Style and substance

When developing energy storage systems for hybrid vessels, leading battery suppliers are realizing the importance of marrying the proper architecture with the correct chemistry

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The architectures of the battery systems helping to power the latest hybrid marine applications can be as different as the vessels on which they are installed. For example, two Saft Seaenergy modules are to provide 800kWh of power for Caledonian Maritime Assets' latest ferry, MV Catriona. Although a hybrid vessel, it won't rely entirely on charging from the diesel engines, instead gaining from an overnight shore hookup while in port. As such, the battery banks need to be more energy-dense and quick on the charge cycle. Saft's patented version of the iron phosphate chemistry, called SLFP, fits nicely with these characteristics.

"The chemistry is very dependent on the installation," outlines Didier Jouffroy, Saft's marine products and applications manager. "Marine installations vary from anything between 200kWh and 1,500kWh, but safety

Below: Saft's acclaimed Seaenergy module technology, which provides 800kWh of power to the MV Catriona, the latest hybrid ferry from Caledonian Maritime Assets

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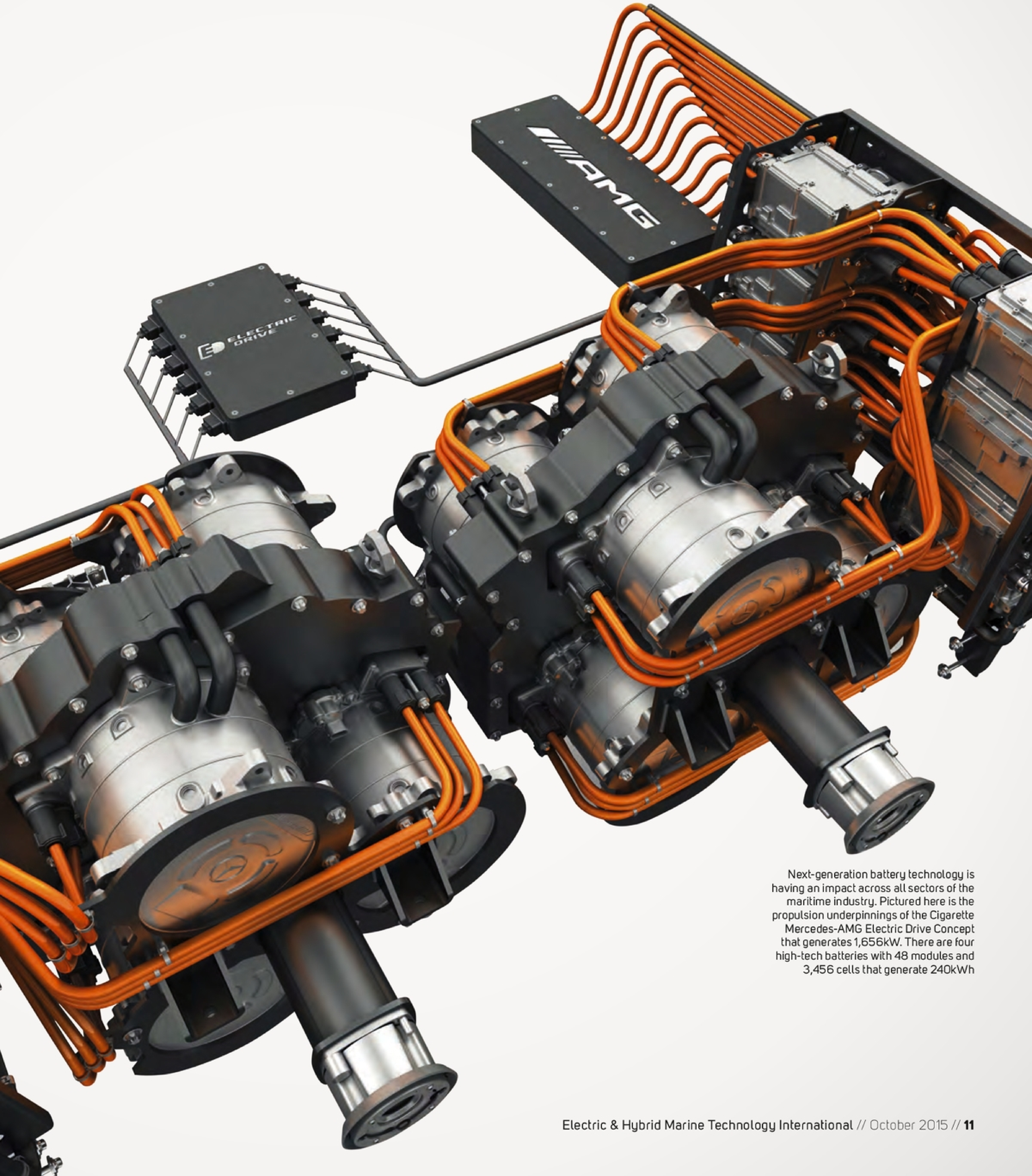
Didier Jouffroy, marine products and applications manager, Saft



