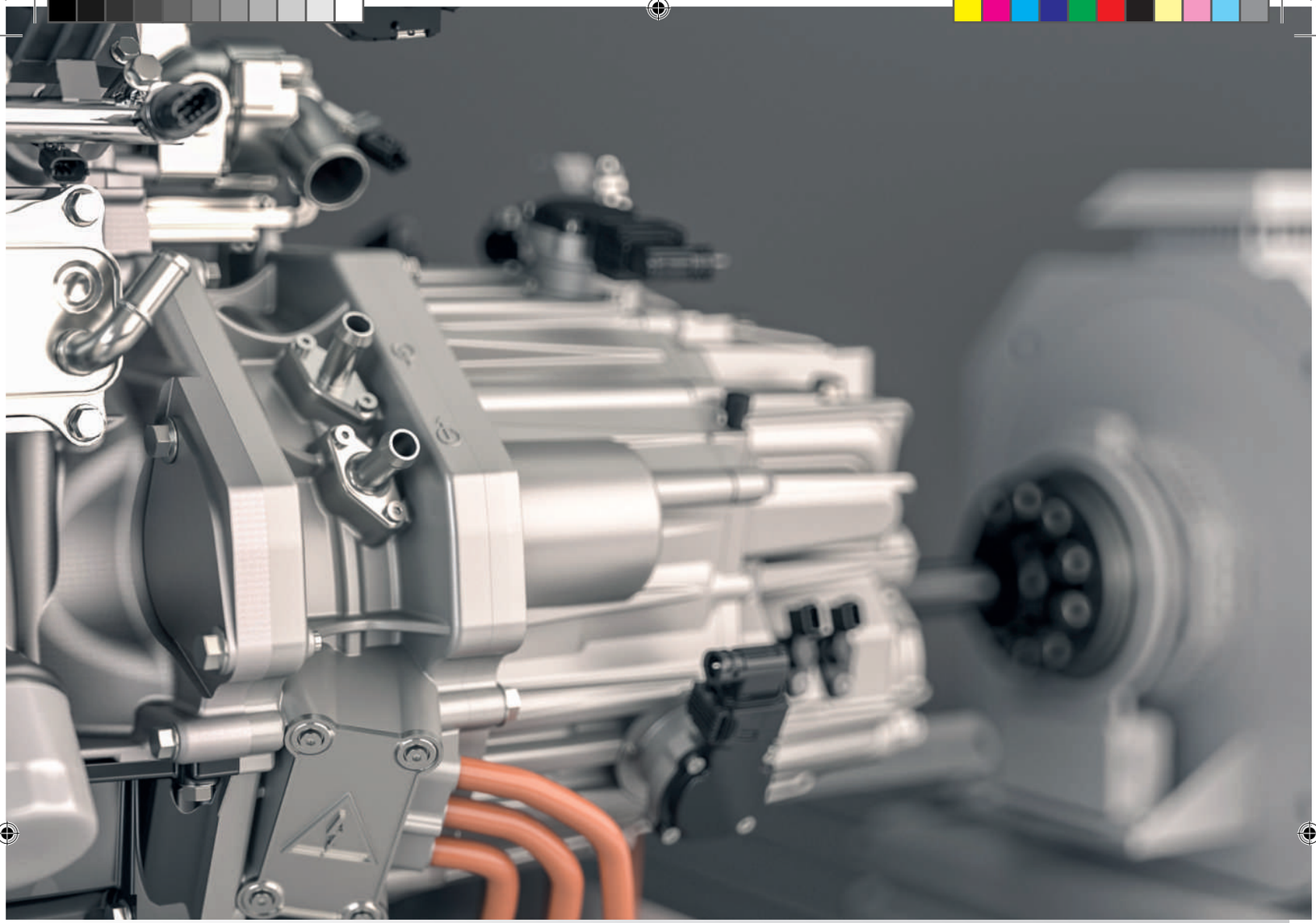

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Battery innovation

A willingness to develop new cell chemistries and formats, and collaboration with universities and innovators, lies at the heart of developing future battery technologies

The battery world has changed in recent years, with lithium-ion becoming the choice for battery pack designers. However, on reflection, the industry hasn't progressed as far as expected, with few alternatives to lithium-ion available until now.

Fine-tuning of chemistries has provided improvements in energy and power profiles, but today's batteries are still limited in terms of pack design options – most new EV packs are based on formats that were created over 30 years ago. While pouch cells are becoming increasingly common, current automotive battery design is still dominated by cylindrical 18650 or 21700 formats. This is driven by an industry-wide inflexible approach to cell design. When customers reach out to cell manufacturers for inspiration, they are often met with dated, standard cell formats.

Little innovation or desire to change is evident, as high-volume manufacturing systems need simple, standard production processes – hence the lack of flexibility. This format-driven design now has wider implications – the adoption of standard cells has caused a marked change in the negotiation stance of major cell manufacturers.

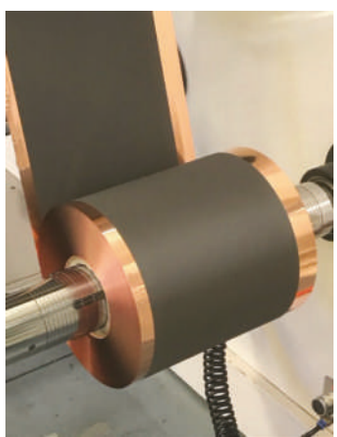
Cell manufacturers are now looking for volume commitments from the automotive industry to guarantee future product supply. Relationships that are driven by volume commitments will see standard cells being delivered in volume, but without any particular incentive for differentiation in product development.

AGM does not accept this position, and has been developing different chemistries and format sizes for a number of years. While still providing improvements in the company's lithium-ion offering, recent product developments have seen AGM make production-scale volumes of sodium-ion cells, the early results of which are encouraging, suggesting safety, size and design benefits. In addition to different chemistries, the inclusion of smart cell monitoring and cell management provides AGM's customers with choice and design flexibility.

Left: AGM is committed to the development of new battery chemistries and format sizes

Research into future battery formats aims to put AGM at the center of the UK's automotive supply chain

AGM has a manufacturing plant in Thurso, Scotland, and works closely with the UK's Russell Group of universities and technology inventors. This approach creates a number of benefits for AGM's collaborators, including early access to a manufacturing plant and a partner that has an appetite for new product implementation. As AGM continues to innovate with cell, chemistry and format options for its customers, this focus on customer-focused outcomes is beneficial.



AGM can offer its customers early access to manufacturing facilities

Having received government support for its approach to battery development, AGM has been instrumental in developing future battery packs which are to be used in the UK's automotive industry, and the company is aiming to be at the center of the UK's future automotive supply chain. AGM is working with well-known companies from across the European automotive industry. One of its partners is Cosworth, where principle engineer Paul Freeland has been working with the AGM team to refine future battery designs. This collaborative approach enables design and customer requirements to be at the forefront of thinking, without the previous limitations and design constraints of older cell formats.

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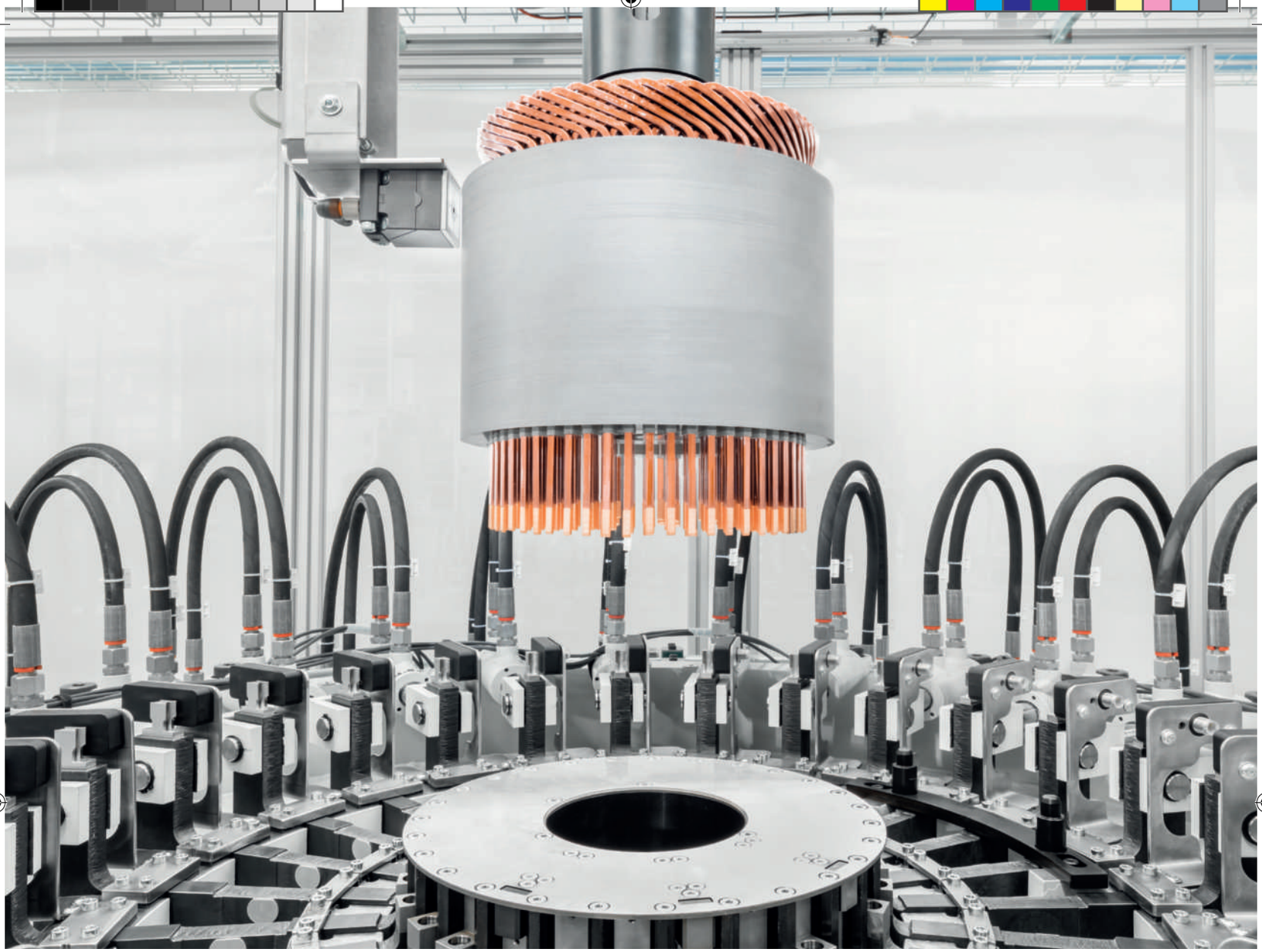

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Automotive SiC diodes

Automotive applications, such as onboard charger systems, can benefit from the increased efficiency that results from the use of the latest SiC technology

As the world's first supplier of SiC discrete power, Infineon has accumulated a considerable market presence and more than 15 years of experience, which began with the introduction of the first SiC 600V Schottky diodes. The company delivers highly reliable, industry-leading SiC devices. The latest entry to this portfolio is the Automotive Gen-5 650V Schottky diode, qualified according to AEC-Q101.

The new diode offers a number of benefits for automotive designers: no reverse recovery charge; no forward recovery; purely capacitive switching; 40-50% reduction in turn-on loss when switched in tandem with an IGBT; no voltage overshoots; switching losses independent from load current, switching speed and temperature; 20-30% higher output power in same form factor; reduced EMI; no need for snubber circuitry; reduced parts count; and high system reliability. The reduction of forward voltage ensures the lowest static losses over the entire load range during operation. In addition, a massively increased surge current capability provides high reliability during surge current events.

Figure 3 shows a schematic representation of the new SiC Schottky diode. Besides the front side metal and the Schottky contact, two other layers are represented – the drift layer, which provides the blocking capability during reverse voltage application, and the SiC substrate, which provides mechanical stability and the back side metal. The current flow direction during forward biased operation is from top to bottom. Infineon thin-wafer technology reduces the substrate's thickness, so the diode's overall resistance is reduced, thus lowering the forward voltage when the diode is conducting. Moreover, the new SiC generation presents a lower dependency of the forward voltage on temperature.

The epitaxial layer of the Schottky diode additionally contains p-doped regions labeled as p+. At low (normal) current densities, the current flows through the Schottky regions (unipolar current). For surge currents, for example the in-rush current to a capacitor during the turn-on of the system, the p+ regions become active and provide additional total current-carrying capability. As a result, the diodes behave as a Schottky diode in normal operation and as a pn diode in surge operation.

As a result of the reduced forward voltage and the absence of reverse recovery, SiC diodes yield a considerably lower figure of merit, or FoM (Qc x Vf, Figure 2), compared with Si diodes. Lower FOM implies lower power losses and therefore better electrical performance. This translates to higher benefits at the system level.

Taking a classical boost PFC (power factor correction) topology in an automotive onboard charge application as an example, Figure 1 shows the improvement in efficiency in comparison to Si diodes (Rapid-1 and Rapid-2) based on the following conditions: switching frequency = 65kHz and continuous conduction mode. The replacement of Si diodes in classical boost systems with SiC diodes results in increased efficiency of up to 2 percentage points compared with the Rapid-2 Si diode, clearly demonstrating the efficiency benefits of SiC diodes.

Compared with Si diodes, the automotive SiC diodes do not show reverse recovery and forward recovery losses, just a small amount of capacity charge losses. This leads to considerably lower switching losses and increased efficiency. Typical automotive applications that benefit from these advantages include PFC systems in onboard charger systems.

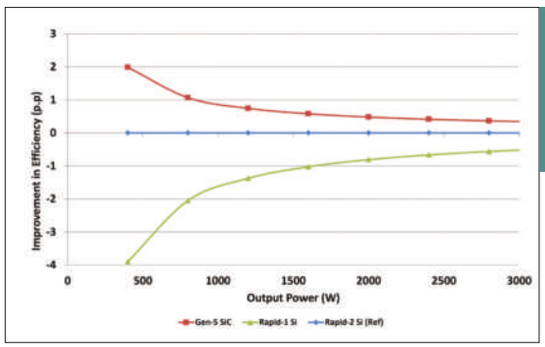

Figure 1: SiC diodes improve the efficiency compared with related Si diodes

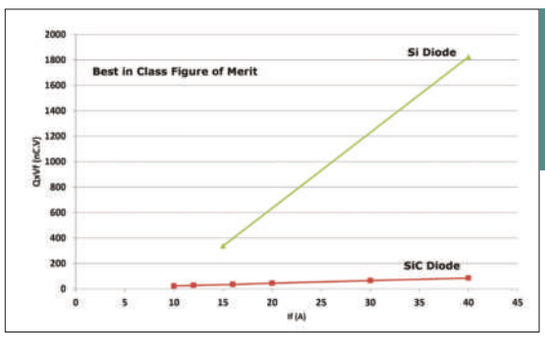

Figure 2: Comparison of the Figure of Merit (FoM = Qc x Vf) between Si and SiC diodes

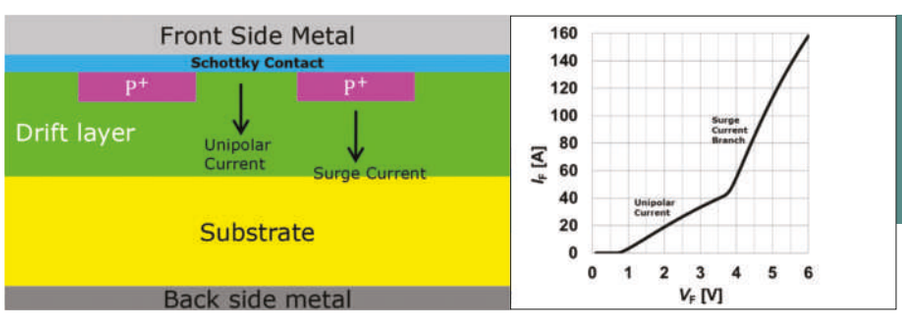

Figure 3: Principle structure of the CoolSiC Gen 5 diodes: Improved surge capability based on the p+ islands

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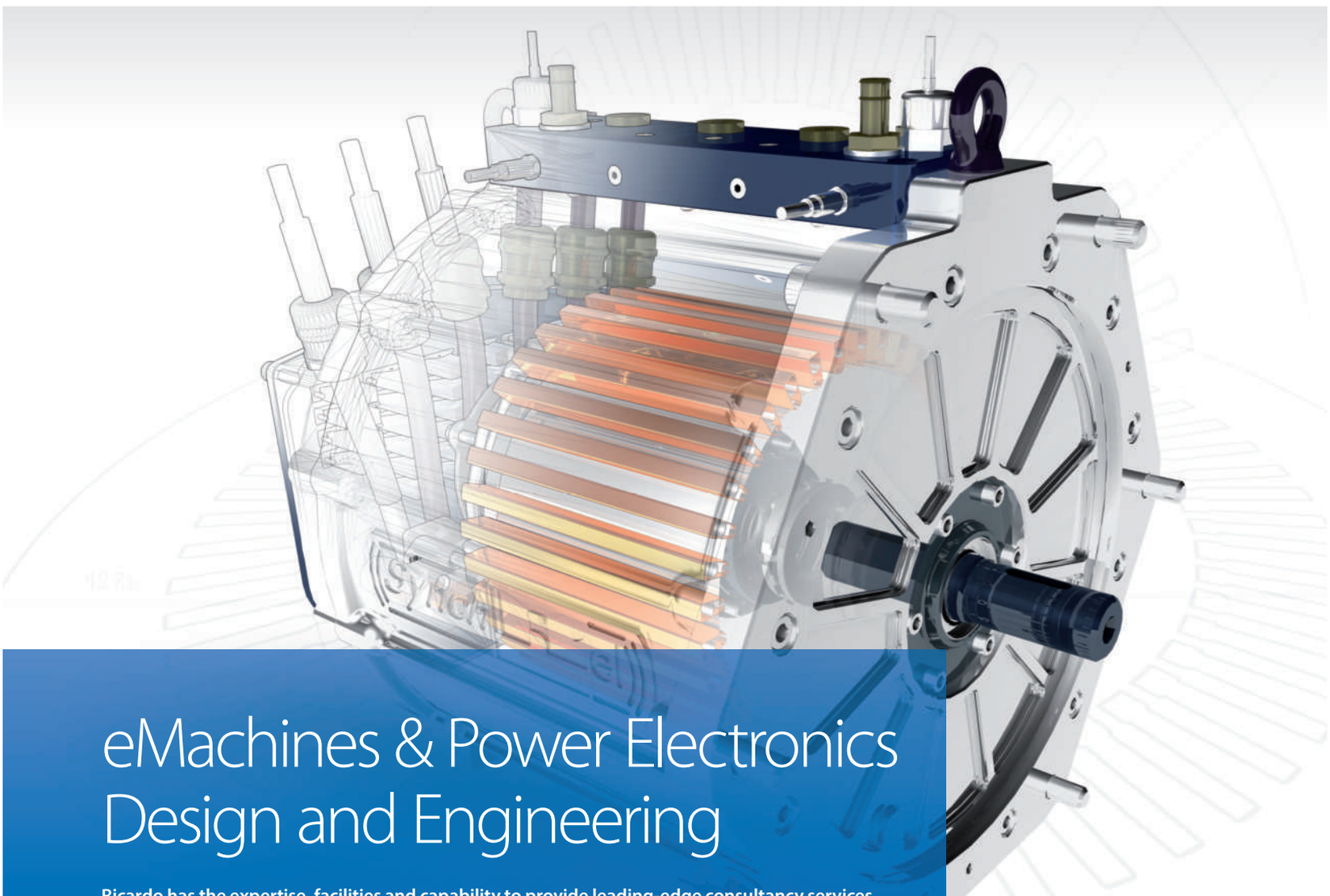

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EVSE infrastructure

Electric vehicles are here to stay, but the success of the electrification movement will be heavily reliant on development of innovative electric vehicle supply equipment solutions

The combination of more competitively priced electric car models and improvements in battery technology have provided peace of mind for those vehicle consumers looking to travel 200 miles on a single charge. Likewise, the commercial transportation segment is embracing the switch to greener vehicles. Public and private transportation entities are overhauling their commercial fleets from combustion to alternative fuel engines. In the USA alone it is estimated that the engines of some 34 million commercial vehicles will be converted to or replaced by alternative fuel engines before 2025.

Despite significant strides in the right direction, most auto makers seem to agree that the industry faces two major obstacles to the adoption of electric vehicles: the need for more government incentives and the installation of a network of electric vehicle supply equipment (EVSE).

Transportation entities are facing additional challenges in construction of EVSE network infrastructure. In highly populated cities, for instance, commercial fleet entities lack adequate space to install EVSE pedestal ports. Most pedestal chargers have a limited number of plugs that can be used simultaneously. Furthermore, being stationary makes them inflexible for future changes or reconfigurations.

Overhead distribution systems counter the inflexibility of pedestals

To address some of these constraints, users are considering alternative overhead systems to distribute power. Starline Track Busway has been a leader in flexible power distribution since electric vehicles were first introduced in the market. Starline offers an overhead busway system with a continuous open channel that allows instant access to power at any point along the busway. This solution provides commercial fleets with unmatched flexibility for power reconfiguration, allowing a fast and reliable point of use power source, multiple electric charging cords and maximum space savings.

Overhead busways ease the uncertainty of elevated EVSE installation costs. The industry recognizes that EVSE installation costs are highly variable, and there is no clear consensus as to which direction installation costs are heading. Starline Track Busway offers an innovative, yet simple, maintenance-free design that allows reconfiguration, repositioning and expansion. Busway systems also eliminate the costly and time-consuming installation of subterranean concrete pads, anchor bolts and conduit from the circuit panel to the charging station. Real-time power monitoring, from load balancing to data management, is an integral aspect of the electric vehicle charging infrastructure. Starline's Critical Power Monitor is uniquely configured to capture data granularity levels ranging from an entire feed down to each individual EVSE charger.

As EVSE networks continue to transform, costly and outdated technology will be increasingly phased out by more innovative solutions. Commercial and consumer demand calls for scalable, reconfigurable charging systems. This is required to maintain a competitive advantage in such a swiftly emerging market. More than ever, the global automotive sector appears to be led by forward-thinking companies and institutions. Equally innovative EVSE infrastructure will be needed for electric vehicles to reach their full potential.

Starline offers an overhead charging system with instant access to power at the point of use

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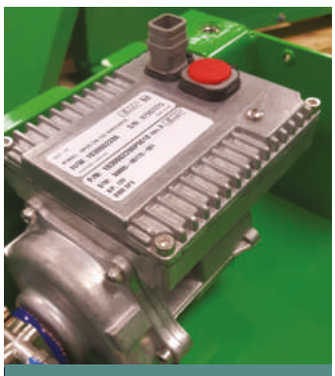
Electronics cooling

New components and systems are vital in cooling the traction and generator motors, battery packs and power electronics used in state-of-the-art electric powertrains

As vehicle electrification technologies continue to advance, a variety of heavy-duty solutions are gaining traction. Companies are developing electric powertrains for a wide range of commercial vehicles, resulting in a need for more substantial cooling technologies. To meet the increasing demand for cooling electric powertrains, Engineered Machined Products (EMP) has developed an array of components in its new SmartFlow product line. The line includes brushless DC electric oil pumps, water pumps and fans. EMP is currently working with technology leaders in the heavy-duty industry to provide components and systems as cooling technology for traction and generator motors, battery packs and power electronics, including drive inverters.

