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An example of a thermal analysis of an 18-650 cell-style lithium-ion battery module before and after adding thermal management methods.



Cool solutions

AKG RESEARCHES BATTERY COOLING TECHNOLOGY. BY **CHAD ELMORE**

the battery fails, there will be a significant impact on productivity. For electrification to have

a real chance in these machines, battery performance must be very stable. That's the area we're focusing on. We will offer our customers a highperformance thermal management system for the entire machine, including the battery."

CONSISTENT TEMPERATURES

The company said its goal with the university-based study was to find a solution to keep the average temperatures of individual cells between 15 and 40° C. Along with maintaining an ideal temperature range, it said keeping that small temperature gradient across each cell would further improve battery life.

"When you have battery cooling that's not consistent from cell to cell, then you have cells operating at a higher temperature than others in the same pack," said Rankin. "And when they operate at a higher temperature, they can wear down faster. Those cells will put more load on the other cells in the battery pack, so you get a cascading effect that leads to the failure of the battery."

For best results, the battery pack must maintain a consistent temperature to ensure each cell has the same lifespan. "The cell facing the highest temperature is the leading cell for the aging process of the entire battery pack," said Haugg. "If you have two or three cells within a battery

ctive and passive cooling is becoming increasingly important in electric vehicles because of the charging speed and power density of lithium-ion batteries. In order to be ready with solutions, engineers for cooling system specialist AKG are deep in R&D mode. The company recently collaborated with two German universities, FH Aachen (University of Applied Sciences) and research university RWTH Aachen, to find the right combination of cooling technologies for a 48V highpower battery module.

"We specialize in engine and hydraulic cooling systems, but we've recognized that hybrid and electric vehicles have some unique cooling needs of their own," said Matt Rankin, director of New Product Introduction and R&D at AKG of America, Mebane, N.C. "At this point, we're partnering in our research efforts to find the best solutions."

"One of our biggest markets is off-road applications, and for these applications there will be battery electric vehicles and hybrid vehicles in the future," said Albert Thomas Haugg, head of New Developments



An example of one of the options for cooling pouch-style battery packs.

at AKG Thermal Systems' headquarters in Hofgeismar, Germany. "In hard-working machines, the performance of the thermal management system is very important. If you have a combine, for example, and



pack with a higher aging rate, the entire battery pack will have a reduced lifetime. By homogenizing the temperature differences between the various cells within one module, we can significantly increase the performance of the battery pack, especially during fast charging cycles. Our overall objective is to double the lifetime of a battery pack."

CFD AND FEA

The research employed computational fluid dynamics (CFD) and finite element analysis (FEA) to test various configurations. The company found that by using active cooling with water-glycol on the sides of each cell and passive internal cold plates, both the maximum temperature and the temperature gradient could be managed reliably and cost-effectively. It also found that the use of fill material improved the heat transfer from the battery to the cooling system, further enabling the design to exceed its goal.

For more than 25 years, AKG has offered cold plates, brazed aluminum liquid-

cooled heat sinks, to help protect sensitive electronics from heat. Cold plates will form part of the heat management system for a battery electric vehicle, said the company.

Electric vehicle systems already reduce thermal rejection when compared to internal combustion engines. Electric motors have an efficiency of as much as 90% and lithium-ion batteries have an efficiency of around 80%. Unfortunately, that efficiency can complicate things when it comes to heating a wheel loader's cab or batteries during a frigid northern Minnesota winter.

"To solve that challenge, we've developed storage systems to capture the heat that's available," said Haugg. "We also need a heat pump system to cool and heat the cabin. There will be some heat released to the ambient and there may also be the reverse. For example, on a hot



A computational fluid dynamics analysis of a pouch-style battery with liquid cooling at two different power levels.

day some heat can be extracted from the ambient and made usable in the machine. The thermal management system of a fully battery electric machine is significantly more complicated than one with a diesel engine.

> "Through our various research projects, we are analyzing how to best optimize this, and it must be optimized not only in thermal performance but also in production costs. We've seen very high interest from our customer base, and our next step with two major projects is to build prototypes for further testing."

BEYOND BATTERIES

While batteries are typically the focus during a discussion of thermal management systems in fully electric vehicles, Rankin cautioned there are also other components that will require cooling, as well. "For example, the electric motors and inverters that manage the voltage are typically cooled, and many vehicles have onboard charging systems that also require cooling. Plus, if it happens to be a construction machine, there will likely a combination of electric and hydraulic systems. They may still need cooling for the hydraulics and the transmission, further complicating the design." NPP

AKG said its constant monitoring of market trends and its continuous work toward new solutions have resulted in a series of forward-looking products for the company. It is now working on the development of cooling solutions for electric vehicles.