Next-generation battery technology is having an impact across all sectors of the maritime industry. Pictured here is the propulsion underpinnings of the Cigarette Mercedes-AMG Electric Drive Concept that generates 1,656kW. There are four high-tech batteries with 48 modules and 3,456 cells that generate 240kWh remains a particular issue across all of them. SLFP is a good choice for this sector because, while it still supplies the necessary energy storage, the thermal runaway potential is lower than pure nickel manganese cobalt (NMC) and, in fact, is lower than most other metal oxide chemistries."

Safety is also enhanced, says Jouffroy, because Saft's chemistry sits in hard-cased, spirally wound cylindrical cells. He claims that the cylinders are physically more robust than other types when it comes to maltreatment and are generally resistant to leakages. What's more, he says that should one cell fall prey to thermal runaway, it is still easier to stop this propagation than with other designs. This is due to the fact that the empty space created by the cylinders not packing together tightly can be used for heat management purposes.

By contrast, Xalt's chosen chemistry is contained in a foil pouch structure, which, the company says, is much thinner and flatter than conventional casings and looks more like a set of tiles. The 12.7mm-thick, 255mm square provides 75Ah, although this can be varied somewhat. And this is important for a number of reasons, explains Subhash Dhar, Xalt's CEO: "Large surface area stacks with wide electrodes means low impedance, and impedance is what drives heat generation inside the cell. Plus, this shape dissipates heat faster."

A third option is prismatic cells, such as those produced by Yuasa. Here, the electrodes are either stacked or wound and then flattened and put inside a substantial, rectangular can to help lend them the physical robustness of cylindrical designs.

Peter Stevenson, Yuasa's senior technical coordinator, says although pouch cells appear to offer a greater energy density, once the necessary outer casing and management devices are added, "there's not so much to choose between them". According to Stevenson, prismatic cells are preferable to other chemistries because they are held together, giving the cells a tighter and more even compression – something that's latterly proved more important than at first thought: "It increases the lifespan and stops non-uniform charging across the cells, which can happen when flimsier varieties get deformed."

The Yuasa engineer says the 'Swiss roll' configuration, common to both prismatic and spiral cells, and single positive and negative terminals at the opposite ends of the pack, all help with the uniform distribution of current flow, "which especially at high current rates prevents some parts of the cell getting used more than others".

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Subhash Dhar, CEO, Xalt Energy

Xalt batteries (above) achieve an impressively high cycle rate thanks partly to the supplier's ultra-clean manufacturing processes that see the cells being built in highly controlled environments (below). As a result, the first time that the electrode and cathode come together is during assembly, and they're not touched by human hands until inspection

Avoiding failure

Thermal runaway potential is one of the main drivers of chemistry development. As a countermeasure to this threat, Xalt's main product uses a NMC-based cathode with graphite anodes. "NMC limits the very high-cost cobalt element and provides a little bit of everything," states Dhar. "Pure cobalt is not just expensive; there's a lot of concern about its failure rate – although you still find it in laptops, it isn't really used in large applications anymore because of the various safety implications."