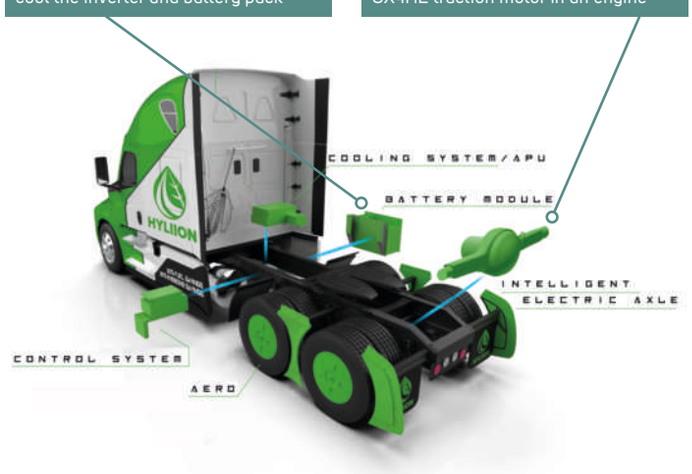
One example of a new cooling application is the award-winning Hyliion 6X4HE electric drive axle. This system offers a creative solution for long-haul over-the-road trucking, replacing the conventional rear passive axle. The 6X4HE has a traction-generating motor, battery pack, and inverter drive controls, all of which require cooling. This drive axle is easily integrated into a truck and boasts fuel savings of up to 30% compared with a typical system due to three technologies; there is a 15% reduction from the hybrid electric drive axle, 12% from the APU, and 3% from aerodynamics.

Faced with the challenge of cooling such an advanced system, Hyliion turned to EMP for a solution. To optimize cooling and lubrication in the traction motor, the 6X4HE uses EMP's new OP3530C electric oil pump, which was recently added to the SmartFlow electric component family. The OP3530C is used because it is specifically designed for motors requiring oil scavenging – for example, BorgWarner's HVH motor series. It has a two-stage design, and is made to be arranged in a dry sump system. The OP3530C also includes SmartFlow technology – a brushless DC motor and an integrated motor drive controller.



The WP29 brushless electric water pump installed on the 6X4HE to cool the inverter and battery pack

Engineered Machined Products' OP3530C system lubricates the 6X4HE traction motor in an engine



The Hyliion 6X4HE electric drive axle system utilizes EMP technology for its cooling and lubrication

Cooling both the battery pack and the motor drive inverter of the 6X4HE is EMP's WP29 water pump. The WP29, just like the OP3530C, features SmartFlow technology in the shape of a brushless DC motor and integrated motor drive controller. Along with the WP29, all of EMP's SmartFlow components are designed for extreme environments. With this technology, users gain full control using PWM/CAN/LIN communication options, full diagnostics with DM1 messaging, and auxiliary sensor feedback options. EMP is working closely with SAE to be OBD II compliant with all devices.

"Hyliion has relied on EMP to provide durable and dependable pumps for our product for two years, and we've been extremely pleased with the performance of the OP3530C Oil Pump and WP29 Water Pump," says Kyle Torrico, Hyliion powertrain engineer. "When working on our new system, EMP was quick to lend a hand and provide the support we needed to reach our goals."

The Hyliion system is just one application of EMP components and systems for electrification cooling. Another recent example is the Kenworth T680 HECT and ZECT day cabs, which use compressed natural gas and a hydrogen fuel cell respectively. EMP cooling technologies are being deployed in nearly every major system of these state-of-the-art green technology vehicles. The SmartFlow pumps and fans can also be found in a variety of other applications and industries, including agriculture, transit, mining, military and marine.

When asked about EMP's future in the electric and hybrid industry, Mark Bader, VP of engineering and manufacturing, explains the company is focused on solutions for this changing market. He says, "With our technology, we believe we are well positioned to provide the cooling solutions required as the industry shifts from traditional to fuel efficient, zero emission advanced powertrains."

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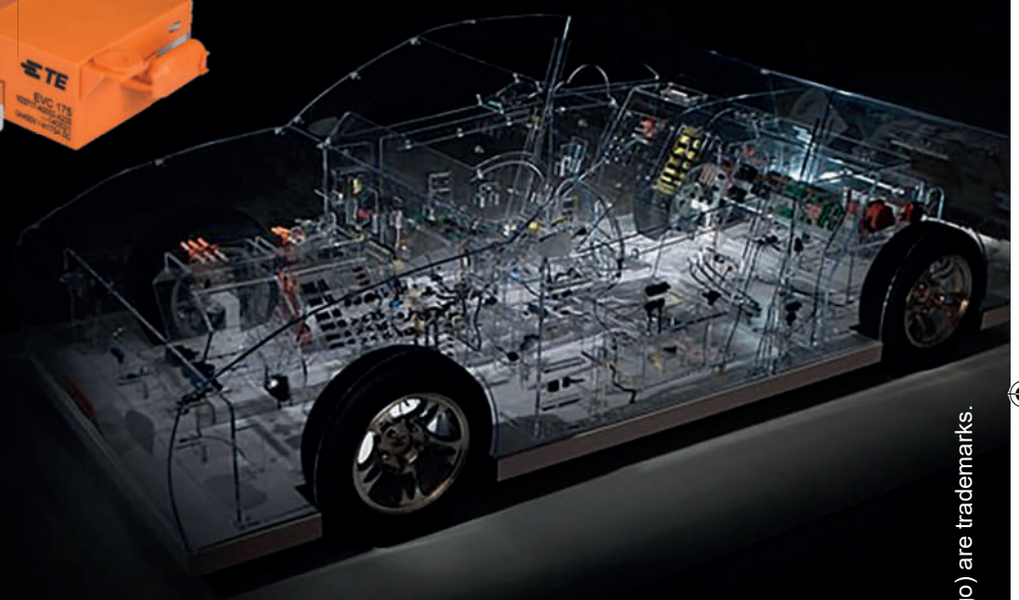

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Oil quality in electrification

The electrification of vehicle drivetrains is resulting in new challenges in oil filtration, demanding high levels of cleanliness and cooling, and reduced friction losses

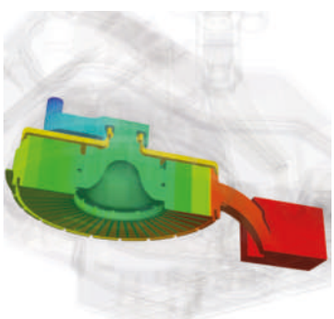
As the development of new propulsion solutions continues, Filtran is focusing on innovative applications in hybrid and electric vehicles, using proven technology from automatic transmissions and transferring this expertise to new applications. Filtran analyzed the requirements of new propulsion systems in relation to the filtration and oil supply, resulting in a range of new products that are already in series production.

Responding to the changes in the market, Filtran is enlarging its product portfolio. As one of the market leaders in filtration for automatic and automated transmissions, as well as in plastic oil pans, Filtran is continually developing new solutions.

Generally speaking, Filtran is focusing on two technologies. The hybridization of vehicles causes, in most cases, a change in the gear application. In addition to the changes in the gear spread, an electrical motor is often integrated in the gearbox housing. This leads to higher requirements for oil cleanliness. Here, the focus is on electrified double clutch and power split gearboxes because of the integrated clutches.

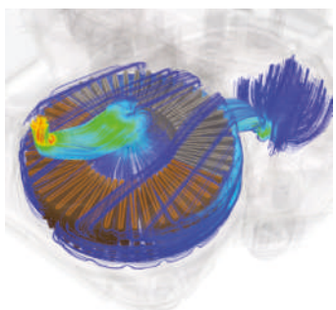
Beside the oil contamination caused by wear, the clutches pollute the oil, mainly with metallic and non-metallic particles. If the amount and size of the particles is not reduced, this can result in a shortened lifetime of the electrical motor when the oil is used for its cooling. Because of these changes in the basic gearbox architecture, Filtran has focused on the development of more efficient filter material. This means that proven solutions, such as oil pans with integrated filter systems, can be used to fulfill new requirements as well.

Module with filter, heat exchanger and oil pump for electrified drivetrains



The pressure drop between the filter inlet and outlet

The second technology that Filtran is focusing on is the drivetrain of fully electric vehicles. These tend to use a gearbox with fewer functions and a lower number of gears. The challenge here is different from those associated with hybrid vehicles. Electrified drivetrains don't have a classic oil sump because of the high rotor speed of the electrical motor, which leads to higher oil share and associated losses.



Stream lines around a pleated filter

To avoid this, Filtran offers modular solutions to supply the gears and the motor with clean oil. These modules can be designed to suit the requirements of a customer's application. The range of products includes external oil reconditioning systems as well as fully integrated modules with filtration, heat exchanger and oil pump. These subsystems can be designed and equipped with sensors and shiftable valves to route the oil flow as it is needed for different operational conditions.

Filtran technology not only makes it possible to ensure the functionality of the next generation of propulsion systems, it also helps to reduce the amount of oil needed, and reduce the losses caused by sharing oil.

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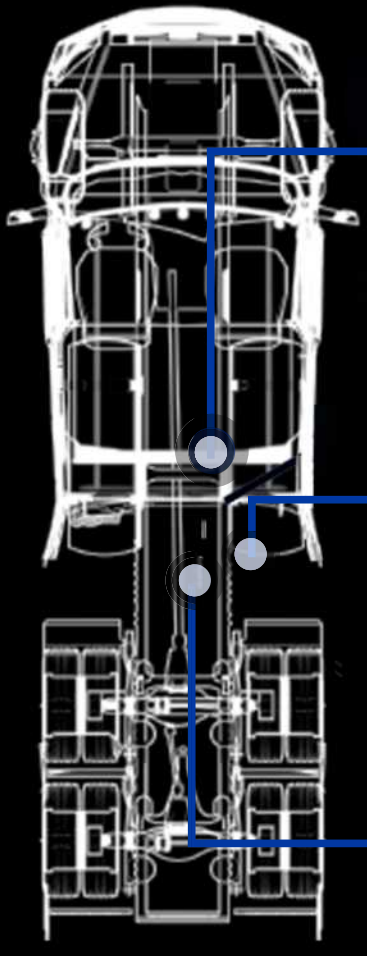

Image courtesy of
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Wide bandgap technology

Innovations in power electronics are boosting efficiency in charging stations for the emerging generations of electric vehicles, and in traction drives that are displacing IGBTs

The number of electric and hybrid vehicles is increasing around the world. The 500,000 electric vehicle units shipped in 2016 will translate into global annual shipments of 65 million by 2040. The energy consumed by these vehicles will rise from 6TWh to 1,800TWh accordingly, which represents 5% of current global power production, and this is driving designs to be more efficient in using that power. Increasing the efficiency by just one or two percentage points can save TWs of power around the world.

Silicon IGBTs and MOSFETs are manufactured cost-effectively, providing 200A to 900A and 400V to 1,200V operation. However, these devices have a bandgap of only 1.1eV, limiting the breakdown voltage that they can cope with. Innovations with regard to multiphase gate drivers that provide six or even nine phases for silicon IGBT components are helping to boost the efficiency of today's chargers, but at the same time other technologies using wider bandgap semiconductors are emerging. These offer bandgaps from 2eV to 7eV, and are capable of operating at higher voltages – thereby providing faster charging and longer range for electric vehicles.

One of these wide bandgap technologies is silicon carbide (SiC), where devices have a bandgap of about 3eV. This delivers a breakdown field that is five times higher than silicon and a thermal conductivity more than three times greater. This means SiC devices can tolerate much harsher operating conditions (including far higher voltages and elevated temperatures), as well as providing enhanced performance benchmarks when compared with similar-sized silicon components.

SiC devices in electric vehicle charging stations often need new driver chips. As a result, there has been a growth in modules that combine multiple power devices with the drivers

SiC devices are used in EV charging stations, allowing them to be a fraction of the size for the same power output. However, they often need new driver chips to maintain tighter control, which generally means that a system previously using silicon has to be completely redesigned to take advantage of SiC technology. This has led to the growth in the use of modules that combine multiple power devices with the drivers. This reduces the redesign needed to boost the performance of a system, as pin-compatible modules with new technologies can sometimes simply be dropped into place to provide a boost in efficiency.

There are now also SiC devices that can be implemented upon a traditional silicon design with the existing drivers and provide higher currents and more efficiency. An example of this is normally-on SiC JFET that is co-packaged with a custom low-voltage silicon MOSFET in an always-off device that emulates a standard MOSFET. The retained charge (Qrr) is about three times lower than that of a silicon MOSFET, consequently boosting the performance.

This is being used first in onboard chargers in the 3kW to 10kW range, but also for the traction drives that are displacing IGBTs. Designers can take out the MOSFET or IGBT and instantly get higher efficiency across the entire load range, or even remove the two 650V silicon MOSFETs in parallel and replace them with one 650V device, remaining compatible with competing SiC MOSFETs.

The real value of wide bandgap technology, though, is using them for new, higher voltage, higher efficiency topologies such as totem pole designs, and this is where gallium nitride (GaN) devices are gaining considerable interest.

GaN provides even higher levels of efficiency than SiC. The 3.4eV bandgap and higher electron mobility that characterize this technology are making it a very attractive prospect. GaN devices have been used for EV chargers with 97% efficiency levels and power densities of as much 2.6kW/l, compared with previous efficiency figures of around 94%. Design implementation tends to rely on a 60A, 650V switch in a two-stage architecture. Other GaN devices are being used for 6.6kW bidirectional onboard chargers to support plug-in electric vehicles. These provide efficiency of over 95%, which reduces volume and weight by between a half and a third compared with silicon. As the technology is a more recent arrival than SiC, some engineers still have their doubts about the long-term reliability associated with GaN, but these devices have been extensively tested over the course of several years and are now qualified for automotive use. This technology is thus driving new designs with higher levels of efficiency for the next generation of electric transportation.

EV drag race technology

Powerful electric drag racing vehicles, designed from scratch by a pair of Danish cousins, rely on the latest battery technologies, controllers and management systems

In 2007 two cousins, Hans-Henrik Thomsen and Glenn E Nielsen, began building an electric motorcycle in their backyard in Denmark, with few resources but big dreams. Today, their Danish drag racing team, True Cousins, holds seven world records under the National Electric Drag Racing Association (NEDRA) with two bikes (Silver Giant and Silver Bullitt driven by Thomsen) and two cars (TC-9 Hornet and TC-X driven by Nielsen) built by the pair from scratch. The team runs only battery-powered vehicles. NEDRA promotes electric vehicle drag racing to increase public awareness of EV performance and to encourage advances in technology.

Thomsen and Nielsen's world record run in higher voltage classes started in 2012, when the Silver Bullitt achieved a record time of 6.75 seconds in the 96V class. In 2013 the bike took a second record in the 144V class with 5.58 seconds. After alterations and rear reinforcements, the Silver Bullitt achieved a hat trick with the quickest time ever for the eighth-mile (200m) track, at 4.82 seconds.

Equally impressive, the team's first electric car (the TC-9, based on the old English kit car the Eagle SS) set two world records in the 240V and 300V classes (7.07 seconds in the eighth-mile). Since the chassis construction was limited, the cousins constructed the TC-X, a full-blown doorslammer drag racer, cast with much lighter glass-fiber bodywork. In 2017 the TC-X successfully posted a world record time of 4.89 seconds on the eighth-mile track at Malmö Raceway in Sweden.

Key to the team's success was the effort put into perfecting the battery. "In drag racing you need enormous power for acceleration for just a few seconds," says Thomsen. The team now uses 5,000mAh lithium cobalt pouch cells in 48V modules, a battery management system (BMS), controllers and a charging system – all produced in-house. The BMS helps to protect the battery cells, carefully surveying the voltage and the temperature.

Above: The Silver Bullitt, meanwhile, can cover an eighth-mile in 4.82 seconds, and achieves 0-100km/h in 1.1 seconds. Image: Photos by Nico

Each cell is measured and inspected visually for imperfections, and is delivered specifically without wires, which create resistance and can burn. The team uses cells with a C-rating of 60-70 and keeps the battery within a range of 3.0-4.15V. If the cells run outside that range, they could destroy the battery or cause a fire.

Thomsen and Nielsen have gained considerable expertise, working closely with their battery cell supplier and building the battery packs with their precision soft-welding tools. They use a permanently installed BMS that constantly checks voltage. To date, the team has not had a fire, and has even started building packs for other racers.

Thomsen, Nielsen and their sponsors are proud of their accomplishments. A 0-60mph (97km/h) in 1.1 seconds is "far quicker than the Tesla Roadster at 1.9 seconds", says Thomsen. The team's aim for 2018 is to break the Guinness record for electric motorcycles over the eighth-mile, and to compete on a quarter-mile track – most likely the Hockenheim NitrOlympX or Mantorp Park.

Above and left: The TC-X can do an eighth-mile in 4.89 seconds, 0-100km/h in 1.1 seconds. Top image: Photophobia; left: Smile B

The True Cousins team credits its sponsors for providing access to the very best battery technology. The main sponsor is Munters Corporation, where Thomsen works as an area sales manager in Denmark. Munters and the True Cousins team share a passion for innovative solutions. Inventor Carl Munters founded the company 60 years ago with a focus on dehumidification and evaporative cooling. Today Munters supplies highly energy-efficient dehumidification, which is installed in lithium battery research and production dry rooms around the world. These systems maintain ultra-dry conditions for new battery chemistries under development for EVs, including the record-breaking vehicles used by True Cousins.

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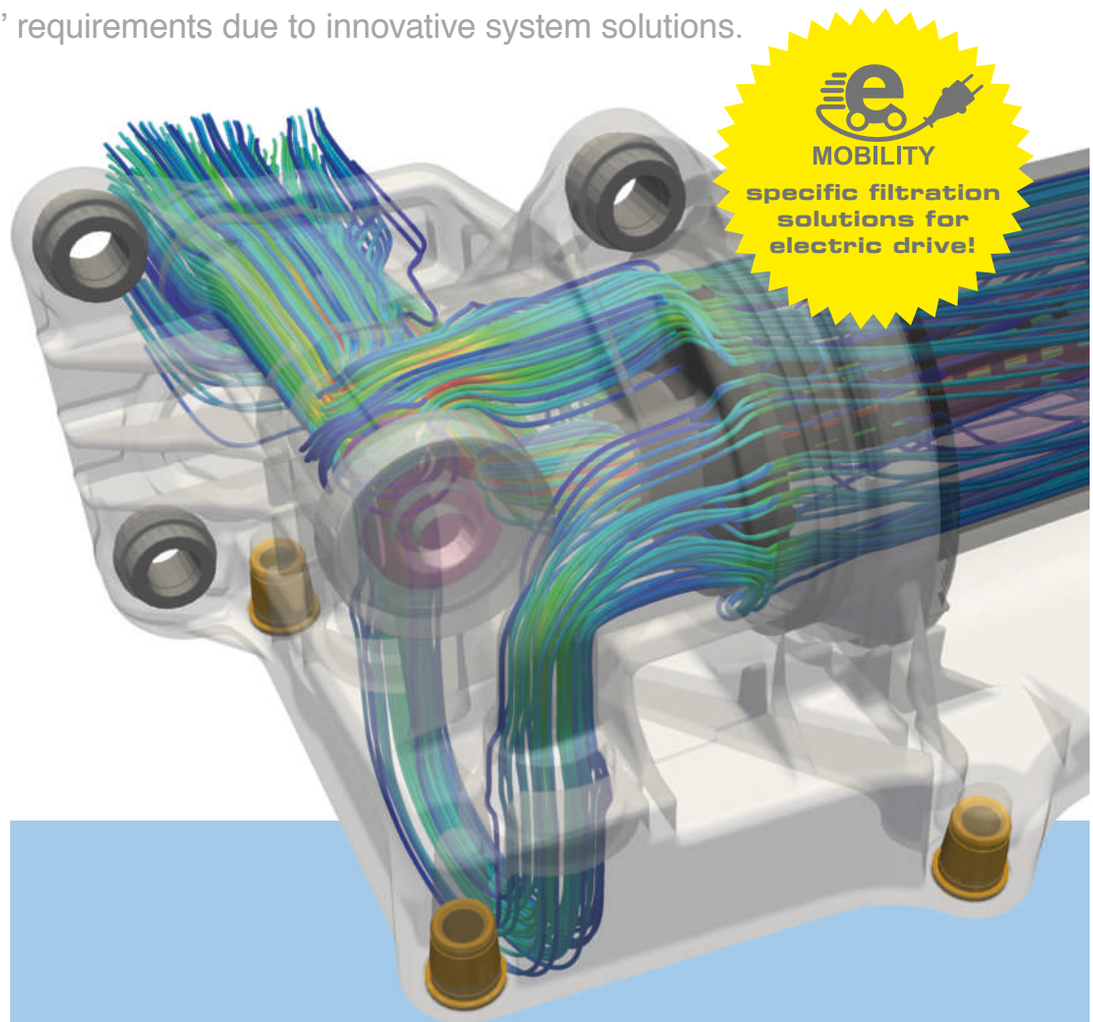

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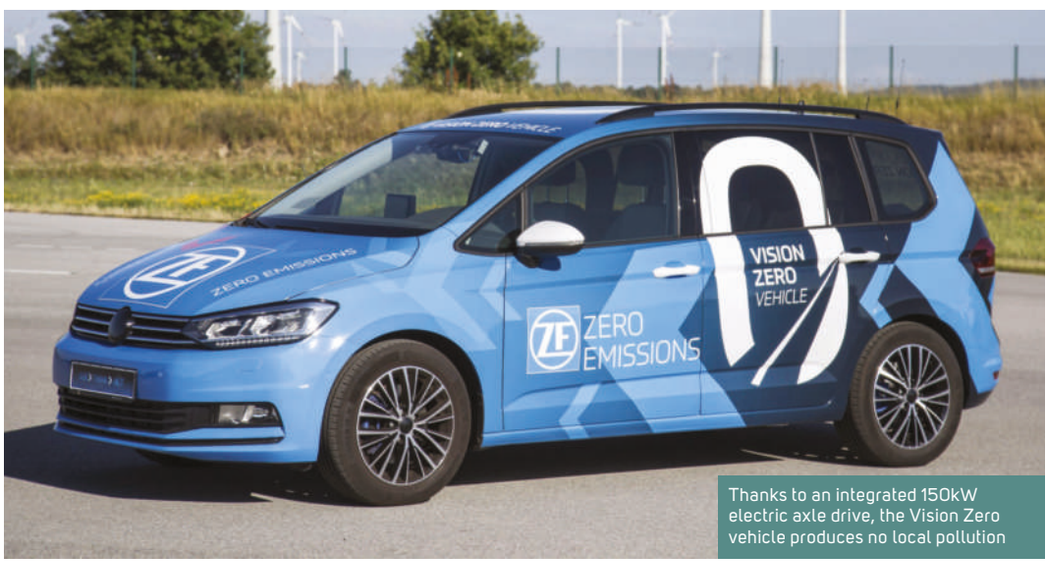
Responding to megatrends

As electrification in the automotive industry gathers pace, a new modular rear-axle system offers a flexible, efficient way to transform existing production vehicles

In line with its vision of safe and emission-free driving, ZF has developed an innovative, space-saving, modular rear-axle system, making the electrification of existing volume production vehicles much easier. The company has named this axle technology mSTARS (modular Semi-Trailing Arm Rear Suspension). It has been combined with a 150kW electric axle drive system, providing dynamic acceleration, creating a prototype that has been installed in a current volume production car. The entire propulsion system, including the integrated power electronics, is combined within the one unit.