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Designed for electric BMW GROUP SUPPLIES E-VEHICLE TECHNOLOGY

BMW GROUP SUPPLIES E-VEHICLE TECHNOLOGY, PRODUCTS BEYOND AUTOMOBILES. BY **CHAD ELMORE**

he ever-expanding world of electric commercial vehicles has given product development teams a new selection of technology partners from which to choose – some new while others are wellknown brands in new roles.

As a case in point, Motiv Power Systems, a 10-year-old company that supplies electric drivetrains to the truck and bus industry, recently signed a supply agreement with BMW Group, a century-old German firm better known for luxury cars and motorcycles, to integrate its lithium-ion battery packs into Motiv's EPIC (Electric Powered Intelligent Chassis) medium-duty chassis.

"When Motiv specs a battery for a chassis, we are looking for factors that matter most to our end users. These include initial cost, reliability over time, and end-of-life replacement costs," said Jim Castelaz, founder and CEO, Motiv, Foster City, Calif.

"With BMW's latest version of its lithiumion packs, commonly found on its all-electric i3 passenger cars, we were able to find a compelling battery solution that checks all those boxes," said Castelaz. "BMW's lithium-ion batteries are well suited for use in commercial fleet vehicle deployments because they represent millions of real-world miles globally – meaning they have seen every potential road condition that Motivpowered vehicles are likely to encounter – and have proven to be both dependable and reliable."

The Motiv chassis that use batteries from BMW i, a brand within BMW Group,

will be available across a range of vehicle applications including walk-in vans, box and work trucks, shuttle and school buses and trolleys.

The BMW i brand focuses on future vehicle concepts that center on sustainability. It is already present in 74 countries with the BMW i3, an electric car designed for urban environments, as well as other automobiles.

"Our industrial clients welcome the usability of the ready-made technology that BMW i components provide, as well as their durability. All of this is evident in well over 100,000 BMW i model sales worldwide," said Uwe Breitweg, head of BMW Group Drive Systems for Industry Clients.

TECHNOLOGY INCUBATOR

BMW i iseeks new business opportunities on behalf of the parent company and serves as an incubator for technology solutions that could later be transferred to the parent company. The brand is already at work in the public transport sector: last year BMW and Karsan signed a supply agreement for motors and batteries to be used in the latter's new electric city bus.

"Collaboration with the BMW Group enables us to meet our customers' needs in the electric vehicle segment, too, as well as helping us take a major step forward in our transformation to becoming a supplier of sustainable mobility solutions," said Okan Baş, CEO of Karsan, based in Bursa, Turkey.

"Electric motor vehicle technologies are very important for us and we continue to develop our co-operations in this field," he said. "In this context, we produce public transport solutions that can be used all over the world by incorporating the power of the electric drivetrain from BMW, which is one of the leading automotive brands of the world. Our goal is to be the most valuable company in our country in its class and the preferred supplier in global markets."

The Jest Electric, a fully electric city bus that was designed and built in-house by Karsan, is powered by a BMW electric synchronous motor rated 125 kW/170 hp with 250 Nm of torque. Energy is supplied via a lithium-ion battery that consists of eight modules comprising 12 cells each that provide a capacity of up to 44 kWh. With two high-voltage batteries, prototypes of the Karsan Jest Electric achieved a capacity of 88 kw hours and a range of 210 km/130 mph. When used on scheduled services, the city bus can reportedly run for 18 hours without a recharge.

BMW said the compact size of the motor and battery were also advantageous in terms of interior space. Just 18 ft/6 m long, the Jest Electric has room for up to 26 passengers – four more than a conventionally powered version of the bus.





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Designed and built in Turkey, the Karsan Jest Electric is a fully electric city bus powered by an electric synchronous motor and lithium-ion batteries from BMW.



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The Jest Electric was proven by BMW engineers on its Maisach, Germany, test track last year. "Jest Electric achieved impressive results in the tests and got full marks," said Muzaffer Arpacıoğlu, deputy general manager for Commercial Affairs, Karsan.

BMW i's electric vehicle technology can be found in other products, as well. It has supplied lithium-ion batteries to Streetscooter GmbH, a subsidiary of Deutsche Post DHL Group that provides trucks that are purpose-built for delivery operations. Batteries developed for the i3 also supply energy for electric boat drives from Torqeedo.