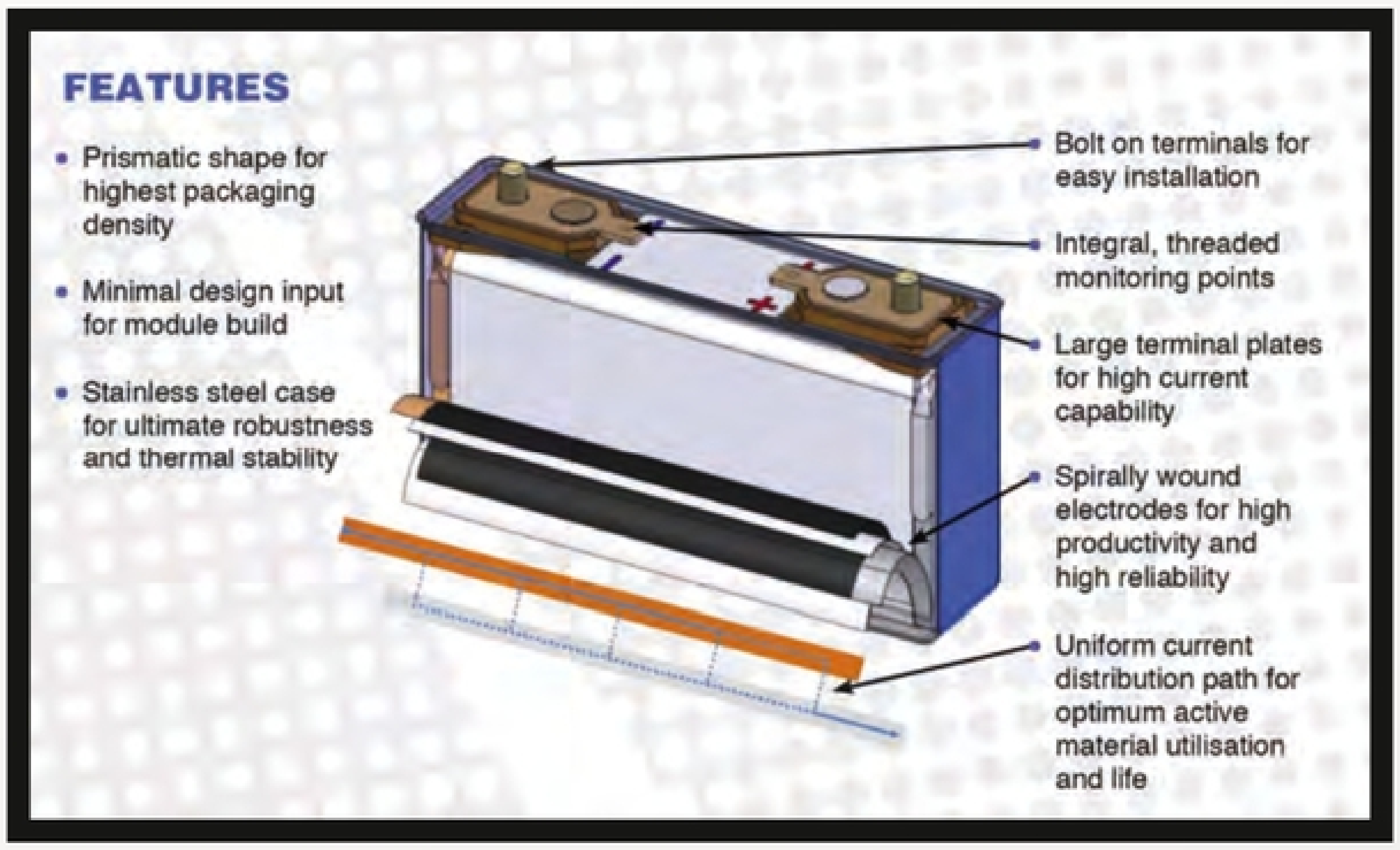
And this is a point that Stevenson takes up – after all it was Yuasa batteries with a cobalt chemistry that went into spectacular thermal runaway onboard the Boeing Dreamliner. However, while he feels cobalt still has a place in aerospace applications, "a manganese oxide chemistry would be more suitable for marine installations because of its lower cost, easier thermal management with good cycling capacity, and energy density equivalent to NMC".

Xalt is also developing a titanate anode, which has a nano-crystal surface that offers around 30 times the surface area of an ordinary carbon type anode. This means it has a faster charge/discharge cycle, making it potentially useful for ferries as they would be able to recharge between hops while also benefiting from short bursts of high voltage output.