The vehicle in which the prototype is installed, known as ZF's Vision Zero vehicle, is a volume production platform for compact and mid-size cars. The mSTARS semi-trailing link independent suspension frees up space between the rear wheels. This is due to its unique integral link design and separate spring damper configuration, which requires less installation space than the conventional rear axle originally installed. Additionally, this means ZF's compact and powerful 150kW electric drive fits readily into the mSTARS system axle carrier. The drive unit itself houses not only the electric motor, but also includes a two-stage, 1-speed spur gear drive, a differential, and power electronics, along with the control software. "We've put our concept of an intelligent mechanical system and clean mobility into this multifunctional axle system, which is aimed at compact passenger car platforms and up," says Holger Klein, head of ZF's car chassis technology division.

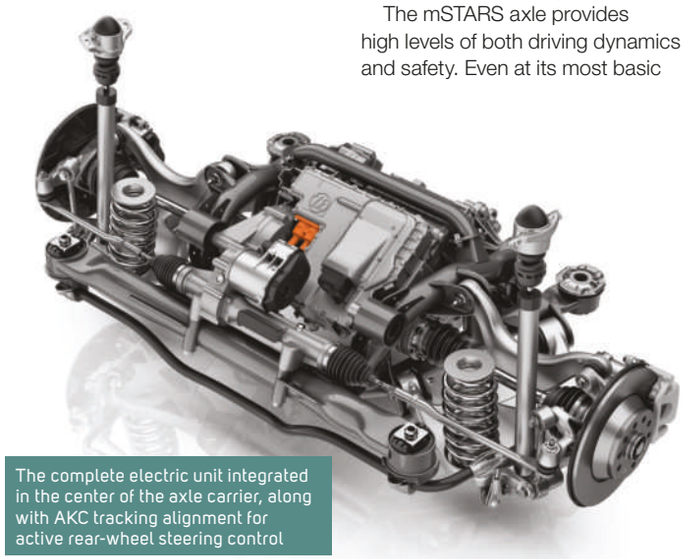
The technology is a suitable solution for hybrid, fuel cell and battery-powered vehicles, as well as in combination with conventional all-wheel modules. This offers vehicle manufacturers the opportunity to respond to a diverse range of market requirements – using just one car platform variant. It can be combined with ZF's AKC active rear-axle steering, too. ZF's Vision Zero vehicle demonstrates how quickly it could help the industry meet the challenge of producing high-performance e-cars or hybrids while "mSTARS gives our customers a basis for a wide range of applications in multiple vehicle segments," says Klein.



Thanks to an integrated 150kW electric axle drive, the Vision Zero vehicle produces no local pollution

The mSTARS axle provides high levels of both driving dynamics and safety. Even at its most basic specification, it delivers the performance of conventional multilink axles typically used for compact premium and sports vehicles – which come with a much higher price tag. Combining the mSTARS with ZF's AKC active rear-axle steering system, which also controls the rear-wheel steering, can further improve agility, comfort and stability, while allowing advanced assistance systems to operate more reliably and effectively.

This innovative technology has been developed as one of ZF's responses to the key industry megatrends. This new rear-axle system not only contributes to emission-free driving, but also to improved safety – helping to bring the company a step closer to its Vision Zero target, supporting an accident- and local-emission-free future.



The complete electric unit integrated in the center of the axle carrier, along with AKC tracking alignment for active rear-wheel steering control

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Cooling and heating tests

Comprehensive testing of cooling and heating system components used in electric vehicles must be conducted under different pressure levels and temperatures

Climate control systems must be able to withstand extreme load changes. Instead of testing the load-bearing capacity in proprietary test setups or in real operation, manufacturers can now analyze components using the special pressure cycling and functional test benches from Poppe + Potthoff Maschinenbau.

In a typical test, the component is inserted into the chamber of the pressure cycling bench. This could be a complete auxiliary heater or components such as valves, hoses and other hollow bodies, which must be able to withstand more than 100,000 load changes over the lifetime of a vehicle (up to 15 years). The test medium is a water-glycol mixture or pure glycol (for example, Glysantin G40, G44, G48). A cooling circuit is typically tested in temperatures from -40°C to +20°C (-40°F to +68°F) while a heating circuit is tested in temperatures from 20°C to 140°C (68°F to 284°F).

A specially developed closed test circuit uses pressure to prevent the formation of alcoholic vapors (which create a risk of explosion). A system can also be analyzed in a climate chamber. The flow rate of the test medium can vary from 1-50 l/min at a pressure of 0.2-12 bar or higher. The load changes are freely programmable with sinusoidal or trapezoidal rise at a test frequency of 0.2-2Hz or faster.

Products made of new materials can be validated using the P+P test systems

The test stand can be used for complete systems, assemblies and components made of various plastics, metals and sealants.

Weak points in the material combination – for example around a weld seam – can be sounded out and optimized early in the development process as well as during production.

In addition, Poppe + Potthoff Maschinenbau offers a functional test bench for electrical appliances such as cooling and heating units, control valves and pumps. Power consumption and performance are typically tested at alternating temperatures – optionally with a low- or high-voltage power supply to simulate operation via onboard battery and generator or the traction accumulator.

In many EVs, the heating and cooling systems drain the battery and negatively affect the vehicle's range. Comparison of test results before and after a load test on the pressure cycling test bench can show how power consumption and performance change over the vehicle's service life. The test object is connected to the power supply (low voltage 0-20V DC/5A) or high voltage (0-600V DC/150A) and the test media circuit. The test medium is circulated at a temperature of between -35°C to +100°C (-31°F to +212°F) and a flow rate of 1-50 l/min. The test can also be carried out in a climatic chamber at -40°C to +140°C (-40°F to +284°F), simulating changing ambient temperatures.

A long-term test usually takes 20-30 days, depending on the frequency of the load changes. The temperature and volume flow of the test medium, as well as the ambient temperature (if the test takes place in the climatic chamber), vary according to the test specification.

The temperature at the inlet and outlet of the test object is measured continuously, as well as the flow rate, pressure and pressure drop, and current and voltage (both in the high and low range). The focus is on the thermal and electrical performance of the heating and cooling unit under varying environmental conditions. Thermal sensors can be mounted on the product to indicate during the test when energy is lost (thermal bridges) or when the component becomes very hot (and thus presents a fire hazard).

Poppe + Potthoff Maschinenbau test systems are easy to operate and extremely safe. The test chamber consists of welded stainless steel and a high-strength polycarbonate safety window. Any test sequences created on the PC can simply be called up manually via coded recipe management or by a handheld scanner.

The integrated LabView software from National Instruments enables efficient data acquisition and visualization. Test procedures and data are automatically stored on the system and can be exported to the network for evaluation. The open software structure makes it possible to integrate additional sensors and data during testing. Poppe + Potthoff Group can also provide numerous testing services, remote maintenance and on-site technicians, if necessary.

An engineer executes a component test on a pressure cycling machine

Components must endure maximum loads in extreme temperatures

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INSPIRING INNOVATIONS

Extending battery life

A continuously calculated and broadcast safe operating envelope limit signal simplifies power control development and can extend lithium-ion battery life

All lithium-ion batteries require careful monitoring and management to optimize their life and performance. Most battery management systems provide state-of-charge and state-of-health information to help an application controller determine the condition of the battery and determine approved operational modes. Using this information properly requires a complex understanding of the fundamental electrochemistry at work in the pack, which means costly processing overheads and controls development time. To greatly simplify application development, San Francisco-based Stafl Systems has developed a sophisticated proprietary Safe Operating Envelope (SOE) technology that provides continuously broadcast power and current limits that can be directly used by the powertrain controller to protect and preserve a battery system.

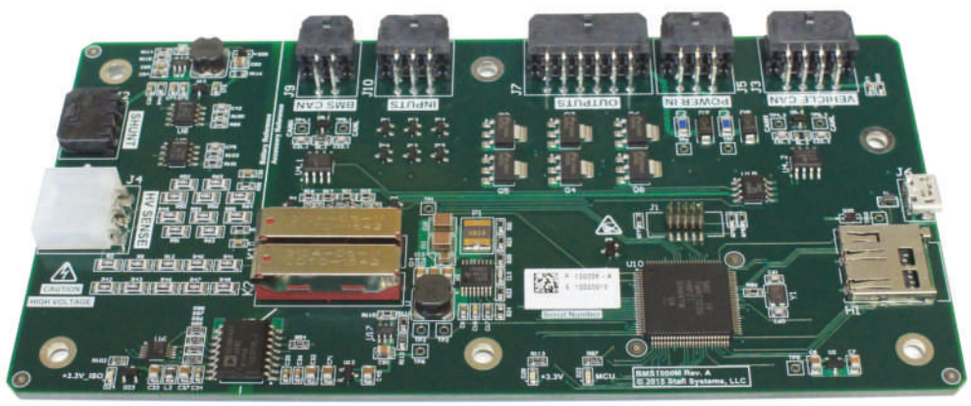
To generate the SOE output signal for a battery pack, the BMS constantly monitors voltage, current and temperature throughout the pack and updates an internal model of the full battery system. Using configuration data generated during individual cell testing and a self-learning algorithm that collects data in the field, this continuously updated model is used to generate a maximum charge and discharge rate that the battery can support while staying within a target operational life.

Another benefit of the SOE technology is fault and failure avoidance. Of the many fault conditions that can occur in a battery pack, most appear gradually (for example, over temperature, over discharge, over charge). Instead of programming an arbitrary cutback or shutoff code into an application controller, following the continuously broadcast maximum charge and discharge rates will avoid conditions that would lead to a battery fault while providing the greatest performance available in a given condition. This avoids troublesome shutdowns, limp-home situations and premature damage to a battery pack.

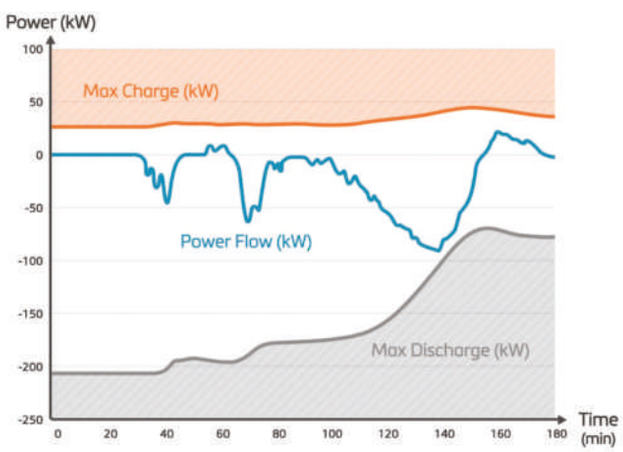
Many OEMs spend a large amount of time and resources integrating a battery pack into a new vehicle or application. This is primarily due to the need to integrate and configure battery pack protection and fault-handling logic. The SOE technology greatly simplifies this integration effort, meaning that valuable development resources can be allocated to higher value development.

For battery pack manufacturers or integrators providing complete battery packs to OEMs, integrating a BMS with an SOE output signal, exception log and warranty tracker can provide risk reduction and peace of mind that the battery pack will be properly used and protected during its life. This can provide the benefit of being able to offer longer warranties while reducing overall warranty exposure risk.

Through its BMS1000 series of battery management systems, Stafl Systems offers a high-performance, scalable BMS solution that includes advanced SOE technology to ensure safe and reliable operation of a lithium-ion battery pack.



The Stafl Systems BMS1000 series runs complex algorithms to provide accurate state-of-charge, state-of-health and SOE values for a battery pack



A simplified example of an application following an SOE limit signal

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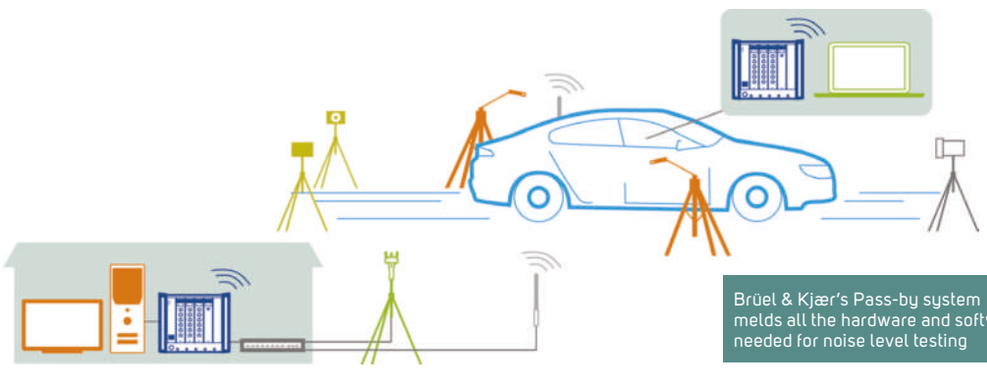
Minimum noise testing

Pass-by software features tailored workflows, enabling simplified testing of new minimum noise level standards for electric and hybrid vehicles

Pass-by noise measurement is a requirement for all automotive manufacturers as part of product certification, with measurement procedures defined in local and regional standards to ensure that noise levels are not exceeded. However, due to the introduction of extremely quiet electric and hybrid vehicles, 'too loud' covers only half the problem. With the growing number of EVs and hybrids, it has become necessary to define minimum noise requirements to ensure the safety of pedestrians in traffic, so in addition to the current noise level requirements for all vehicles, new standards, specifically for EVs and hybrids, have been introduced: Federal Motor Vehicle Safety Standard (FMVSS) 141 and United Nations (UN) Regulation No. 138 (UN 138). Additional regional and national standards are in various stages of approval.

Along with minimum noise levels, FMVSS 141 includes stipulations for a shift in the amplitude (dependent on changes in velocity) of specified frequencies. Similarly, UN 138 defines minimum noise levels, but requires a shift in the frequency (dependent on changes in velocity) of specified frequencies. And because quiet vehicles (such as EVs, and hybrids when they are not using their ICE) cannot meet those requirements, they must be equipped with an Acoustic Vehicle Alerting System (AVAS). In the European market, all new types of quiet vehicles must be equipped with an AVAS and must comply with UN 138 by July 1, 2019. All new vehicles must comply by July 1, 2021.

Brüel & Kjær's pass-by solutions provide tools for performing outdoor and indoor pass-by measurements according to the new UN and FMVSS standards, as well as the customary range of international standards. PULSE vehicle pass-by solutions are complete data acquisition and analysis platforms, including relevant software (indoor or outdoor), LAN-XI data acquisition hardware, pass-by related accessories (such as photocells) for giving absolute position reference, a speed sensor (radar, GPS or other device) for providing continuous speed and position information, and a weather station for providing environmental parameters. The system is scalable, ranging from conformance test configurations to multi-vehicle configurations with onboard vehicle measurement channels. Single-person operation is also supported.



Brüel & Kjær's Pass-by system melds all the hardware and software needed for noise level testing

Outdoor pass-by measurement of minimum noise level at Millbrook

To ensure that measurement according to the standards is as simple as possible, a dedicated user interface has been developed for FMVSS 141 and UN 138. It provides a workflow that takes the user from setup through all the different conditions to the results table. After setting up the hardware according to the on-screen instructions, the relevant standard is selected from the dropdown list, and the user interface will guide the operator through the workflow to ensure that the data will be correct and valid. The results are calculated and presented in the results table, from which reports can be easily exported to a spreadsheet.

Due to the increased demands the new standards place on the operators, the user-centric workflow reduces the process complexity (simply selecting the standard and following the built-in workflow) so that the operator can focus on the task of driving according to the standards. This process concept is the same for the UN 138 frequency shift requirement and FMVSS 141 amplitude shift. For example, after selecting UN 138 frequency shift as the standard, the measurements are performed according to the built-in workflow, and the frequency shift for each speed is displayed.

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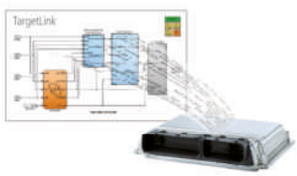

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Development

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Scalable pack testers

A new generation of comprehensive testing systems for high-power battery packs is scalable up to 1MW, and offers the features required for vehicle and grid storage

Having developed a reputation for its cell cyclers and high-precision test equipment, Arbin Instruments has also been attracting attention for its new generation of scalable, high-power testing systems. These Regenerative Battery Test (RBT) systems offer all the advanced features needed for testing xEV and grid-storage battery packs, whether large or small.

The RBT systems are scalable, so multiple independent systems can be combined to achieve charge/discharge power of over 1MW. This enables Arbin's test equipment to scale over time, along with application requirements – where 200kW or 400kW may be needed initially, future growth will demand higher power requirements and these demands can be met.

Relatively low-voltage systems (60V or 100V) are also available with multiple channels for smaller battery packs, using the same regenerative technology that minimizes operational costs without requiring any specialized facility infrastructure. Multichannel systems such as this enable channels to be connected in parallel to increase the current handling capability – another way in which Arbin's test equipment offers a scalable solution.

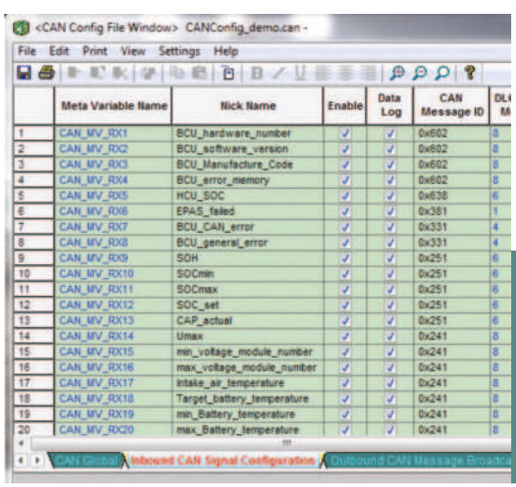
Arbin's RBT equipment provides CANbus communication to interact with the battery management system (BMS) inside most battery packs. The MitsPro software enables Arbin to both receive CAN messages from and transmit CAN messages to battery packs without the need for third-party equipment or third-party DLL packages or licenses. Additionally, each cell in the pack can be monitored directly by means of auxiliary voltage inputs. This allows an independent measurement to compare and verify the BMS readings, while both can be used for safety monitoring purposes.

Multiple layers of hardware-defined and user-defined safety limits help ensure a safe testing environment. An internal UPS safeguards the startup and shutdown sequence of the tester even in the case of a power failure. Any test running at the time will reset to a default open circuit to avoid drain on the battery during the stoppage.

Arbin's new generation high-power test equipment using regenerative circuitry. The unit is scalable up to 1MW

In addition to communicating with an internal BMS via CANbus, Arbin's technology can also interface with most temperature chambers, making it possible to control them from within the main test profile. Setpoint temperature is recorded in the data, and auxiliary thermocouple or thermistor sensors may be used to independently record temperature. This enables multiple points of reading in a large space, or makes it possible for any number of sensors to be connected to a battery pack (or even each cell within the pack) to monitor temperature. This temperature data is synchronized with charge/discharge results and can be used as a safety limit or other control condition in the test.

Drive cycle simulations can be performed, such as the Federal Urban Drive Schedule (FUDS) or other proprietary industry drive profile with hundreds of thousands of datapoints. These simulations do not require any programming knowledge to accomplish, as data recorded by Arbin, or from an outside data profile, can be loaded into the software and run automatically. The MitsPro software makes it easy to create simple charge/discharge profiles, as well as highly complex real-world test profiles.



Arbin's CANbus interface is a turnkey solution allowing users to send and receive CAN messages to communicate with battery management systems

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INQUIRY NO. 515

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Component integration

Integrated electrified systems can boost transportation efficiency as HV hybrid systems become more prominent in the commercial vehicle sector

Fleet operators increasingly demand emission and noise reduction, as well as attractive total cost of ownership. Electrification is one solution for trucks and buses operating in urban areas, and has the additional benefit of meeting local noise regulations.

The design and integration of e-components – axles, batteries, fuel cells, motors etc. – strongly influences the performance and operational efficiency of the vehicle.

AVL's e-drive integration starts with the definition and development of the right powertrain architecture, considering the vehicle, defining the boundary conditions and requirements, and balancing the trade-off between performance and cost.

E-drives enable new topologies for powertrain systems and highly effective recuperation possibilities. Transportation applications requiring long driving ranges and high payloads will result in different kinds of hybridization.

In addition to hybridization with 48V systems, which will be standard in most commercial vehicle powertrains in the future, dedicated high-voltage hybrid systems (Figure 2) will become more prominent. Future solutions will need to balance highly efficient highway operation with reduced fuel consumption in typical inner-city operations. This can be achieved by using a power-split transmission with different operating modes. Based on two e-machines in combination with planetary gears, such a hybrid system is capable of operating purely electrically up to mid-range speeds, using all energy converters in power-split mode, as well as allowing pure ICE driving.

The combination of operating modes enables a broad range of vehicle applications for these hybrid powertrains and achieves a substantial reduction in fuel consumption – up to 40% in city cycles.

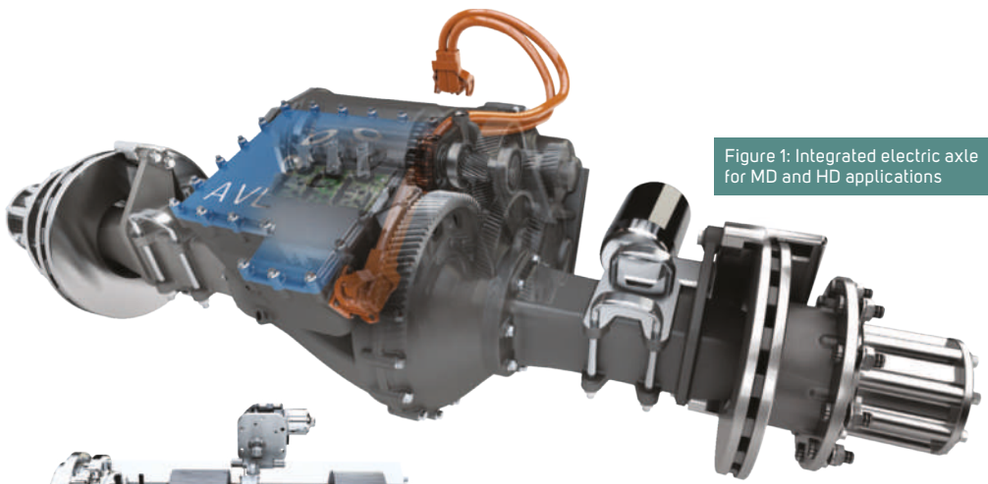

Figure 1: Integrated electric axle for MD and HD applications

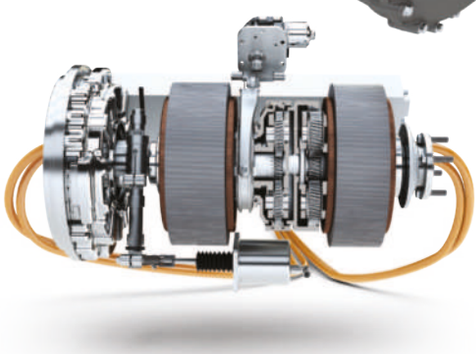

Figure 2: Dedicated hybrid transmission for MD and HD applications

Battery, fuel-cell electric or range-extender powertrains require e-drive systems with e-machine(s), inverter(s) and transmission(s). High-speed e-motors have become more common thanks to reduced packaging space and higher efficiency. To increase the e-motor speed, the high-speed transmission must be capable of coping with challenges associated with bearings, lubrication, sealing and NVH. Forced lubrication must be applied to ensure that enough oil is used at high speeds, as well as during working conditions of high torque.