BMW Group said the increased demand for applications beyond its own electrically powered vehicles and plug-in hybrids highlight the universal character of BMW i and its holistic orientation toward sustainability. It said the company's expertise with electric motors and high-voltage batteries can be used in a wide range of products and applications.

An engineer for Motiv Power Systems takes a reading from a battery pack in the company's Foster City, Calif., shop. Motiv is sourcing its lithium-ion batteries from BMW for its 2019 EPIC electric chassis which is primarily used for commercial trucks and school buses.



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product offering, an integrated inboard electric propulsion system for larger and heavier boats.

Launched in 2005, the German company has focused on bringing electromobility into the traditionally conservative marine industry. Starting small with low-powered lightweight outboards for canoes, kayaks, dinghies and small runabouts, the company has steadily been moving the needle upward into higher-powered electric and hybrid systems for bigger boats. Torqeedo was acquired by Deutz last year.

This year, Torqeedo made another technology leap with the introduction of the new Deep Blue 100i system, which it said is the first fully integrated inboard electric propulsion system for larger planing and displacement vessels, featuring a major improvement in power output and energy storage.

At the heart of the system is a Deep Blue 100 kW direct-drive electric motor, which the company said has twice the power output of its predecessor. The product is offered in high-speed and slow-speed versions. The 2400 rpm model is designed for fast planing motorboats, producing 390 Nm continuous torque across the entire rpm range. The company said test results have revealed an even faster time to plane than an equivalent internal combustion engine.

The slower-speed 900 rpm version, with a continuous torque of 1000 Nm, delivers the low rotational speeds needed to power displacement hulls. Torqeedo said its direct-drive design provides maximum efficiency and silent operation with minimal maintenance requirements.

The new Deep Blue 40 kW motors are paired with the latest in automobile-grade lithium-ion battery technology from the motor works of BMW, extensively marinized by Torqeedo for safe operation in the marine environment.

DEEP BLUE PACKAGE

With 40 kWh capacity, the new Deep Blue batteries provide a 30% boost in energy storage over the previous version with no increase in footprint, said Torqeedo. It can be charged to 75% capacity in as little as 1.5 hours from a properly equipped shore power source, the company said. Torqeedo's CEO Christoph Ballin said that in designing the new-generation Deep Blue package, the company took a systems-based development approach, which he said is critical for advanced marine electric and hybrid propulsion.

The motors, batteries, chargers and controls are engineered to fit into a fully integrated, modular and scalable propulsion and energy management system, he said, while the cockpit control console gives the operator a clear picture of system status at a glance, including range, speed, state of charge and revolutions, as well as the energy balance of the entire vessel, showing overall power consumption, including all 24V house loads served via DC/DC conversion.

For range extension, the Deep Blue hybrid system includes a small DC generator that can keep the batteries charged when underway. The system can also pull power from renewable onboard sources, such as photovoltaics or hydrogeneration.

In recent months, Torqeedo also announced several upgrades across its full line, including a new mounting system for its Ultralight 403A kayak outboard, a new direct-drive 1.1 kW Travel 1003

outboard and a new higher-capacity 24V power battery with an energy density of 138 Wh per kg.

Torqeedo has introduced the new Deep Blue 100i system, an integrated inboard electric propulsion system for larger planing and displacement vessels. The heart of the system is a Deep Blue 100 kW direct-drive electric motor.



Electromobility at

COMPANY TAKES FULL-SYSTEM APPROACH, LEVERAGES VOLVO GROUP TECHNOLOGY. BY **CHAD ELMORE**

ith the mobile on- and offhighway equipment industry looking for ways to meet the latest diesel emissions regulations while also investigating their options in electric powertrain technology, Volvo Penta has been working on solutions. Recently, the company showed its latest powertrain products in cities as widespread as Bologna and Shanghai. Attendees of the giant 2018 Bauma China construction and mining equipment show in Shanghai, for example, could learn about the manufacturer's latest diesel engines as well as a transmission for an electric vehicle.

The electric driveline on display in the company's stand was based on bus technology developed by Volvo Group — the company has reportedly delivered more than 8000 hybrid and electric buses since 2010. When collaborating with engineering teams at original equipment manufacturers (OEMs), it can leverage proven platforms developed by Volvo Group to create electromobility solutions for a wide range of applications.

Volvo Penta has pledged to offer electric drivelines across its product range by 2021, buoyed by advances in electricdrive technology and improved battery capacity. To achieve that goal, it is growing its electromobility department while also working in close partnership with OEMs.