Dennis Doerffel, CEO of REAPsystems, a leading battery designer and integrator that has worked with a number of different chemistries and architectures, says that pouch type batteries tend to have the highest energy density for volume overall as they can be stacked closely together and are lighter because they don't have the extra outer packaging. However, this characteristic is both at the heart of their attraction and their flaw.

"The inside is almost jelly-like," explains Doerffel, meaning their 'shoulders' can get crimped or folded over "to fit inside something like the circular body of an autonomous underwater vehicle". He explains that while the cells will work initially, the internal structure will become stressed to the point that the battery can break down and start to leak. Furthermore, although damaged cells "can blow up like a balloon", more common issues include aging and pouch cell swelling, which "impacts on the overall tolerances for any packaging".

Stacking the cells closely together inside a restrictive case is also problematic, says Doerffel, as adequate cooling can be difficult to achieve. He explains that REAPsystems has patented a design that holds the pouches in a frame that clamps onto the edges of the cells without restraining them too tightly, although vibration should also be considered. "These are issues everyone claims to have solved – but you have to ask manufacturers how long they have put the final product onto the vibration table."



The inner workings of Yuasa's prismatic cells, which, thanks to their design, give the cells a tighter and more even compression, increasing lifespan and stopping non-uniform charging

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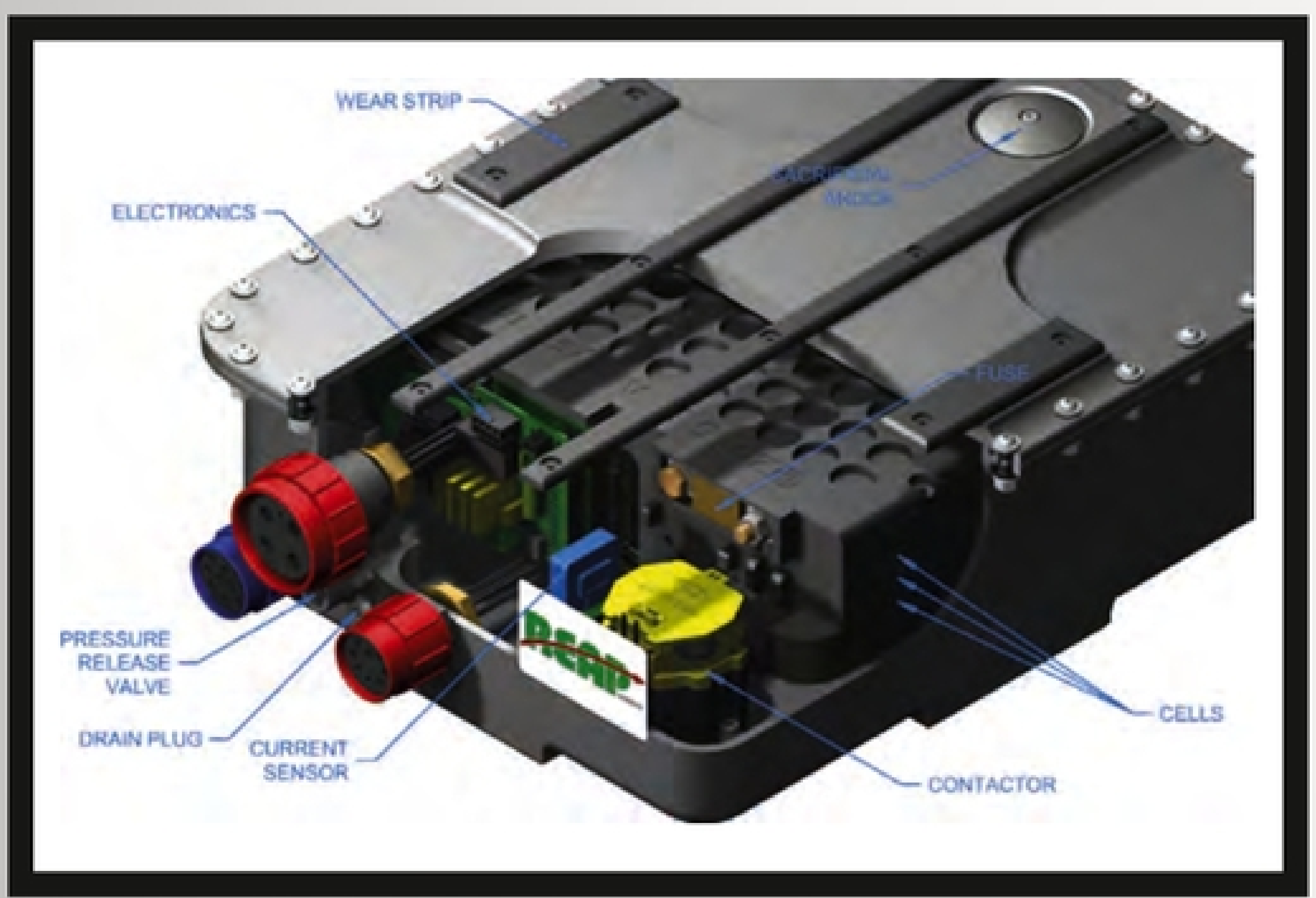