Due to the high average power needed for the propulsion of commercial vehicles, direct winding cooling is a prerequisite for thermal management of the e-motor, which also enables high continuous power density. Hence, cooling systems for electrified powertrains with different temperature levels must provide highly durable powertrain components such as inverters and batteries.

Packaging space for batteries, as well as the compact nature of drivetrains, requires a high degree of integration. The e-motor, inverter and transmission are combined in a single housing to minimize the overall system size. Combined lubrication and cooling systems in the e-drive system are also integrated in these concepts to reduce the number of interfaces in the vehicle. For vehicles with a gross vehicle weight up to approximately 18 tons, integrated e-axles (Figure 1) are the preferred solutions in terms of cost and weight. Higher gross vehicle weights require – based on packaging space – a larger transmission speed range (number of necessary gears), integration of a durable brake and power take-off. Consequently integrated central drives represent an interesting solution.

The integration of the inverter in the e-drive housing ensures that the EMC behavior is smooth and only requires a minimum number of external connections. All AC lines are kept within the e-drive body. Medium- and heavy-duty vehicles require a multiple gear transmission with a smart shifting strategy – a high integration approach enables implementation of the transmission control in the inverter controller. An additional advantage of a highly integrated central drive is scalability for different powertrain variants, in combination with standard axles for conventional trucks. This includes variations in power class due to e-motor length and transmission ratio adaptations.


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Combined charging

Implementation of a fast-charging infrastructure network will be instrumental in reducing range anxiety among consumers, and is a popular choice for commercial vehicles

A global distributor dedicated to the automotive and transportation industry, Power & Signal Group is offering comprehensive support for Aptiv's new product line family of Combo 1 and Combo 2 charging inlets for CCS (Combined Charging System) applications in electric vehicles. Aptiv, formerly Delphi Connection Systems, is already established as one of the market leaders in EV technologies, and the new solutions will ensure that OEMs can meet the fast-growing demand for automobiles and commercial vehicles. These new solutions offer the flexibility of both AC and high-speed DC charging.

Aptiv's new charging inlets have been in serial production for a leading European OEM since 2015, and therefore offer all the benefits of a thoroughly field-proven design. Moreover, volume quantities are available with immediate effect via Power & Signal Group's extensive supply chain network. Power & Signal Group is Aptiv's first distribution partner to provide backing for the new range, and is fully committed to putting both inventory and expert technical assistance within easy reach of customers worldwide.

The Combo 1 design is primarily used in US markets. Combining a Type 1 interface with two additional DC interfaces for fast charging, it is fully compliant with the requirements of IEC62196-2 Type 1 (SAE). Rated at 125A/600V DC and 32A AC (single phase), it also offers improved performance in AC mode compared with the 16A-rated Combo 1 inlets that are currently available on the market.

The Combo 2 typically targets European designs and is fully compliant with the relevant standard (IEC62196-2 Type 2) as well. It is rated at 125A/600V DC and 20A 3-phase AC. Furthermore, investment in the Combo 1 and 2 range is ongoing. Upgraded solutions will support up to 200A and are expected to go into production by the end of the year.

The Combo 1 combines a Type 1 interface with two additional DC interfaces

The Combo 2 is fully compliant with IEC62196-2 Type 2

Notably, the fixings on the two parts are identical, eliminating the need for OEMs to undertake any other vehicle design changes to suit different regions or markets. Other advantages include the option of removable dust caps, along with the actuator for safe connector locking/unlocking that is also required under IEC62196.

According to IHS Markit, global EV production is expected to grow from 1.2 million this year to 2 million in 2020, and the option of fast DC charging, particularly at public stations, is seen as another key landmark in addressing range anxiety among consumers. Beyond the consumer automotive market, DC charging is also proving an increasingly popular choice to support the large batteries and heavier workloads that are typical of electric vehicles (especially buses and coaches) in the commercial vehicle sector.

Alongside the benefits of technical assistance and a streamlined and responsive supply chain, Power & Signal Group also offers customers low-volume assembly of the new inlets – for testing and prototyping, for development phases. The use of Aptiv's own tooling ensures that high quality standards are consistently maintained.

"The ability to fast-charge electric vehicles is rapidly being recognized as a must-have feature in both the automotive and CV markets," says Luc Maillet, global account manager for CV e-mobility and infrastructure for Aptiv. "These new Combo 1 and 2 solutions offer OEMs a winning combination: tried-and-tested products with the full backing of Power & Signal Group. As ever, Aptiv and Power & Signal Group also stand ready to work in partnership with OEMs to tailor product solutions in order to meet individual requirements."

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INQUIRY NO. 517

Super-fast charging

A new charging system aims to guarantee fast, convenient and safe charging, alleviating one of the primary barriers to increased consumer electric vehicle uptake

When consumers consider purchasing an electric vehicle, one of the biggest concerns is how long they will have in between charging, and how long charging will take. In areas where charging stations are few and far between, it becomes a 'postcode lottery' as to where to park up to charge – nobody wants to be left standing on the roadside for hours waiting for the vehicle to power up.

With more service and petrol stations offering these systems, car buyers are slowly becoming less anxious and more open to the idea of opting for an electric vehicle. During the past four years alone, there has been a remarkable surge in demand for electric vehicles in the UK, with more than 150,000 switching to plug-in vehicles compared with only 3,500 in 2013, according to Next Green Car. A rise of more than 75% confirms that EVs could soon replace combustion engine cars. The popularity of electric vehicles, which produce fewer climate-warming carbon emissions, is being driven by growing concerns over air pollution. In the UK, where toxic air is at illegal levels in most urban areas, sales of diesel vehicles have plummeted by 30% in the last year – while sales of electric cars have soared by 37%.

Now, as the public's perception of them warms up, electric vehicles no longer find themselves the new kids on the block. With consumers constantly looking for the easiest way to charge the vehicle in the shortest time, fast-charging solutions have never been more vital. Currently, charging times are lengthy and disruptive to everyday life, as many charging spots offer average outputs of 7-50kW, with full charging taking more than three hours.

Huber+Suhner's HPC technology delivers power up to 400A and 1,000V, and is future-proofed for higher power ratings

Huber+Suhner, a Swiss-based manufacturer of components and systems for electrical and optical connectivity, has developed an innovative power cable solution to enhance electrical charging stations. This has gone from strength to strength in the past year and was recently implemented in a high-profile project in the USA. Thanks to an integrated cooling system, it cuts the time for the charging of electric cars to less than 15 minutes (80% state of charge), while still ensuring it is safe and easy to operate.

The Huber+Suhner Radox HPC (high-power charging system) guarantees safe performance for power delivery up to 400A and 1,000V. With the Internet of Things going from strength to strength, and bandwidth and demands continuing to change, the Radox HPC system has been developed to be flexible, easy to handle and lightweight, enabling even higher ratings, to ensure it is future-proofed. The upwards compatible and customizable system helps the utility provider to be prepared for future needs and, as a result, secure vital investments.

To bring more advanced and adaptable electrical cars successfully into the market, a solid network of charging stations is also required. Along with the existing standard charging points for electric cars at home, work and in car lots, a new generation of high-power charging points along main travel routes is being implemented to ensure drivers are not restricted, with experts suggesting, in the UK, charge points will outnumber fuel stations by 2020.

With the ability to charge an EV in less than 15 minutes from a convenient station and enough battery to last for hundreds of kilometers, Huber+Suhner believes it makes sense for motorists to switch to electric cars as their favored method of transportation. The state-of-the-art infrastructure will not only make lives easier and safer, but with more charging points with the HPC implemented around the world, charging an electric car away from home no longer becomes uncertain – drivers can park up, plug in and speed off in record time.

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INQUIRY NO. 518

Battery heat shields

Preventing a single damaged cell from causing damage to the rest of an electric vehicle's battery can be achieved with a silicone-based elastomer heat shield

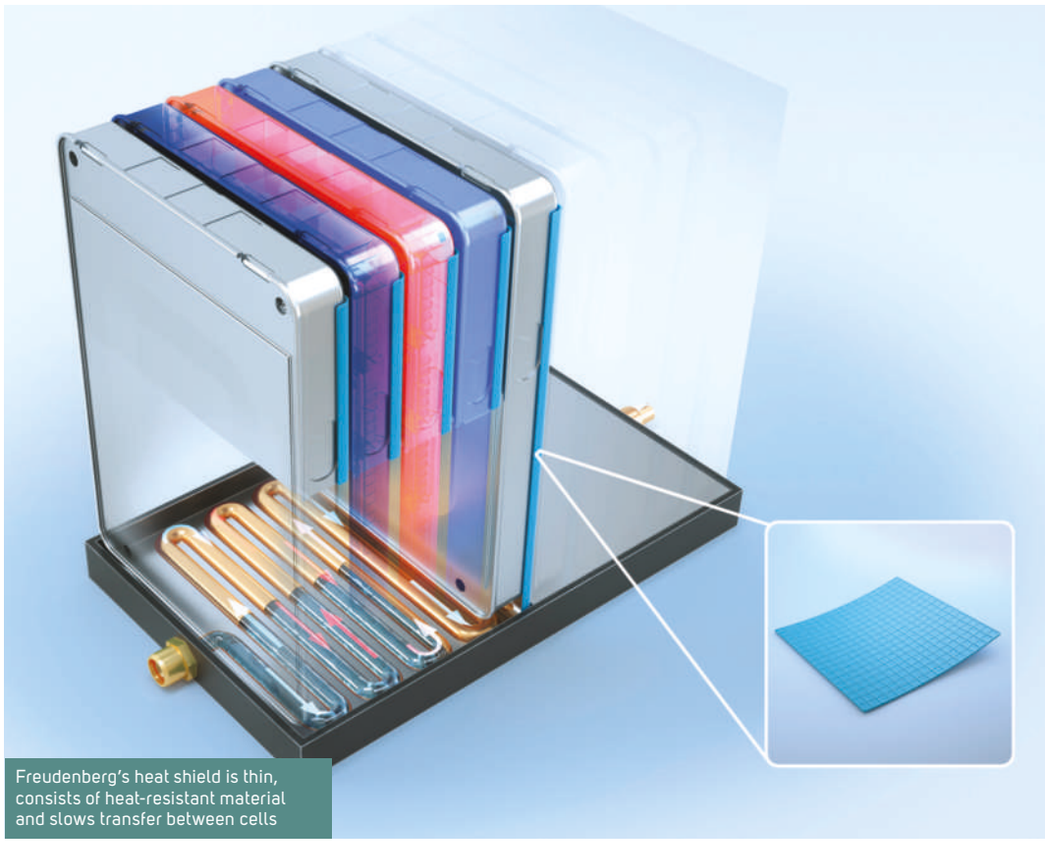
Due to the growing energy density of battery systems, the developers of lithium-ion batteries must satisfy ever higher safety requirements. It is especially crucial to keep a single damaged cell from overheating the entire battery module. Freudenberg Sealing Technologies has developed an innovative heat shield for use in prismatic and pouch cells with almost no impact on the required installation space. It combines the high heat resistance of a silicone-based elastomer with the high insulating properties of air.

The goal is greater range without the battery increasing in size and weight. Such high energy density, which has been battery developers' top priority, creates a basis for the broad acceptance of electric vehicles. But the more energy is stored in a confined space, the greater the safety requirements. Precautions are essential in case a damaged cell overheats.

Experts call the phenomenon thermal runaway, and it can cause the temperatures in a cell to rise as high as 600°C (1,100°F). The risk is that the battery's cooling system would not be able to drain the heat away quickly enough under these conditions. If the heat build-up causes neighboring healthy cells to heat up, a chain reaction can ensue that, in the worst case, could cause the entire battery system to explode.

Freudenberg Sealing Technologies is countering this risk with a new development. Heat shields between individual cells are designed so the heat from a damaged cell remains isolated until it can be drained away.

The heat shield has three key characteristics. First, the shield itself consists of a heat resistant material, a silicone-based elastomer. Second, it slows the heat transfer between the cells with a waffle-like structure, with tiny pockets of air providing outstanding heat insulation. Third, the shield is very thin, with a maximum thickness of just 1mm. The loss of energy density due to the shield's use is hardly noticeable.



Freudenberg's heat shield is thin, consists of heat-resistant material and slows transfer between cells

Freudenberg created a new test procedure for the development of the heat shield. This involves mounting samples of the heat shield on a surface heated to 600°C and recording the temperature on its rear side with thermocouples. Series of tests have shown that temperatures significantly under 200°C (400°F) occur on the rear side after 30 seconds.

"This will adequately protect a neighboring cell against the destruction of cathode material or the separator," says Freudenberg expert Peter Kritzer. "The exact boundary values admittedly depend on a multitude of specific parameters such as the chemistry and geometry of the battery cells."

Consideration has even been given to the heat shield's mounting. Since the air pockets adhere well to the smooth metallic surface of a prismatic cell – thanks to a suction effect – an individual shield can be precisely positioned. It would even be possible to expand the function of the heat shield with additional development steps. If this flexible formed part were extended over the top of the cell, it could enclose and seal the rupture disk there. In the event of overpressure in the battery cell, the rupture disk ensures that the resulting partially toxic gases escape in a controlled way.

"Even more than energy density, safety is the most important characteristic of future battery generations in terms of quality," Kritzer says. "It can be significantly increased with the help of relatively nondescript components like our heat shields."

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INQUIRY NO. 519

Easy MOSFET power

High power levels and possibilities for integration make the latest generation of inverters suitable for vehicle electrification and industrial applications

The vehicle electrification boom calls for inverter systems in a wide range of applications. Many of these require customized solutions for technical reasons, or simply justify them because of cost.

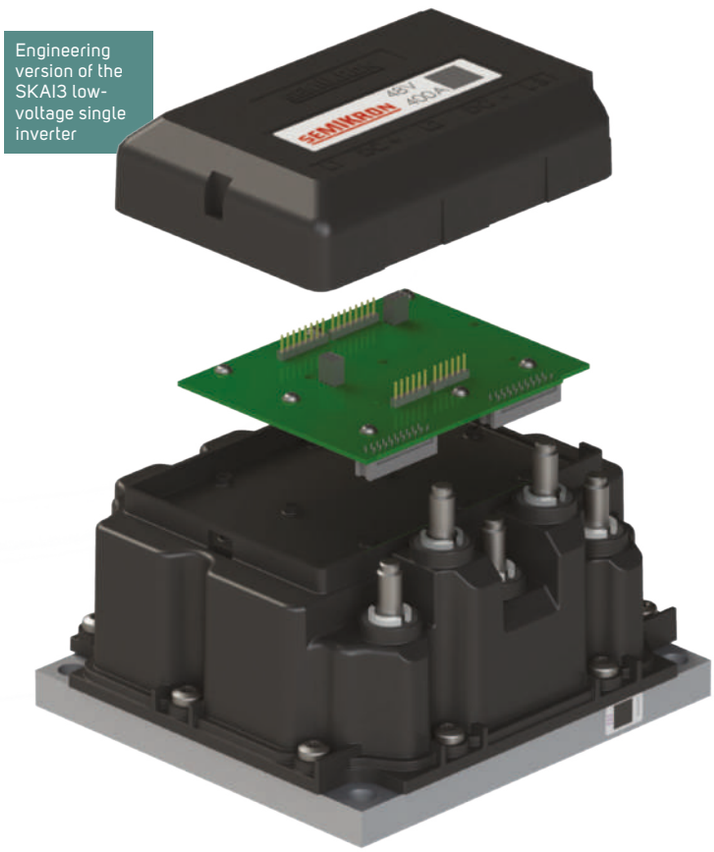
A major requirement for MOSFET-based inverters is integration, as space is typically a major issue in lower-power systems and for auxiliary functions. Inverter systems should ideally connect direct to the motor and take up as little space as possible to fit neatly into the vehicle space. Additionally, long AC and DC cables are a significant cost and source of EMI noise. Furthermore the inverter-controller functionality must match the overall vehicle control structure.

MOSFET-based AC inverters have been evolving for more than 20 years into the ready-to-use products that are available today. For today's applications, however, these solutions are often not sufficient.

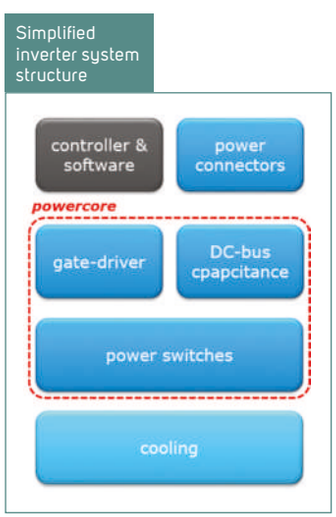
An inverter system is composed of several elements. Power switches, gate driver and DC bus capacitance form the power core of the inverter, transforming DC to AC and back. The peripheral elements – cooling, power connectors and controller with software – form the interface to the system environment. The requirements for the interfacing elements will change with every application, affecting function and form, while those for the elements of the power core will remain similar, possibly just needing to be scaled in power requirement.

Even if designing the control part of the inverter in-house to match the application system is feasible, developing a new customized power section is difficult. Particularly in MOSFET-based systems, parasitic effects can easily limit the performance beyond acceptable limits. This is one of the reasons why standard module technologies do not work for MOSFETs and are rarely found on the market. The high currents and need for minimum losses require a dedicated power technology design with low resistive and inductive commutation circuits, resulting in dedicated spatial arrangements. To compensate for its limited flexibility in arrangement of its individual elements, this power technology must be compact.

With the upcoming SKAI3 LV, Semikron's third generation of MOSFET-based inverters, a lot of power is available in a very small volume, while leaving maximum flexibility for system integration. The SKAI3 LV is a compact power core, and needs a control board. With a power density of more than 25kVA/liter and a total volume of less than 1.8 liters, the design fits into many applications with its standard case. For designs with special space requirements, cooling or power connectors, the design can serve as a starting point for a customer-specific design.



Engineering version of the SKAI3 low-voltage single inverter



Simplified inverter system structure

The interface between customer controller and gate driver has an easy-to-use structure and requires only a single 12V supply. Fed-back control signals are already voltage scaled. Current and temperature sensors are routed to a separate connector to maintain electrical isolation.

To simplify controller and software design, a dedicated housing is available, providing easy access to the controller PCB while using the power section at its full functionality and performance. With an adapter board, Arduino or Raspberry Pi platforms can be installed, giving the ability to quickly evaluate different µ-controller solutions, as many are available off-the-shelf for these platforms.

The SKAI3 LV family is designed for battery voltages with a wide range of input voltages, from nominal 48V up to 144V DC, covering all typical batteries used in industrial and most vehicle applications.

Advancing energy systems

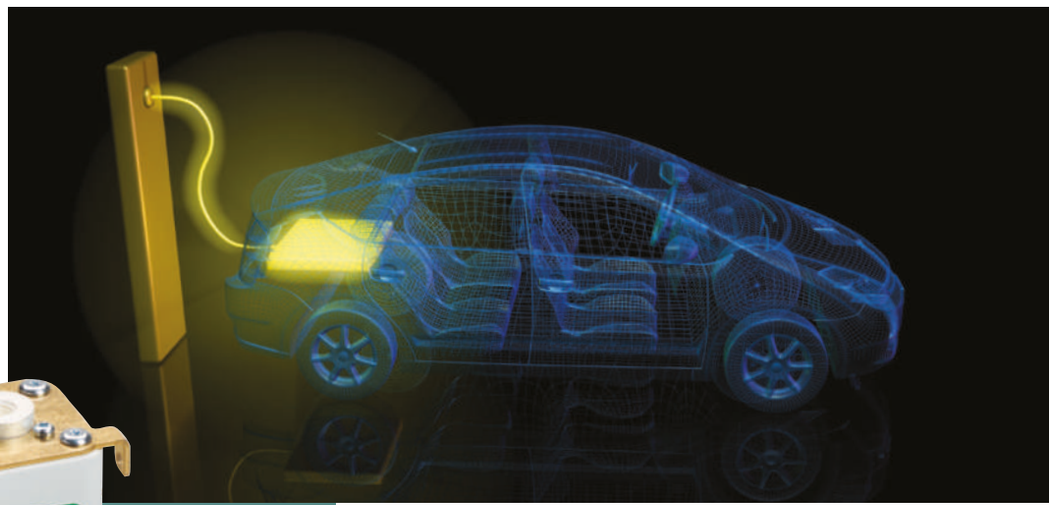
A wide portfolio of solutions can improve the safety, reliability and performance of electrified vehicle components and systems, and is key to the optimization of high-power applications

The battery can be responsible for a high proportion of an electric vehicle's cost and weight, while the goal is to minimize both to meet emissions targets. Continuous improvements in battery technology will lead to higher volumes, resulting in an even better cost situation and the possibility to integrate even more effective technologies in EVs.

Differences in OEM and market requirements lead to a variety of solutions – for example, three different battery voltage domains (aside from 12V) have been established: 48V will dominate the mild hybrid vehicle segment until 2022, overcoming the large additional cost related to battery voltages above 60V; 320-500V is currently considered the predominant battery voltage for plug-in, full hybrid and pure electric vehicles with medium-sized batteries for an electric range of up to 50km (31 miles); ~800V is seen as a potential solution for faster charging, crucial for city vehicle applications.

Standards help to optimize systems, but are regionally defined and are often still works in progress for high-voltage systems in road vehicles (traditionally the 12V technology domain).

In order to compensate for this lack of standardization and to accommodate regional standards, automotive suppliers need a high degree of flexibility in providing customized solutions, a large product portfolio for scalability, and a strong engagement with automotive manufacturers to understand the system requirements and break them down into product requirements.



Littelfuse is expanding its portfolio of power fuses for DC electrical power

The main difference between onboard and off-board charging systems lies in where the conversion of power from AC to DC occurs. All batteries in electric vehicles are DC systems and require DC power to charge. Onboard chargers perform power conversion from AC to DC within the vehicle. Advantages of this approach include: the vehicle can be plugged into widely available sources of AC power; low levels of investment are required; and charging can occur at convenient locations, such as homes and parking areas.

However, disadvantages include: slow charging due to the limitations of power that onboard systems can adequately handle; additional weight in the vehicle; and the introduction of new electrical threats to the vehicle, as onboard systems will interface with the electric utility grid.

Off-board chargers come in a variety of categories based on the type (AC or DC) and amount of power they provide. Most off-board chargers are AC chargers and provide differing rates of charging based on the amount of AC power fed to the vehicle's onboard charger. However, some off-board chargers are DC chargers – often called fast chargers as they provide large amounts of DC power direct to the battery system. Advantages of this technology include: fast charging of a vehicle battery (most systems can achieve 80% charge within 30 minutes); and a reduced need for converting power within the vehicle (reduced weight and cost).

Littelfuse solutions can improve safety, reliability and system performance

Disadvantages include: a large initial investment for charging equipment and installation; and frequent fast charging of EV batteries reduces battery lifetime.