"We are engaging with customers quite early in the development process to learn and to mutually benefit from this development work," said Niklas Thulin, electromobility director, Volvo Penta, Gothenburg, Sweden. "For many of our customers this is their first electromobility product. We want to learn together, and in some senses it's a new way of working together. We will engage earlier with customers when we explore these new technologies."

PROOF-OF-CONCEPT

While the driveline platform has been proven in thousands of bus applications, Volvo Penta's first internal proof-of-concept work was a hybrid terminal truck. The powertrain was comprised of a 120 kW electric motor, a 5.2 kWh lithiumion battery pack and a Volvo AMT gearbox. The truck was tested in ports around Gothenburg and logged performance comparable to a conventional diesel truck along with a 30%

Volvo Penta showed an electric vehicle transmission alongside its diesel engines at several exhibitions recently, including the 2018 Bauma China construction and mining equipment show. A terminal tractor equipped with a battery electric system developed by Volvo Penta.

reduction in fuel usage.

For electromobility customers, the company said its strategy will be to deliver the complete powertrain, which it said will help ensure the system is safe. It also means OEM engineers have a single point of contact with their e-drivetrain supplier.

"We believe that's how we can help our customers get electrified the quickest," said Thulin. "That's also how we can ensure that the safety solutions we have already developed for the trucks and buses are in place. For example, such as how we measure isolation and detect isolation faults in the system and how you check the integrity of the high voltage system when you start up the machine. We also have proven procedures for how one decommissions the machine's electrical system before it gets worked on in the field."

Thulin's title is new for the company, although he has worked on electromobility



Volvo Penta

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Rosenbauer Intl. and Volvo Penta have signed a supply agreement to develop an electric driveline for the Rosenbauer Concept Fire Truck, the company's first electric fire truck. It's scheduled for 2021.



solutions for Volvo Group since 2004. He joined Volvo Penta less than two years ago. "The market was starting to ask for this technology in our industrial and marine segments," he said, "and we saw a good opportunity to apply the technology we had developed in a new context.

"During the two years I've been at Penta, many of our bigger engine customers have really matured guickly, going from being curious about electromobility to asking for products and creating their own programs. The awareness in the industry and among customers is much greater today because people have practical experience with electric bikes or with electric cars. People are more aware and less afraid of the technology now, compared to a few years back. The acceptance is much higher. That, in combination with higher climate ambitions in many countries or specific regions and cities, is helping drive the need for zero emissions technology, as well."

FERRIES AND FIRE TRUCKS

Recently, the company announced the names of two of its electromobility customers. First, its headquarters city, Gothenburg, said it plans to start a new electric ferry service as part of its ElectriCity program. The ferry is expected to start carrying passengers on the Göta River by the end of 2020. The program already employs full-electric Volvo buses on the city's streets.

The ferry – Älvsnabben 4 – will be converted to all-electric drive by Volvo Penta in collaboration with the vessel's operator. The work involves removing the original driveline and replacing it with a batteryelectric propulsion system. Initially the ferry will be charged overnight supported by an onboard gen-set that runs on HVO (hydrotreated vegetable oil). Fast-charging of the ferry is expected to be added in a later stage of the project.

The city already uses diesel-electric ferries on short routes across the river. Volvo Penta said the new vessel will be the first fullyelectric ferry in the city able to complete longer, multi-stop routes.

"The competing needs of environmental sustainability and customers' business requirements are getting ever closer, as electrified options become increasingly feasible," said Peter Granqvist, chief technology officer, Volvo Penta. "There is now a clear trend from all customer groups: the need for cleaner, quieter and more fuelefficient drivelines." Rosenbauer Intl. is reportedly the first industrial OEM to sign an agreement with Volvo Penta. It will develop an electric driveline for an electric fire truck, the Concept Fire Truck (CFT), using the system delivery approach. The truck is scheduled for 2021.

"Emission-free driving is a key feature of our innovative Concept Fire Truck," said Dieter Siegel, CEO at Rosenbauer, Leonding, Austria. "For this reason, I am very glad that the heart of the CFT – the electric driveline – will be provided by Volvo Penta. Thus, we are going to be the lead user of proven electromobility technology, today used in Volvo buses and trucks. We have been cooperating with Volvo Penta for many years, which, as a pioneer, has started looking after pollutant reduction early and is putting a strong focus on electromobility."

Volvo Penta already provides Stage 4/Tier 4 final and Euro 6 emissions-compliant diesel engines to the manufacturer.

"This partnership with Rosenbauer is the first of many as Volvo Penta expands its competence in the field, and builds an innovative electromobility platform for the future," said Björn Ingemanson, president, Volvo Penta.