REAPsystems battery module. The supplier has now patented a design that holds the pouches in a frame that clamps onto the edges of the cells without restraining them too tightly

Cost cutters

When it comes to batteries and battery development, price is the perennial lament, but it's not so easy to drop. "Around 65-70% of the cost – depending on the chemistry – is down to the materials. So even if you have invested heavily in a sophisticated manufacturing plant, you are still pushing around the margins on that remaining 30-35%," Dhar explains.

This is where a flexible plant can help. As Jouffroy points out, "It's easier to modify the thickness and length of the electrodes with the cylindrical coil manufacturing process – and with the same hardware you can tip the balance and either have high energy output or high power density."

In this respect, prismatic cells can also be physically tailored for a number of different characteristics: "We can go from a cell with a peak current measuring 5C or 6C, to producing something that will yield four or five times that, using the same chemistry," says Stevenson.

Jouffroy adds, "I would say the quality is generally better with coiled cells; it's simpler to manufacture and there are fewer production troubles so the overall output tends to be more even, especially when it comes to very large quantities."

However, although pouch cells are regarded as the cheap-and-cheerful product option (largely because of the swathes of occasionally dubious Chinese exports), Xalt is focusing on producing extremely high standard, long-life lithium-ion cells. The supplier's 75Ah cells last for around 8,000 cycles at 80% depth of discharge, although even at 100% discharge they still manage around 4,500 cycles in total, which Dhar claims is around two or three times longer than the cycles offered by its industry competitors.

How Xalt achieves this, according to Dhar, lies in its manufacturing process: "We build the cells in very controlled and clean environments, as contamination and humidity are real killers," he explains, before adding that the anode and cathode processes are physically separated. "The first time that the electrode and cathode come together is during assembly, and they're not touched by human hands until inspection. It's a lot of investment, but worth it as this is what gives the batteries the cycle life."

Cooling advances

There's no doubting that thermal management is an important topic for battery developers and manufacturers – and not just for safety reasons. As Doerffel points out, "The closer the battery is operated to overheating, the faster it will age. This means that the internal impedance will rise and the battery will get even warmer and age even faster. So, the further a battery stays away from overheating, the longer it will last."

Although the battery management system deals with a number of different technical elements, including balancing charge and strategies for reliance, power derating and aged cells, one overriding important aspect that's closely tied in with the architecture is the pack's cooling arrangement.

Jouffroy explains how Saft has progressed from the original air-cooled system to develop a high-tech water-cooled variety: "It's far too simple to say these are for high power applications as really it's a matter of power compared to battery size. If you want to keep the temperature down, you have to look at the draw; it's the power divided by energy equation that's key."

Finally, Xalt engineers have also worked on a liquid cooling solution, and rather than relying on an alloy sheet as the initial medium to pull the heat away from between the cells, a water/glycol mix cools one face of each cell by direct contact. The arrangement sees a parallel configuration that ensures that the temperature of the liquid going into the pack is the same for each cell.

And with developments striding ahead, it's not just chemistry but also battery architecture that will continue to present marine applications with some interesting choices and challenges.