Littelfuse's vision and purpose is to improve the safety, reliability and performance of its customers' products and systems that use electrical energy. With regard to off-board chargers, the company is looking to expand its portfolio of power fuses to cover the growing number of applications using DC electrical power. Littelfuse also continues to expand its portfolio of power semiconductor technologies. The company's investment in silicon carbide technologies enables it to provide solutions that can optimize the reliability and performance of high-power systems. Littelfuse's acquisition of IXYS is a perfect fit, as it enables the company to inherit a rich history of innovation in the power semiconductor space.

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INQUIRY NO. 521

Calibration and validation

Optimization of electrified powertrains is reliant on testing and calibration, which can help to increase power density and prolong service life of components

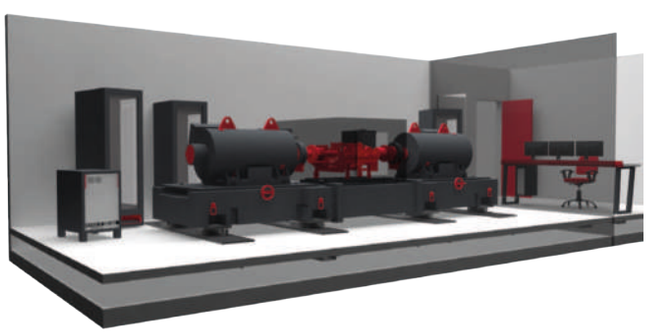
As far as hybrid vehicle development is concerned, one of the main challenges is to define the energy management system (EMS) control laws and optimize the system. Ensuring the right design means the e-motor can be used in the most efficient way, either in combination with the engine or not – that is, with the longest possible autonomy, a high level of safety, and long-life characteristics for the battery and the e-motor. Thermal management of the rotor and stator, for example, together with de-rating operations, helps to increase the power density and prolong the service life of e-motors and keep the vehicle autonomy at an acceptable level throughout its life.

FEV, an internationally renowned service provider in the area of vehicle development, benefits from in-house e-powertrain testing facilities, and has unique expertise in e-powertrain calibration and optimization. With its range of software and testing solutions, the company provides equipment and e-motor test bench solutions that meet market standards. Morphee – FEV's powerful and versatile automation, calibration and simulation system – forms the cornerstone of e-motor and driveline optimization, as well as EMS calibration on both the desktop and the e-motor test bench.

Usually, the first operation in the e-powertrain optimization procedure is to characterize the inverter and the e-motor using an e-motor test bench. The key aspect of this type of test bench is its ability to test at very high speeds and in a highly dynamic process. Vibrations are taken into consideration. FEV operates, plans and implements state of-the-art e-motor test benches. This involves the use of FEV dynamometers and conditioning systems, as well as tailor-made solutions meeting customer-specific requirements.

FEV conditioning units provide constant boundary conditions

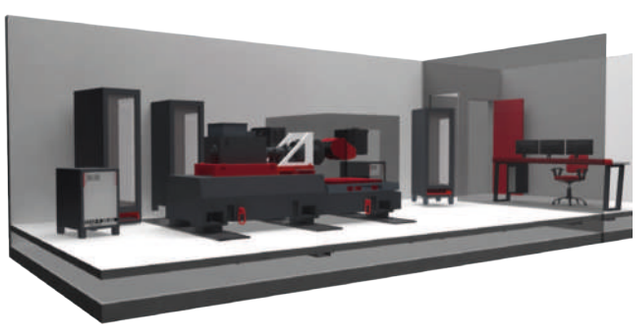
To date, FEV has built e-motor test bench solutions enabling rotational speeds of 20,000rpm and above. At this characterization stage, the goal is to build models using this e-motor test bench. These models will be used in two cases in future stages of development: first, in an engine-in-the-loop test bench with a real engine, to simulate a hybrid vehicle while keeping the real combustion engine, as this is the most difficult component to model; and second, on the desktop or the hardware-in-the-loop test bench in the case of a pure EV, in order to model the complete vehicle. This requires that real conditions be replicated as accurately as possible. These conditions may relate to the climate or the actual driving itself – calling on models simulating elements such as the driver or the road.



The portfolio now includes equipment for testing EV components such as e-axles

The e-powertrain is optimized by taking several use cases (freeways, urban environments or rural areas) and several factors (voltage and current signals, frequency versus angular position and speed, transient torque management, and so on) into consideration. In this case, FEV's Osiris power analyzer serves to analyze the efficiency of the e-powertrain system by measuring the power before and after the inverter, and before and after the e-motor. The results are used in Morphee, or could be used in a separate software package if required in the future.

FEV offers unique solutions facilitating not only the optimization, but also the validation of the complete driveline. Durability tests simulating mechanical cycles (vibration, reducer, differential) and thermal shocks (cooling, rotor thermal management) can also be conducted. In this configuration, a good solution is to test not only the e-motor, but also the complete drivetrain: this is achieved on the so-called e-axle test bench. This makes it possible to test the entire system in the downstream steps of the development process and involves using both Morphee and Osiris, as well as FEV dynamometers and conditioning systems together with tailor-made solutions designed to meet specific customer requirements.



FEV's specialized test cells are able to accommodate the complete e-powertrain

Electric motor topologies

Each electric vehicle has a different set of technical requirements and thus there is no single motor topology that is a perfect fit for every application

Over the past 20 years, TM4 has developed and marketed multiple motor topologies to meet various technical requirements.

The first permanent magnet electric motors TM4 produced used a topology derived from in-wheel motors – external rotor surface-mounted permanent magnet (SMPM). This topology proved to be a great contender for applications where high torque density is required. The winding configuration used was distributed.

Between 2012 and 2013, TM4 launched the Sumo HD and MD powertrain series targeting city buses and heavy-duty vehicles. The motor is designed to be connected directly to the rear differential of trucks and buses. To allow such a configuration and because of the removal of the transmission, the motor needed to have the highest possible torque density.

The Sumo family has been a success in the market as its price/performance yields considerable benefits as opposed to a higher-speed motor combined with a transmission. It also offers reliability by reducing the number of parts and increasing driveline efficiency.

In 2016, TM4 revamped its Sumo MD family to better target the requirements of medium-duty vehicles. Permanent magnet variable reluctance (PMVR) technology was introduced and aimed at increasing the range of the motor in speed and in torque. TM4's PMVR technology is specific to its outer rotor configuration and provides a design option that can tailor the torque curve of the motor to the application, especially for high-torque direct-drive applications.

In 2017, TM4 started developing a line of generator products, dubbed the Sumo HP line. The technology developed for this series uses interior permanent magnet (IPM) technology, but with concentric windings combined with a new internal rotor design. The goal was to use the characteristically short end of concentric winding to reduce the total length of the generator. One application for these generators is parallel hybrid powertrains, where space is limited for the electric motor/generator placed between the ICE and the transmission.

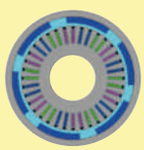
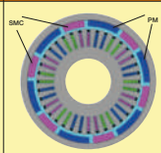
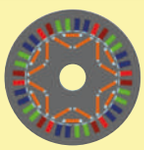
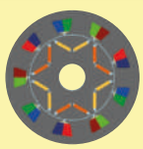
The IPM topology is extremely versatile and allows for optimization of the power electronic size. As the generator power curve needs to match the engine speed, the generator design does not need as much constant power speed range. For that reason, the current output of the power electronics can be reduced, enabling the system's cost to be reduced.

With high power density and performance that matches a combustion engine, the Sumo HP motors can also be used in applications such as multispeed transmissions for commercial vehicles. In fact, TM4 believes that this application is well suited for the Sumo HP family since there are currently an increasing number of transmissions becoming available in the commercial EV market.

Later in 2017, TM4 began developing a product line for light-duty vehicles. This market segment requires higher maximum and operational speeds. The selected technology is based on IPM in a rotor core that sits in the middle of the motor. It uses a standard arrangement that is more common in the industry and better suited for high-volume automated production lines. This technology is implemented in the upcoming Sumo LD line of product, set to be launched later this year.

Since the company's creation, TM4 has been able to innovate and provide powertrains tailored to the application from in-wheel, geared, direct-drive, or even engine mounted.

TM4 supplies its powertrains to a number of OEMs in North America, Europe and Asia. Production takes place at TM4's Canadian facilities in Boucherville and at its Chinese joint venture, Prestolite E-Propulsion Systems in Weifang. Both sites are equipped with high volume, flexible and automated production lines, and a large range of testing capabilities, making it possible to conduct full validation and certification of electric and hybrid powertrains.

	Surface-mounted permanent magnet motors	Surface-mounted PMVR	IPMSM distributed winding	IPMSM concentric winding
				
TM4 family of products	**SUMO HD**	**SUMO MD**	**SUMO LD**	**SUMO HP**
Applications	• Medium- and heavy-duty trucks • Direct drive configuration	• Medium-duty trucks • Geared and direct drive	• Light- and medium-duty trucks • Passenger	• Motor for multispeed transmissions • Generators
System benefits Torque-to-weight ratio	Good	High	Good	Low
Power-to-weight ratio	High	Good	High	High
Constant power speed range (CPSR)	Good	Good	High	Low
Inverter current	High	Good	Good	Minimal

A comparison of motor topologies within TM4's Sumo product family

Efficient 48V application

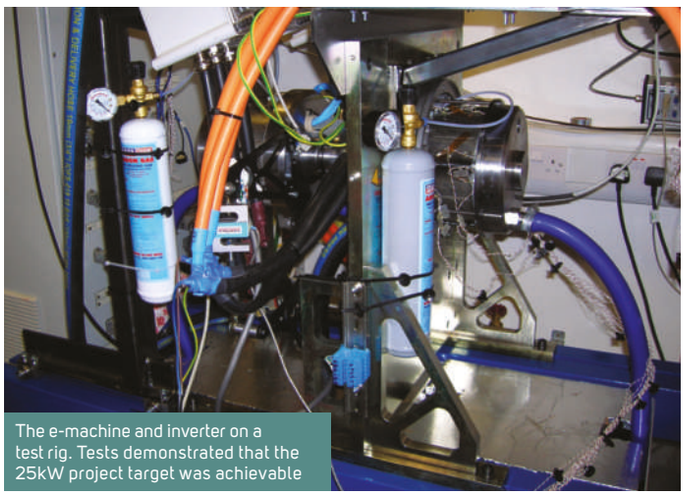
Research and development into 48V applications in mild hybrid electric vehicles calls for efficient delivery of power, overcoming the challenges of belt-driven systems

Cars are starting to use 48V systems to improve engine efficiency, manage stop/start smoothly, and supply power-hungry ancillaries. Ricardo has worked on 48V technology for many years, notably on the ADEPT (Advanced Diesel Electric Powertrain) project, which demonstrated CO_2 reduction of 6.6% on the WLTP (11% on NEDC), with a further 2-4% benefit predicted from advanced thermal and lubrication improvements enabled though electrification. This project combined the alternator and the starter motor in a Belt Starter-Generator (BSG), to provide a cost-effective solution typical of that being introduced in production today.

Since 48V is rapidly becoming established as the default mild hybrid solution, the question of how far to push 48V arises, R&D projects are exploring this. Increased power enables increased electric vehicle operation but it needs to be delivered efficiently, which is challenging with today's belt-driven systems. Moving the e-machine to the transmission side of the clutch enables exploration of the upper limits of 48V power delivery, removing the limiting factor to the system's current capability and the cost of the associated electrical equipment.

The ECOCHAMPS project (European Competitiveness in Commercial Hybrid and Automotive Powertrains) – a €28m (US$32.8m) part-funded Horizon 2020 project with 25 partners – aims to achieve efficient, compact, lightweight, robust and cost-effective hybrid powertrains for passenger cars and commercial vehicles to meet increasingly stringent global CO_2 and pollutant emission requirements. One of Ricardo's activities (as a partner in the project) was to set targets, and simulate and evaluate a suite of partners' technologies for B and C segment light-duty hybrid-electric vehicles, some of which were based on 48V architectures.

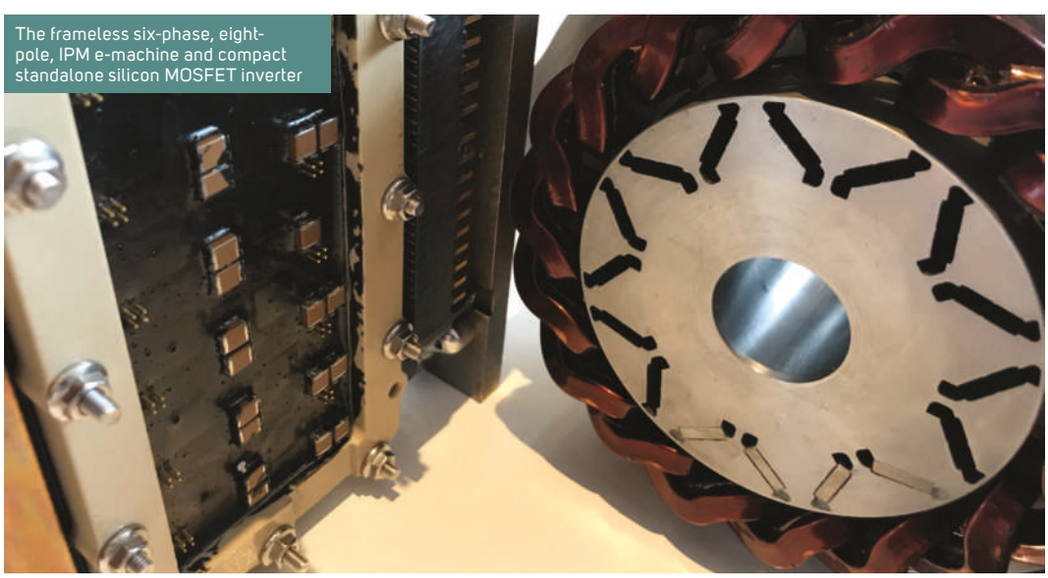
One of these 48V systems was based on a DCT – currently fitted with a 15kW induction e-machine that enabled regenerative braking and acceleration assistance. Simulation identified a 25kW practical limit for 48V energy regeneration, so Ricardo proceeded to design and develop a new motor to keep within the 15kW e-machine's envelope and deliver the increased performance (a 67% increase in power density). In addition Ricardo designed and developed the associated power electronics and, to simplify system integration into the transmission, used the gearbox oil for cooling both units.



The e-machine and inverter on a test rig. Tests demonstrated that the 25kW project target was achievable

The solution – a frameless six-phase, eight-pole, IPM (interior permanent magnet) e-machine – has hairpin windings cooled by oil sprayed from the rotor. The inverter, a compact standalone oil-cooled silicon MOSFET design with low thermal resistance, was much smaller than a conventional unit.

The prototypes were rig tested and showed that the 25kW target was achievable – the resulting mild hybrid vehicle would be capable of achieving an excellent powertrain efficiency. By restricting the system to 48V, this also provided an extremely cost-effective solution, without needing to go to costlier higher voltage systems. This project has received funding from the EU's Horizon 2020 research and innovation program under Grant Agreement no. 653468.



The frameless six-phase, eight-pole, IPM e-machine and compact standalone silicon MOSFET inverter

Electrification solutions

A new business unit aims to target the rapidly expanding demand for HV electrified vehicle technologies by leveraging extensive industry expertise

Recently formed by Eaton, the new eMobility business aims to address demand for high-voltage electrified vehicle technologies in the areas of intelligent power electronics, power distribution and circuit protection. The new business is poised to capitalize on a global vehicle electrification market projected to grow to 22 million battery-electric, hybrid and plug-in hybrid, and 22 million mild hybrid vehicles by 2030.

"We have a unique capability that differentiates us from competitors participating in this electrification trend," says Scott Adams, senior vice president of sales and product strategy at eMobility. "We have extensive expertise in the vehicle market, including system integration, and we understand the demands of developing products with high reliability and durability.

"Additionally, Eaton has a very large electrical power management business where we provide high-voltage power distribution, circuit protection and advanced power-quality systems. Our products are installed in some of the world's largest data centers, hospitals, factories and other areas that consume large amounts of electricity and where uninterruptible power flow is critical. Furthermore, our nine R&D centers, global footprint and transferable technical expertise uniquely position Eaton in this space."

The eMobility business was formed by combining products, expertise and global manufacturing capabilities from Eaton's Electrical and Vehicle Groups. Prior to eMobility, Eaton was already a proven leader in vehicle electrification, with more than 15 years of expertise in developing hybrid systems. Eaton currently has more than 15,000 HEV and PHEV systems on the road with more than two billion miles of safe, reliable service.

Eaton has a reputation for building highly reliable DC/DC converters and can design custom solutions to meet unique customer requirements

As a global supplier, Eaton also has extensive knowledge of vehicle dynamics and safety standards, and experience managing high-voltage electrical power. Eaton plans to invest more than US$500m over the next five years to develop new products and technologies, including smart diagnostic technologies, and intelligent and predictive health monitoring, to further strengthen its global capabilities.

"Our understanding of the unique needs of bus and truck fleets, along with our experience in transmissions and power electronics in the hybrid space, give us a distinct advantage over other CV suppliers," says Jeff Lowinger, president of eMobility. "We also have high-voltage, fast-acting fuses for circuit protection and high-voltage DC/DC converters in automotive, battery-electric and hybrid applications.

"We understand the working dynamics of drivetrains across the commercial vehicle and automotive segments and the demands they face, not just in normal conditions when things are going well, but in abnormal hostile conditions, too."

The new business primarily focuses on three areas: power distribution and protection, power electronics, and power systems. The power distribution and protection category includes fuses, supercapacitors and power distribution units, while convertors and onboard chargers fall under the power electronics umbrella. Power systems include EV transmissions for a variety of medium- and heavy-duty applications, as well as a 48V regenerative accessory drive system for heavy-duty trucks.

"We're not going to play in all the component spaces our competitors are in," says Adams. "As a leader in high-voltage power management we will differentiate by helping our customers solve their most difficult challenges in power electronics, power distribution and protection."

Eaton's existing line of electrified products – DC/DC converters, power distribution units, hybrid and battery-electric transmissions, and high-voltage fuses – serves as the foundation for eMobility to build additional growth in the passenger car, commercial vehicle and off-highway markets as electrification increases. Eaton projects its current electrified portfolio will account for approximately US$300m in revenue in 2018, and forecasts revenues of US$2bn-US$4bn by 2030 as new products and customers are added to the eMobility portfolio.

The Eaton Bussmann series EV fuses are designed for the protection of high power battery charging systems, critical components such as the traction inverter, and other key system components

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INQUIRY NO. 525

High-quality contactors

Performance contactors are designed to deal with harsh and hazardous environments, and are manufactured to the exacting standards required of military applications

Contactors come in all shapes, sizes, standards and prices to match myriad applications. Choosing the right contactor for the job can often be a compromise between quality and cost.

Usually UL or CSA approved, mass-produced contactors which are used in consumer appliances, computers and the automotive sector typically feature unsealed plastic cases and are often simply function-tested without the rigor of full parameter testing.

Applications such as battery charging, energy storage and power distribution in harsh environments (such as aerospace, marine and military, where performance, integrity and reliability are critical) demand another order of contactor quality.

Typically hermetically or environmentally sealed and ruggedized for use in harsh or hazardous environments, these high-performance products are subject to rigorous testing and often carry mil-spec approvals (rather than UL/CSA). They also tend to be manufactured in smaller quantities, to higher standards and, as a result, are invariably more expensive than standard contactors.

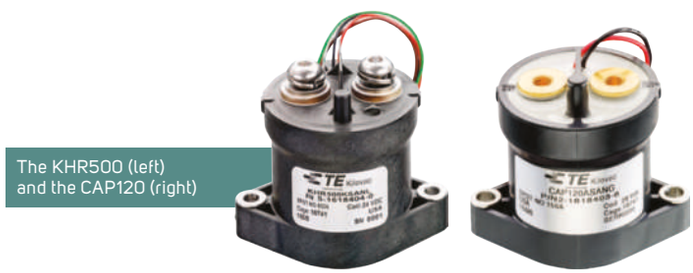
Available in the UK from authorized distributor Dalroad, a notable example of this type of highly specified contactor is the Kilovac K1K high-voltage contactor from TE Connectivity. Designed to handle up to 1,000V/1,000A in harsh or explosive environments, the K1K offers exceptional performance in new technology, higher voltage/current battery and energy storage applications, yet despite its high specification is among the smallest and lightest contactors around.

Hermetically sealed for long performance without oxidation or contamination of contacts, even over long periods of non-operation, the small, lightweight Kilovac K1K contactor is capable of bidirectional switching from 5-1,000V DC and can be bottom- or busbar-mounted in any position. The contactor also features an integrated dual-coil electronic economizer with internal suppression for optimum efficiency.

Ideally suited to carry and interrupt battery fault currents, power/motor control circuit isolation, circuit protection/safety, and energy storage/power distribution, TE Connectivity's Kilovac K1K contactors tick all the boxes for performance, versatility, size and weight for use in charging stations, electric vehicles (including military), hybrid vehicles, solar farms and wind farms.

A number of other next-generation, high-performance TE Connectivity Kilovac contactors are also available in the UK from Dalroad.

The Kilovac K1K high-voltage contactor



The KHR500 (left) and the CAP120 (right)

The KCS01 (left) and the KCS03 (right)

The KHR500 high-voltage, high-rupture, 600A contactor is the smaller, lighter and more advanced replacement for the popular EV500 Bubba. Hermetically sealed for use in harsh and explosive conditions, the KHR500 can handle inrush currents up to 4,000A and is capable of bidirectional power switching. Typical applications include aerospace, ground vehicles, marine, solar, automotive and energy storage systems.

The CAP120, a reduced size version of TE's MAP and CAP series contactors, offers exceptional performance for a compact and light device with high break levels (1,000A at 400V DC and 600A at 600V DC), further increasing system flexibility and reliability. Designed to deliver reliable, long-lasting performance in military ground, military/commercial aerospace and marine environments, typical applications include energy storage systems, power distribution, high-current battery systems, lithium-ion battery systems and solar power.

The KCS01 and KCS03 current-sensing high-voltage contactors are small and lightweight. Despite their diminutive size, advanced features include bidirectional switching and integrated dual-coil electronic economizers with internal coil suppression. EMC-compliant with no radiated coil emissions, they can be mounted in any orientation. Typical applications include energy storage/battery storage, power distribution, power motion control, high-voltage DC converter systems, alternative energy, military and commercial electric vehicles and test equipment.

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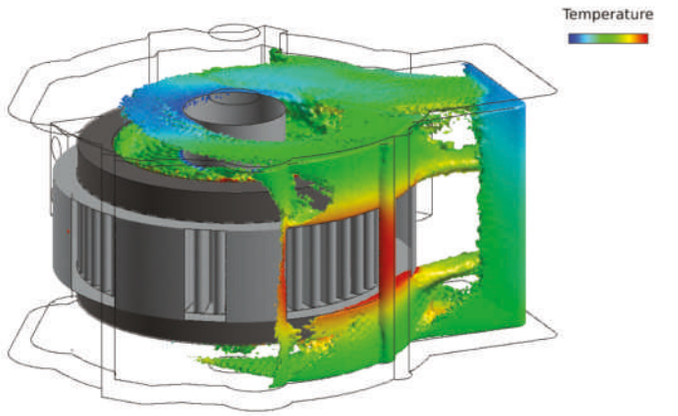
INQUIRY NO. 526

GPU-based simulation

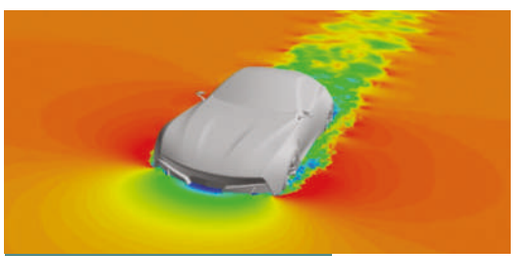
Innovative CFD technology can improve electric vehicle efficiency, reducing fuel consumption, improving aerodynamic performance and limiting losses

In the past decade much effort has been made to electrify vehicle powertrains, delivering unprecedented efficiency gains. On a global level, improvements of more than 95% have been observed in powertrains using electrical motors and control electronics, compared with around 45% in ICE applications. However, vehicle efficiency depends a lot on mechanical friction. The progressive replacement of traditional physical tests with simulations has highlighted the limits of big fluid-flow models and complex mechanical assemblies. GPU-based (graphical processing unit) CFD simulation technology enables optimized performance in a shorter time, reducing fuel consumption, improving the vehicle aerodynamic performance or limiting transmissions' mechanical losses.

The lattice Boltzmann method provides users with superior performance, dramatically reducing the preparation time for large, complex models. Altair's UltraFluidX software takes advantage of this methodology to solve large-scale internal and external aerodynamics problems for a broad class of applications, including ultra-fast prediction and evaluation of vehicle, building and environmental aerodynamics. The integrated volume meshing and fast transient analyses deliver short turnaround times, resulting in completely new possibilities for simulation-driven design and significant cost savings. Conventional simulation approaches need thousands of CPU cores to achieve the turnaround times of this new technology. Its GPU-based solution increases throughput, reducing hardware and energy cost, while delivering the fidelity of a transient large eddy simulation (LES) aerodynamics simulation.



Temperature analysis of a motor coil using the lattice Boltzmann method



UltraFluidX enables engineers to perform simulations within just a few hours on a single workstation

This solution is ideal for external aerodynamics investigations of any type of transportation vehicle in a wide range of operating conditions. It enables designers to reduce fuel consumption by minimizing the aerodynamic drag, but transient flow analysis also helps them to determine aerodynamic forces and moments (for example drag, lift, roll, pitch, yaw) and investigate separated flow regions and vortices, or even improve driving stability.

Improving EV range by reducing drivetrain losses remains a key challenge for designers, since they have been identified as the largest energy draw at constant speed up to approximately 80km/h (50mph) – even more so than the vehicle's aerodynamic drag.

Gearboxes, differentials and planetary gears (such as those encountered in common powertrain assemblies) are composed of complex rotating components with lubricated elements, which makes interactions complex to explore with traditional methods, with several computations and weeks of computing time needed for a few test points.

The new approach, based on smoothed particle hydrodynamics (SPH) methodology coupled to GPU technology, reduces the simulation time from weeks to just a few days and increases the accuracy of analysis. Altair's nanoFluidX SPH fluid dynamics simulation tool predicts the flow in complex geometries with complex motion. For example, it can be used to predict the oiling in powertrain systems with rotating shafts and gears, and can analyze forces and torques on individual components of the assembly, even for systems spinning at thousands of rpm. Moreover, thermodynamics simulations will improve thermal management, increasing the oil volume without incurring extra churning or windage losses.

New CFD approaches based on more recent simulation methodologies are particularly well suited for parallelization. With the rise of GPU technology, simulations with high fidelity can be performed in just a few hours on a single workstation, when days or weeks were necessary with traditional approaches. These new capacities support designers and further impact the design process by reducing losses at the vehicle aerodynamic level and also at various local transmissions levels.

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INQUIRY NO. 527

Testing EV/PHEV batteries

To accelerate battery development, a new line of battery testers, simulators and safety test equipment has been designed and built by experts in electric vehicle powertrain testing

As the automotive industry advances electric vehicle technologies, Chroma has been actively improving cell, module, and pack-level battery testing performance by developing flexible regenerative battery test systems and battery safety testers. The company has developed substantial expertise in the design and manufacturing of automated test equipment for the entire powertrain of an EV/PHEV, and is a leading developer of new systems designed specifically to test Li-ion batteries to EV/PHEV standards.

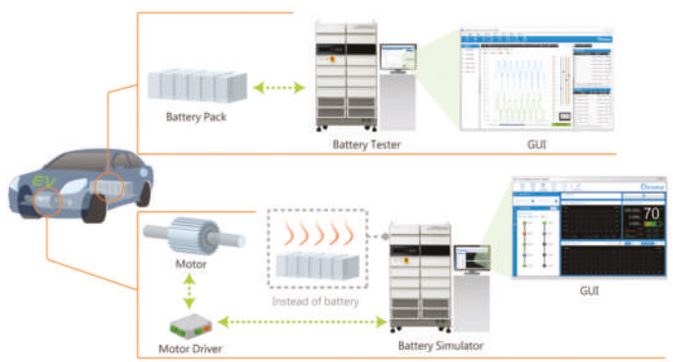
Building on the success of developing the world's first UL-approved SAE J1772 EVSE Communication Protocol Test System, Chroma developed two regenerative battery test systems that are gaining acceptance from battery manufacturers and test labs all over the world. These systems are high-precision, integrated battery test solutions that include high efficiency (>90%) regenerative discharge that recycles energy discharged by the battery back to the channels in the system or to the grid. The systems are configurable with multiple channel capabilities that can be upgraded as testing requirements change.

The systems have multiple safety features including over-voltage, over-current and over-temperature protection, as well as external parameter detection to ensure batteries are protected during charge/discharge testing. The systems satisfy charge rate, discharge rate, and SOC with accuracy in measuring voltage, current, temperature and power, both statically and dynamically.

The Chroma 17020 battery test system is a high-precision bidirectional solution designed for modules and packs up to 500V and 60kW per channel. Accurate source and measurement ensures the test quality is suitable for performing exact, reliable testing critical for inspection as well as capacity, performance, production, and qualification testing. The 17020 features independent channels to support charge/discharge tests on multiple units, each with discrete test characteristics. To provide increased flexibility between high channel count and high-current testing, channels can be paralleled to support higher current requirements. Chroma's advanced architecture can create seamless transitions between maximum charge and maximum discharge with a rapid 50ms conversion. This enables charge/discharge modes to simulate real-world conditions.

Far left: Chroma's 17020 Battery Test System

Left: Chroma's 17040 Battery Test System



Above: An illustration of battery testing via Chroma's Battery Pro software, and simulation for testing battery connected devices via Battery Simulator software

The Chroma 17040 battery test system supports higher power testing up to 1,000V and 360kW with built-in parallel channels and dynamic profile simulation functions. The parallel capability increases charge and discharge current and power to its maximum, thus increasing efficiency. Dynamic profile simulation enables the loading of a battery waveform of a given drive profile, in either current or power mode, to meet the NEDC/FUDS requirements. The test system's bidirectional architecture ensures that the current will not be interrupted during the charge and discharge transient state, so that driving conditions can be accurately simulated in line with appropriate ISO, IEC, UL and GB/T international testing standards.

Both of these testing systems come equipped with Chroma's Battery Pro software, and the company offers an optional Battery Simulator function for testing battery connected devices. Battery Pro provides real-time monitoring, easy-to-reference icons, authority management, and fault record tracking. Battery Pro provides flexible test editing functions to perform independent channel tests and conforms to diversified requirements for efficiency, reliability and safety. It also supports power failure recovery functions that ensure test data is not interrupted.

For testing battery connected devices such as motor drivers, onboard chargers and DC/DC converters, Chroma's Battery Simulation software confirms if the device under test is performing as intended. Integrated with the 17020 and 17040 bidirectional battery testers, battery state is simulated, eliminating charge/discharge wait time for an actual battery. Real-time test results include voltage, current, power, SOC%, charge/discharge state and capacity.

Chroma also provides equipment for safe batteries. Electrical safety testers support AC/DC hipot, leakage current, insulation resistance and partial discharge, at very high speed and accuracy to ensure the quality of cells and modules before they go to the next level of production.

Whether validating designs, running functional tests, or verifying electrical safety, Chroma's experts understand the need for reliable, high-quality test systems.

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INQUIRY NO. 528

Power analysis solutions

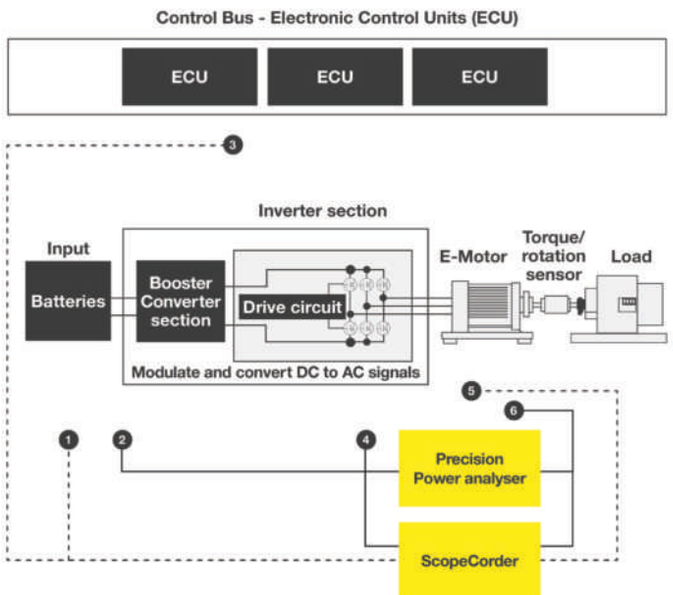
Government efficiency directives, emissions standards and volatile oil prices have caused major automotive manufacturers to head toward an all-electric future

Despite efficiencies that far outstrip those of ICE vehicles, electric vehicles still face several barriers to mainstream adoption – charging infrastructure, range anxiety and cost of ownership. For Anoop Gangadharan, product marketing manager at Yokogawa Test & Measurement, there are key challenges facing electric vehicle system designers, who must thoroughly and accurately evaluate power parameters to verify compliance with requirements.

The advances in power semiconductors, charging technologies and drivetrain systems provide an optimistic outlook for the future of EVs as manufacturers optimize powertrains, vehicle communications, braking efficiency, suspension systems and more. However, achieving lower emissions, greater efficiency and increased driving range will require reliable and actionable insights across the development cycle.

"Meeting consumer demands for greater charging capacity, shorter charging times and greater range will require thorough evaluations of the powertrain, the charging system, brushless DC motors, ECU communications, steering systems and more," says Gangadharan. "The result will be an increasing number of testing scenarios, measurement parameters and associated challenges."

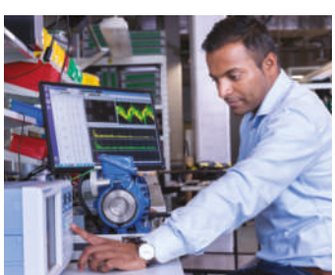
The problem is clear: Powertrains require accurate evaluation of electromechanical efficiency and torque, while brushless DC motors may require analysis of PWM signals and transients. Similarly, while evaluation of battery charging and discharging requires positive and negative cycle analysis, wireless charging will need measurements at lower power factors and frequencies in the hundreds of kilohertz.



Test setup for powertrain evaluation of efficiency, communication bus signals and transient behavior

Furthermore, while embedded electronics, engine control units and communication bus signals need precise waveform analysis, the evaluation of inverter waveforms must account for and reduce harmonic superimpositions through isolated inputs, high-speed sampling and lengthy observation.

Measuring electric and hybrid vehicle efficiency will typically need multichannel DC and AC analysis along with physical parameters such as rotational speed, fuel injector pulse times and crank angles measured from sensors and rotary encoders. However, from R&D to manufacturing to compliance testing, the measurement of efficiency, harmonic content, battery charging/discharging and communication bus signals requires progressively greater accuracy and consistency in measurement over the specified ranges and conditions.



Precision power analyzers are ideally suited for motor evaluation

"In the early stages of development of individual components, engineers may only need waveform analysis at limited accuracies, but when a multicomponent subsystem or system is concerned, optimizing the entire system takes precedence over the individual components," says Gangadharan. "Optimizing for efficiency in this ecosystem of components, systems and subsystems requires repeatable and accurate measurements."

Engineers today are faced with a choice of instruments with which to address their measurement challenges. Oscilloscopes focus on waveform analysis, power analyzers focus on accuracy, and hybrid instruments extend the scope of measurement to areas such as time-domain measurements and flexible data acquisition. But with measurement needs varying and evolving depending on application type and stage of development, it is often not possible to solve every measurement challenge with a single solution.

For example, precision power analyzers are ideal for motor evaluation as they go beyond measuring electrical parameters and enable measurement of rotation speed and direction, torque, mechanical power, synchronous speed, slip, electrical angle, motor efficiency and total system efficiency from the analog or pulse outputs of rotation and torque sensors. On the other hand, ScopeCorders offer a single real-time overview of CAN/LINbus measurements with electromechanical measurements to greatly speed up development and fault finding.

"It is important to assess measurement technology requirements against stage-based objectives of accuracy class, number of channels, input ranges, electromechanical measurements and computational capabilities. These assessments will enable you to invest in solutions to achieve long-term improvements in manufacturing productivity, time to market and product quality," concludes Gangadharan.

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INQUIRY NO. 529

BMS and SOC accuracy

Implementing a high-performance battery management system can reduce inaccuracies in state-of-charge measurement, making vehicle design and operation more efficient

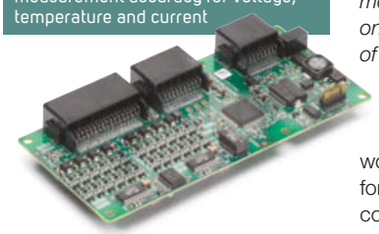
Accurate state-of-charge (SOC) measurements are critical to the overall performance and cost-effectiveness of battery systems in electric vehicles. When SOC accuracy is either unknown or low, it is difficult for the driver to use the vehicle at low SOC, as the system may run out of power in an inconvenient or dangerous situation, such as in the middle of the road, during dense traffic, or at night.

Even when SOC inaccuracy is known (for example, 5%), the driver will have to apply a similar safety margin when operating the vehicle – such as avoiding driving below 5% SOC. This is equivalent to oversizing the useful battery capacity by 5% and, in effect, corresponds to a 5% higher battery price.

The possible inaccuracy of the SOC estimation depends on a range of parameters.

First, the SOC algorithm. Here there is typically a trade-off between complexity and accuracy. Commonly used algorithms in order of increasing complexity are: coulomb counting; coulomb counting combined with OCV-based SOC estimates after sufficient relaxation time; a Kalman filter.

Second, the battery chemistry. Some lend themselves to more accurate SOC algorithms than others. For example, LMO/LTO cells have little hysteresis and a significant slope on the SOC-OCV curve compared with LFP/C cells, which typically have a noticeable hysteresis combined with a SOC-OCV curve, which is very flat in certain SOC areas.



The compact C-BMS manages up to 24 battery cells with high measurement accuracy for voltage, temperature and current

Finally, the accuracy of the battery management system (BMS) that monitors the cells and estimates SOC. In particular, the accuracy of the cell voltage and current measurements affect the SOC accuracy considerably.

Assuming a representative operational pattern for a given battery system, it is possible to theoretically quantify the typical and worst-case SOC inaccuracy in different cases, as has been done by Maitane Garmendia Elorza in her 2017 PhD thesis '*State-of-charge (SOC) algorithm design methodology for implementation on battery management systems of industrial Li-ion battery packs*'.

To illustrate the importance of BMS measurement accuracy, Figure 1 shows the estimated worst case as well as typical values for SOC inaccuracy for a combined coulomb counting/OCV-based SOC algorithm operating on NMC/C cells. This is performed for two different sets of BMS accuracy. For the high-performance BMS, the voltage accuracy is better than 1mV and current accuracy better than 0.1%. For the standard BMS, the results are 5mV and 1% respectively.

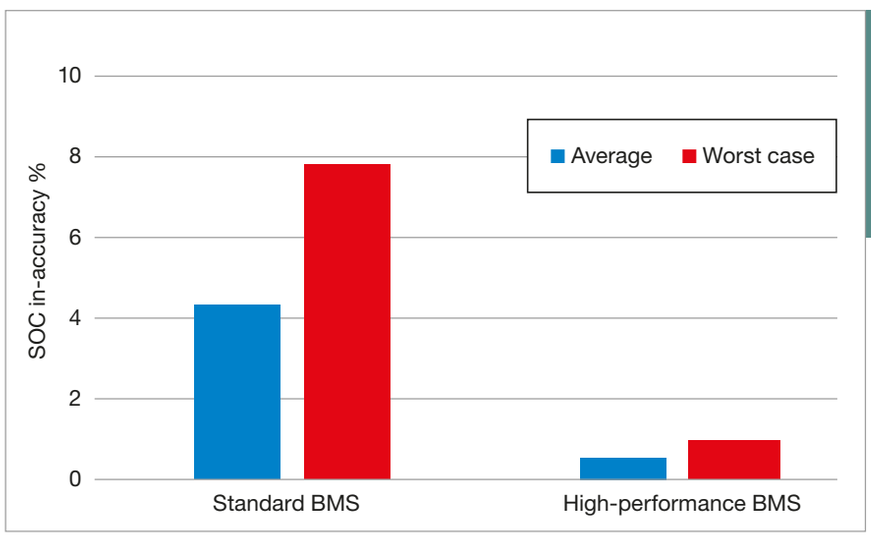
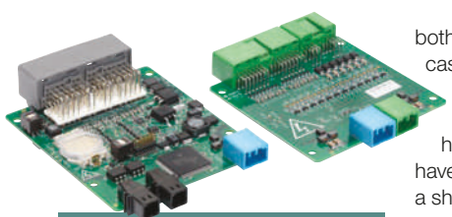


Figure 1: The impact BMS measurement accuracy has on the inaccuracy of a combined coulomb counting/OCV-based SOC algorithm for NMC/C cells



The ISO26262-compliant modular N-BMS measures cell voltages at an accuracy of ± 1.5mV in the entire temperature range of -40°C to 85°C

The difference in BMS measurement has a high impact on SOC inaccuracy, as the standard BMS will result in an average SOC inaccuracy of above 4% and close to 7% in the worst-case scenario. By comparison, a high-performance BMS with more accurate voltage and current measurements results in SOC inaccuracy below 1%, both on average and in the worst-case scenario.

Lithium Balance's N-BMS and C-BMS are examples of high-performance BMSs. Both have a voltage accuracy of 1.5mV, a shunt current measurement accuracy better than 0.1% and rapid update rates. With basic coulomb counting algorithms, customers have shown average SOC inaccuracy below 1% with these BMS platforms, but the software also allows the use of more advanced and customized coulomb counting/OCV and Kalman filter-based SOC algorithms. Both the modular N-BMS and the single-board C-BMS are designed for ISO26262 compliance with an ASIL C rating, with a compact design and carefully selected components to meet the quality standards and cost targets for an affordable BMS.

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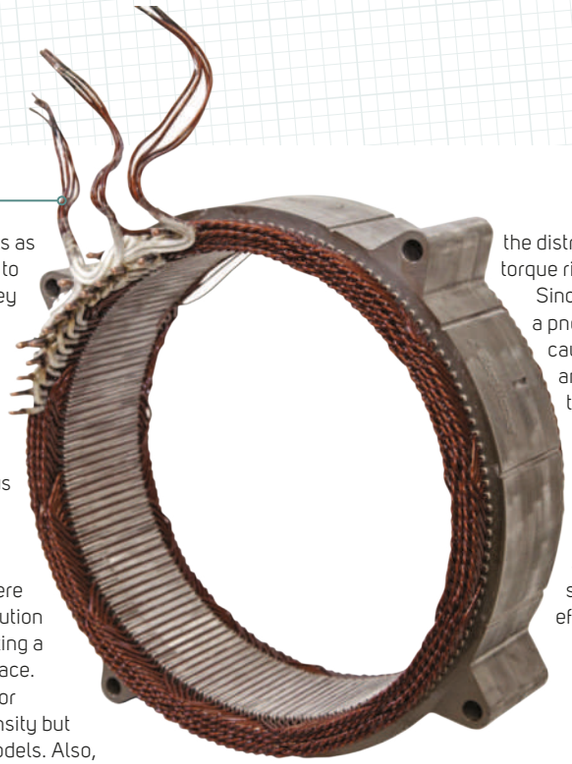
INQUIRY NO. 530

Wire forming technology



The industry is undergoing major changes as greater environmental awareness continues to drive the demand for clean technologies. Key to meeting this challenge is BorgWarner's S-wind wire forming technology for electric motors and alternators.

This innovative manufacturing process allows for the mass production of smaller and more powerful high-voltage electric motors with up to 350V, providing numerous advantages. Firstly, the technology will drive the growth of the HEV and EV market as, among others things, it facilitates high power density and saves space because there is less stress on the wire insulation. The solution is also suitable for P2-type hybrids, supporting a trend toward electrification that is gaining pace.

What's more, the company's S-wind stator delivers a more than 50% higher torque density but is nearly 30% shorter than conventional models. Also, the distributed winding facilitates cooling and reduces torque ripple for smoother rotation and lower NVH.

Since ordinary S-wind stators are formed using a pneumatic anvil punching process that may cause stress on the wire insulation, there was an increasing desire for an alternative process to maximize motor durability and reliability.

BorgWarner's engineers overcame this challenge by creating a forming process that minimizes stress on the wire insulation while eliminating additional stress during assembly. By allowing faster cycle times, reducing scrap and decreasing floor space needs, this ideal solution can help auto makers achieve cost-effective, high-volume production.

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INQUIRY NO. 531

Hybrid vehicle traction inverter

The WTI-Traction Inverter series from Curtiss-Wright Industrial's Arens Controls brand offers cutting-edge technology and an innovative design for hybrid and pure-electric applications. Operating with AC induction, PMS, and IPM type motor technologies, its major components – IGBTs, capacitors, filters and circuit boards – are all automotive-grade and certified to AEC-Q100, Q101 and Q200 to ensure electrical reliability and an impressive power cycle rating exceeding seven million.

High levels of self-protection are achieved with both current and transistor temperature measuring locally to the IGBTs, rather than with remote components. This delivers fast and accurate measurements, offering effective protection against adverse high-current conditions.

Advanced motor control algorithms using field-oriented control with space-vector modulation, combined with a 2-10kHz variable switching frequency, ensure a high operating efficiency and increased operation time. A fundamental frequency up to 1,000Hz enables WTI-Traction Inverters to drive high pole pair, high-speed motors, which are popular in hybrid applications. A torque motor control mode is also available for hybrid applications, speed mode for pure-electric applications, or DC bus voltage mode, in which the inverter can moderate adverse and damaging voltages from regenerative braking, and so on.

WTI-Traction Inverters offer a versatile connection to master control systems by either standard J1939 or customer-specific CANbus protocols. A customizable discrete interface also enables the support of digital, analog and solenoid-drive control options.

Other features include rugged, die-cast aluminum construction; 360-650V DC supply and 90-530KVA peak power; heavy-duty, automotive-grade components throughout; IP67/69K protection against ingress of liquids and dust; and rapid discharge of internal high voltages at shutdown.

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INQUIRY NO. 532

Precision metal forming

A J Rose Manufacturing, with two plants in the Cleveland, Ohio area, and one in Nasik, India, is a top precision metal forming company in the automotive industry. AJR specializes in powertrain products for either electric or combustion powertrain systems, including components for motors, engines, brakes, transmissions, differentials, converters, and more. Having been in business since 1922, AJR has amassed expertise, capabilities, patents, and more, enabling it to integrate this know-how with today's technological manufacturing systems.

AJR then utilizes premium raw material grades, enhancing this expertise and yielding virtually defect-free components for these critical functioning applications within the powertrain. The oncoming EV, HEV and newer combustion powertrains are bringing an entirely new range of precision metal formed products and capabilities, and AJR will be one of the few producers able to meet these new requirements.

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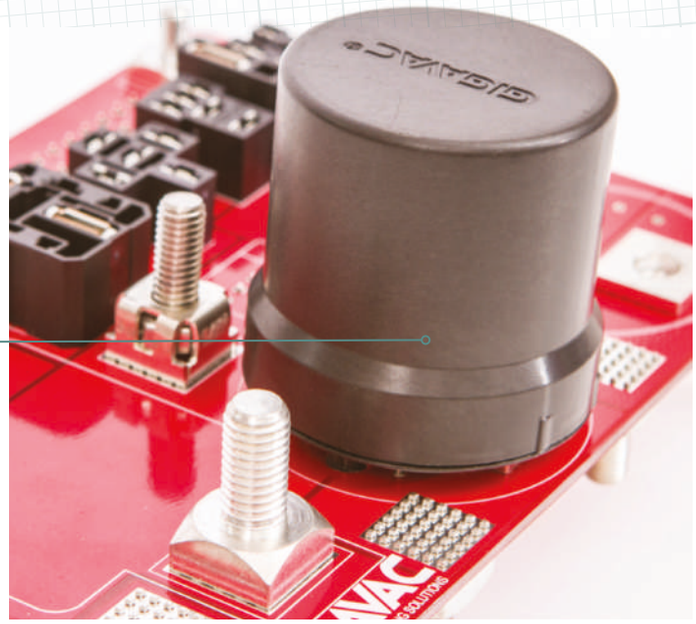
INQUIRY NO. 533

High-performance power contactors



Gigavac, a global leader in sealed switching solutions, has developed a unique series of PCB-mountable contactors to address the demand for lower cost, higher performance, smaller package solutions for today's HEV and EV applications.

These unique PCB contactors eliminate unnecessary wires, cables and bus bars, resulting in shorter build times, error-proof assembly and simplified designs. PCB contactors can be integrated directly into a BMS or ESS power distribution system. Rated for up to 1,500V and 1,000A, Gigavac contactors can handle most high-current, high-voltage applications such as precharge circuits, main battery disconnects, charging circuits, high-voltage junction boxes, and a wide variety of electric accessories. Due to their simplified packaging, PCB-mounted contactors can cost up to 25% less than traditionally mounted stand-up or side-mounted units.

All Gigavac contactors are hermetically sealed and exceed IP67 and IP69k, making them ideal for rugged environments and demanding applications. The sealed chamber inside each switch ensures there will be no internal contamination or contact surface oxidation over the life of the switch, which results in extremely low contact resistance. This provides a competitive advantage for performance-oriented applications.

Furthermore, all Gigavac contactors are designed from the ground-up to be orientation agnostic with high vibration and shock ratings. They can be installed in any position, even upside down, without a reduction in performance. Gigavac sales partners located around the world can provide local support.

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INQUIRY NO. 534

EV control software development

New Eagle, an engineering company specialized in control systems, is changing the way EV developers approach how they create production control systems for their machines.

For many developers, creating control systems is one of the most complicated challenges to overcome on the road to production. Selecting trustworthy hardware components and stringing them together with custom software can be time-consuming and tedious, leaving room for errors that could prove dangerous in end machines. With New Eagle's EV supervisor, developers can own the software and take control of their development process.

The EV supervisory software application guides developers in creating validated startup and shutdown sequences, torque management, component control and diagnostic strategies for their EVs. This helps developers navigate the process of creating reliable control system software more efficiently. The application can be customized by either the developer's team or New Eagle's team of ASIL-certified engineers for nearly any EV project, a perk that could help bring EVs to production faster.

"We hope that our EV software application, coupled with our ability to provide production hardware components and engineering support, will bring more EVs off the idea board and onto the road," says New Eagle president Rich Swortzel. "With our solutions, New Eagle is the one-stop controls production provider for today's needs."

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INQUIRY NO. 535

Oil management system for hybrid electric vehicles

Castrol's innovation business Nexcel is focused on adding value to hybrid electric vehicles, bringing the maintenance and sustainability advantages of its sealed cell oil management system to the sector. BP's 2018 Energy Outlook forecasts substantial growth in the number of cars worldwide to 2040, and commentators believe there will be an increasing proportion of hybrid electric vehicles along with a continued rise in the number of cars with internal combustion engines.

Nexcel's system provides a 90-second under-hood oil change, ideal for mobility-on-demand operators with a hard-working hybrid electric vehicle and customers to serve. Additionally the system reduces cold-start warm-up and CO_2 emissions by limiting the quantity of oil in the sump, appropriate for hybrid ICEs that run infrequently.

Re-refining used oil is a proven and sustainable way to preserve valuable feedstock, but with used oil being lost or contaminated with other grades or products, recovery rates are low. Returning sealed cells to Nexcel after use ensures a high-quality, uncontaminated supply of used lubricant for re-refining, overcoming a major drawback with the process and keeping used lubricant from entering the environment.

Looking to the future, hybrids will benefit from ICE packaging innovations, courtesy of Nexcel's ability in remote management of the oil system, meaning the ICE can be sited more innovatively, potentially freeing space for greater battery storage.

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INQUIRY NO. 536

Plug-in hybrid transit trial

Revolve Technologies is a UK-based company, world renowned for providing expertise in a number of low-carbon technologies. In 2017, Revolve was asked to join a consortium of partners to work on a multimillion-pound trial project, designed to help improve air quality in London as part of a global electrified vehicle push.

The project, headed by Ford Motor Company and the APC, and supported by Transport for London, features a 12-month trial of 20 new plug-in hybrid (PHEV) Transit Custom vans, in which Revolve offered program support, geo-fencing and vehicle telematics. The purpose of the project, supported by a £4.7m (US$6.4m) grant from the UK, is to explore how partners can contribute toward cleaner air targets, while boosting productivity for operators in urban conditions, and Revolve's engineering expertise was deemed essential in the fight to reduce emissions and costs in London.

Currently in its trial stage, since the completion of vehicle builds, Revolve's involvement with this breakthrough project consisted of the creation of geo-fencing technology plus datalogging abilities, which will ultimately be an invaluable resource for the future of low-carbon transport.

Electric and hybrid technologies is just one area of expertise offered by the Essex-based company, together with its state-of-the-art involvement in hydrogen systems, dual-fuel technologies and fuel cell range extenders.

This project demonstrates once again that Revolve is at the forefront of green technology, pushing boundaries for the deployment of low-carbon technologies.

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INQUIRY NO. 537

Rapid state-of-health evaluation

Chen Tech Electric (CTE), a battery test equipment supplier from Taiwan, is a pioneer in battery state-of-health (SoH) evaluation technology. The company developed a rapid and precise SoH evaluation solution in 2014, which has been used in several industry-leading EV/E bus makers and power tool makers. In the past few years, an abundance of test data has been collected from these applications. Several SoH evaluation templates have been created based on various battery materials, enabling the CTE solution to be used for efficient evaluation of all different kinds of batteries.

To ensure highly precise results, artificial intelligence (AI) technology has also been applied to CTE's solution. Thanks to the continuous input of test data, the battery SoH prediction model has become more accurate. Currently, CTE is looking for partners interested in battery SoH evaluation and second-life EV battery repurpose. By collecting more and more testing data from different batteries as well as application fields, CTE aims to provide a universal SoH evaluation model that can determine battery characteristics and generate precise results in an extremely economic way, thus enabling battery second-life applications.

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INQUIRY NO. 538

Enabling the electrification of drivetrains

Developments in automotive technology are ever more centered around the electrification of the drivetrain. Unsurprisingly, automotive OEMs and suppliers are constantly seeking ways to improve the overall performance of their xEV drivetrain architectures in order to achieve a higher conversion efficiency, reduced costs, lower weight, better thermal management and a higher power density.

In a power module, more efficient use of the power semiconductors is enabling more cost-effective solutions in traction inverter applications. To get the best performance out of the semiconductors, a multidisciplinary approach is required to address material science, new bonding and joining technologies, and innovative cooling technologies.

One way to meet the stringent performance requirements of power semiconductors is to develop a new power module technology platform. The Danfoss DCM technology platform is specially designed to match the technical requirements of automotive traction inverters and is based on market-leading technologies. This includes the Danfoss Bond Buffer, which combines sintered die attach and copper wire bonding, with transfer molding processes for a robust package; and liquid cooling technologies such as the ShowerPower and SP3D solutions.

The new automotive traction module platform can be effectively integrated into electric traction drives and covers power ratings above 200kW, making it applicable for various drivetrain architectures.

The DCM is a robust chip-independent technology platform designed for Si and SiC semiconductors. The system is well-defined, based on proven technologies, scalable and customizable to meet specific requirements.

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INQUIRY NO. 539

Battery-electric vehicle simulation

A BEV consists of numerous systems that have to be tested. These include the battery as the core of the BEV and its electric energy source, electric machines, various electric consumers, a torque manager, additional ECUs, and a serial regenerative braking system in addition to the conventional hydraulic braking system.

A vehicle drive often consists of one electric machine at the front and one at the rear axle. A serial regenerative braking system can be installed for energy recuperation. In development, many questions about the system could arise. How much torque needs to be transferred to the front axle and how much to the rear? How will this affect the vehicle's dynamics? How much of the braking force can be applied by the electric machine and how much by the conventional hydraulic braking system? The torque manager, a master ECU, deals with these tasks. It captures the driver's accelerator and brake pedal commands, and forwards the torque request to the ECUs that control the electric machines and serial regenerative braking system as required.

For this task, dSpace offers a BEV model for simulating various systems – including subsystems through to the complete BEV. An air-conditioning system is included as the electric consumer. An integrated battery charging station allows for additional tests, for example to evaluate the communication between the BEV and the charging station (in accordance with the CHAdeMO, ISO 15118, and GB/T 20234.2 standards).

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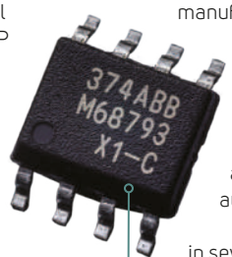
INQUIRY NO. 540

Fully integrated magnetic position sensor

Melexis has launched a next-generation monolithic magnetic sensor family, consisting of the MLX90371 and MLX90372, which provides robust absolute position sensing for automotive applications including powertrain actuators, pedals and gear shifters.

Both new devices consist of a Triaxis Hall magnetic front end, an analog-to-digital signal conditioner, a DSP for advanced signal processing and an output stage driver. Thanks to the integrated magneto concentrator (IMC) they are sensitive to magnetic flux in three planes (x, y and z). This facilitates the decoding of the absolute rotary or linear position of any moving magnet, enabling the design of non-contact position sensors. The MLX90371 offers analog or PWM output, while the MLX90372 offers SENT (SAE J2716 rev Apr 2016) or PWM output.



A key feature of both parts is the robustness against stray fields that are increasingly present due to the electrification of modern vehicles, especially in EVs and HEVs. By measuring a magnetic field gradient, the device is intrinsically insensitive to stray fields up to 4kA/m (or 5mT), which are the levels required by many major automotive manufacturers. Their ability to operate with a reduced magnetic field means that smaller and lower-cost magnets can also be used – ideal for space- and cost-constrained automotive applications.

The devices are available in several versions for rotary and linear motion sensing. A PCB-less dual mold package (DMP) is available for integration directly into an assembly without requiring a printed circuit board.

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INQUIRY NO. 541

Solar vehicle project

ElringKlinger has secured a high-revenue contract within the field of battery technology from Munich-based company Sono Motors. The purpose of the agreement is to develop and produce complete battery systems for a fully electric solar vehicle. The purchase order covers a total volume of several hundred million euros over a period of eight years. The start of series production is scheduled for the second half of 2019.

"In securing this contract, we managed to convince a next-generation OEM of the innovation and performance offered by our battery technology," says CEO Dr Stefan Wolf. "ElringKlinger will develop and produce a battery system at one of its domestic plants. This is an important statement of intent for Germany as a business location."

Sono Motors is pursuing an entirely new approach with its all-electric drive concept. The vehicle it has developed, the Sion, is positioned within the budget segment of the market and is targeted primarily at customers in urban areas. Its battery can be recharged either via the power supply grid or by means of solar cells integrated into the bodywork of the vehicle. This provides the basis for CO_2-neutral driving. What is more, the battery is also designed to provide energy – turning the car into a mobile power station. The battery system supplied by ElringKlinger is designed to give an actual range of 250km (155 miles). The vehicle is due to be launched on the market in the second half of 2019.

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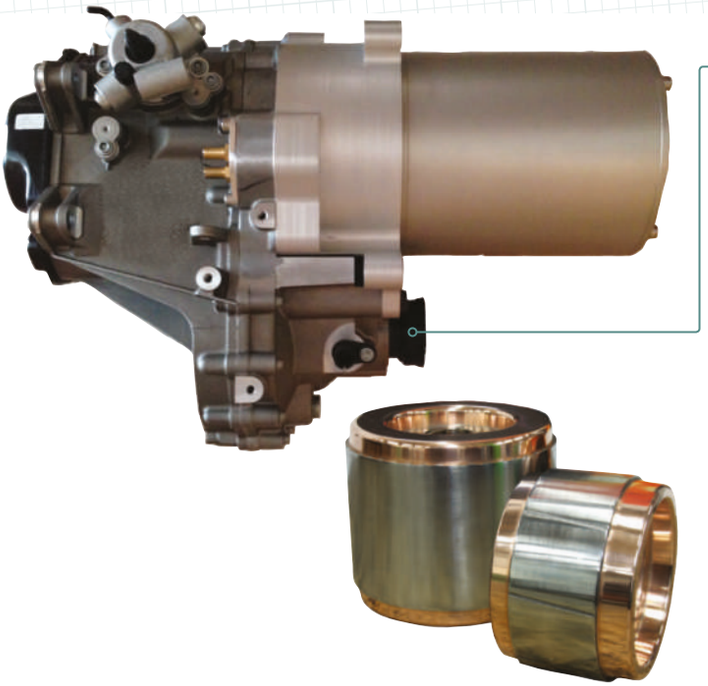

Pressure die-cast copper rotors for EV and HEV motors

Car manufacturers always look for maximum power from the smallest possible motor volume – most of them have turned to permanent magnet synchronous motors to achieve this goal. But this leads to a very high demand on the market, where the sources of the rare earth materials necessary to magnets production are highly concentrated in one country. This leads to strategic issues such as the uncertain long-term availability of rare earth permanent magnets and high cost volatility. Last but not least, the extraction process involved in obtaining rare earths is not environmentally friendly.

This makes alternative magnet-free motor architectures of great interest, and among these, induction motors with copper rotor is one of the most interesting, showcased as it is with Tesla and the Model S.

Since 2002, Favi has produced pressure die-cast copper rotors for high-performance induction motors, offering a reliable (more than two million copper rotors already produced) and affordable solution for high-performance magnet-free motors.

Favi is a Tier 1 automotive supplier, IATF TS 16949 certified, specializing in production of aluminum pressure die-cast components and subassemblies.

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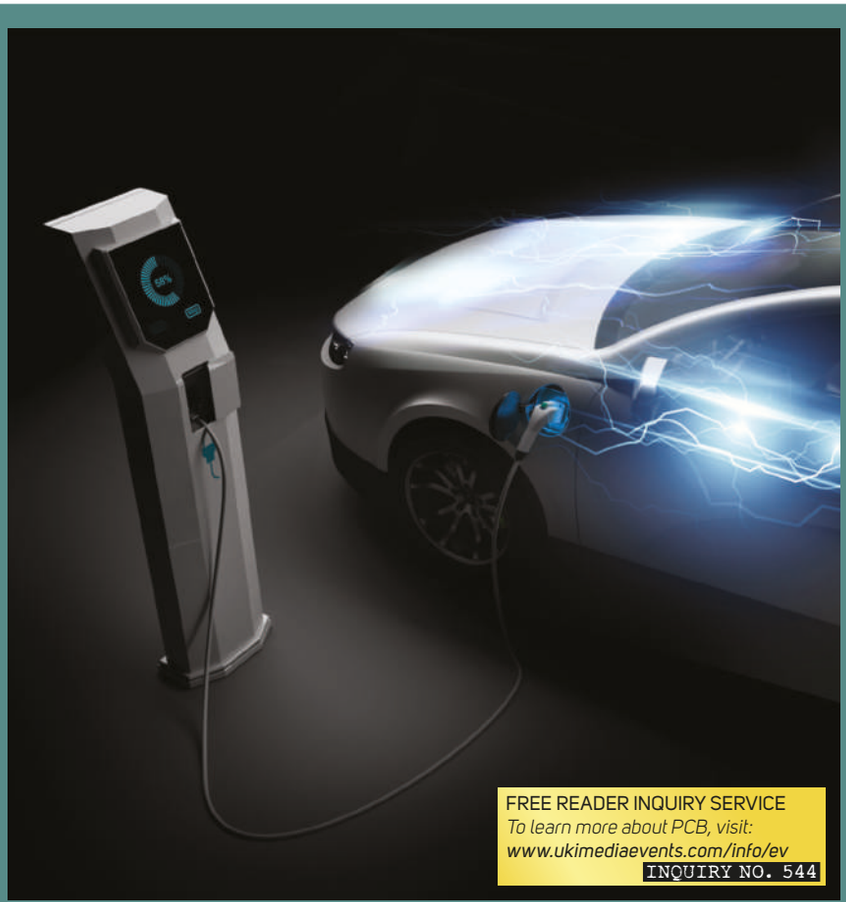
www.ukimediaevents.com/info/ev
INQUIRY NO. 543

NVH testing in electric and hybrid vehicles

PCB offers a wide selection of products for testing electric vehicles, hybrid electric vehicles and fuel cell vehicles, to meet all the demands posed by the rapidly changing engineering challenges of current and future technology.

Hybrid and electric vehicles present NVH testing challenges due to vehicle complexity, characteristics, and potential problems with electrical isolation. NVH issues related to the addition of new electrical devices, gear whine and vehicle resonances increase the number of NVH areas to be tested. PCB's broad line of accelerometers is engineered to meet these challenges, with ground and case isolation. These accelerometers are ideal for use in strong electrical fields generated by EV and HEV drive systems. Electrical isolation reduces noise in these fields and eliminates ground loops.

Noise sources are distinct between electric vehicles and conventional vehicles due to their different types of power. Electric vehicles have systems that contribute differently to the interior and exterior noise levels and quality. PCB's line of microphones is ideally suited for the task, featuring the precision needed to make accurate measurements in electric and hybrid vehicles. PCB's model 378A04, the industry's first pre-polarized low-noise microphone and preamplifier system, allows measurement of the extremely low amplitudes found during electric and hybrid vehicle testing. The ICP design significantly improves ease-of-use and lower per-channel cost when compared with externally polarized models.



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INQUIRY NO. 544

Li-ion ESS for public transportation and heavy-duty vehicles

Impact Clean Power Technology (ICPT) designs, develops and produces lithium-ion energy storage systems (ESS). ICPT delivers innovative solutions to the e-mobility, robotics, power industry and telecommunications sectors, and the company's core competencies and expertise are in modular construction, superior integrity, thermal management, control and safety.

ICPT is proud to present the first compact NMC and LTO Li-ion ESS for public transportation and heavy-duty vehicles. The UVES concept was developed, based on a modular approach. Battery modules can be connected in numerous configurations to match specific individual requirements of the EV. The UVES range complies with R100.2 UN regulations, which address up-to-date, demanding safety standards and extensive tests requested by modern public transportation. The compact dimensions of the ESS permits electric bus manufacturers flexibility as to the positioning of the system on board the vehicle – whether that's on the roof, in the engine compartment, or the floor of the vehicle. Climate conditions may become a challenge in various geographical locations. Therefore, ICPT's ESS may be equipped with cooling and heating options depending on the operation profile and individual requirements. ICPT can also equip its ESS with advanced telematics solutions to provide life information with key indicators available for the operator.

ICPT has been designing Li-ion batteries for over 12 years. Electric vehicles equipped with ICPT's lithium-ion ESS have driven more than 3,000,000km.

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INQUIRY NO. 546

Power management expertise in e-mobility

The boom in HEVs and EVs has increased the demand for high-voltage components and system solutions. Established manufacturers and startups in the e-mobility environment utilize the competence of Würth Elektronik ICS (WE ICS) in many projects. Besides products for 12/24V networks, the company develops components for high-voltage network architecture such as junction boxes, high-voltage power distribution units, or battery cells connection boards. With technical solutions ranging as high as 800V and hundreds of amperes, WE ICS engineers can work with customers to develop custom solutions, which solve the high-power distribution challenges that electrical vehicle designers are facing.

WE ICS can point to many strengths in e-mobility projects. The company's developments and expertise in press-fit technology and the processing of high currents on PCBs are a strong argument. Press-fit connections are thermally and mechanically superior to soldered and can be the basis for particularly stable systems in EVs. PCB-based systems enable a significant reduction in assembly time for such systems, making them economically efficient. They also enable cleaner integration, removing most of the cables needed to connect fuses, contactors and connectors.

WE ICS also benefits from many years of experience in automotive projects. For more than 20 years, manufacturers of mobile machines and CVs have relied on the company as a supplier of system solutions for signal and power distribution, control and display and operation of vehicle functions.

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To learn more about Würth Elektronik ICS, visit:
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INQUIRY NO. 545

Control and protection technology for charging

Aptiv (formally Delphi Connection Systems) claims to offer the ultimate in end-user safety for grid-to-EV/HEV vehicle charging with its new Mode 2 Generation 2 charge plugs, which are fully compliant with the new IEC 62752 standard, including Type B RCD protection. Offered throughout Europe by distributor TTI Europe, this sealed IP67 in-cable control and protection device incorporates residual DC current protection and thermal sensing capability to detect any abnormal overheating from the grid side.

Aptiv, as a leader in Mode 2 charge plugs, has already had its technology in use at multiple major OEMs. This new generation offers performance and reliability benefits that extend well beyond compliance with relevant standards.

Features include: vehicle interface according to IEC62196-2-2; EVSE provides restart in the event of power grid; dual thermo sensors in the grid plug provide superior overheating protection; and grid cord as required by country of use.

Devices are CE marked and rated at 240V with 6-15A (depending on country regulations.) Product options are available for all European markets, including specific country requirements. TTI brings a highly responsive supply chain and support team that can satisfy the demands of today's automotive industry.

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To learn more about TTI Europe, visit:
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INQUIRY NO. 547

Exploring new electrification performance potential

Electrification is transforming the automotive market. Radical redesigns of powertrain architectures are pushing the potential of EVs and HEVs to greater limits to deliver the level of performance customers expect, from longer range to faster vehicles enabled by higher speed bearings.

SKF has the expertise and support capabilities to help its OEM customers lead this change. Thanks to its proprietary digital simulation software and industry-leading test facilities, the company has the knowledge to help its customers explore entirely new dimensions of performance with confidence.

SKF has been partnering with some of the world's leading hybrid and electric powertrain OEMs since they first started exploring the technology. In collaboration with these customers, SKF can bring a high level of experience and knowledge to their solutions and a range of bearings built for these specific applications. This means customers can get to the most reliable answer faster, enabling them to build in increased performance in reduced development time.

One OEM was finding that traditional bearing designs were failing in tests because they could not handle the high speeds required in EVs. They needed a new design, fast. SKF developed advanced simulation software to optimize bearing component design for high speeds, resulting in a radically re-engineered cage design. SKF was then able to test the bearing using its aerospace test rigs. From design and validation to mass production took less than 18 months.

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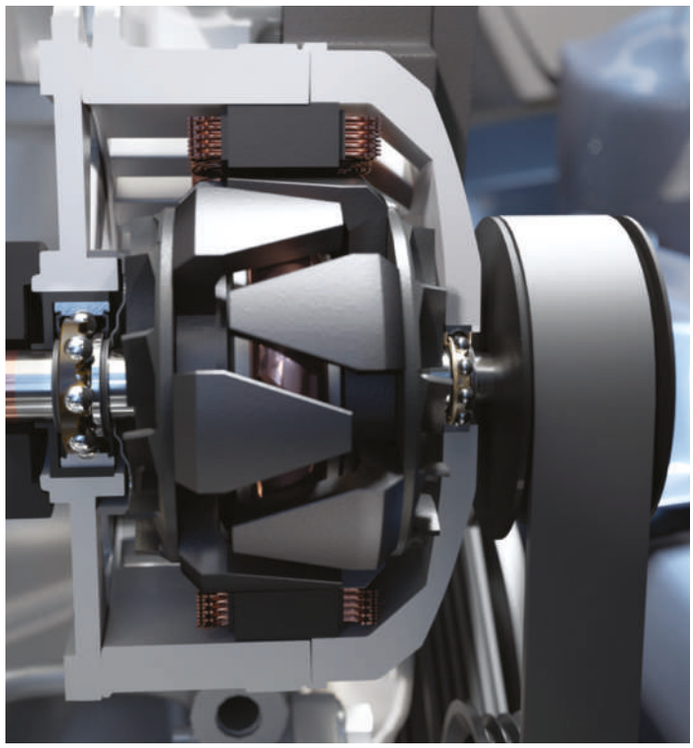


Total accessory electrification without added infrastructure

Vanner has a rich history in the bus industry. In 1984, when engine and transmission manufacturers introduced 12V electronic control on 24V buses, a device was needed to equalize the 12/24V batteries. Vanner invented and introduced the Vanner Equalizer which, today, is installed on the majority of buses and coaches in operation.

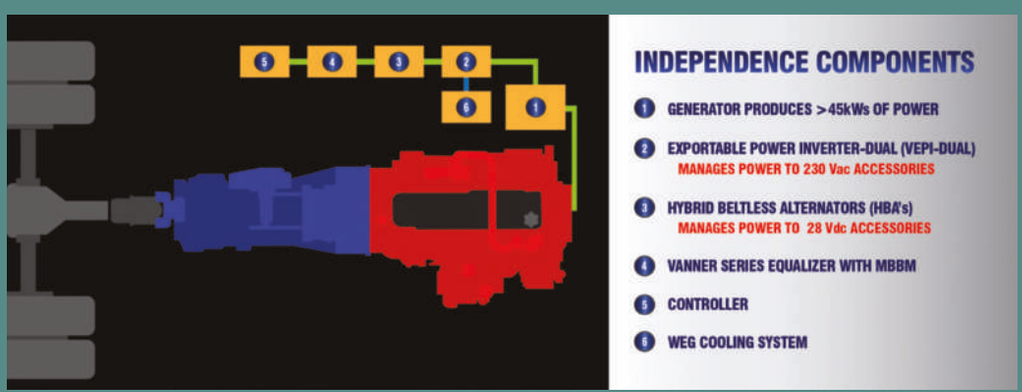
In 2010, Vanner introduced a 600V DC to 24V DC solid-state DC to DC converter for hybrid and battery electric buses. By eliminating belt-driven alternators, the technology was nicknamed the Hybrid Beltless Alternator – or HBA.

As a result of these technology breakthroughs, Vanner is now delivering total accessory electrification on hundreds of buses with Allison Hybrids to SEPTA, the Southeastern Pennsylvania Transportation Authority.

The company has continued to innovate. Understanding the significant challenge and expense of developing an electric bus charging system, and the associated operational range anxiety, Vanner developed Independence – an economic, compact, total accessory electrification system for CNG and clean-diesel buses.

This system completely decouples accessories such as the alternator, air-conditioning, power steering, and air compressors from the engine. This increases efficiencies by operating electric powered accessories independently of engine speed, thus decreasing fuel usage and emissions with the added benefit of lower NVH for passenger comfort.

Independence has successfully demonstrated total accessory power over 45kW (enough for a 60ft articulated bus) with efficiencies nearly equal to hybrids. What's more, independence greatly reduces operational and maintenance costs – and more importantly – eliminates the up-front infrastructure costs of an electric bus charging system and the need to replace expensive hybrid batteries.



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INQUIRY NO. 549

Modular testing concept for automotive test laboratories

Increased vehicle complexity and new power sources require advanced testing capabilities in the automotive industry. The demand for hybrid, full-electric powertrain and EV battery testing is rapidly increasing.

Proventia offers a modern and flexible approach with modular test laboratories and centers. Proventia Test Solutions enable customers to rapidly increase the capacity, change the setup at any time or expand the capacity in stages, without disturbing operations in other test cells.

As Proventia Test Units are manufactured and pre-commissioned before delivery, they are fast and convenient to deploy. This leads to a quick and optimized testing capacity increase for the customer. Each Proventia Test Unit is an independent test laboratory that can be equipped with a customer-specific combination of key equipment.

The competitive advantage of Proventia Test Units lies in the modularity. It offers the flexibility that today's continuously changing testing requirements demand. Proventia's scalable test center concept does not require heavy investment in the main building facilities. It allows the test center to grow step by step, spreading the investment over a period of time as the center grows.

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INQUIRY NO. 550

Hybrid drivetrain for motorsport and transportation applications

A recent project for a global manufacturer of a hybrid drivetrain for motorsport and transportation applications called for high-quality manufacturing expertise from HV Wooding.

The challenge on this particular manufacturing project was to develop a process for accurately stamping motor laminations 300mm in diameter using 0.1mm electrical steel. Parts were required to be burr-free with demanding tolerances of sub-20µm.

Following extensive supply chain and customer discussions, the complex geometry for the lamination profile was agreed and a prototype motor stack was produced using wire erosion for the manufacture. Once validation and testing were completed, the design and manufacture of a complex compound tool was undertaken by HV Wooding. Due to the complexity of the product, this included a fully integrated catcher unit that would automatically remove the part from the tooling to avoid damage. Final inspection was conducted on a contact CMM.

The development had a successful outcome, producing a high-quality lamination to specification, while at the same time providing the platform for next-generation product/motors, establishing a successful route of manufacture.

The technology has now been successfully introduced to the mass transit market, helping to reduce emissions and create a greener planet.

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INQUIRY NO. 551

Fuel cell and infrastructure development

Due to the heavy reliance on diesel fuel by trucks, buses and other heavy-duty vehicles, there is an increasing need for carbon reduction in the transportation industry. The good news is that there is a viable solution to reducing emissions – by converting to a fuel cell electric engine.

Hydrogen fuel cells are a clean fuel source. The combination of hydrogen and oxygen gas only emits water, as opposed to the harmful by-products generated by burning fossil fuels with ICEs.

Fuel cells offer a seamless transition from diesel to zero-emission with virtually no impact on service, range or durability. Heavy-duty fuel cell trucks will be able to travel long distances of 1,500km on a single tank of hydrogen. They will require no on-route refueling or charging infrastructure; they can drive their daily route and be fueled quickly, typically in less than 10 minutes. This is not a stretch – already today Hydrogenics fuel cells are moving passenger trains carrying 300 people over 1,000km on a single tank of hydrogen.

Fuel cells enable OEMs to get a step closer to reducing emissions. They have zero emissions at the tailpipe producing zero nitrogen, zero oxides and zero particle matter. Fuel cells operate quietly, reducing the level of noise pollution.

Hydrogenics, a global hydrogen technology company, is playing a critical role in the move to hydrogen-powered transportation, by providing both the fuel cells for hydrogen-powered vehicles and also the fueling infrastructure technology to advance it.

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INQUIRY NO. 552

Scalable and easy-to-use hardware interface for ECUs

Nowadays, all real-time application behaviors are simulated over a hardware-in-the-loop system. However, most of the available hardware-in-the-loop systems are quite complex, geometrically large and expensive due to diversification.

To improve this, MicroFuzzy has developed its own HIL product. The ISB14 is highly scalable, remote programmable, modularly designed and easy-to-use – for any electronic control unit (ECU) debugging.

The ISB14 – intelligent switch box – is a breakout box, designed to support integration tests and streamline the debugging phase of ECUs. The hardware includes several power modules with current and voltage sensors and can be controlled remotely via a software interface to regulate the power, switch clamp, or test configuration. The smart interface prevents all misconfiguration from the user, control power and bus-matrix features. The bus matrix includes a 106 relay matrix to connect or open the bus connection between ECUs and the restbus simulation tools.

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INQUIRY NO. 553

Electrical engine management

Vehicle electrification is drastically changing the automotive powertrain ecosystem. Engine management, an important added value in traditional IC-powered cars, is now moving to electrical engine management.

Inverters are playing a key role in managing the electrical power that is transmitted to the engine. Monitoring voltage and current in the inverter provides direct access to speed and torque parameters.

To address the needs of the market, automotive current measurement expert LEM has introduced the HAH3DR family. The new three-phase, galvanically isolated current sensor offers best-in-class performance for motor control applications.

The HAH3DR-S07 variant is born from a co-development between LEM and Infineon to fit perfectly in Infineon's HybridPACK Drive power modules. It offers a plug-and-play solution with best-in-class overall accuracy up to 1.75% over temperature, high bandwidth and low consumption.

The HAH3DR family offers a competitive advantage over alternative solutions with strong immunity to cross talk and phase shift. This high performance level is a key enabler for perfect torque monitoring in automotive applications.

LEM is now extending the family with new housing versions while working closely with OEMs, and inverter and module manufacturers in order to improve sensor integration, while continuing to provide best-in-class performance.

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INQUIRY NO. 554

Thermal management solutions

Lord Corporation's CoolTherm brand is the company's latest advancement in thermal management and blends high-performance thermal interface materials with Lord Corporation's world-class service and support. The company's thermal management portfolio is recognized for its reliability and custom solutions for use in electric vehicles, energy storage systems, motors and other power electronics. Lord's CoolTherm brand blends highly responsive technical expertise with a leading portfolio of thermal management technologies, delivering tailored products for managing heat issues and increasing power density.

Lord CoolTherm products include potting and encapsulation, gap fillers, structural adhesives, gels and greases. They are offered in a variety of customizable thermally conductive chemistries including: silicones, epoxies, urethanes and acrylics, to meet customers' performance, cost and schedule targets.

Not every heat problem can be solved with a standard, off-the-shelf solution. Lord Corporation works closely with its customers to meet their very specific application and design needs. It aims to solve not only the customer needs of today, but also those of the future, with quick-to-market, expert solutions. The company's portfolio of thermal management solutions is tailored to its customers' every need.

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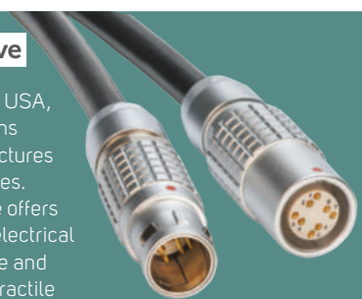
INQUIRY NO. 555

Connector and cables for automotive



Swiss company LEMO has been manufacturing electrical connectors for more than 70 years. The circular connectors are adapted to automotive testing tests, which are run in the development phase of car manufacturing. LEMO also offers a wide range of high-quality push-pull connectors for CANbus and Ethernet communication (CAT6 and CAT6A). In addition to connectors, LEMO can also offer cable assembly solutions and cable harness design with the help of Northwire cables, a LEMO Group company based in the USA, which designs and manufactures custom cables.

Northwire offers a choice of electrical vehicle cable and CoilBoss retractile cords that are compatible with charging applications, whether it be at residences, commercial establishments, parking facilities, or dedicated charging stations. These cables can be used, for example, in electric and hybrid vehicles. Northwire's custom EV cables are engineered to withstand harsh environments and high temperatures (up to 105°C). These cables are also resistant to abrasions, crushes, oil, chemicals, ultra-violet rays, weld flashes and weld slags.

Suitable for wet locations and compliant with RoHS2, Northwire's EV cable is UL 62 listed, compatible with SAE J1772 connectors as well as UL 2594 and NEC 625 charging systems. FT2 rated, Northwire's 300V and 600V EV cable is non-marking and available with standard straight or retractile options and custom configurations that include composite designs, custom colors and private labels. Jacket material options include TPU, PVC and TPE.

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Electric and hybrid vehicle strategy source code

Recognizing that many organizations have a need to quickly develop new electric and hybrid powertrain concepts as the market for these types of applications heats up, Pi Innovo has developed a full set of vehicle supervisory control applications that are available as Simulink source code. These control models have been proven on multiple vehicle applications, to showcase new proof-of-concept electric and hybrid drivetrains, as well as full production electric and hybrid electric vehicles.

The control models that are provided are configurable for different powertrain architectures, and have been developed with functional safety in mind, having been used in an ISO2626 ASIL-D development project. AUTOSAR has also been considered in the architecture of the control features to provide the maximum possible flexibility. The model-based approach, Pi Innovo believes, is the most straightforward way for most development teams to quickly get a new concept running. Full access is provided to modify the control algorithms within each of the features making up the overall control strategy, and each feature comes with detailed documentation describing the requirements against which it was developed. Overall system architecture diagrams are also provided, along with traceability tags that are helpful when moving beyond the proof-of-concept phase into production development.

This software IP can be acquired for a one-time license fee, and is developed in native Simulink and therefore hardware agnostic. Pi Innovo can provide engineering support services for prototyping and production development, as well as rapid controls prototyping hardware from the OpenECU product range.

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INQUIRY NO. 557

Testing expertise

The testing and verification of high-voltage batteries used in EVs and HEVs is a typical application requiring modern testing systems. Whether it be performance, lifespan under defined loads or environmental conditions, the documentation of charging and discharging processes or resistance measurements – the systems used not only need to deliver the usual standards of measurability, reliability and reproducibility, but must also be cost-effective, safe and flexible. Innovative technology and short delivery times are necessary to defend a leading industry position, and Heinzinger is well-prepared to cope with these increasingly demanding situations.

Heinzinger's ERS series has been successfully used for more than 10 years in sophisticated testing processes. The portfolio includes different bidirectional DC sources in all power classes. With special software packages, such systems can realize all applications for battery test and simulation.

The latest development from Heinzinger is a power output stage with voltages up to 1,200V, currents up to 1,200A and a power of up to 1.2MW in parallel mode.

A compact system for 48V applications is also coming soon. Its strengths will be its dynamics and smart software functions. By the end of 2018, a full product range will be available, later followed by a test sequencer, a function generator and predefined sequences according to LV-148. The primary technical data is 60V output, 400A continuous current (500A peak) and power of 20kW.

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INQUIRY NO. 558

High-voltage power distribution

E-mobility is playing an increasingly important role in the design of new-generation commercial vehicles, including trucks, buses, construction and working vehicles. The move to electric drive systems brings a number of environmental advantages, but also poses some major challenges with handling high onboard power and charging currents, and meeting stringent safety requirements under possibly harsh operating environments.

Kissling is a leading manufacturer of high-quality and robust components and systems for power switching and distribution in all types of heavy vehicles. Building on decades of experience with power distribution, the company has developed both specialized switching components and complete power distribution systems covering the 480-900V range current used in the heavy vehicle e-mobility market segment.

Kissling is the first manufacturer to produce a HV relay based on a non-gas-filled ceramic contact chamber in combination with blow-out magnets to solve the typical arcing problem in HV contactors and provide better long-life safety performance. The HV relay is able to switch 15,000 times under full load of 500V DC at 300A without risking a gas leakage.

Kissling has also developed market-leading high-power press-fit PCB technology for use in HV power distribution units. By replacing conventional cable harnesses with high-power PCBs (up to 1,000A continuous) and replacing solder connections with low-resistance press-fit (cold-weld) connections, the company offers highly reliable power distribution solutions for vehicle manufacturers. These solutions are generally custom designed for customers' application and Kissling's team of experienced engineers is prepared to work with specific requirements.

Kissling's solutions are in use today in trucks, buses and a wide variety of military and specialized vehicles all over the globe.

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INQUIRY NO. 559

Dataloggers for EV powertrain and battery validation

The latest datalogger software generation from Ipetronik, IPEmotion RT (real time), is supporting the validation of electrical and hybrid vehicles. Due to the modular datalogger's hardware and software architecture, the system is designed to cover a wide functional spectrum for the field validation of components such as electrical drives and gear systems, battery thermal management, and the simulation of passenger compartment HVAC systems. The unique plug-in concept is able to integrate with, aside from the ruggedized Ipetronik module, almost any third-party data acquisition hardware. The Linux 64 bit-based IPEmotion RT datalogger software records ECU vehicle bus data across different transportation layers such as CAN, LIN, Ethernet and FlexRay, along with low- and high-speed analog measurements in a synchronized single file format. Data formats standards such as TDM, MATLAB, MDF4.1, BLF traffic are covered too.

In regard to electrical vehicle applications, the loggers are frequently used to monitor unplanned discharging processes when the vehicle is in stationary mode. The whole vehicle network needs to be monitored to analyze the root causes for parasitic undesired energy losses due to unplanned inter-ECU communication. Battery power drainage is experienced not only during long-term parking, but also on overseas transports on ships.

With the Ipetronik datalogger toolkit, these types of problems can be easily analyzed. However, the loggers are also a particular useful toolbox when users would like to run MATLAB Simulink models in order to collect the data directly processed, saving a lot of post-processing time.

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INQUIRY NO. 560

Test systems for climate chambers

Kübrich has more than 15 years of experience with door slam systems for fatigue and durability testing in climate chamber usage (-40°C to +85°C [-40°F to +185°F]), end-of-line test solutions, and test solutions for the complete e-mobility vehicle generation.

Thanks to its Actere software, Kübrich has come up with a turnkey system individually designed for laboratories or test facilities. The company has developed a complete actuator and robot program for endurance and durability tests focused on climate chamber usage. All Kübrich systems are designed to simulate lifetime testing, enabling up to one million cycles.

Testing of components such as starter generators, e-drive motors and complete e-drive units has become a major part of Kübrich's operation, as well as component testing for autonomous drive systems development. All components interfaced with the Actere testing software allow users to create their own test sequences, displays and reports.

The DuT (device under test) module enables a wide range of measurement possibilities and simulations via CANbus or LINbus, and for climate chamber usage. With the company's latest development – a starter generator test stand for 48V systems – Kübrich continues to innovate.

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INQUIRY NO. 561

Breakthrough charger technology

In 2015, when Medatech Engineering Services began developing its AltDrive powertrain, it realized that there was a significant gap in the power electronics available on the market.

Medatech sensed the urgency to make onboard electronics available with a capacity of delivering high-voltage DC to the batteries using a 480-575VAC supply. "In the context of mining machinery, we already had a 480-575VAC supply readily available and wanted to provide each piece of equipment onboard electronics to charge the batteries from substations anywhere in the mine," says Robert Rennie, president of Medatech. He further observes, "A few suppliers were using IGBT technology and we were having limited success with the electronics and needed a higher power solution."

Driven by marketplace demand, Medatech decided to forge a partnership with Bel Power Solutions to develop a first-of-its-kind onboard charger. "We developed our own 25kW charger believing that the industry would eventually move toward higher-powered systems. This is just one example of how we are investing heavily in technologies to support our AltDrive system," says Rennie. According to Medatech, it has the most power-dense charger in its class today, which is half the size of the predecessor, delivering 20% more power.

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Despite finally hitting its weekly target production rate of 5,000 units of its mass-market Model 3 EV, the pressure on Tesla and Elon Musk remains high

Burning out?

It was Lao-Tzu, an ancient Chinese philosopher and writer from the sixth century, who said, "The flame that burns twice as bright burns half as long." What a brilliant, insightful and powerful saying.

And when you think about it, it perfectly suits electric car maker Tesla. At the end of June, the Californian organization marked eight years of being a public company, but in its current guise, who would bet on Tesla being around in another eight years?

That sounds like an extraordinary question to pose, but personally, I think it's an important one.

Putting aside (for just one moment) all the well-documented internal troubles Tesla has faced recently (and we'll get to those shortly!), the big high-impact blow that's about to land nose-on will come from those that have watched enviously in the shadows.

WORDS: **DEAN SLAVNICH**

As Model S went from strength to strength, the likes of Daimler, BMW, Porsche, Audi, Volkswagen et al. couldn't believe Tesla's supersonic EV trajectory. And they all thought: "We need a piece of that!"

So, coming very soon to a showroom near you will be BEV products from all the above. And not only will some of them match (actually probably exceed!) Tesla's famed performance offerings in terms of range, power and acceleration (I'm especially thinking here of future Porsche developments in addition to the Taycan), all of these car makers will roll out EVs that are 100% glitch-free, are assembled flawlessly, and work, in essence, as well as their IC-engined counterparts. And if that's not a big enough blow to Tesla, having the know-how and experience to meet demand means Daimler, BMW, Porsche, Audi, VW and the rest will produce these BEVs without any trouble and angst. They will flood the market with all kinds of BEV derivatives and offshoots as Tesla struggles to keep pace.

So those are the external worries. But making it worse for Tesla is what's happening within. Looking from the outside, it seems like the company is imploding.

I have said before that out of all the chief execs I've been lucky enough to interview, Elon Musk was the most presidential. When he walked into a room, he owned it; when he spoke, everybody listened. What a guy. Now, though, he looks broken. And for me, he's not helping matters.

Until very recently, the company had failed to meet Musk's own target (which had been revised a few times over) of producing 5,000 Model 3s per week. It's been a long road to get to such a point, and the question is, can Tesla maintain such a production rate?

A tired-looking Musk gave a most insightful interview with US media earlier this year, admitting to sleeping at the factory to save time. I could never see the leaders of, say, BMW and Daimler doing this, but even if they did, they'd certainly not make it public!

Much like the production of Model 3, Musk gets bogged down in a mire of trouble on Twitter. And again, looking from afar – and that's an important point as I am a mere observer here – people seem justified in questioning whether boy wonder is losing the plot. He has recently accused a former employee of sabotage and, perhaps the lowest point yet, he has indicated he wants to create a website that allows people to rate the credibility of journalists and news organizations. Ouch.

Tesla entered the auto industry as the brightest of bright sparks, ripping up the rulebook and almost single-handedly powering the EV movement forward, influencing industry, governments and consumers. It was – and still is – one of the great modern-day automotive pioneers. But, I just can't help coming back to Lao-Tzu's adage.

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